Study Number:	**SD2002-18**
Title:	**Development of a Maintenance Decision Support System**
Report Type:	**Detailed Summary Report on Tasks**
Report Period:	**November 2002 – June 2003**
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OVERVIEW

This report constitutes a comprehensive report on task work results to date for the study, Development of a Maintenance Decision Support System (MDSS) - SD2002-18. This report spans the period from November 2002 -July 2003. The specifics provided in the task accomplishments are comprehensive and cumulative for each task since the beginning of this MDSS project in November 2002.

SUMMARY OF EFFORT

Before summarizing the status of project work efforts, it is appropriate to reiterate the philosophy being followed by Meridian in developing the Maintenance Decision Support System. The Pooled Fund Study (MDSS PFS) is a deterministic approach based upon physical and chemical laws of nature. The model deals with the surface conditions atop paved highways or bridge structures and focuses on the addition and subtraction of materials within the transient layer immediately atop the pavement. Additions to this layer may include precipitation, dew, frost, absorption of moisture, various chemicals, and grit materials. Subtractions from this layer include plowing, runoff, traffic impacts, evaporation, and sublimation. The PFS model simulates the state of this transient layer handling the balance of materials into and out of the layer, the balance of heat, the physical state of the water component (solid, liquid, or slush), and the concentration of chemicals or grit materials in the mixture. The PFS model attempts to emulate the existing and future condition of “contaminants” on the pavement at numerous locations along a segment of highway based upon what has happened in the last few hours and what is forecasted to transpire in the next several hours.

The benefits of this deterministic approach include:

- A continuous estimate of the conditions within the contaminant layer at numerous points along a segment of highway

- The ability to adjust the current state of the modeled contaminant layer at any point based upon road reporting information, known chemical and grit application rates, and known plowing actions
- The ability to integrate pavement condition information from RWIS sensors into the current state of the contaminant layer
- The ability to factor localized effects into the emulation of surface conditions such as the slope of the road, construction features, shadows, crown slope, traffic volumes, etc.
- An estimate of the residual chemical content as a first guess of the material present at the inception of the next meteorological event
- The ability to suggest different treatment scenarios for different locations along a segment of highway in response to their unique environmental situations
- The ability to suggest treatment scenarios that represent the minimum use of material to permit successful removal of the contaminant layer in the anticipated route cycle time
- The ability to suggest variable treatment rates to meet various route cycle times
- The integration of other decision support modules that work interactively with a maintenance response module, e.g.:
  1. a materials inventory module
  2. an equipment status module
  3. a personnel schedule module
  4. a blowing snow module

Two major components of the study were to identify and prioritize the maintenance needs and existing capabilities of the participating states (Tasks 3 and 4) and assess the receptivity of MDSS-related activities amongst maintenance personnel (Task 5). The technical panel agreed on the methodology to accomplish all three of these tasks and who should participate in each phase of the study in a series of exchanges that took place during the first quarter of 2003. Most of the states had selected and confirmed their key participants in the MDSS study by April 2003 and confirmed the anticipated test areas for field tests as part of phase 2 of the study. Iowa's involvement in the FHWA MDSS Functional Prototype (FP) operational test and the FHWA's late decision to extend the test into Winter 2003 – 2004 created some uncertainty in both the participants and the field test location in Iowa. Following the MDSS FP review in early June, Iowa redefined its test area to northwest Iowa. Based upon an early agreement amongst technical panel members to define test areas contiguous with adjacent states, Minnesota and South Dakota currently are reevaluating the exact boundaries of their test area(s) and whether additional and/or different personnel become participants in the field study.

The efforts during the past quarter have covered many of the first seven tasks outlined in the project workplan. The question set for Tasks 3 and 4 were completed in April and the first interviews were done in the Columbus sub-district of Indiana on May 1. In addition, Bob Hart traveled through a substantial portion of the Columbus sub-district with Tony McClellan looking at the geographic features and discussing how these features and weather can impact maintenance operations within the sub-district. Subsequently, initial interviews were done with personnel from the Grand Forks and Fargo districts of North Dakota on June 12th and the Monticello and Columbus sub-districts of Indiana on June 24th and 25th.

At this time, surveys associated with Task 5 (assess the receptivity of MDSS-related activities amongst maintenance personnel) have been distributed to personnel in North Dakota, South Dakota and Indiana according to the contact lists provided by Ed Ryen, Dave Huft and Tony McClellan. There have been a total of 625 surveys mailed during the dates of June 5th through June 20th. To date, approximately one-third of the surveys have been returned. Registration of returns and tabulations are being made as the surveys return. Details of the design elements and deployment methods will be discussed in greater detail within Task 5.

TASK REPORT

The following narrative summarizes work on tasks and sub-tasks addressed during this reporting period by Meridian Environmental Technology, Inc. (Meridian) for this project.

TASK 1. MEET WITH THE PROJECT'S TECHNICAL PANEL TO REFINE THE PROJECT SCOPE AND WORK PLAN.

Based upon the desire to see the Maintenance Decision Support System (MDSS) program reach fruition, representatives from the Departments of Transportation (DOT) from the States of Minnesota, North Dakota, and South Dakota met with representatives from Meridian Environmental Technology, Inc. on January 3, 2002 to determine the feasibility of developing an operational prototype MDSS. Subsequent to this meeting the Indiana Department of Transportation indicated interest in joining the project. The four agencies involved in the initial meeting agreed to have Meridian present a white paper outlining the development effort necessary to create an operational MDSS. This white paper, submitted to the respective Departments of Transportation on February 5th, 2002, outlined many of the features Meridian foresees the MDSS providing, realistic first-year MDSS development goals, and a proposed budget for the entire development effort. Meridian still believes the first year goals outlined in the white paper are realistic, but given the later than expected start date for the project, some of these features may not be ready in time for evaluation during the 2002-2003 winter season.

Upon award of contract, Meridian will use monthly progress reports to provide details of work accomplished and project management efforts. This effort will extend also to the participating state DOTs for their contributions in the area of project management such that a detailed picture of progress being made and critical milestones being reached of the combined public and private aspects of the project. Meridian will devise a detailed work plan to accomplish each goal of the MDSS development effort and will present this work plan to the participating Departments of Transportation for review. Meridian will then send key representatives to meet with the project's technical panel to refine the work plan.

At this meeting, Meridian will first present a brief overview of the intended research tasks and introduce persons involved with the project. The Technical Panel will also be given an opportunity to present any specific questions or concerns about the content of the proposal and work plan. Meridian also proposes to use this meeting to identify participating state DOT personnel who are instrumental to the project's eventual success, and to establish the lines of communication between these personnel and Meridian (i.e., exchange of names, phone number, e-mail addresses, etc.).

SUB-TASKS

1.1 Determine extent of the study population

The initial step is to define the objective of the study. This requires a clear definition of what information is required and who will provide the source of this information. Meridian will define the information categories that it understands are the intent of this study and specify what personnel or groups within each state DOT shall serve as the resources to add definition to the selected categories. Meridian will distribute the list to the state DOTs for review. It is anticipated that the state DOTs will suggest modifications that will then be incorporated into a set of defining guidelines for the study plan.

STATUS: Completed

Task 1.1 was submitted to the technical panel on March 10, 2003 for review. The study objectives were accepted in their final form on April 23, 2003. A set of the approved objectives is included in Appendix A.

A second component of Task 1.1 was a list of the points of contacts for the study. The following list indicates what materials have been received. In addition to the requirements in the original Task 1.1 request, in late May, Meridian and Dave Huft requested a list of personnel within each state to whom the Task 5 surveys should be sent. Finally, at our face to face meeting in Des Moines on June 17, the group agreed to submit an organization chart and/or a set of job classifications to assist in the demographics of the survey. The following table indicates whether the requested materials have been received by Meridian as of July 8, 2003.

Resources/Material	INDOT	IADOT	MNDOT	NDDOT	SDDOT
Champions	YES	YES	YES	YES	YES
Research support	YES	NO	NO[1]	NO	NO
Test area people	YES	YES	NO[1]	YES	YES
Others	YES	NO	NO[1]	NO	NO
Survey list	YES	NO	NO[1]	YES	YES
Org chart/job classification	YES	YES	NO[1]	NO	YES

[1] MnDOT has these materials; they have not been transferred to the principal investigator as yet. Bob Hart erroneously informed Curt Pape in Des Moines that the documents had already been received.

1.2 Determine mode(s) of investigation

Meridian, in consort with the states; Departments of Transportation, needs to define what forms of investigation are necessary to obtain the desired results. Possible options are interviews (direct and phone), questionnaires, time-study analyses, feedback on interface prototypes, and unstructured discussions of expectations, procedures, and concerns about MDSS.

STATUS: Completed

Task 1.2 was submitted to the technical panel on March 14, 2003 for review. The modes of investigation were accepted in their final form on April 23, 2003. A set of the approved modes is included in Appendix B.

1.3 Identify personnel to contact in each state

This task is to define who the MDSS champions are within each state and define the modes of communication that work most effectively with each champion. The champion may be a member or members of the Technical Panel, or other individuals selected by current members of the Technical Panel, who will guide the routine activities associated with the MDSS development effort.

STATUS: Completed

The list of participants was requested as part of Task 1.1. All states have responded with the names of their state champions and field personnel in the test area. Indiana provided a complete listing of personnel in all categories requested in the Points of Contact section of Task 1.1.

1.4 Identify how each state wants their personnel to participate

Through discussions with the champions, determine how the state desires to enlist the participation of their maintenance personnel in the program and in particular within the Phase I information-gathering component. Once the approach is defined, it will be necessary to acquire the names and contact information for all of the state participants for scheduling purposes.

STATUS: Completed

Although discussions concerning the composition of the MDSS technical evaluation team started with the initial talks about a pooled fund study, formal consideration began in March with the request for the Points of Contact list in Task 1.1. Through personal conversations between either Bob Hart or Leon Osborne and the member states, it was determined that Indiana, Minnesota, and South Dakota desired widespread participation amongst their personnel in the MDSS discussions and Iowa and North Dakota preferred to concentrate their involvement amongst smaller groups, primarily team members in the designated test areas. Once it was decided in mid February that the Task 5 user receptivity analysis would be done as a general survey encompassing a sample from throughout each of the states, Indiana decided to focus its MDSS field participation within two sub-districts in Indiana that were receptive to participation in the field study. Indiana submitted their contact list on March 31. The remaining states defined the groups that would participate in the interview process during May and June and provided the contact lists during June.

Iowa had to delay their decision due to their involvement in the FHWA MDSS Function Prototype test. Iowa had been advised late in the winter that the FHWA might want to continue the functional prototype test for a second winter. Dennis Burkheimer did not feel that the individuals involved in the FHWA test would be willing to participate in the pooled fund effort as well. The FHWA did not inform Iowa of its decision to continue the FP program until the MDSS meeting in Des Moines on June 17. Because of this FHWA decision, Iowa has opted to move the MDSS test area to the District encompassing the northwest corner of the state. Dennis Burkheimer is in the process of confirming the four individuals he has selected for the test program are willing to participate in this program.

1.5 Design a strategy to collect the data using the modes of investigation defined previously

This sub-task combines the Meridian resource pool, the requirements of each of the modes of investigation, and the timeframe necessary to develop a plan to achieve Phase I.

STATUS: Completed

When the pooled fund study contract commenced it was envisioned that data would be collected for Tasks 3, 4, and 5, as a single data collection process. Prior to January, 2003 it became evident that the study population for each of the tasks were different and the strategy to collect the information required different techniques for each task. Task 3 needed to be direct interaction between the Meridian team and those individuals directly involved in winter maintenance operations. Direct face to face interviews done in groups of 20 or less was the methodology selected. The state resource team for Task 4 involved those individuals involved in the road condition reporting process and the communications people who do or will have input on the communications infrastructure necessary to transport data from the field to a central collection and processing site. Because the number of individuals involved in this area is somewhat limited and the topic is technical in nature, the team feels that a structured discussion format is more appropriate. The population for Task 5 covered a broad spectrum of users at all levels within the maintenance organization and the primary interest of the task was to assess the specific sentiment of DOT personnel to technological issues. The most appropriate instrument for this requirement was a survey.

The intent of the interview process associated with Task 3 was to more fully understand the processes maintenance personnel use to make routine operational decisions. In order for the Meridian team to develop an effective interview process, it was necessary to develop a good understanding of the dominant DOT maintenance issues and processes involved in the decision process. Task 3 included a number of sub-tasks to understand the maintenance practices documented in each of the states and assimilate the considerable research that has already been completed on MDSS. Meridian developed a series of questions designed to initiate discussion on eight areas associated with winter maintenance activities. These questions were formulated into a formal question set in early June.

In early January, research into the different styles and methods of designing, conducting and analyzing surveys was begun. The research efforts ranged from searching the internet to personal interviews with staff at the Center of Innovation who have designed and conducted surveys to Dr. Robert Tangsrud, Assistant Professor, Department of Marketing, University of North Dakota.

Through the review of the above-mentioned resources, the key components that need to be maintained were determined to be goals and objectives, methodology, target audience, survey length, the questions, confidentiality, panel approval, production, delivery, and analysis.

The first draft of the survey was circulated in house (Meridian) on February 17th with the revised draft being shared with some Technical Panel members on February 21st. On April 8th the survey and cover letter were sent through the reflector site for review and modification suggestions requested.

1.6 Generate a tentative schedule based upon requirements in the design and availability of Meridian interviewers

Expand sub-task 1.5 into a tentative schedule.

STATUS: Completed

The first approach was to define a firm schedule and then coordinate those dates with each of the states. Schedule conflicts with members of the Meridian team forced us to scrap that plan. There were also conflicts trying to schedule a sequence of interviews in individual states due to other obligations amongst state participants; therefore, scheduling has become an iterative coordination process between Meridian and the participating states. The initial interview process was completed in North Dakota and Indiana and scheduling is in process in the remaining three states.

1.7 Identify coordination procedures

An important component of the development effort is close coordination between Meridian and the participating states. Meridian envisions defining a clear mode of communication so all participants and other interested parties have access to the evolution of the MDSS project. Initial proposals that will be investigated include a MDSS website (with internal user and external user access), a list-serve for communication amongst members, mutual access to a project management tool, and a published list of personal contact information of the champion list (phone numbers, e-mail, pagers, etc.).

STATUS: List-serve completed; personnel list is mostly complete

Since January 10, 2003 an email reflector has existed (mdss-project@meridian-enviro.com) to facilitate a uniform exchange of information to all MDSS project participants. Present membership on this reflector includes the following individuals and their affiliations:

Bob Hart	Meridian
Jon Becker	South Dakota DOT
Dennis Belter	Indiana DOT
Dennis Burkheimer	Iowa DOT
John Foreman	South Dakota DOT
Jerry Horner	North Dakota DOT
Dave Huft	South Dakota DOT
Bruce Hunt	FHWA
Henry Lieu	FHWA
Tony McClellan	Indiana DOT
John Mewes	Meridian
Kathy Osborne	Meridian
Leon Osborne	Meridian
Curt Pape	Minnesota DOT
Paul Pisano	FHWA
Rudy Persaud	FHWA
Ed Ryen	North Dakota DOT

To date, the primary use of this reflector site has been for coordination of material exchange, scheduling of meetings and teleconferences, and distribution of report materials. And while the reflector site does provide for uniformity in information distribution, it has not insured that information exchange is taking place in a bidirectional manner. Often times after information has been distributed across the reflector site, it has been necessary to still make individual follow-up contacts with members of the reflector site in order to obtain requested information. However, while it was expected that the reflector site would provide a higher volume of information exchange, it is recognized that, owing to the busy nature of the technical panel members, achieving a consistent high level of information exchange is not always realistic. It is anticipated that as the program continues to develop that the utility of the reflector site will continue to grow.

In addition to the use of the reflector site for exchange of information via e-mail, it is anticipated that further communication tools will be necessary in the future as the nature of products expand i.e., graphical user interface and software-related products. The reflector site shall be coupled with a project website that contains both public and project-only material, including project personnel contact information. The design of this website began on June 15, 2003 but the site is not anticipated to become available before August 15, 2003.

Meridian personnel have made extensive use of a basic project management tool for schedule coordination and event tracking. Milestones Professional 2002 (Copyright KIDASA Software, Inc.) is used by senior project personnel regularly to manage project activities. The software supports web-based displays and read-only viewers and can be used to provide the Technical Panel access to Meridian's management documents for the project. At the direction of the Technical Panel, this access will be established.

1.8 Obtain copies of questionnaires created by NCAR for Mn/DOT and IADOT as part of the FHWA MDSS Functional Prototype

In preparation for the following tasks, it would be helpful to get copies of the work already completed under the FHWA MDSS Functional Prototype and review the material to augment our efforts.

STATUS: Completed

Meridian determined through inquiries to Bill Mahoney at NCAR and the project managers in Minnesota and Iowa who had been involved the MDSS FP that the NOAA National Labs team had not prepared a questionnaire as part of their field tests over the past two winters nor had they gone through any organized query process with the states. Therefore, the task could not be completed as anticipated.

TASK 2. CRITICALLY EVALUATE THE RESULTS OF THE FEDERAL HIGHWAY ADMINISTRATION'S (FHWA) PROJECT TO DEVELOP A PROTOTYPE OPERATIONAL MAINTENANCE DECISION SUPPORT SYSTEM.

The FHWA prototype operational Maintenance Decision Support System (MDSS) project is a multi-year effort to prototype and field test advanced decision support components for winter road maintenance. Meridian has been involved in the national discussions of the MDSS development from the outset of the federal efforts and continues to play a prominent role in the national discussion on MDSS. A Maintenance Design Support System is a complex integration of several independent, but inter-related components. From a functional perspective the MDSS design may be viewed as five basic components:

- *The Weather System*
- *The Pavement Forecast System*
- *The DOT Operations and Control System*
- *The MDSS Decision Logic System*
- *The Delivery and Display System*

Meridian has already invested over fifteen man-years in the development and refinement of the Weather System, the Pavement Forecast System, and the Delivery and Display System that will be included in an MDSS. Some additional enhancements are needed in each of these components to meet the specific MDSS requirements, but Meridian will be able to utilize this infrastructure as part of the conduit to input weather and pavement guidance into the MDSS Decision Logic System and deliver the resulting MDSS products to the MDSS user. Thus significant portions of three of the five components are already complete. As a result Meridian is in a unique position to critically evaluate the results of the federal prototype MDSS.

Where necessary, the evaluation of the federal prototype will include implementation of software elements for the purpose of more thorough study. From the critical evaluation of the MDSS federal prototype, Meridian will submit a technical report that summarizes the salient elements that are candidates for inclusion in this pooled fund study, citing why these elements are beneficial. In a similar manner, those elements that are not realistic candidates for inclusion will *also be identified, including the reason for such a decision. Where possible and practical, Meridian will maintain a close collaboration with the federal MDSS prototype development effort. This will help to ensure that an efficient and practical operational MDSS results from this project.*

SUB-TASKS

2.1 Acquire MDSS Functional Prototype (FP) software and documentation

Meridian will request a copy of the current MDSS FFP software and make copies for distribution amongst the individuals involved in the evaluation.

STATUS: Completed

The MDSS Functional Prototype (FP) version 1.0 software and documentation was released in late September 2002. However, a miscommunication between Meridian and NCAR resulted in Meridian not requesting a formal copy of the version 1.0 software until mid-November 2002 with the arrival of the code at Meridian corporate offices on December 9, 2002. Only the open-source version of the release was obtained as Meridian did not believe acquiring the proprietary binary release of the Road Weather Forecasting System would provide meaningful information in the evaluation of the code composition and functionality. Furthermore, the code that was anticipated from the NOAA Forecast Systems Laboratory was not included in the version 1.0 release and subsequently has not been available to date for review by this project. A copy of the version 1.0 software source code was installed on Meridian computer systems and copies of the software documentation were distributed to members on the evaluation team. This evaluation team consisted of Dr. John Mewes, Mr. Robert Hart. Mr. Leon Osborne, Mr. Bryan Hahn and Mr. Douglas Rand. All of these individuals are employees of Meridian. Dr. Mewes, Mr. Hart and Mr. Osborne had the primary role of evaluating the meteorological aspects of the MDSS release (software and documentation) while Mr. Osborne, Mr. Hahn and Mr. Rand had the primary role of evaluating the computer-related aspects of the MDSS release.

During the March 31, 2003 Technical Panel conference call, Mr. Osborne requested that Meridian be given access to a more recent interim release of the FP. However, as of the end of June 2003, this access had not been granted. At the FFP June 18, 2003 program review in Des Moines, Iowa, Mr. Bill Mahoney (NCAR) agreed that an interim release of the software (referred to as version 1.5) would be provided by July 1, 2003. This interim release would not include revised documentation. As of the writing of this quarterly report in early July 2003, this interim release has not been made available to Meridian.

2.2 Install software and resolve setup issues

Meridian will assure that the software loads properly and will work with the National Oceanic and Atmospheric Administration (NOAA) National Labs to sort out any startup issues. We will document the processes involved in the setup and include these comments as part of the final evaluation.

STATUS: Completed

Working with the MDSS FP version 1.0 software referenced above, the process of installing and configuring the software to run on Meridian systems began in late December 2002. The software available from NCAR in the release included two CD-ROMs. The first CD-ROM included only public domain software while the second CD-ROM included the NCAR proprietary Road Weather Forecast System (RWFS) executables (obtaining these executables requires a license from the University Corporation for Atmospheric Research Foundation) and assorted miscellaneous public domain support programs and configuration files. The latter included software to decode METAR observations and configuration files to properly process input data from the Unidata Local Data Manager (LDM) software. Meridian requested only the public domain release (CD-ROM number 1) as the binary executables for the RWFS would not provide appropriate source code for systemic review and due to Meridian's belief that the RWFS is not necessary owing to Meridian's existing advanced weather forecasting capabilities. However, not receiving the second CD-ROM did require Meridian to acquire the METAR decoder software and the LDM configuration files separately. The former was downloaded from NCAR's UNIDATA web site and the LDM configuration file was acquired from the University of North Dakota Regional Weather Information Center. Table 1 summarizes the code acquired for the MDSS Functional Prototype. It is noted that the NOAA Forecast Systems Laboratory ensemble modeling system was not available in the September 2002 release. This code will not become available until September 2003.

Module	Source Code Obtained?	Binary Code Obtained	Source Code Language	Successfully Tested?
Road Weather Forecasting System	No	No	Not available	N/A
Road Temperature Module (SNTHERM)	Yes	Yes	FORTRAN	Yes [1,3,5]
Road Condition and Treatment Module (RCTM)	Yes	Yes	C++ & FORTRAN	Yes [1,3,5]
Precipitation Algorithms	Yes	Not Available	C++	Yes [1,4,5]
Rules of Practice	Yes	Yes	C++	Yes [1,5]
Chemical Concentration Algorithm	Yes	Yes	C++	Yes [1,5]
Display data formatter	Yes	Yes	C++	Yes [1]
MDSS GUI	Yes	Yes	Java	Yes [1,5]
Assorted NCAR library routines	Yes	No	C++	Yes [2]

The testing of each module was completed following a consistent set of steps. The initial system used for the installation and testing was an Intel-based workstation running FreeBSD UNIX and GNU C, C++ and G77 FORTRAN compilers. After problems were encountered with the use of G77 FORTRAN (see comment 3 below), the FORTRAN-based software was moved to a SUN UltraSPARC 60 running SUN OS version 5.8 with SUN C, C++ and FORTRAN 77/90 compilers.

The first step in testing the software involved creating a home directory for the MDSS software and attempting to install the software on the workstation following the installation instructions found in Appendix G of the MDSS FP documentation. After repeated attempts without success, the files were manually copied to the installation directory. After the contents of the CD-ROM were loaded onto the workstation, the compiling of the software was attempted. However, difficulties quickly ensued as noted by the superscripted flags in the testing column in the table above. The value of the superscripted flags relate to the following difficulties:

[1] – The software distribution Makefiles found in all source directories referenced an environment variable (*RAP_MAK_INC_DIR*) that was on a #include that pointed to a non-existent directory in the release expecting to contain two dependency files for the Makefile (*rap_make_macros* and *rap_make_targets*) to resolve against. There were additional undocumented environment variables set for RAP_INC_DIR and RAP_LIB_DIR, which pointed to the expected locations of include and library files for support packages of netCDF and the assorted NCAR library routines included with the distribution. The latter two environment variables, along with the environment variables for the compiler and link loader flags, were quickly discovered and changed without much delay. However, a significant effort and considerable time was involved in replacing the two dependency files. Eventually, these files were reconstructed manually and the compiling of the code could commence.

[2] - The construction of the NCAR libraries in the distribution required manual execution of the C++ compiler and formation of the necessary library archives. No documentation was provided to indicate where the libraries were to be located after their formation. Fortunately, there were no hidden dependencies and common sense and experience in installing libraries in the past permitted the installation to proceed without significant difficulties.

[3] – Difficulties developed when compiling and constructing executables involving the FORTRAN routines associated with SNTHERM and the RCTM. The FreeBSD workstation in use only supported a GNU version of FORTRAN (g77). Various routines in the distribution for the RCTM required FORTRAN 90 and a number of routines in the SNTHERM distribution, which was all FORTRAN 77, would not compile immediately with g77. The solution to this was approached in two ways. The first and most expedient solution was to move SNTHERM and the RCTM to a Sun OS machine that supported both FORTRAN 77 and FORTRAN 90. With this move, no additional compiler difficulties were encountered other that having to once again modify the required Makefile process. The second solution that was approached over time was to make appropriate modifications to the source code to permit compiling on the FreeBSD machine. For the FORTRAN 90 code, this was accomplished by recasting the code in C++. This was simple to do as the routines were small and did not involve any intrinsic FORTRAN capabilities (it was curious as to why this code was even released in the MDSS FP as FORTRAN 90 code). The conversion of the SNTHERM code to a version supporting g77 took significantly longer, particularly the process of verifying that no damage was done to the precision and computations inherent in the original code.

[4] – Working with the National Severe Storms Lab (NSSL) precipitation algorithms were significantly different than other routines since it had no connection with the code distributed in the strictly public release, i.e., the precipitation algorithms are used in the FP MDSS only with the RWFS. Hence, to test the code required developing driver routines that not only provided data to the precipitation algorithms, but also extracted the data for inspection. Further, since no meaningful documentation existed for this code, it required time to 'read' the source code to determine the data constructs expected on input and output. However, after some time the appropriate driver code was developed.

[5] – The most time consuming effort to test the routines involved providing observed and forecasted weather information. Prior to acquiring weather data, it was necessary to ensure that appropriate data handling software required by the FP software was in place. This required software included:

GNU gcc	2.9.5	http://gnu.org/
NcFTP	3.1.4	http://ncftp.com/
Java	1.3	http://java.sun.com/
Perl	5.0	http://www.cpan.org/
Python	2.0	http://python.org/
Unidata LDM	5.1.4	http://www.unidata.ucar.edu/packages/ldm
Unidata netCDF	3.4	http://www.unidata.ucar.edu/packages/netcdf
Unidata netCDF-perl	1.2.1	http://www.unidata.ucar.edu/packages/netcdf-perl
Unidata UDUNITS	1.11.7	http://www.unidata.ucar.edu/packages/udunits.

The data standard used for exchange between FP modules is the Unidata netCDF (network common data format) standard that is in widespread use within the meteorology community. The data standard employs a self-describing data method encapsulated in a definition file known as the common data language or CDL. With the CDL it is possible to describe the spatial and temporal nature of the data, the data units, the data limits, etc. While the standard does not promote compression and can become unwieldy for large binary files, the standard is acceptable for the transfer of most, if not all, of the data exchanged within an MDSS.

The FP MDSS is built around the Unidata Local Data Manager (LDM) for information. The data flow at Meridian is based upon a dramatically different data acquisition scheme than LDM. Although both can utilize NOAAPort data as input, the LDM system is built upon a flat-file system whereas the Meridian data base system is designed around a MySQL data base manager. This results in greater efficiency in the Meridian system. However, for the purpose of testing the FP MDSS in its native form, it was necessary to have a LDM data feed. Fortunately, the University of North Dakota was able to provide this data feed as they support the LDM as an active member of UNIDATA. Unfortunately, configuration of data sets through the LDM configuration were still required. Finally, in late March the data flows were completed and testing of the FP MDSS was able to be completed.

The testing of the graphical user interface (GUI), beyond the difficulties encountered in completing a fresh compilation of the java code, preceded without much difficulty. Using the jar files in the distribution, it was possible to run the software immediately after copying the files to the workstation and setting the proper CLASSPATH values. And while the distributed java was developed using JDK 1.3.1 and the workstation had JDK 1.4.1 installed, no problems were encountered in running the software.

As a final comment regarding the FP MDSS software release, it must be stated that for the private sector entities lacking in sophisticated computing resources and knowledgeable software engineers and meteorologists, the installation and execution of the FP MDSS software will be tremendously difficult. The documentation provides only limited descriptions of the algorithms contained in the software release and the documentation of the java software associated with the graphical user interface is virtually non-existent. Regarding the latter, it would have been found to be useful to have javadoc capability when attempting to make modifications to the source code. Even had all the software been straightforward in its documentation of the algorithms, the use of the code in supporting an operational environment is difficult and time consuming to establish. While the federal laboratories extol the software as being a step forward in providing the private sector with the building blocks to construct MDSS applications, these building blocks have many rough edges and are a long way from being ready for serious usage without a major personnel commitment to restructure the code into something more usable within the private sector. As a caveat it must be noted that the software reviewed was a first release software and the discrepancies encountered are typical with other first release software Meridian scientists have dealt with in the past. Fortunately, Meridian personnel involved in the evaluation and assessment of the FP MDSS software had worked with many of the elements used in the foundation of the FP MDSS software and were able to find work-arounds to most problems encountered. However, the time required to perform the evaluation was significantly greater than anticipated and budget for this project. It is hoped that subsequent releases of the software will come with better documentation and a complete distribution of all codes, scripts and utilities.

2.3 Evaluate software performance and make notes about functionality

Meridian will exercise all components of the software and determine how each of the components interacts with the others. The evaluation will look at both the internal, or "behind the scenes," interactions and the external user interface. Meridian will assess which components appear to be good candidates for integration into the MDSS, which components show promise but need additional enhancement, and which components would likely provide better support for the state DOTs if they are addressed in a different manner. Meridian will document and justify each of its assessments.

STATUS: Completed

As stated above, all components of the non-licensed, required FP MDSS were compiled and interfaced with real-time data. It is important to note that the FP MDSS is designed to be a predominantly server driven system. This is to say that all data is processed off-site from the state DOT client and then distributed to the client at prescribed times. In performing this evaluation the FP MDSS software reviewed was found to have a serious flaw in the use of interprocess communications that was based upon file transfers. This method imparts unnecessary delays in the data processing, analysis and forecasting efforts. After discussions with Mr. Bill Mahoney in February 2003, Meridian was informed that NCAR was aware of this difficulty prior to this past winter's field demonstration and significant modifications were made to improve the interprocess communications. Unfortunately, Meridian has not had the opportunity to review this new code to date.

Besides the issues associated with the interprocess communications, Meridian encountered significant difficulties with the use of the Unidata LDM as the backbone for weather information for the system. Although the data provided via UND for this test came to the university over an Internet 2 connection, the lack of reliability of the data flow from the upstream site made the use of an internet-based LDM questionable. Meridian is aware that LDM has been configured to ingest directly from a NOAAPort satellite downlink and believe that if LDM is used that this method must be used rather than relying upon the Internet as a data source. However, issues were not only with the reliability of the data flows into LDM, but with the stability of the LDM software. On seventeen occasions during the period of January 15, 2003 to May 31, 2003, the LDM software release at UND failed to function properly in the ingest of data. While several patches and upgrades were made to the software during this time, the lack of reliability of the software and the inability to identify specific software maintenance personnel to immediately be devoted to rectifying software irregularities makes the use of this public domain solution less than optimum for the private sector. Therefore, it is recommended that an alternative to the LDM backbone of the FP MDSS be used for the pooled fund MDSS. Since this data provision is external to the client-side application of the MDSS, this recommendation is not anticipated to impact the client-side software components of the MDSS while providing a more reliable source of data.

Since, the present pooled fund MDSS did not acquire the NCAR RWFS, the assessment of this module cannot be made by Meridian. Further, since no operational tests were conducted with the remaining modules, there can be no statistical basis for assigning value to these modules. However, from the review of the software construction and physical content of the code, it is believed that three components of the FP MDSS bear closer consideration for use within the pooled fund MDSS efforts. These three components are 1) elements of the graphical user interface, 2) the chemical concentration algorithm and 3) the road condition treatment module framework.

The development of a final graphical user interface for the client-side application will take considerable time to design. In lieu of the short time remaining before this coming winter's field tests, it is recommended that the FP GUI be adopted as a starting point for the pooled fund GUI. This will permit considerable code reuse and will provide support for utilization and acceptance testing with maintenance personnel before winter. It is also noted that while the initial GUI would parallel the FP GUI, there are no certainties that this will continue indefinitely.

The chemical concentration module of the FP appears to be established from sound principles albeit for a limited variety of chemicals. As with the FP GUI, it is recommended that the FP code be considered for adoption at this early stage of the pooled fund MDSS. Building upon the experience gained from field test during the past two winters, Meridian will work to expand this chemical module to a more robust and inclusive algorithm. However, it is not recommended to continue with the rules of practice algorithm in the FP. This decision is based not on the quality of the code, but rather on the concept of best practices and the inherent ambiguities associated with this concept. Early interviews with maintenance personnel indicate that this algorithm must be far more dynamic and flexible to be effective and representative of existing practices.

The final recommendation of code adoption is the framework that comprises the RCTM. Although, for reasons just cited, it is not recommended to adopt the Rules of Practice algorithm, it is believed that the code framework constituting the RCTM is worthy of consideration for code reuse in the pooled fund MDSS. The module must be expanded to provide for a more dynamic interaction with road condition and maintenance databases, but the incorporation of the code could save valuable time as Meridian works to prepare a test release of code for the coming winter season.

2.4 Read through the detailed documentation and write an evaluation of the design and expected performance.

The NOAA National Labs published extensive documentation with the release of the software. Meridian will summarize this documentation and provide a critical evaluation of the design of the system.

STATUS: Draft document completed

The MDSS FP developed by the NOAA National Labs is structurally an analog approach to decision support. Input to the decision support logic of the FP is almost exclusively limited to forecasted weather information. Output from the decision support system is based upon typical responses derived from years of experience; thus the decision made today is based upon experience and practices carried out over the last several years.

More than half of the document discusses the Road Weather Forecast System (RWFS) and its automated support components. The RWFS is a data fusion system used to generate ensemble forecasts for sites having verifiable data. The ensemble forecast routine is limited to those meteorological parameters available in the MOS system. This does not encompass all of the parameters needed for the Road Condition Forecast System. Best approximations for these non-verifiable parameters are used (e.g., radiation flux or the alternative, cloud cover percentages). The majority of the code comprising RWFS was developed over the past several years, much of it as a dedicated project for a special concern. The FY2002 budget indicates a proposed expenditure of $241,000 for this effort.

The Road Condition and Treatment Subsystem (RCTS) utilizes an energy/mass balance model that takes its input from the RWFS and transforms this point specific weather forecast data into the most probable pavement temperature and pavement conditions for the given weather input. RCTS uses SNTHERM as its energy/mass balance model. This model was developed at CRREL in the 1970’s and 1980's to emulate snow accumulation characteristics over open terrain. The research objective had been a high-resolution physical representation of the snow layer(s) above bare or vegetation-covered ground surfaces. Since subsurface conditions and the earth/atmosphere or earth/contaminant interfaces were not the focus of the research, the author made several gross assumptions that did not affect the modeling of the snowfield characterization above ground. However, these assumptions do impact the energy and mass flux relationships for a paved surface and its concomitant physical infrastructure. From previous research and evaluation of the model, it is known that the model:

- does not permit an impermeable layer
- fails to emulate the true flow of moisture in the subsurface
- is not designed to handle the hydrological balance of the water-ice components on the surface of the pavement.

Further, the FORTRAN code was developed for a single run research analysis and is not configured to work in a redundant, operational environment.

The treatment component is not designed to model the physical state of the contaminant layer on the surface of the pavement. This layer is the mixture of snow, ice, water, various chemicals and mixtures of chemicals, grit, and extraneous other materials added to applied materials. RCTS does not directly deal with the state changes and the associated mass balance of the liquid phase and the combined ice/water combination (slush) induced when chemicals are present in the mix. Rather, the approach taken in the RCTS is to assume a no treatment scenario and monitor for precipitation events that exceed some pre-specified criteria (freezing rain, snow depth > *x* inches, etc.). Once one of these criteria is met, the model employs a treatment response derived from the Manual of Practice and then uses the SNTHERM model and integrated chemical analysis module to project the pavement surface conditions based upon the interaction of the treatment with the forecasted snow/ice/water in the forecast.

There was no indication in the documentation of proposed maintenance responses to potential frost conditions, the development of black ice, potential icing conditions tied to blowing snow, potential refreeze conditions, and refreeze conditions associated with the ice cream freezer effect induced by applying chemical to slush.

The Road Condition and Treatment Subsystem does not directly address the physics and chemistry of highway maintenance practices. Winter maintenance is the practice of keeping the winter weather induced contaminants atop the pavement in a workable consistency sufficient to permit plowing action to remove the contaminants from the pavement surface without the development of a bond between the ice and the pavement. One of the primary values of MDSS is to project the most efficient use of materials to permit physical removal of the contaminants in subsequent passes during the storm. At the end of a storm MDSS must project the proper use of chemicals – or the lack of use of chemicals – to permit effective removal of residual materials from the pavement surface through melting and runoff, evaporation/sublimation, or removal by the effects of traffic. The RCTS cannot address these issues because it does not assess the ongoing road condition and/or state of the contaminant layer and compute the optimal treatment to achieve the best maintenance outcome..

The user interface offers several good ideas. The main screen contains five components:

- alert status screen
- geographic locator or state map screen
- weather or treatment category selector box
- time and animation controls
- treatment information

Each of these components is critical in the operation and display components of the graphical user interface. Display options such as point specific or route specific information may be selected by simple use of the mouse to select the desired location. The time and animation controls permit excellent control of the displays.

Users can easily navigate from the main view to the route view to view local guidance. From the local or route view users may view weather forecast information, route condition forecasts, and treatment options. For each treatment plan the display can present such parameters as the pavement temperature, snow depth, mobility index, and chemical concentration values in a time series display for a specific route. The time series illustrates the effect on each of the display parameters for no treatment, the current selected treatment, and the recommended treatment. The user may also define treatment options that then become a treatment option in the user interface selection set. Users may try what-if scenarios by selecting one or more of these alternative options and viewing the effect of that treatment on the various pavement condition parameters.

The graphical user interface contains a wealth of information and user options. The display is complex and initially is busy, if not overwhelming. With use, the tools available in the interface become more straight-forward and navigation through the various windows and drop down menus becomes more logical. However, maintenance users have a wide spectrum of understanding and technical experience. For some, the GUI will provide an effective tool. For many the interface will be too complex. It may be necessary to provide the option to present key elements of the information in a much simpler display format. As mentioned in an earlier sub-task, the documentation for the java software was virtually non-existent and seriously handicaps the ability to modify the provided code. Further, the application does not provide extensive user help nor rigorous end-user documentation or user guide. Some limited definitions of terms and functions are available within the software help. The authors instead rely upon training and user experience to develop understanding of the application. This is a serious drawback and reflects the lack of experience of the developers in preparing software distributions comparable to those found within the private sector software industry.

TASK 3. INTERVIEW FRONT-LINE AND MID-LEVEL MAINTENANCE SUPERVISORS FROM EACH OF THE PARTICIPATING STATES TO IDENTIFY AND PRIORITIZE NEEDS FOR MAINTENANCE SUPPORT FUNCTIONALITY.

A crucial requirement for a successful MDSS is the encapsulating of knowledge from experienced maintenance supervisors. Since the MDSS will be designed to support their efforts, it is imperative that these individuals be the key resource in the design phase of the project. In order to design a system that embodies the most thorough knowledge gained from user experience and that will be well received by maintenance personnel, Meridian will place a significant emphasis on refinement of the MDSS to address the needs and priorities of front-line and mid-level maintenance supervisors. The needs information will be gathered in a systematic manner to facilitate better incorporation into an algorithmic framework. A set of graphical tools will be provided to stimulate feedback from the supervisors as to functionality of possible MDSS features. These tools will consist of either web-based or client-based applications that partially integrate pieces of weather, road condition, and treatment information in a manner suggestive of the envisioned MDSS display interface. Where possible, these tools will be fully functional in their content and will be available to the maintenance supervisors on a routine basis. However, due to the commencement of this pooled fund study near the beginning of the winter maintenance season, a preliminary version of a more fully integrated, comprehensive, and functional client-based MDSS interface is not expected to be available until near the end or after the end of the 2002 – 2003 winter season.

Coordination with state DOT project leaders will be required to best identify points-of-contact for Meridian. Meridian personnel will conduct both on-site and telephone interviews to solicit the required information. Where possible, Meridian personnel will shadow maintenance supervisors to collect time-in-motion information related to decision making processes during winter storm events. The level of on-site work will be dictated by existing weather conditions and the thoroughness of the data and information collection process. Monthly updates will be coordinated with state DOT representatives to maintain good communications between Meridian and state DOT representatives on planned activities. From the information garnered, a report summarizing the needs and priorities will be delivered after each of the first two winters for review and discussion with the Technical Review Board.

SUB-TASKS

3.1 Determine prospective graphical interface(s) for a potential user interface for DOT personnel

Meridian will evaluate a number of graphical user interfaces that have been effective in allowing users to interact with data similar to that proposed for the MDSS. We will search for examples from various sources (industry, Internet, marketing experts, university sources, and via personal experiences). Meridian is especially interested in the input from the state DOT participants in this study. Their guidance regarding applications that they find easy to use yet effective in their handling of complex information are of particular interest.

STATUS: Completed.

In completing this task Meridian sought advice from computer science faculty members at the University of North Dakota, who specialize in software engineering design practices and graphical user interfaces. These direct interactions were supplemented with a background review of published literature on graphical user interface design practices. In addition, Meridian held internal discussions amongst its software engineers who have considerable experience in the design and implementation of Microsoft Windows client-based software packages.

The complexities of graphical user interface design mandated Meridian exercise caution in deploying such interfaces too soon in the development process. Based upon the assessment of GUI design practices and the recommendations of the university computer scientists consulted in this task, the decision was made to take a more pragmatic approach and develop an understanding of present computer literacy amongst DOT personnel before presenting sample GUIs. This cautious approach has provided Meridian the opportunity to perform the necessary design research, review accepted GUI design standards, and take advantage of the lessons learned from the MDSS FP field test in Iowa. Appendix C provides a summary of GUI development to date.

3.2 Design the graphical interface or interface options

From the graphical interface prospects, Meridian will work with the DOTs to define one or more options to develop into a prototype interface. Meridian will design the interface and storyboard its operation. The state DOT participants will have an opportunity to critique the design. Meridian will modify the design to incorporate the DOT suggestions.

STATUS: Ongoing.

The design development of the graphical user interfaces to be used in the client-based portion of this MDSS project is at present an ongoing activity. Early GUI samples are provided in Appendix C. As the samples become more mature in their design, the draft graphical user interface will be available on the MDSS project web site for the purpose of review and comment. It is anticipated that these samples will be available in early August 2003.

3.3 Program the interface(s) to permit users to get a sense of interface approaches

Meridian will create the necessary software modules to permit state DOT participants in the MDSS test and evaluation to interact with the interface and determine whether the interface meets their expectations.

STATUS: On hold pending the outcome of sub-task 3.2

As the samples are reviewed and commented upon by the technical panel and their designated representatives, a draft graphical user interface that includes full mockup capabilities for this winters functional test, will be constructed. This mockup will be made available on the MDSS project web site for the purpose of review and comment. It is anticipated that this mockup will be available in early September 2003.

3.4 Review the needs assessment done by the FHWA as part of the STWDSR and MDSS projects

In preparation for the interview process, the principal investigators will review the needs assessment done by the FHWA and organize the needs defined in their published documents into a summary document. The summary document will provide two functions: (1) it will permit the investigators to commence viewing the maintenance requirements from the maintenance user's perspective, and (2) serve as a baseline for the development of the questions, discussions, and other interactions between the investigators and the state DOT participants in the study.

STATUS: Completed

The MDSS program evolved from a number of separate efforts in the mid-1990's to establish more effective tools to support the winter maintenance decision processes of DOT and public works personnel. The concepts emerged from two separate venues, the Road Weather Information Systems (RWIS) program and research efforts on advanced, high-resolution forecasting techniques. The formal program to develop a Weather Information for Surface Transportation Decision Support System (WIST-DSS) grew out of the rural ITS program of the ITS Joint Program Office (ITS-JPO). The first formal program was the Surface Transportation Weather Decision Support Requirements project.

"The STWDSR project originated in work of the FHWA Weather Team, created in January 1997. The Weather Team was founded with membership from various FHWA offices involved in weather programs and a state DOT representative from the AURORA pooled-fund research consortium of states concerned with weather information and winter road maintenance. The first major actions of the Weather Team were to draft its White Paper based on a stakeholder symposium in 1997, and initiate the Foretell™ operational test of advanced weather information for road maintenance and other users. The White Paper defined the FHWA weather information program focus and Foretell, which is undergoing a 3-year evaluation funded by the ITS-JPO, will be an important experience base for WIST-DSS development and requirements validation. The Advanced Transportation Weather Information System (ATWIS) operational test in the Dakotas is also an important basis for the WISTDSS along with other weather-related projects sponsored by the USDOT and the many commercial developments of the VAMS." [1]

Mitretek performed the background research for the FHWA and released the first STWDSR V1.0 report in December, 1999. At the same time the Office of Federal Coordinator for Meteorological Services and Supporting Research held its first WIST symposium. The STWDSR program continued during 2000 with stakeholder meetings in February and May. A second report, STWDSR V2.0 was released in June, 2000. STWDSR V2.0 contains a compilation of the needs assessment information submitted as part of the two stakeholder meetings and follow-up dialog Mitretek had with the states participating in the STWDSR meetings.

Based upon input from the states, Mitretek developed a needs assessment summary for a decision support system. The compilation was fairly extensive and served as an excellent framework for the initial understanding of the unique needs of the maintenance community. The analysis broke the decision process into a composite time and space scale. Decisions made 48 hours prior to the initiation of an event (threat in the STWDSR document) were associated with broad scale decisions. As the forecasted time to the initiation of the event got shorter, decisions addressed more localized issues. During the event, maintenance personnel tended to focus on very local issues, especially where small scale differences in weather conditions impacted minute by minute adjustments in the maintenance response. As decisions become more focused on the local issues within the maintenance "warning" category, the requirement for weather information gravitates to a very high resolution forecast.

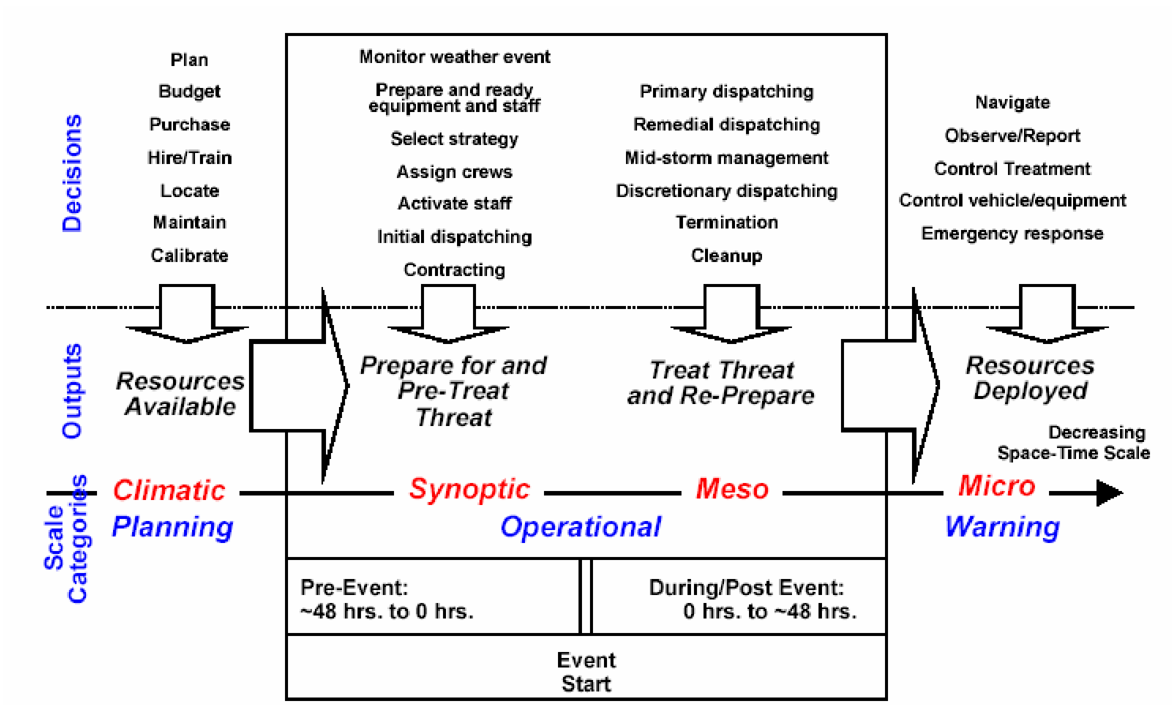


Figure 3.4.1: Scales of Decisions and Outputs Relative to Threat Event [2]

The analysis of the DOT-provided data suggested that decisions may be classified into decision clusters which are effective in different time intervals. Within each of these clusters there exist a number of time-dependent needs. A full classification of the needs are included as Appendix D.

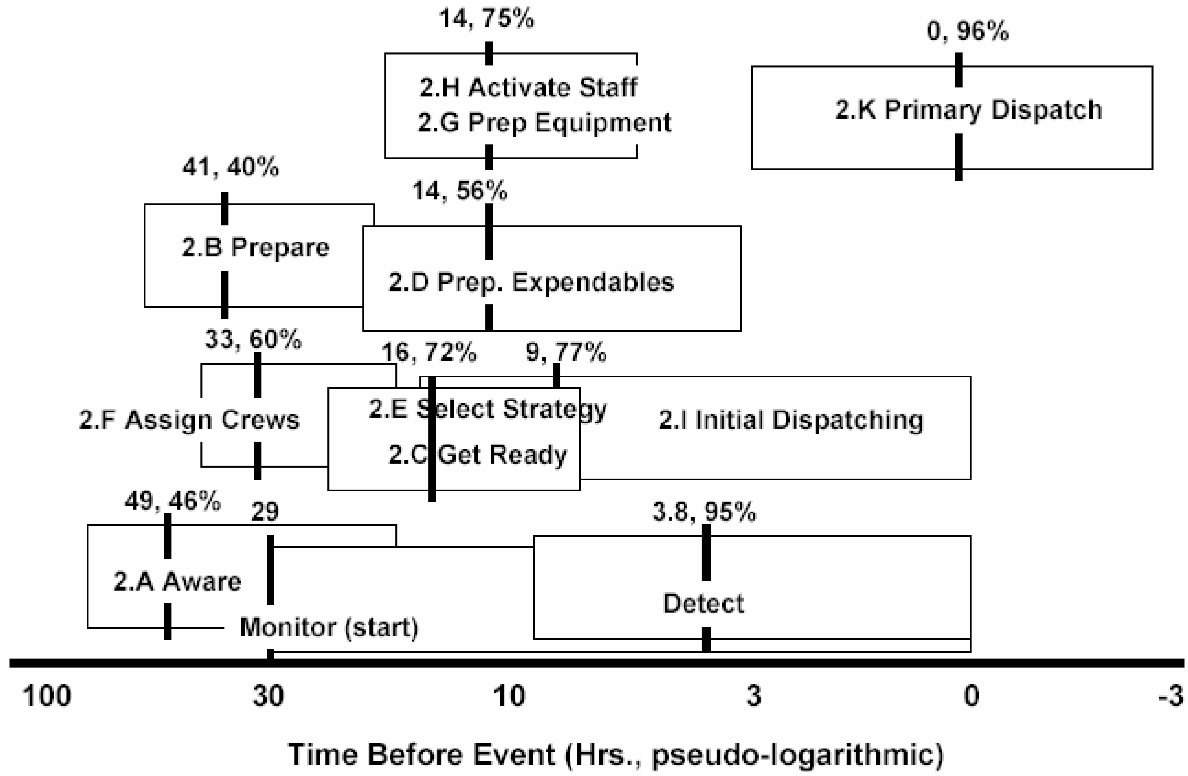


Figure 6.1.4: Decision Clusters, Time Lead and Confidence

Figure reference [3]

The materials presented above and in Appendix D were extracted from the original STWDSR documents and assimilated into an organized file. The file served as a baseline reference for the development of an extended, needs assessment set and was the fundamental guide to the development of the interview question set. The needs assessment document is so well organized and complete that the principal investigator has reviewed the material at numerous times in the completion of Tasks 3.7 – 3.13.

[1] FHWA. 2000. Surface Transportation Weather Decision Support Requirements, Version 1.0. Office of Transportation Operations, Federal Highway Administration. Page 11.

[2] FHWA. 2000. Operational Concept Description, Surface Transportation Weather Decision Support Requirements, Version 2.0. Office of Transportation Operations, Federal Highway Administration. Page 67.

[3] FHWA. 2000. Operational Concept Description, Surface Transportation Weather Decision Support Requirements, Version 2.0. Office of Transportation Operations, Federal Highway Administration. Page 70.

3.5 Get copies of the Manuals of Practice or other guidance documents specifying established maintenance practices in each state

A second component in understanding maintenance from the state DOT's perspective is to read and understand maintenance practices that are either mandated or recommended within each state. Meridian will work with the champions in each state to acquire the critical documents used within each state to guide maintenance practices.

STATUS: Completed

The following list of documents represents those materials provided by the states in response to a request for documentation of each state's Policies and Practices sent out on January 13, 2003..

AGENCY	DOCUMENT	CONTENT
INDOT	Total Storm Management Manual	• Administrative management • Environmental issues • Personnel issues • Equipment • Snow & ice control materials • Weather information systems • Storm operations • Special considerations
IADOT	Snow and Ice Control Instructional Memo 8.010	General guidelines
IADOT	Snow and Ice Control Instructional Memo 8.030	Preparations for winter
IADOT	Snow and Ice Control Instructional Memo 8.100	Snow and ice removal operations
IADOT	Snow and Ice Control Instructional Memo 8.400	Chemical and abrasives
MNDOT	Maintenance Manual	• Snow and Ice Formula • Winter Plan of Operation • Equipment • Materials • Road Condition Reporting
MNDOT	Maintenance Bulletin No. 99-1	Winter Rescue Law clarification
MNDOT	Maintenance Bulletin No. 02-1	Non-Interstate Road Closure, Operations Manual
MNDOT	Guidelines for Anti-icing (Electronic Copy)	• Mn/DOT Anti-icing Guidelines • References • Chemicals
MNDOT	Bare Lanes (PowerPoint presentation)	Pictorial of bare lane and non bare lane observed states
MNDOT	Application Rates Guidelines (PowerPoint presentation	Series of guidelines for various chemicals and weather situations
MNDOT	Maintenance Manual – Snow and Ice Control Guidelines	Operation guidelines for snow and ice control and clean-up operations
NDDOT		
SDDOT	Policy Letter OM-1996-04	Reassignment of equipment during winter storms
SDDOT	Policy Letter OM-2002-06	Winter Operations Priority One Routes
SDDOT	Performance Standard 2501	Drift prevention
SDDOT	Performance Standard 2524	• Plowing • Sanding
SDDOT	Memorandum #10	RWIS utilization guidelines

The materials received represent a broad spectrum of detail on maintenance practices. The following table summarizes the materials received. The MATERIALS column indicates the type and volume of information in the pieces of documentation received; the VALUE column provides an estimate of the value of the documentation in assisting the project investigators to more fully understand the specific needs of personnel in each of the member states (10 = extremely valuable, 0 = minimal value); and the COMMENTS column lists reasons for the value specified.

AGENCY	MATERIALS	VALUE	COMMENTS
INDOT	Single maintenance summary document, 164 pages in length	10	Complete, well written, descriptive, well illustrated
IADOT	Four instructional memos, each 3 to 5 pages in length	5	Incomplete documentation of winter maintenance guidance
MNDOT	Maintenance manual & update (~ 50 pages), bulletins on related policies, support presentations	10	Complete, well written, descriptive, well illustrated
NDDOT	None	0	Guidance documentation available in Grand Forks & Fargo offices (per interview discussions); have requested documents from these participants, but have not received yet
SDDOT	Two policy letters and two performance standard documents, each 1 to 3 pages in length	3	Incomplete description of winter maintenance guidance

3.6 Read through these documents and extract the formal maintenance procedures from each state

The investigators will read these documents and create a summary of practices that will need to become part of the MDSS decision logic.

STATUS: In process

Although there was a wide spectrum in the amount of information provided by the five states, the content within the separate documents did cover several specific topics. Typically, these topics included information that could be classified into the following categories:

- administrative issues
- safety considerations
- emergency response requirements
- traffic control responsibilities
- level of service obligations
- chemicals – storage, characteristics, application rates, , special guidelines
- equipment – type, use, maintenance, and operational regulations
- communications and reporting events from the field
- crew scheduling procedures and personnel issues
- weather information resources
- response guidelines for specific weather situations

The information from Indiana and Minnesota was extremely helpful and served as the basis for the development of the interview questions. The investigators found the material from these two states quite comprehensive and at times specific guidance or recommendations a bit difficult to assimilate. During the initial interviews, DOT personnel made comments regarding topics or operational instructions that helped shed light on the material in the documentation that seemed fuzzy. The documents have become resource materials and since the start of the interviews, the investigators often return to the maintenance documents to confirm and/or solidify topics covered in the interview discussions.

3.7 Classify the needs assessment requirements into information classes

In order to structure the questions and discussions, the investigators will create an outline revolving around the key elements defined in the documents listed in sub-tasks 3.4 through 3.6. This outline will become the framework for the development of questions and topics for discussion.

STATUS: Completed

During the Technical Panel conference call on March 31 Bob Hart presented a document on Needs Assessment for maintenance personnel. The document laid the infrastructure for the approach Meridian selected to extract information from the STDWSR research and the maintenance documentation provided by the states. Meridian chose to view the DOT needs as a response to the needs of its constituents or customer base – those individuals who use the state's highways for commerce, business, or personal travel. Interactions with DOT maintenance personnel involved in daily operations indicate that routine maintenance responses are often modified to address specific needs of the traveling public. To assure the MDSS design retains the flexibility to address these extraneous influences, Meridian felt it was important to address these factors from the beginning of the design. The needs of the travelers were summarized into seven categories:

- Mobility
- Safety
- Access to personal services
- Convenience
- Aesthetics
- Limited environmental impact
- Infrastructure

The two dominant factors are mobility and safety.

Meridian's analysis evaluated the maintenance action or actions necessary to resolve unmet traveler needs or to assure the stated need remained satisfied. These actions are the maintenance response scenarios that form the core of the maintenance decision support system. The purpose of MDSS is to assist in the selection of the correct response action and to assure the action is executed in the most efficient way to meet the travelers need.

Each maintenance action is affected by a number of external factors that the maintenance provider must evaluate in order to execute the response action in the appropriate manner. For example, to plow and treat roadways, the DOT maintenance operator/supervisor needs to know information about the availability of personnel resources, the status of available equipment, chemical resources, road conditions, weather conditions, weather forecast (tactical and strategic), DOT policies, local DOT practices, route variability, social issues, etc. These are the needs that affect maintenance decisions. It is imperative that these needs are modeled properly in the MDSS in order to recommend the best response options.

Based upon this needs assessment evaluation and the summaries of the state maintenance documentation, Meridian separated the DOT needs requirements into seven separate categories:

- Level of service
- Materials
- Equipment
- Road reporting
- Scheduling
- Weather
- Winter weather scenarios

Each of these categories was composed of a number of sub-categories and for each sub-category there were a list of potential DOT needs.

3.8 Create a set of questions to expand the needs assessment done by the FHWA and/or redirect the survey to capture needs not necessarily viewed from a meteorological perspective

Using the FHWA questions used in Minnesota and Iowa as part of their FFP tests and the needs assessment from the literature review, Meridian will create a set of draft questions and discussion issues. These questions and discussion topics will be forwarded to the DOT champions for review. Based upon feedback from the champions, Meridian will compose a final set of questions and discussion topics. One key emphasis Meridian wants to include is the consideration of user needs that are not specifically weather related. These topics are an important component of the MDSS and may have received insufficient consideration in development of the FHWA MDSS FFP.

STATUS: Completed

Meridian evaluated the categories and the associated needs developed under Task 3.7 and prepared a series of questions in each of the categories. The question set also contains a set of “introduction” questions designed to determine the background and experience of the individuals involved in the interview. The series of questions is included as Appendix E. The original intent had been to formally send the questions through a technical panel review. From experience with Tasks 1.1 and 1.2 that process was replaced with a test run of the questions that was done on May 1 in Indiana. This trial run proved successful. In addition, the principal investigator had been involved in a similar interactive process with the leads for the RWIS program in Iowa and had developed a similar set of questions for a review of the forecast service in Iowa during this past winter. Using these experiences, Meridian opted to use the set of questions developed by Bob Hart. The following table indicates why the categories were selected and how the information within the category will figure into the design of the MDSS.

CATEGORY	**WHY**	**EXPECTED USE**
Level of Service	• Determines maintenance outcome • Determines extent of effort • Specifies response by route • Defines travelers expectations	• Influences crew allocation • Influences route return time • Impacts type of material • Influences application rates • Impacts selection of equipment
Materials	• Chemicals reduce freeze point of ice • Chemicals prevent ice bond to road • Chemicals keep snow/ice workable • Chemicals aid return to bare road • Chemicals minimize frost potential • Chemicals are a maint. tool; inventory management is an important factor • Grit aids traction • Works with traffic to minimize effect of snow and ice	• Analysis of chemical concentration at any point in highway system • Feedback to road condition processing module • Determination of percent ice in slush to assess workability of slush • Analysis of frost potential • Analysis of traction index • Evaluation of the effect of different chemical combinations • Assessment of adverse treatment response • Assessment of residual chemical
Equipment	• Essential for removal of snow & ice • Essential for application of materials • Number & type of vehicles, plows, & applicators determine response time to LOS requirements • Serves as mobile communication hub	• Analysis of plowed conditions at any point in system • Feedback to depth of layer as part of road condition processing • Input into route cycle time • Input into a routing module to assess optimal use of limited equipment • Input into an equipment servicing module to assess return to service time for inoperable equipment
Road reporting	• Essential for ground truth of road condition • Depth of snow/ice/slush layer essential for MDSS model	• Reset initial surface conditions for any point in road condition processing module • Adjusted surface condition impacts chemical concentration, assessment of slush content, traction index, residual chemical • Provides input into traveler advisory services
Scheduling	• Policies dictate potential use of crews • Availability of individual crew members impacts all operations • Scheduling and activating crews is major supervisory activity • Performance levels dependent upon having experienced crew available at critical times	• Input to a crew scheduling module • Scheduling module will integrate local policies and practices that affect labor • Scheduling interacts with decision support timing which feeds back to road condition, equipment, & materials modules • These feedback mechanisms create a looped feedback that, in turn, affects the scheduling module
Weather	• Weather is a forcing function that impacts nearly all modules in MDSS	• Primarily affects the road condition module which then impacts the forecast component of nearly every other module in the MDSS design
Winter scenarios	• Scenarios permit integration of all the above components into a cohesive	• Scenarios are a synthesis process that affect differing modules

	plan of action • Scenarios point out which impacts and response activities are most important • Scenarios draw out the exceptional situations that require special treatment rather than the routine situations	throughout the MDSS • Scenarios will permit the investigators to gain a better understanding of how the modules/components of MDSS must work together as a cohesive package • Scenarios will highlight critical local events that need particular attention in the design and development of particular modules

3.9 Define an interview strategy or a query technique that permits Meridian to assess the priority of different needs

The design of the MDSS must focus on satisfying or resolving the dominant needs affecting maintenance practices. Addressing these dominant needs must become the highest priority in the resulting decision support system. It is essential that the query schema be structured to define the key elements and rank these elements based upon their influence on maintenance decisions.

STATUS: Completed

Meridian decided to utilize professional guidance in the selection of the appropriate investigative technique. Kathy Osborne took the lead on this program and did some background research on the potential methodologies. The primary resource in her survey of techniques turned out to be Brenda Badman, Marketing Consultant for the Center of Innovation in Grand Forks, North Dakota. Ms. Badman reviewed the intent of Tasks 3, 4, and 5 and recommended the interview technique as the most appropriate for Task 3 and stressed that the focus of the interview questions must be pertinent to the audience (the person being interviewed). The one difficulty with the interview process is the lack of an absolute metric to assess the relative importance of user responses. Following discussions, it was decided that the primary intent was to permit flexibility in the discussions and allow DOT personnel to highlight issues that were important to them. This focused the intent of the interview process on more general topics with the latitude to allow the interviewees to direct the emphasis of the talks. The selection of this investigative process puts considerable pressure on the interviewer or the interview team to capture the content of the discussion. The metrics are more subjective in this format and derive from capturing the recurring issues raised by the DOT personnel. Interviewers must not only capture the issues but be cognizant of the individual raising the issue and what position in the organization this individual fills. Where permissible, Meridian has opted to record the interviews and then extract the data at a later time.

3.10 Define what methodologies are needed to acquire the information required for this study (interviews, dialogues, case study reviews, experiential, ….) and determine the time necessary to execute each option

Using the investigation modes from Task 1 and the detail generated in the Task 3 sub-tasks preceding sub-task 3.10, Meridian will formalize the interview process and clarify the timeframe necessary to achieve the objectives within this process.

STATUS: Completed

The questions Meridian developed under task 3.8 were worded to address the interests of the audience and allow the interviewer to try to extract as much detail from the interviewees as possible. It was also hoped that the questions that were chosen would entice DOT participants to take the lead in the discussions and relate their experiences. The questions were more of a road map for anticipated discussion topics than a series of specific queries that needed specific answers. Unlike the questions in the Task 5 survey, the question set was more open-ended. The questions sought concepts and specific procedural approaches rather than specific yes-no or fill in the blank type responses.

Excluding the test run in early May, the initial set of interviews in each of the five states need to be completed before the first week in August. Interviews were completed in North Dakota and Indiana during June.

3.11 Organize the data acquisition components into a draft inquiry document and circulate this document to the state coordinators for critique and revisions

Meridian will create a formal plan describing the information it expects to retrieve from the state DOT participants. Meridian will send this document to the MDSS champions and solicit feedback on the content of the plan.

STATUS: Completed

Based upon the decision to forego a formal review process as discussed in Task 3.8, this task is considered complete. The task definitions in the original plan were defined in considerable detail to make sure that the development process was as complete as possible. Some of the sub-task series were proposed in too great of detail. The sequence of sub-tasks from 3.7 to 3.12 is one of those series. Further, the original Phase 1 plan was originally intended to be close to a year’s duration. The original plan also did not adequately anticipate the time it would take to get Technical Panel approval on a number of tasks. Schedule compression associated with the official start of the project in November and the poor estimation on the duration of certain tasks has added further compression into the later portion of the schedule. These factors all played into the decision to by-pass the approval loop for the question set and move directly to the interviews.

3.12 Formulate a final data acquisition plan

Based upon the feedback from the state DOTs, Meridian will create a final document.

STATUS: Completed

As with 3.11 the question set was completed without task 3.12.

From the initial interviews, the vision Meridian originally held has changed somewhat. Meridian originally viewed the interview process as the essential component of the information gathering process. It was anticipated that the interviews would permit the investigators to extract the detailed information to aid the design of the MDSS architecture. However, the interviews held to date have been overview in nature and have only allowed Meridian interviewers to scratch the surface in most cases. Meridian will need to delve much deeper to extract the specific details necessary to create an effective MDSS.

The interviews have proven excellent in providing an overview of the essential elements that concern DOT personnel. In addition, the other real benefit of the overview interview process has been the opportunity to learn who the champions are amongst the field personnel. In many cases the states have already identified these individuals, but it is important for the Meridian team to meet these individuals first hand and attempt to establish a rapport for future interactions. The interviews to date and a couple of visits directly to unit garages in Indiana indicate that the plan will need to put greater emphasis on direct contact with a smaller number of champions and field representatives. Meridian initially felt that much of the material would come out of an interview procedure; it now appears that the MDSS requirement will take greater interface with individual users to permit Meridian to capture the detail necessary to build an effective MDSS. The other observation the Meridian team has made is the information resources exist in a hierarchal order. The base information (e.g., the maintenance manuals, local policies and practices, and published guidelines) are broad scale and relatively general, in nature. As the discussion moves toward the interests of the individual the issues become more complex. This increasing complexity is inversely proportional to both space and time. The result of this relationship is the MDSS design will likewise need to evolve in a similar hierarchal mode from a simplistic, highly parameterized approach to a gradually more complex, highly modularized solution.

Initial observations suggest the outcome of this series of tasks under Task 3 may become extremely important in understanding how the design within Phase 1 must move forward to (1) demonstrate progress is being made in the short term and (2) ultimately achieve the longer-term ultimate objective of MDSS. Those who have participated in the interviews have already indicated an enthusiasm to “try MDSS”. At the same time, participants were fairly adamant that they want MDSS to correctly address their critical local issues. The challenge will be to create an effective first pass at a fairly simplistic design level yet make sure the design is adequately well thought out to permit the addition of a number of sophisticated new components that address the user’s complex local issues.

3.13 Evaluate the level of effort to acquire information for Tasks 4 and 5 from the same group of DOT resource personnel required for this task

The entire Tasks 4 and 5 run parallel to Task 3. As the design of each of these tasks matures it is important that the requirements of all three tasks be merged into one inquiry.

STATUS: Task eliminated

As the project evolved it became obvious that the modes of investigation for tasks 3, 4, and 5 would not be the same; therefore the original supposition that the development efforts would be parallel efforts became invalid. Thus, this sub-task is no longer pertinent and the sub-task will be ignored as part of the development of the MDSS plan.

3.14 Layout the interview process and determine a schedule to collect the desired input

This step involves the scheduling process. Based upon the availability of the maintenance participants, the availability of the investigators, and the level of effort specified in the design document (sub-tasks 3.12 and 3.13), Meridian will develop a tentative schedule.

STATUS: In Process

The set of questions for the interview was completed and approved in May. Meridian projected that the interviews could be completed in June and early July. Scheduling conflicts amongst the interviewers made scheduling difficult in June. Interviews were done in North Dakota and Indiana but the other three states are in the process of determining when the interviews will work in their states.

3.15 Create a tentative schedule and get approval from the state coordinators

Meridian will organize the tentative schedule to exclude conflicts and inefficiencies in the investigative logistics. Once a tentative schedule is in place, Meridian will work with the state MDSS coordinators to confirm the schedule will work.

STATUS: Completed in North Dakota and Indiana; in process in South Dakota, Minnesota, and Iowa

As indicated in Task 3.14 it was necessary to permit flexibility in the scheduling process and work with each state coordinator individually to arrange interview dates.

3.16 Perform the interviews, calls, onsite studies, and other data gathering techniques developed as part of the data acquisition plan

The investigators will perform the study prescribed by the plan.

STATUS: Initial interviews completed in North Dakota and Indiana

Interviews were completed in North Dakota and Indiana. North Dakota sent two individuals from the Grand Forks district and two individuals from the Fargo district to participate in a joint interview. The interview was done June 12 in Grand Forks. Indiana provided the facilities for two separate interviews. The first was done in the Monticello sub-district office on June 24 and involved 12 INDOT staff members primarily from the Monticello sub-district or the LaPorte district office. The majority of the participants were operations engineers or unit foremen. The second interview was held in Columbus, Indiana in the Columbus sub-district office on June 25. The group included 5 INDOT staff and was primarily the foremen for the sub-district unit garages.

3.17 Consolidate the information gathered from the various sources, perform any statistical analyses indicated in the design phase, and organize the data into a cohesive report.

Meridian will perform the first phase of the investigative study and summarize the results from the series of interviews, discussions, and phone conversations. As the study progresses or during the composition of the draft report, it may be evident that the investigators were unable to acquire certain pieces of information. These deficiencies should be noted.

STATUS: Awaiting unfinished interviews in South Dakota, Minnesota, and Iowa

3.18 Evaluate deficiencies and repeat sub-tasks 3.15 through 3.18 if necessary

The investigators with the assistance of the champions should determine if the draft evaluation has some weaknesses that need further attention. If it is determined that further interaction is needed, Meridian will propose a program to perform the follow-up investigation and coordinate the scheduling of the return visits.

STATUS: Awaiting evaluation in tasks 3.16 and 3.17

3.19 Distribute the draft report amongst the member agencies for critique

Once the investigators have completed their fieldwork, they will compose a draft report and send copies to each of the agencies for review. It is anticipated that the participating state DOTs will provide constructive criticism that will assist in the completion of a refined document.

STATUS: Awaiting completion of predecessor tasks

3.20 Modify the document to incorporate the comments from the member states and generate the final report

Meridian will rewrite the document based upon the feedback received from the states. The modified document will become the final report on needs assessment.

STATUS: Awaiting completion of predecessor tasks

TASK 4. ASSESS THE PARTICIPATING STATES' CURRENT AND NEAR-TERM CAPABILITY TO REPORT CURRENT ROADWAY CONDITIONS AND TRACK MAINTENANCE ACTIVITIES ON SPECIFIC HIGHWAY ROUTES.

Due to current relationships between Meridian and the pooled fund states in this project, much is already known regarding the states' current and near-term capability to report current roadway conditions and track maintenance activities. However, this information will be reviewed and summarized with an assessment of capability as it relates to the objectives of deploying MDSS in each state. Special consideration will be given to the states' individual abilities to monitor and report current road conditions, track treatment information, and gather verifying data upon which the MDSS effectiveness can be evaluated. Included in this assessment will be recommended actions and technologies that may facilitate improved reporting of roadway conditions and maintenance tracking activities. Subsequent action upon these recommendations and the enhancements they provide will be included in the design of the prototype MDSS. It is anticipated that states will differ in their capabilities and this variance will need to be accounted for in the MDSS design. This report will be presented to the Technical Review Board by Meridian for review and discussion at a Technical Panel meeting.

SUB-TASKS

4.1 Determine the appropriate contact to acquire information on the collection of current road conditions within each state and a point of contact to acquire current or proposed methodologies to collect information on operational maintenance activities

Meridian will work through the champion or Technical Panel point of contact to find the "expert(s)" within each state concerning road condition data collection and processing.

STATUS: Incomplete

Contact information has been developed for MNDOT, NDDOT and SDDOT. Outstanding at this time are points of contact for IADOT and INDOT.

4.2 Call or meet with each of the contacts and collect information on the road condition and maintenance tracking processes for that state

Where possible the communications with state personnel will be handled through telephone or electronic methods; however, some situations may require a face-to-face visit. The communications that take place will include descriptions as to how the information will be used and the limitations as to the re-distribution of any information that a state wishes to impose.

STATUS: Incomplete

A meeting was held with NDDOT and MNDOT on June 6, 2003 for the purpose of discussing another pooled fund study involving the use of road condition reporting data. Subsequent to this meeting discussions have occurred on potential methods of road condition reporting infrastructure development that might occur over the coming winter to provide Meridian improved access to road conditions information. Much of this effort is being leveraged from Meridian's 511-related activities in both states. A meeting was held on July 1, 2003 in Pierre, SD to discuss the ongoing development by Meridian of a new road condition reporting system for SDDOT.

4.3 Acquire any documentation on the processes of activity reporting

As the information is acquired it will be assimilated into a composite format with other states to facilitate reduction through analysis. The methods to be used will depend upon the general formats by which the information is presented to Meridian. It is anticipated that simple database or spreadsheet methods will be used such that queries can be supported for analysis purposes.

STATUS: Incomplete

The database schema developed by Meridian for the SDDOT will be used as a baseline for evaluating the detail of road condition information available for each of the participating MDSS states.

4.4 Determine the appropriate contact to acquire information on the communication infrastructure (existing and proposed)

The individual responsible for the communications or who is most knowledgeable is probably not the same person who understands the road condition data collection process. Thus it is important to find the proper communications or IT person who oversees this area or better yet understands the detail involved in the communications process.

STATUS: Incomplete

This activity has been on hold pending the Technical Panel meeting on July 10, 2003. As the topic of information technology is often a sensitive issue, it has been deemed most appropriate to discuss the coordination of this activity in a face-to-face meeting where a strategy may be developed to ensure that contact with the most appropriate state IT personnel can be established.

4.5 Call or meet with the contacts to understand the existing and/or proposed communications architecture within each state

Effort will identify communications protocols within the data flows and identify the hierarchy of the data transfer through the state system. It will also address the potential barriers to the flow of information within the system.

STATUS: Incomplete

This task is awaiting the completion of Task 4.4.

4.6 Define the specifications of the maintenance data required to support the different levels of MDSS processing

This specification is driven by an internal requirement within the MDSS processing scheme. The primary component driving the demand for operational maintenance information is the Pavement Forecast System functional component. For example, the chemical concentration module with the Pavement Forecast System requires an accurate assessment of the chemical added at a specific point along a highway, the amount of precipitation added to the surface mixture, and any plowing action that took place at the location.

STATUS: Incomplete

At the recent FP MDSS meeting in Des Moines, Iowa underscored the critical importance of obtaining quality high spatial and temporal resolution maintenance data for a successful MDSS. The specifications of the data required to support MDSS processing are only now being fully addressed. However, early results of this investigation indicate that none of the participating states presently exceed the optimum data volume required to fully support comprehensive MDSS processing. Thus, the effort has evolved into an identification of the minimum level of maintenance data required as the primary emphasis of the investigation. This analysis is anticipated to be complete by late July 2003 with a summary report to be included in the next quarterly report and in the draft final report.

4.7 Define the difference between existing data acquisition capabilities and the MDSS requirements

This effort will permit each state to assess the potential need for additional resources to collect, process, and distribute data required for the MDSS.

STATUS: Incomplete

This effort is awaiting the outcome of Task 4.6.

4.8 Recommend modifications in procedures, data acquisition platforms, and communications infrastructure that would close the gap between existing capabilities and MDSS requirements

This effort will prepare the necessary data elements, system specifications, personnel requirements, etc. that are necessary for developing the MDSS. The results of this sub-task will be summarized in the sub-task below.

STATUS: Incomplete

This effort is awaiting completion of Task 4.7.

4.9 Prepare a draft report for each of the states and distribute the draft to each of the states for review

The report will assess potential steps the state might take to acquire the type of data necessary to effectively compute the pavement conditions at any point along the highway.

STATUS: Incomplete

This effort is awaiting completion of Task 4.8.

4.10 Modify each of the state reports to include the state comments and consolidate the individual state reports into a final capabilities report

Upon completion of a review of individual states an aggregate report will be prepared that is a consolidation of the individual state reports. This final capabilities report will highlight similarities and differences between states and will serve as a fundamental basis for the prototype development design considerations.

STATUS: Awaiting the completion of Task 4.9 and the appropriate state review.

TASK 5. ASSESS INSTITUTIONAL RECEPTIVITY TO MAINTENANCE MANAGEMENT DECISION SUPPORT IN THE PARTICIPATING STATES AND RECOMMEND ACTIONS TO OVERCOME POTENTIAL BARRIERS.

The implementation of MDSS will constitute a significant paradigm shift in maintenance management practices and how information is conveyed across a state's information infrastructure. This will result in an opportunity for opposition from groups and/or individuals who either do not welcome such a shift in methods or from groups who believe the information infrastructure might be compromised. The extent to which these restrictions to MDSS reception exist will be assessed by Meridian through engaging in discussions and meetings with important stakeholders in each state. These discussions and meetings will address issues ranging from a general overview of receptivity within a state's maintenance infrastructure to the identification of issues associated with costs and the specific cause of receptivity. In order to successfully complete this task, it will be the responsibility of the state DOTs to provide assistance to Meridian in establishing the required contacts and introductions to these stakeholders including assistance in identifying critical points-of-contact. Upon completion of an assessment of possible institutional barriers to maintenance management decision support, Meridian will provide a summary report that not only identifies level of institutional receptivity, but also provides potential barriers with recommendations for mitigation. The subsequent action upon these recommendations will be used in the design of the prototype MDSS. As in the previous task, it is expected that the level of receptivity will vary by state and possibly within a given state. As a result, special considerations may be necessary to provide MDSS customization on a state-by-state basis. This summary report will be provided collectively for all participating states and supplied to the Technical Panel.

SUB-TASKS

5.1 Define the techniques desired to acquire personal views regarding MDSS and its impact on operations

The desired information is subjective in nature and needs to be acquired using techniques different from those incorporated in Tasks 3 and 4. Meridian will contact a research organization at the University of North Dakota that specializes in this type of survey. Meridian will define those techniques that have proven effective in the collection of subjective data.

STATUS: Completed

Research into the different styles and methods of designing, conducting and analyzing surveys ranged from searching the internet (Creative Research Systems at www.surveysystems.com and StatPac Survey Software at www.statpac.com) to personal interviews with staff at the Center of Innovation, Della Kapocius, Grant/Research Consultant, and Brenda Badman, Marketing Consultant, who have designed, reviewed and/or conducted surveys to Dr. Robert Tangsrud, Assistant Professor at the University of North Dakota in the Department of Marketing. Dr. Tangsrud provided information in the general sense of market surveys as well as providing a textbook titled "Market Research by Alvin C. Burns and Ronald F. Bush". Published by Prentice Hall, 1998 – ISBN -0-13-896606-0, 661 pgs.

Within this research it was emphasized that the questions must not show bias or in any way attempt to direct the replies given. The approach would have to be consistent using similar the phrasing of the questions and procedures for acquiring the answers, particularly in how the recipient is asked to tally or mark their responses. Some may be ranked on a scale of 1-10 giving a description on each end of the ranking as to the inference. Other questions would provide a list of entries to be ranked from most to least importance. For all questions, wording and style were constructed with this in mind.

Using the resources listed above, the following elements were used within the design and delivery of the survey for Task 5:

- Goals & Objectives – which were already defined within the scope of Task 5;
- Methodology – timing and possible lack of internet access indicated that the best method of delivery would be through the mail. This required that recipient names and addresses be provided by each state;
- Target audience – this would be determined by each state;
- Length of survey – research showed that normally shorter surveys receive a better percent of return but if the topic is deemed of importance to the surveyed, they will take the time and effort for a longer survey. For the Task 5 survey the number of questions and the style in which the responses were requested evolved into three page survey;
- Questions – needed to be focused on a single issue or topic, be fairly brief, clear and concise and not open to multiple interpretations, use core vocabulary of the audience, and be grammatically simple sentences;
- Confidentiality – it was determined that this would be accomplished by assigning an identification number to each survey that would in turn relate to the individual completing the survey. Meridian will maintain this list. The

survey responses will be tabulated and then individual surveys will be destroyed since the analyses will be conducted on the whole population, and not the individual responses;
- Approval by the technical panel; and
- Production/delivery – this must be perceived and represented in a fashion that tells the survey recipient that the survey is important enough to warrant his or her response.

Meridian will tabulate the answers from the returned surveys and present the results in a final report.

5.2 Create a survey instrument to capture the personal views of maintenance personnel regarding MDSS

Based upon the prospective techniques Meridian will select the most appropriate information gathering technique and develop a survey to capture user feedback.

STATUS: Completed

Using the information gathered in Task 5.1, the survey was created. There were multiple modifications and reviews of the document within Meridian before the first draft document was shared with ND and SD Panel members at a meeting on February 21st. Information to be gathered included how decisions were derived, levels of computer interaction, policy and procedures guideline usage, and perceived needs.

Requests from the Technical panel were made three times for review of this document (April 8th, April 21st, and May 27th) with stated deadlines for responses to be returned. After the deadline of May 29th passed, it was assumed incorrectly that the survey met the approval of the Technical Panel. Due to this assumption, the survey was distributed to the ND list of recipients on June 5th. After which, notification was received that the survey did not meet approval by all. At this time Dave Huft, Bob Hart, and Leon Osborne redrafted the survey where most of the intent was the same but the presentation and request mechanisms differed a bit from the survey that was distributed to ND. It was determined that the content did not differ enough to warrant resending the survey and taking a chance of offending the survey recipient by requesting them to redo the survey.

A copy of the final survey is attached as Appendix F.

5.3 Define an interview strategy or a query technique that permits Meridian to assess the priority of different concerns or benefits of MDSS

It is anticipated that this effort will require involvement of personnel within a state's maintenance division and beyond a state's maintenance division. External involvement will likely include personnel from state communications agencies and information technology agencies. As a result it will be necessary to closely coordinate Meridian's work with project Technical Panel members to ensure that a *coordinate request for information is made that meets with state protocols for requesting information.*

STATUS: Completed

Since maintenance tasks cover a wide scope, it was determined that we would need to have some demographics about the individual who was completing the survey. With confidentiality being a factor, the main demographics that were needed were district/region or sub district, job title/position, number of years of experience, and age. Knowing a job title or position only addresses the job description in a general sense; therefore, it was necessary to request the job descriptions from each state.

5.4 Define what methodologies are needed to acquire the information required for this study and determine the time necessary to execute each option

Meridian will select the methodology that is most likely to permit the accurate collection of information regarding users' views of the MDSS program. Once the methodology is selected Meridian will estimate the time it will take to acquire the information for the state DOT users.

STATUS: Completed

Several requests have been made via the reflector email site, as well as by telephone, for mailing lists of DOT staff who should participate in this survey. At the present time, only three states have had surveys distributed (ND, SD and IN). Six hundred and twenty-five (625) surveys have been mailed out to date. Fourteen (14) out of twenty-eight (28) surveys to ND have been returned. One hundred twenty (120) out of three hundred thirty-one (331) of SD surveys have returned, with a return by date of July 3rd. Fifty-five (55) out of two hundred sixty-six (266) have been returned for IN with a return by date of July 7th. The return rate is at approximately one-third of what has been mailed out.

Using the above returns, it appears that three to four weeks turn around from the time the survey is mailed is when one can expect to see most if not all of the returns expected.

5.5 Organize the data acquisition components into a draft inquiry document and circulate this document to the state coordinators for critique and revisions

Meridian believes it is important to obtain state DOT feedback to assure that the instrument does not cause any negative response to the inquiries themselves. The states recognize sensitive areas and they can guide Meridian from asking questions that the state or user may deem to be inappropriate.

STATUS: Completed

The first draft of the survey was circulated internally (Meridian) on February 17th with the revised draft being shared with some Technical Panel members on February 21st. On April 8th the survey and cover letter were sent through the reflector site for review and modification suggestions requested. On April 23rd, the documents were sent to the reflector site for a decision to accept the documents as presented. Requests for review of this document were sent again on May 27th by Dave Huft with modification deadlines of May 29th.

5.6 Formulate a final data acquisition plan

Based upon the feedback, Meridian will develop a final data acquisition plan. An interview guideline document will be prepared by Meridian comprised of the elements from the previous sub-tasks to be used in performing the information collection process. The interview guideline will require review and approval by the Technical Panel as well as their assistance in the implementation of the guideline in each state.

STATUS: Completed

Based upon the comments received, modifications to the survey were incorporated. The process of survey production and distribution included printing of the surveys, mailing labels (specifically designed with no reference to Meridian or any of the participating states) and the mailing of individual surveys or packets of surveys to Operation Foremen. Surveys were distributed within one day from the receipt of the mailing lists. 28 surveys were mailed to ND recipients on June 5th. 331 surveys were mailed to SD recipients on June 18th. 266 surveys were mailed to IN recipients on June 20th.

All surveys were identified with a unique identification number and each number was recorded. Each survey was provided with a postage paid, pre-addressed envelope in which to return the completed survey. With the exception of ND surveys, there was a “Return by” date included.

5.7 Capture the desired information as part of the interview and data acquisition plan in Task 3

Meridian will integrate the questions relating to receptivity into the material on user needs and collect the information concurrent with the information for Task 3.

STATUS: Collection method modified

A data reduction and analysis plan has been developed to collate the information gleaned from the interviews. This method involves the classification of information by question category and the summative responses received during the interview. While a subjective classification of the information will be performed, it is believed that a consistency will be achieved, as the interviewers will be the same individuals throughout the interview process

5.8 Consolidate the information and organize the data into a cohesive draft report.

Upon completion of the interviews by the investigators, the responses related to receptivity will be compiled and synthesized into a summary report.

STATUS: Awaiting completion of survey

Task activity is awaiting return of surveys and completion of interviews

Tabulation of the data is only a small portion of analyzing the information returned on the surveys. Discussions with the consultants from the Center of Innovation, stressed that we would need to look at the returns in respect to the percentage of returns, the quality of the answers (i.e. were instructions followed or all questions answered?), open comments, and job title or position of the surveyed.

5.9 Distribute the draft report amongst the member agencies for critique

The summary report in the previous sub-task will be distributed to the appropriate Technical Panel members for review and comment.

STATUS: Awaiting completion of survey

Awaiting completion of Task 5.8.

5.10 Modify the document to incorporate the comments from the member states and generate the final report

Upon review of the Technical Panel, modifications will be incorporated for inclusion within the final report.

STATUS: Awaiting completion of survey

Awaiting completion of survey and draft report preparation.

TASK 6. BASED ON RESULTS OF PREVIOUS TASKS, PROPOSE IN A TECHNICAL MEMORANDUM TO THE PROJECT'S TECHNICAL PANEL THE HIGH-LEVEL FUNCTIONAL AND USER REQUIREMENTS FOR AN OPERATIONAL MAINTENANCE DECISION SUPPORT SYSTEM AND PROPOSE AN ARCHITECTURAL FRAMEWORK FOR THE SYSTEM. SEPARATELY IDENTIFY THOSE REQUIREMENTS THAT CAN BE IMMEDIATELY SATISFIED AND THOSE THAT WILL REQUIRE FUNDAMENTAL RESEARCH.

The creation of a comprehensive and fully functional Maintenance Decision Support System is a substantial, multi-year project. However, the development process is modular and fits well into a structural development pattern. That is, each of the core elements discussed in the Development Plan has a core infrastructure that provides the basic user tools. Once this infrastructure is in place, the MDSS capabilities grow through the addition of modular enhancements.

Meridian has already created the infrastructure for the Weather System, Pavement Forecast System, and Delivery and Display System. First year enhancements to these three components of the MDSS will positively impact the forecast accuracy limitation highlighted in the Background section and improve the way the maintenance user interacts with the volume of weather and pavement information. Thus our first MDSS objective should be to do a better job of integrating the road condition and weather information onto one display device. The second immediate objective is to start building the infrastructure of *the DOT Operations and Control System and the MDSS Decision Logic System to support the longer-term development effort.*

A reasonable basic prototype MDSS is expected to include:

- *A state DOT data collection system that feeds "current conditions and operational states" to the pavement forecast model;*
- *A scenario based, maintenance decision logic system;*
- *A verification system for forecasted pavement and weather conditions;*
- *An alarm and alerting system;*
- *Forecasts of weather and pavement conditions updated hourly;*
- *The first phase of an operational chemical concentration model;*
- *Well defined data exchange formats between MDSS components and the external environment; and*
- *An initial graphic user interface for test and evaluation.*

The prototype MDSS will include a detailed architecture that includes module interfaces and their protocols plus data flow diagrams documenting what data is required and where it most appropriately is used within the MDSS.

The development approach beyond the basic prototype needs to follow a project management cyclical decision process that includes these stages: operational experience, user feedback, routine assessment and evaluation, group recommendations, and acceptance of the next stage development document. Following this approach, the group can determine – through experience – what works effectively and what deficiencies warrant the most attention.

Some MDSS modules or elements will require additional development time due to complexity in design/development and/or the need for additional research before the element can provide value in the MDSS environment. Meridian is already anticipating certain core technologies that must be substantially developed before numerous desirable functionalities of the proposed MDSS can even be evaluated. Meridian will identify these technologies during the initial meeting (Task 1), at which point it will seek the Technical Panel's approval to commence immediately with their development (so as not to unduly delay the deployment and evaluation of other features of the MDSS). Aside from these core technologies, Meridian will identify the remaining elements of the MDSS and clearly state which elements can be satisfied immediately and which will take longer to develop. A specific timeframe for implementation and/or development will be provided for those that can be immediately satisfied. A best approximation for the longer-lead requirements will be provided in order to assist the Technical Panel in prioritizing their scheduling for development and/or implementation.

SUB-TASKS

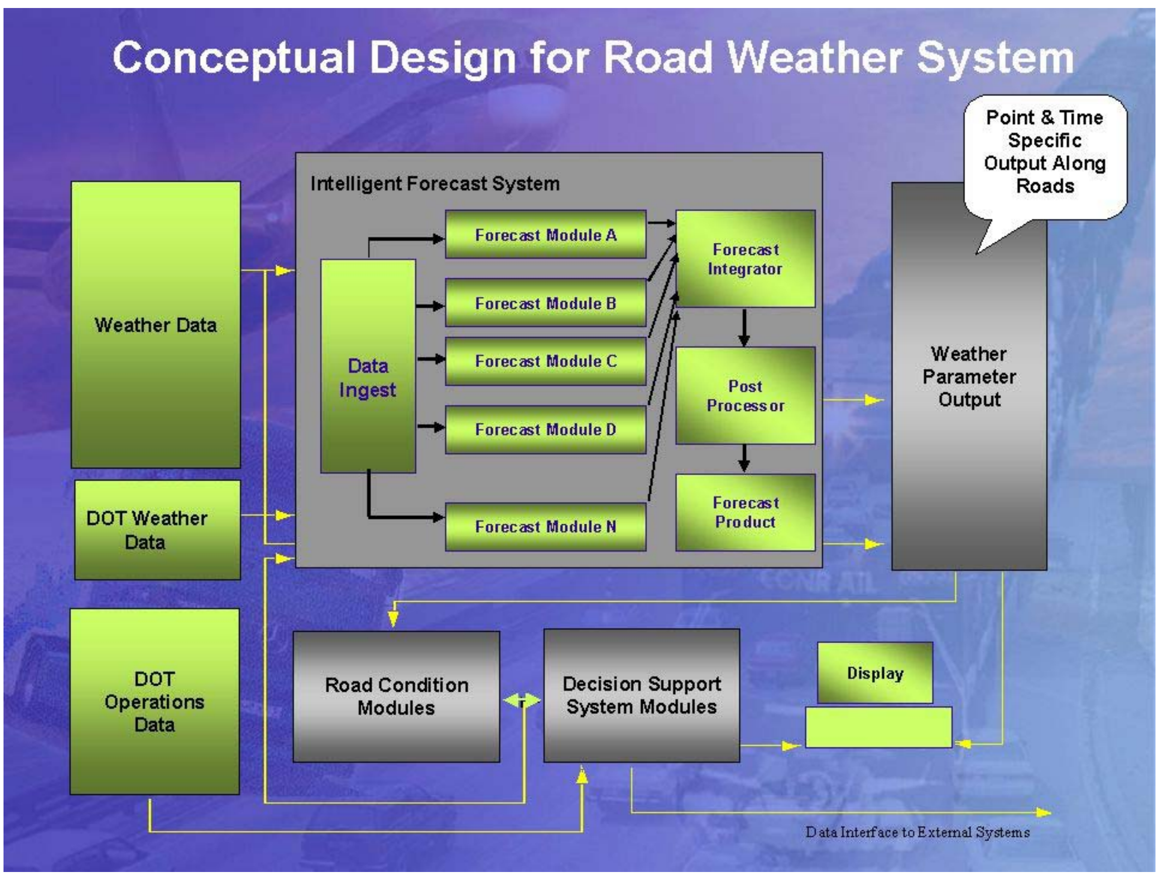
6.1 Define the basic functional infrastructure of the MDSS

Meridian presented a discussion of the functional infrastructure in a white paper presented during early discussions of the MDSS. That paper, and Meridian's review of the federal functional prototype, will become the basis for a revised discussion of MDSS.

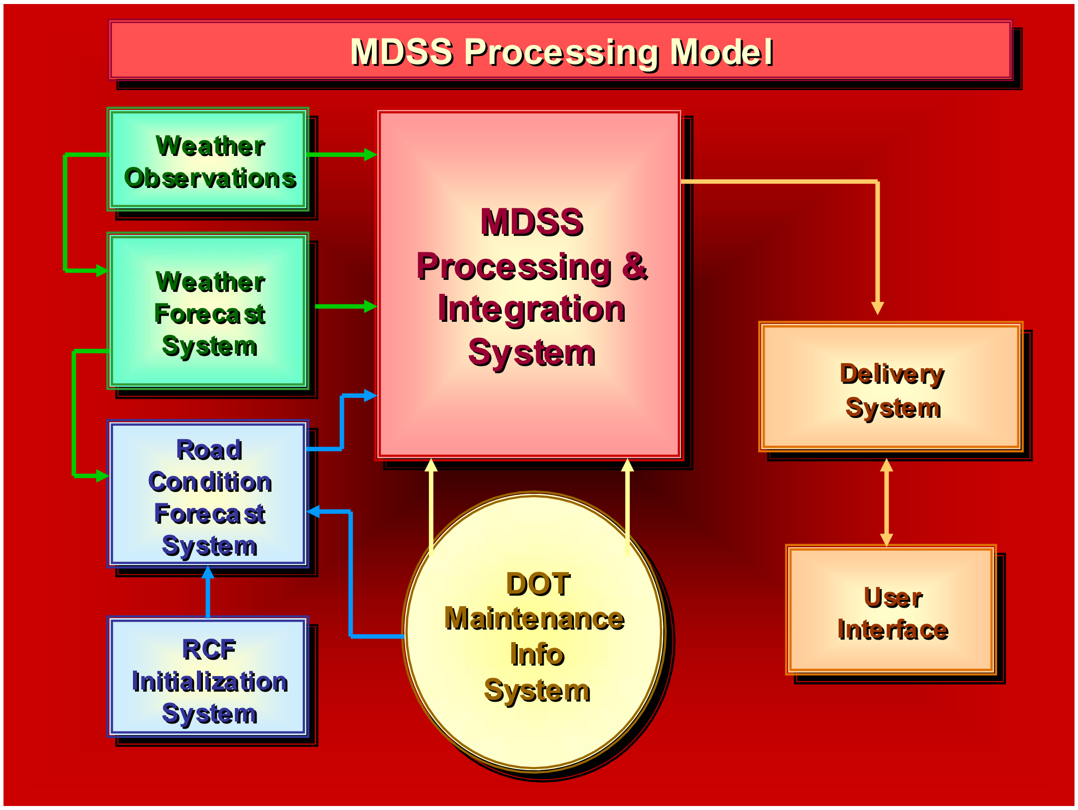
STATUS: Complete

The components of the functional infrastructure discussion are the original white paper, the review of the FHWA functional prototype, and an analysis of the natural logic necessary to transfer maintenance requirements and actions to components of the MDSS architecture. The white paper is included in this report as Appendix H and the review of the FHWA functional prototype was discussed under Task 2.4.

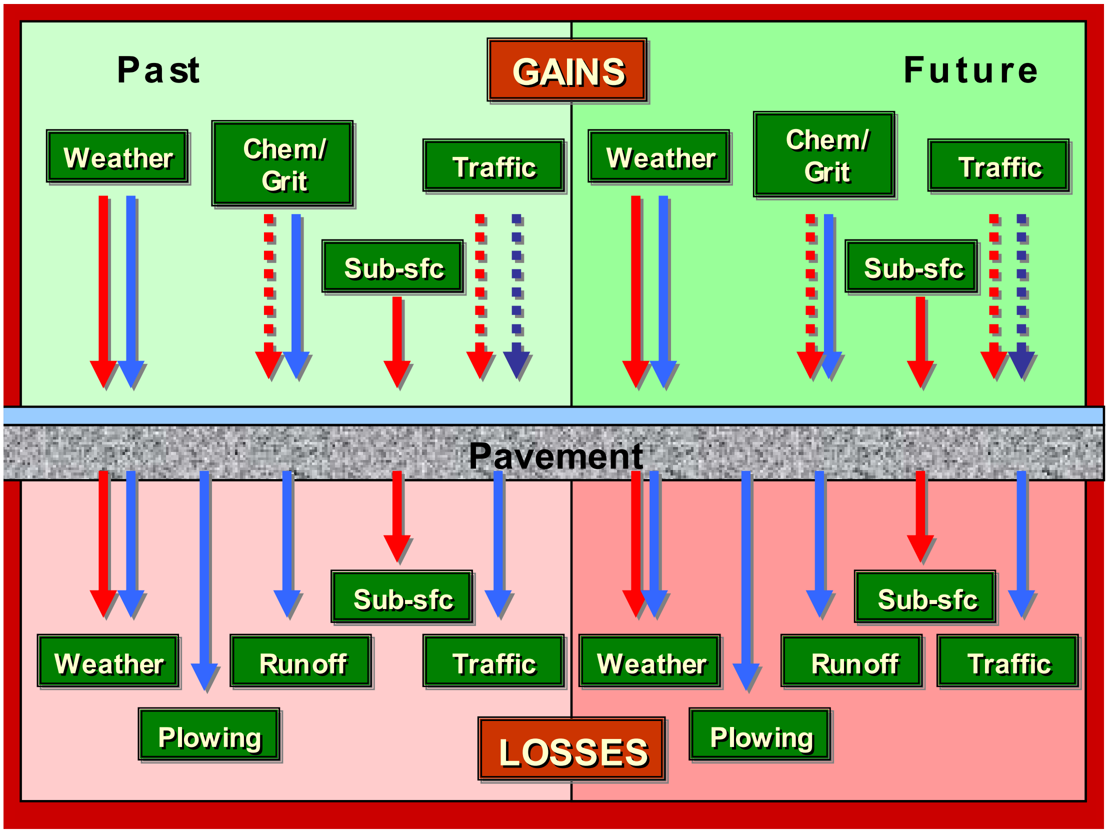
The fundamental architecture of the FHWA functional prototype and the pooled fund study design are structurally quite similar. The conceptual design of the functional prototype taken from the MDSS FP Project Description webpage (www.rap.ucar.edu/projects/rdwx_mdss/mdss_description.html) lays out the functional design in the following manner.



The pooled fund study functional overview organizes the same functions in the following diagram.



The color codes in the pooled fund study diagram represent the five fundamental functional components of the MDSS. These five components exist in both approaches. The basic difference between the two approaches lies in the internal design in the Weather components and the Processing and Integration component of the decision support system. In the design of the Weather component the functional prototype uses a totally automated ensemble forecasting technique; Meridian uses a similar weather forecasting technique but modifies the weather forecast outcomes using the expertise of professional meteorologists. In the design of the Process and Integration System the functional prototype uses the FHWA Rules of Practice to generate the appropriate response scenario. The fundamental processing scheme is weather information as input, determine the appropriate response based on previous maintenance experience (Rules of Practice adjusted to local policies and practices), and output the “maintenance rule”. This is defined as an analog modeling technique: current response based upon an average or normalized response from previous experience. The pooled fund study approach is a more dynamic modeling technique. It views winter maintenance practices as the necessary actions to minimize the impacts of snow, ice, slush, and water on the pavement surface in order to permit the highest level of safety and mobility. The approach argues that each weather induced situation is unique and the appropriate response must address the particular conditions created by the existing and forecasted weather conditions, the current pavement surface conditions (temperature and existing road conditions), and the state of the snow, ice, slush, water on the surface (chemical concentration, layer thickness, per cent ice and water). Diagrammatically, the process becomes a balance between what is added or removed from the pavement surface, both in the form of materials (shown as blue lines) and heat (shown as red lines).



The outcome from the pooled fund study approach is based upon input from the Weather component, the Maintenance Information component, and the Road Condition component, and it provides decision options that represent the most effective and efficient response scenarios for the current situation.

The pooled fund study architectural design is a simulation of actual practices that occur in the field. The following table illustrates how the MDSS functional design transfers actual maintenance actions into simulated process in the MDSS package. The table considers weather events or maintenance actions that occur over a period of time. Each event or action creates a road condition that must be simulated in the MDSS model. The table indicates the situation as one would observe it and the concomitant state of the layer with which the model deals. The last column in the table indicates what processes must be executed to emulate the effects of the event or action in the first column. At the end of each description is a list of modules that are necessary to produce the simulation. To save space the module names are abbreviated. A description of the modules is attached at the end of the table. This particular table only addresses a simple snow situation. Similar simulation analyses may be associated with other winter weather scenarios (e.g., freezing rain, frost, blowing snow, refreeze, snow showers, etc.)

MODELING MAINTENANCE PRACTICES

ACTION/EVENT	SITUATION	LAYER STATE	PROCESSING
	(after event/action)	(after event/action)	
None	Dry pavement	Temp < 32 F; small residual salt conc.	None
Anti-ice with salt brine	Thin brine layer or	Water layer with known	Compute total salt

	swaths	salt concentration	concentration in solution on sfc and amount of water in layer (Mtls Ap, Chem, HiCAPS, Residue, & Traffic)
Allow water to evaporate	Dry pavement with salt layer	Thin layer of salt bonded to pavement	Compute amt of salt bonded to pavement (Chem, HiCAPS, Residue, & Traffic)
Traffic but no snow	Dry pavement with decreasing salt layer	Thin layer of salt bonded to pavement	Compute reduction of salt due to traffic (Residue, HiCAPS, & Traffic)
Snow begins	Predominantly damp pavement with snowflakes melting as they reach pavement	Water layer with brine concentration: residual bonded salt below brine layer; and thin film of melting ice crystals on top of brine layer	Add snow (estimate temp.& water content), increase snow layer, convert snow to brine as salt goes into solution, calculate ice/brine components of layer, and adjust residual bonded chemical (Chem, HiCAPS, Residue, & Traffic)
Snow continues	Predominantly damp pavement with snowflakes melting as they reach the pavement	Layer transitions from brine plus salt phase thru eutectic point to dissolved salt in water state with decreasing salt concentration	Compute the transitional states of snow and salt components in relation to the increasing liquid layer (Chem, HiCAPS, Residue, & Traffic)
Snow continues	Predominantly damp pavement with snowflakes forming slush	Layer transitions from salt-water solution to ice/water/salt mixture	Determine the conc. at freeze point and from there compute percent ice in ice/water/salt mix (Chem, HiCAPS, Traffic)
Snow continues	Slush transitions from wet slush to predominantly icy or sticky slush	Ice crystal component of layer mix increases from near 0% ice towards 100% ice	Compute percent ice as more ice crystals are added and the salt conc. decreases due to dilution (Chem, HiCAPS, Traffic)
Treat with prewetted salt	Salt dissolves in slush forming wetter slush or salt water layer	Ice crystal component of layer mix gradually decreases as salt and prewet chemical goes into solution	Compute percent ice as chemicals cause increase in chem. conc. (Mtls. Ap., Chem, HiCAPS, Traffic)
Snow continues	Slush transitions from wet slush back to predominantly sticky slush	Ice crystal component of layer mix increases once again towards 100% ice	Compute percent ice as more ice crystals are added and the chem. conc. decreases due to dilution (Chem, HiCAPS, Traffic)
Plow and apply salt	Thin layer of slush left after plowing that transitions to wetter slush	Slush cover is reduced to thin film and ice percentage decreases as chemical goes into solution	Reduce depth of layer to plowed depth and compute concentration as chem.. goes into solution (Mtls. Ap., Plow, Chem, HiCAPS,

			Traffic)
Snow begins to taper off, winds pick up, and temperature drops	Slush transitions from wet back to more ice and pavement temp cools	Ice crystal component increases due to additional snow (falling and blowing) and lower pavement temperatures	Compute percent ice as more ice crystals are added and the chem. conc. decreases due to dilution and lower pavement temperature (Blowing, Chem, HiCAPS, Traffic)
Plow snow	Reduce layer to thin film of slush	Ice percent should remain the same even after slush is reduced to a thin film	Adjust the thickness of the film and continue to compute the chemical conc. and the percent ice in the mixture (Plow, Chem, HiCAPS, Traffic)
Allow pavement to become damp or dry	Wind, evaporation of water component, sublimation of ice component, and traffic reduce thin layer causing it to change to damp or dry pavement	Evaporation, sublimation, and traffic action reduce the water component and permit an increase in the chemical concentration	Compute the thickness of the layer and the chemical composition of the remaining mixture plus the ice percentage (Chem, HiCAPS, Traffic)
Allow pavement to become dry	Dry pavement with salt layer	Thin layer of salt bonded to pavement	Compute amt of salt bonded to pavement (Chem, HiCAPS, Residue, & Traffic)

Modules

Blowing	Blowing/drifting snow
Chem	Chemical concentration computations
HiCAPS	Road condition and pavement temperature model
Mtls. Ap.	Input of materials applied to road surface (type(s) and rate(s))
Plow	Plow type and plow activities
Residue	Bond of chemicals to pavement surfaces
Traffic	Traffic volume and rate

6.2 Designate the data flow through this MDSS architecture

Meridian will expand the functional infrastructure discussion into a process diagram that illustrates the flow of data through the various components that comprise the MDSS.

STATUS: Complete pending Technical Panel review.

Within version 4.0 of the National ITS Architecture (NITSA), maintenance decision support is presently defined to be an equipment package for the Maintenance and Construction Management subsystem. According to the NITSA documentation “This equipment package recommends maintenance courses of action based on current and forecast environmental and road conditions and additional application specific information. Decisions are supported through understandable presentation of filtered and fused environmental and road condition information for specific time horizons as well as specific maintenance recommendations that are generated by the system based on this integrated information. The recommended courses of action are supported by information on the anticipated consequences of action or inaction, when available" (FHWA, 2002).

The NITSAA has already been identified detailed data flows constructs associated with the Maintenance and Construction Management (MCM) subsystem and various terminators (Figure 6.2.1). The NITSA defined maintenance decision support equipment package is found within two market packages of the MCM; the Winter Maintenance Marketing Package and the Roadway Maintenance and Construction Marketing Package. Per the direction of the Technical Panel to emphasize winter maintenance operations in the present MDSS, only the assessment of the current MDSS design relative to the NITSA winter maintenance marketing package was evaluated. The winter maintenance market package is given in figure 6.2.2. It is readily noticed in the difference in complexities between figure 6.2.1 and 6.2.2 that a significantly complicated system should prevail by considering only winter maintenance operations in the initial efforts of the MDSS design and development. The number of terminators between these two packages drops from an initial thirteen to seven. It is important to note that the original number should have been higher, as the terminators in the MCM did not completely correspond to those required in the Winter Maintenance package.

Further inspection of figure 6.2.2 reveals that several of the conceptual items addressed in the Meridian designed pooled fund MDSS Processing Model (see sub-task 6.1) become apparent in the winter maintenance marketing package. These include the presence of the "maintenance and construction administration" and the "other MCM," which are analogous to the pooled fund "DOT Maintenance Info System". The "weather service" and the "surface transportation weather service" in the NITSA document is represented in the pooled fund "Weather Observation" and "Weather Forecast System". If it is implicit that the representation of the maintenance decision maker in the NITSA is embedded within the process within the maintenance and construction management, then this accounts for the "Delivery System" and "User Interface" portion of the pooled fund concept. This leaves the pooled fund "Road Condition Forecast System" and the "Road Condition Forecasting Initialization System" as the only non-NITSA elements in the high level overview of the MDSS architecture. However, this appears to be a possible shortfall in the NITSA, as this data flow does not explicitly exist anywhere within the national architecture, but has been identified by the FP MDSS and this present project as a crucial element in a successful MDSS design. This discrepancy may be due to an implicit expectation that the road condition forecasting is to be only found external to the NITSA within the surface transportation weather services terminator.

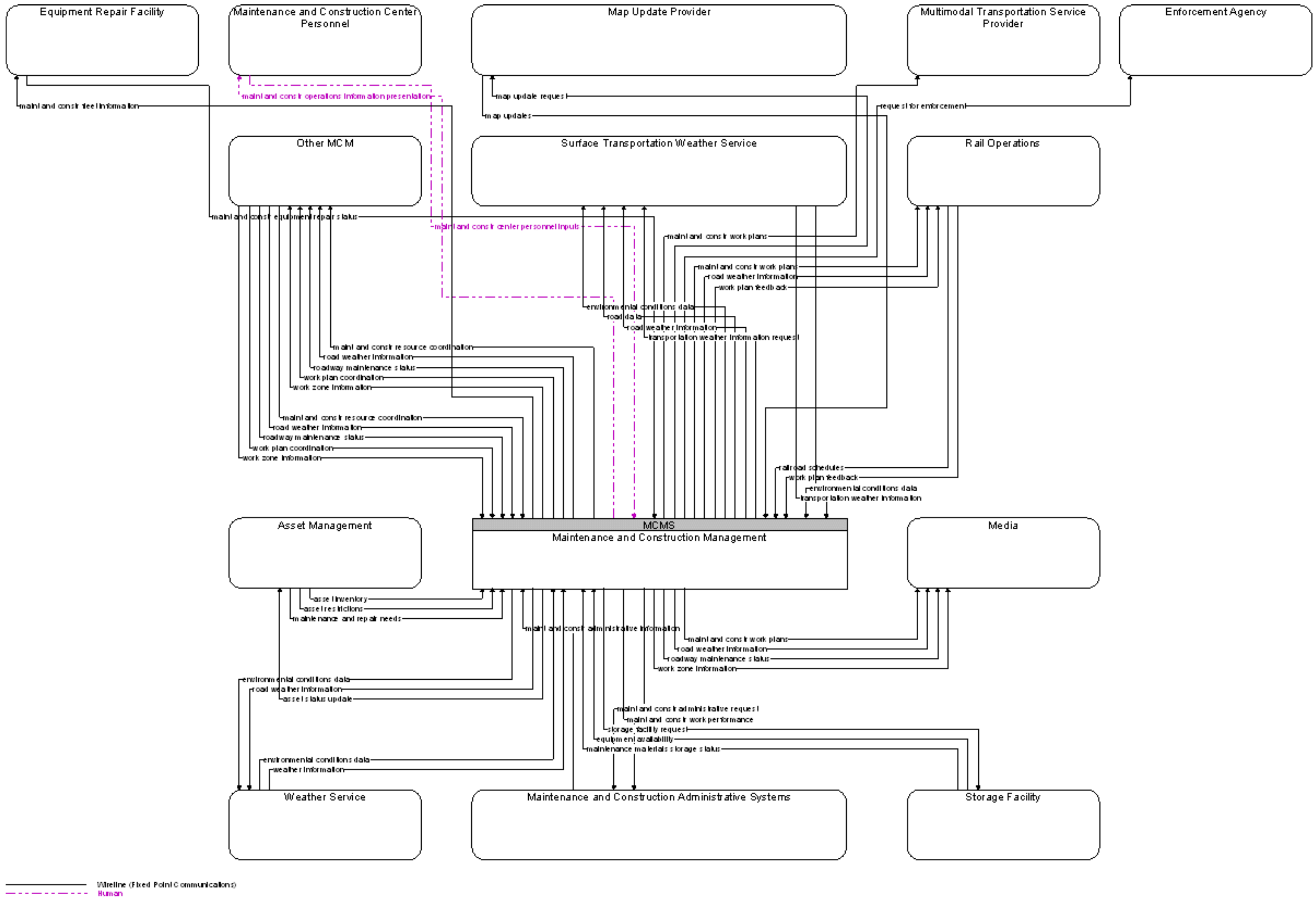


Figure 6.2.1. National ITS Architecture (ver. 4.0) Maintenance and Construction Management subsytem and terminators.

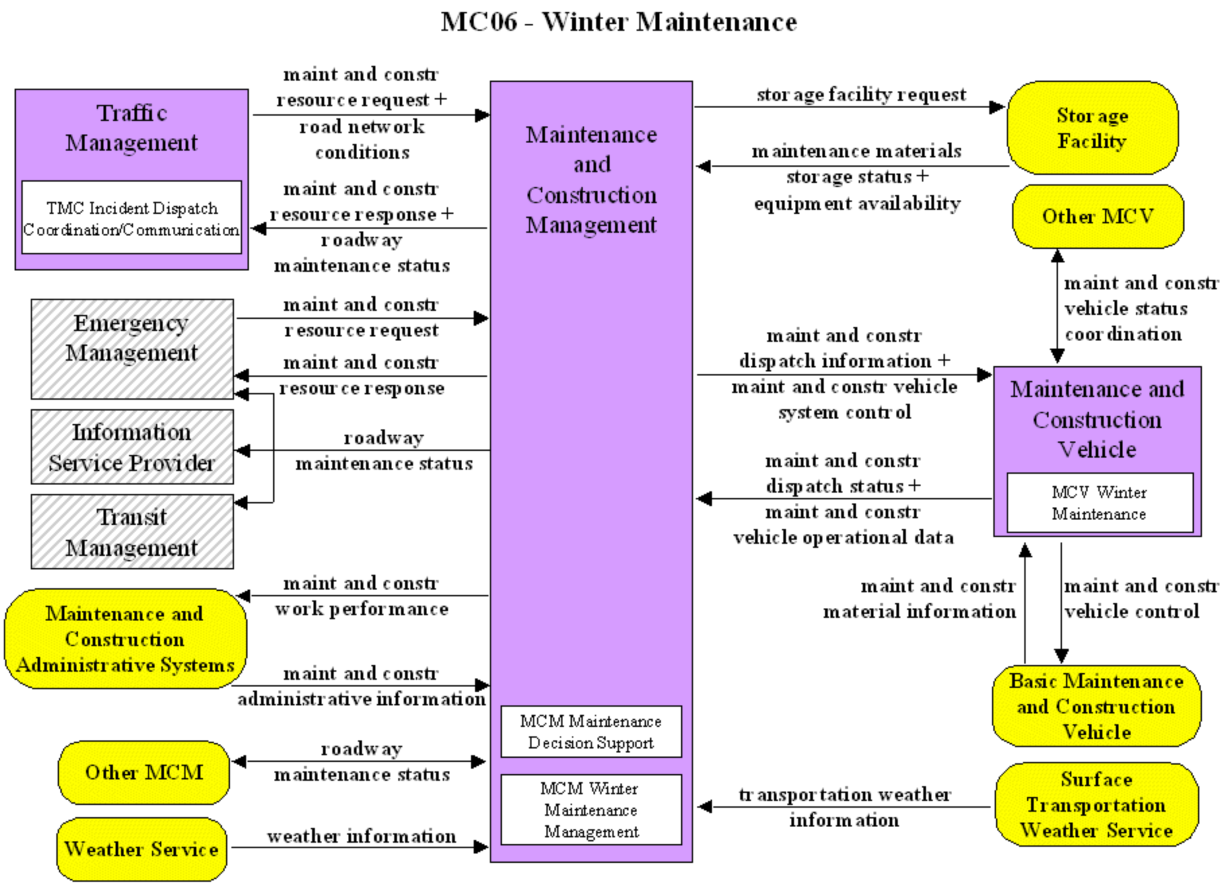


Figure 6.2.2. National ITS Architecture (ver. 4.) winter maintenance marketing package. Terminators are denoted in yellow.

Before turning attention to the data flow diagram associated with the present pooled fund MDSS design, it is worthwhile to review the data flow diagram in the NITSA that specifically addresses maintenance decision support (Figure 6.2.3). In inspection of this data flow diagram, it is seen that three processes are directly interfaced by the NITSA MDSS. These include 1) Manage Maintenance and Construction Resource Needs, 2) Determine Roadway Maintenance and Construction Needs, and 3) Determine Winter Roadway Treatment Needs. A fourth process is found in the data flow diagram that flows into the "determine roadway maintenance and construction resource needs". This process is the "collect roadside equipment status" process and provides data on a host of information delivery and collection platforms along the roadway. Of significance in this diagram are the presence of twelve existing identified data flows into or out of the maintenance decision support and the presence of a process specifically identified to assess the need for winter roadway treatment. It is logically within this process that the "road condition forecast" process should be found. Unfortunately, except for the data flows in and out of the later process, no further definition of this process is specified.

The twelve NITSA identified maintenance decision support data flows are:

- env_and_weather_data_for_decision_support--In
- env_info_for_decision_support--In
- m_and_c_activity_status_for_mdss--In
- m_and_c_resources_avail--In
- m_and_c_view_of_road_network_for_mdss--In
- maint_dec_support_parameter_updates--In
- mdss_recommended_actions_for_operator--Out
- mdss_recommended_actions_for_personnel--Out
- mdss_recommended_actions_for_resource_needs--Out
- mdss_recommended_actions_for_roadway_maint_needs--Out
- mdss_recommended_actions_for_winter_treatment_needs--Out
- terf_mdss_recommended_actions--Out

Of these, six are designated as inputs (the first six) and six are listed as outputs to the maintenance decision support process. While these data flows are not necessarily all of equal weight in importance, **it is significant that of the six input items, only one is specifically related to weather**. The remainder of the input data flows pertain to other critical information needed in the decision making process, i.e., activity status, resources available. This is further support of the present pooled fund MDSS design efforts that emphasize the role of both weather and non-weather elements as central to the decision making process.

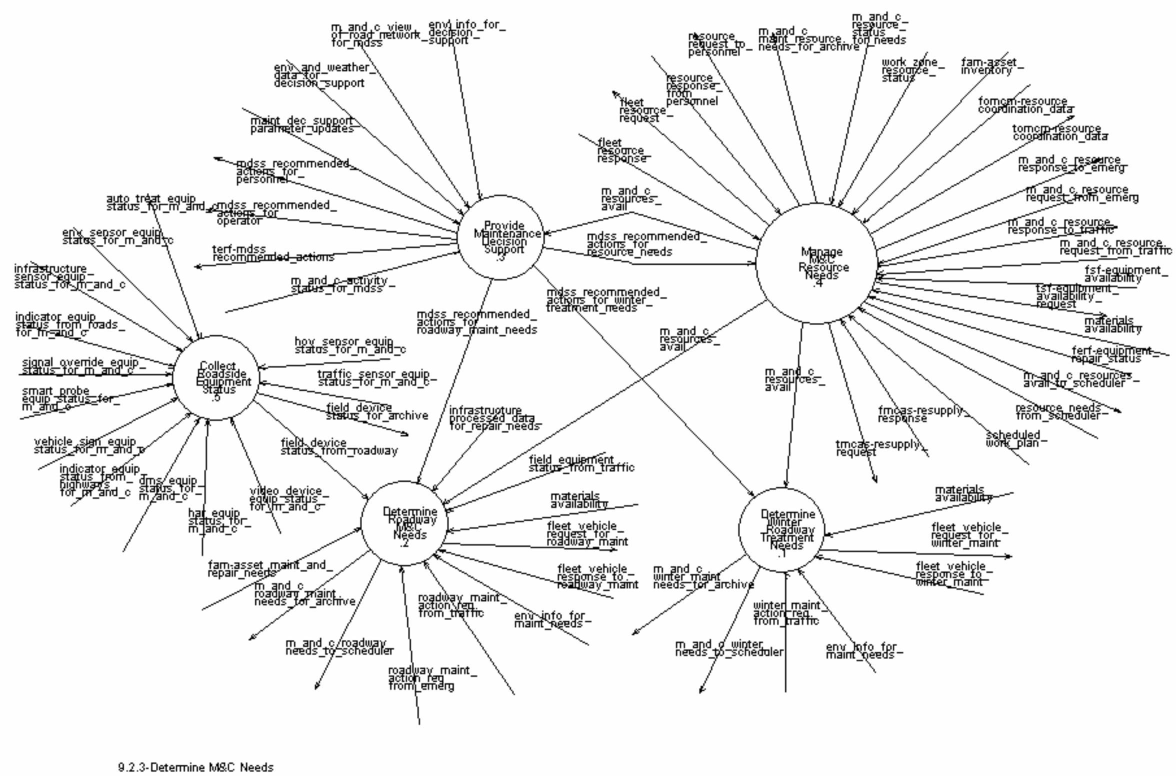


Figure 6.2.3. Data flow diagram associated with maintenance decision support found within the National ITS Architecture (ver. 4.)

Having identified and discussed the place MDSS holds within the National ITS Architecture, it is incumbent upon Meridian to work with the participating state DOTs to make sure the resulting MDSS meets with the respective architectures within each state. Assuming the state architectures follow reasonably close to the NITSA, incorporating the data flows that exist within the NITSA will ensure this goal is met. However, it will be equally important to be mindful of where the results of this project can provide new insights into possible expanded capabilities or revisions to the NITSA. The following specific considerations are important to recognize in developing the data flow diagrams of the present pooled fund MDSS with respect to the NITSA:

- Focus initially on winter maintenance,
- Maintain best consistency possible with the NITSA defined data flows when describing the present MDSS,
- Decision support involves a collection of data flows beyond weather, and
- Weather services (federal and private) are terminators and are considered external processes to the MDSS.

The latter bullet is important for two reasons. First, it identifies that the development of weather elements for MDSS will involve processes that will exist entirely beyond a state DOT unless states are prepared to establish their own dedicated meteorological services divisions. While some state DOTs have meteorologists on staff, these individuals play only a limited role in the development and delivery of forecast products. Considering the significant investment in personnel and equipment that will be necessary for weather support to MDSS, it is not envisioned that this role will shift to state DOTs in the foreseeable future. The second important aspect of this bullet is that the coordination of the interface between the weather terminator and the MDSS equipment package will need to be carefully monitored for potential standards that might be set. Of the approximately ten standards development organizations involved in ITS at present, none are actively involved as major standards organizations involving weather information. Following the premise that MDSS components should be capable of plug-and-play, developing standards that manage the data flows is imperative. This pooled fund MDSS, along with the present FP MDSS, will play a significant role in evolving the necessary standards for MDSS and its affiliated plug-and-play capabilities.

With the previous discussion as background, the elements in figure 6.2.2 are adopted for use as a basis for the context diagram of the present pooled fund MDSS data flow diagram (Figure 6.2.4). For the purpose of simplification and employing the guidelines set by the Technical Panel, figure 6.2.4 provides a more focused description of the MDSS context. In this figure the references to construction activities have been eliminated and the various maintenance management terminators are consolidated in the “maintenance administrative systems” terminator. Similarly, all associated references to maintenance vehicle terminators have been consolidated into the “maintenance vehicles” terminator. Also, the “surface transportation weather services” terminator has assimilated the “weather services” terminator for the pooled fund MDSS efforts. Hence, the private sector surface transportation weather services provider will, at this juncture, be considered as the conduit for all National Weather Service information that may be passed through to the MDSS display and information systems. The data flows linking the MDSS to the terminators reflect elements of the NITSA data flows identified earlier. However, a new data flow has been added to the “surface transportation weather services” entitled “weather_data_request”. This is an important addition to the data flow as it provides a link back to real-time weather resources to provide for interactive updating of tactical surface transportation weather services. These tactical weather services will be identified as the processes within the surface transportation weather services terminator are developed in the data flow diagrams.

It is significant that at this high-level of the data flow, the maintenance personnel involved in the MDSS can be at any level. The specific functionality of the various classifications of maintenance personnel will defined as the processes within the MDSS are developed. In fact, it is conceivable from this context diagram that the operator of the maintenance vehicle could be operating the MDSS.

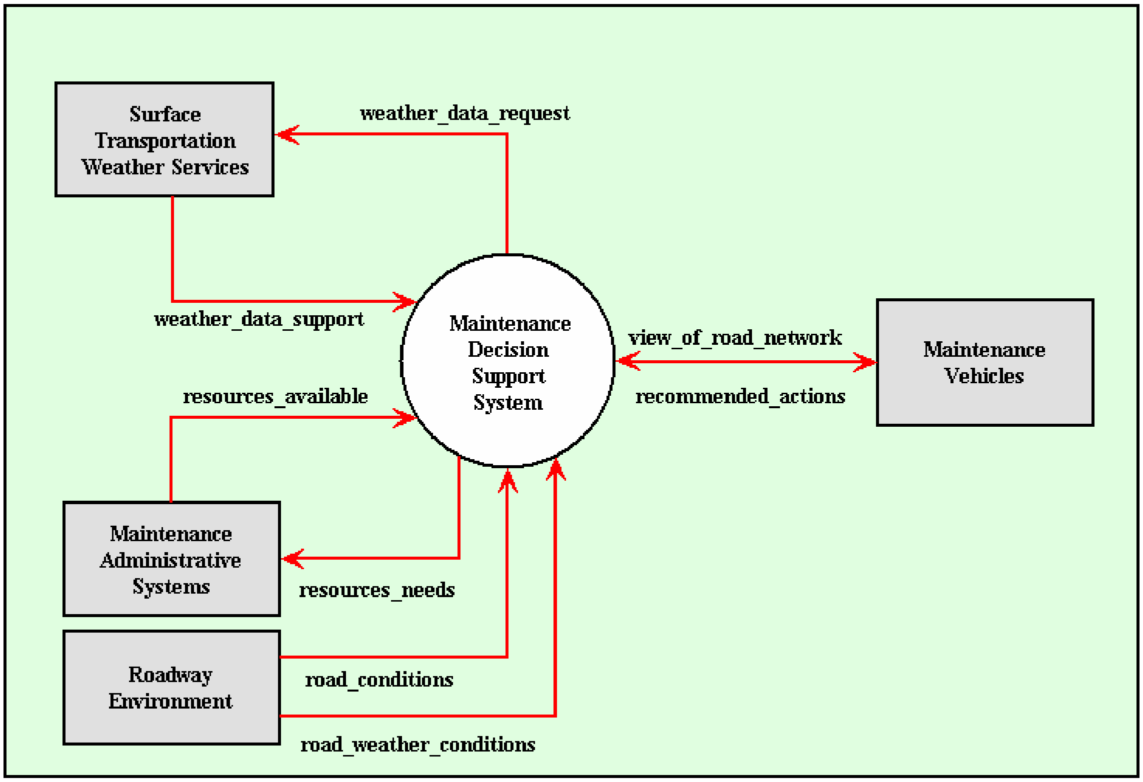


Figure 6.2.4. Pooled fund MDSS context diagram. Adapted from the National ITS Architecture. Grayed boxes denote terminators.

At this point the traditional method of data flow diagramming would limit the level 1 and beyond data flow diagrams to those processes found within the MDSS and not those found within the terminators. However, the impact of the weather information content and processing on the design development of the MDSS functionality requires that an exploration of the data flows within the surface transportation weather services terminator be developed in parallel to that of the MDSS. Figure 6.2.5 provides the level 1 data flow representation of the MDSS. The core processes serve as the foundation for the menu structure found in the windows environment and for the interface functions to the three terminators. The nine core processes are:

- Weather data action listener – interface process to the weather data stream that continually monitors for weather data traffic to and from the surface transportation weather services provider.

- User input listener – as the name implies this process is where the user interacts with the MDSS client software through either mouse or keyboard inputs.
- Graphics generator – process responsible for generating all computer graphics displays.
- Message dispatch – process responsible for sending information to users outside the MDSS client server.
- Scenario generator – core process responsible for decision support.
- Window manager – classical window manager processor that managers all window traffic associated with the user and display functions. Analogous to a data router in that all messages are processed through the window manager.
- Road condition processor – interface process to extract road condition information from the road condition reporting system.
- Inventory analyst – interface process to extract and store information pertaining to the maintenance inventory database.
- Maintenance practice evaluator – interface process to acquire and interpret information pertaining to maintenance practices.

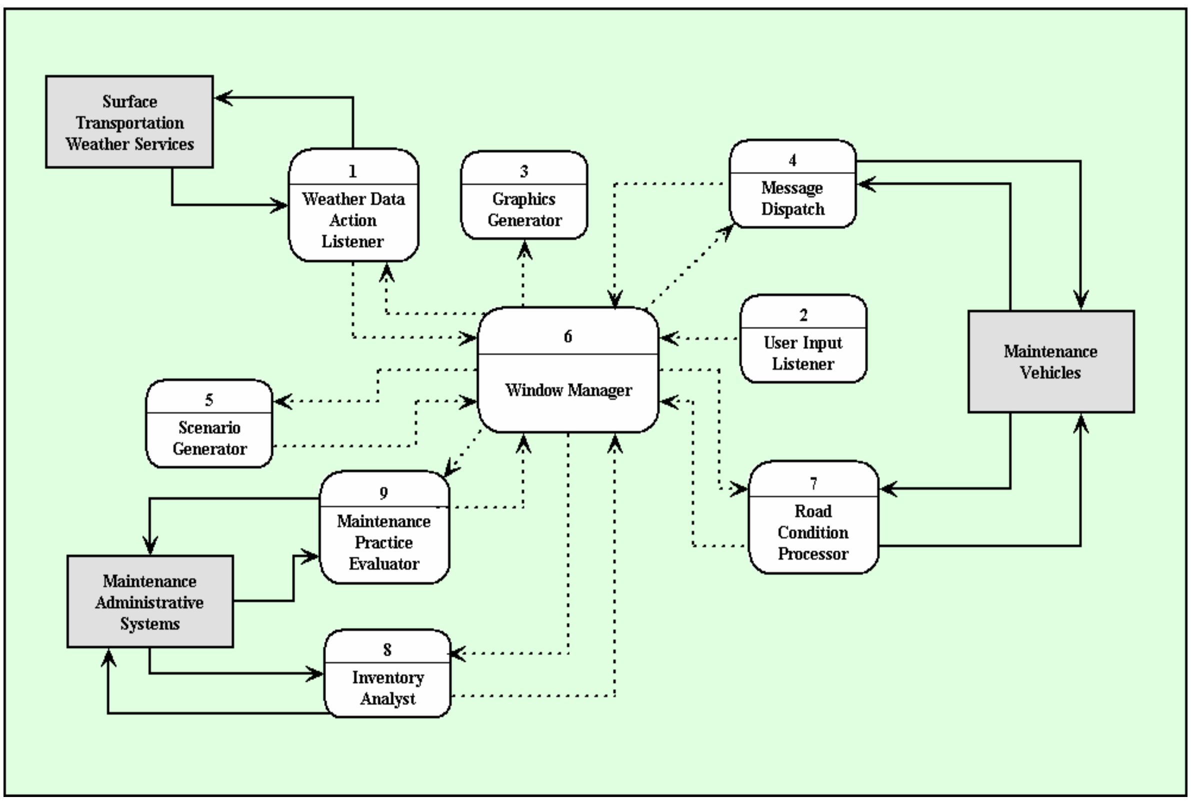


Figure 6.2.5. Pooled fund MDSS level 1 data flow diagram. Rounded rectangle denote processes, solid lines denote data flows, dashed lines denote controls between processes, and grayed boxes denote elements (processes and terminators) external to the data flow.

As can be seen from figure 6.2.5, the majority of the flows in the pooled fund MDSS application involve traditional window's based transactional services. This is somewhat consistent with the FP MDSS design where no decision support processing is found on the client-side workstation, only decision support displays. However, within the pooled fund MDSS, there are processes that are directly related to activity support of decision support client-side processing. The "scenario generator" specifically is designed to handle client-side decision support through dynamic interaction with local and remote data sources including weather, maintenance activities and current road conditions. However, to support these actions requires the presence of frequently updated data on maintenance treatment activities, maintenance vehicle locations, materiel inventories and detailed (time and space) road condition reports. Without the "scenario generator" the client-side applications largely defaults to something similar to the FP MDSS graphical user interface.

The next level of data flow detail is provided in level 2 data flow diagrams. At this level specific processes found within each of the number processes in the level 1 diagram are mapped according to their relationship to input and output data flows as well as through internal processes, data flows, and controls. Figure 6.2.6 provides the level 2 data flow diagram for the scenario generator discussed above. The eight processes internal to the scenario generator provide more detail as to the structure involved within the level 1 data flow. However, even at the 2nd level the algorithmic detail is not obvious although a clear connection between processes is visible and a representation of data exchanges required are available. [NOTE: The data flow diagrams below the context diagram level will eventually have named pipes. However, the detailed naming of pipes is premature at this time and will be done as coding of the processes commences.]

In reviewing the data flow diagrams, the reader is cautioned to refrain from associating the numeral after the decimal point as indicating an order to the data processing. These data flow diagrams are presenting logical connections of processes together. The order or sequence of the process execution is dependent upon control features and staging of data. To gain an understanding of the order of the processing, one would have to review a detailed flowchart of the process' algorithm.

The remainder of the data flow diagrams for the pooled fund MDSS are found in Appendix I. In addition to the MDSS data flows, the data flows for the surface transportation weather services (STWx) are provided. Attention is directed to the STWx level 1 data flow diagram where the complexity of the weather information becomes apparent. Further, in this diagram not only are forecast conditions supported, but support is also provided for surface transportation analysis generation. This process specifically addresses the issues encountered in the Iowa DOT FP MDSS test where there was a lack in tactical decision support.

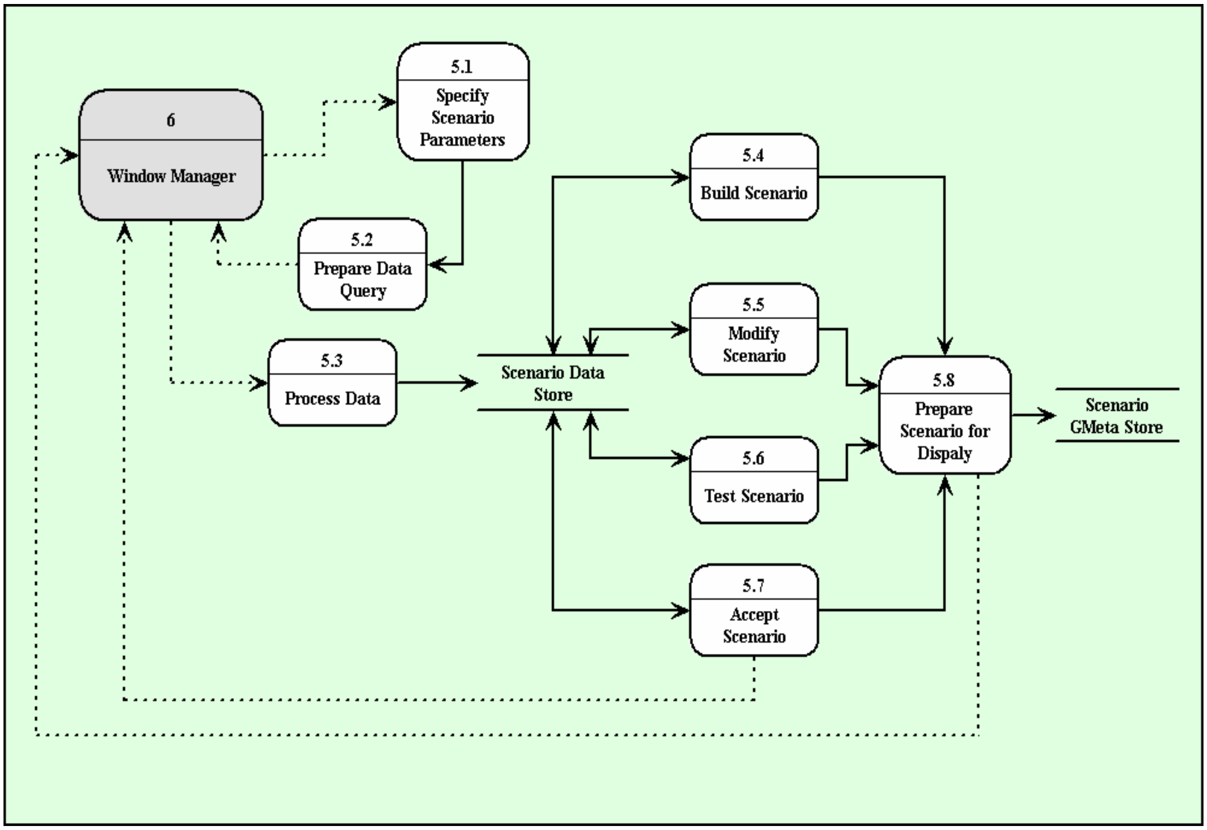


Figure 6.2.6. Level 2 MDSS scenario generator data flow diagram. Decimal values within the process boxes denote process number within the naming of the level 1 data flow. The parallel horizontal lines denote data store where information is accumulated.

6.3 Using the information gained from the evaluation of user needs in Task 3 amend the architecture to satisfy needs not addressed in the original MDSS proposal

The functional infrastructure presented in the original white paper and the FHWA FP both integrate forecasted meteorological conditions into a maintenance decision support system. Several of the member state DOTs in the study have indicated there are ancillary non-meteorological decisions that need to be added to the decision process. The needs assessment study will likely define several of these non-meteorological decision modules. Meridian will amend the original architecture to include these associated modules into the architectural and data flow diagrams.

STATUS: This effort will not be able to proceed until completion of Task 3.

This activity is awaiting completion of the evaluation of user needs as outline in Task 3.

6.4 Characterize the structural components (hardware, firmware, software, communications) necessary to implement the MDSS architecture (original plus added components)

Using information gathered in previous tasks relating to existing infrastructure and likely future infrastructure, this sub-task will prepare a description of required components that will be necessary to deploy the prototype MDSS. Where possible the information provided will include a range of systems rather than specific systems to permit individual states to prepare requisition materials that may require bidding. In addition, a cost estimate will be provided that lists a range of costs associated with the above list.

STATUS: Completed

A comprehensive review of the Functional Prototype (FP) MDSS structural component requirements has been completed to serve as a baseline for requirements in the present pooled fund MDSS efforts. A presentation of these requirements will be made at the July Technical Panel meeting.

6.5 Create a baseline by delineating the degree of completion of each of the structural components

The proposed project management package provides guidelines on the progress of the project, but it does not indicate the percent completion of the MDSS components themselves. Meridian will select a display system that permits the development team to illustrate the progress of the various components of the MDSS.

STATUS: Completed

The task has been initiated, but is not complete as of the end of June. A brief discussion of this topic was held at the June pooled fund Technical Panel meeting in Des Moines, Iowa where it was indicated that sufficient completion of structural MDSS components would exist to permit a field test sometime during the 2003-04 winter in each participating state.

6.6 Define the development process indicating what components can be developed with the existing knowledge base and what components require technologies needing additional research

There are a number of issues that will require information beyond the current understanding of the science that goes into supporting the processing modules. Meridian will delineate a number of these research items and recommend methodologies to support the necessary research for future enhancements of the MDSS.

STATUS: Completed

This topic has been reviewed by Meridian scientists in consultation with atmospheric scientists at the University of North Dakota. A presentation on current thought regarding this topic is an agenda item for the July Technical Panel meeting.

6.7 Starting with the baseline, recommend a development program that optimizes the use of existing processing capabilities while incrementally adding features that satisfy the specific needs defined in the modified architecture in Sub-Task 6.3

The effort will define as clearly as possible the extent of additional work necessary to complete the construction and deployment of the prototype MDSS. This will include project definition, personnel requirements, timelines and costs.

STATUS: Completed

This work is in progress as of June 30, 2003 and is expected to be to a draft completion by mid-July. Input from the Technical Panel on this topic will be sought at the July Technical Panel meeting.

6.8 Organize the information from these sub-tasks into a final report on the proposed MDSS architecture

Prepare a final report for distribution and presentation to the Technical Panel.

STATUS: In Process

A draft final is presently under development.

TASK 7. UPON APPROVAL OF THE PANEL, CONSTRUCT A BASIC PROTOTYPE MDSS INCORPORATING THOSE REQUIREMENTS THAT CAN BE IMMEDIATELY SATISFIED.

As the panel provides approval, construction of a basic prototype MDSS incorporating immediately satisfied requirement6s will commence. This development will include monthly construction updates with demonstrations as appropriate. As development proceeds and a client-side interface becomes available, Meridian will provide interim versions of the interface to designated individuals in each state for informal evaluation purposes prior to an organized pilot deployment. As components are tested and meet with the panel's approval, they will enter into a functional state whereby they will be continually supported as available maintenance decision tools. Formal evaluation of these tools will not be conducted until such time as the pilot deployment and evaluation period has *begun; however, comments will be welcomed at all times from appropriate state DOT individuals assisting in the testing and evaluation process.*

SUB-TASKS

Certain development efforts will become clearly established early in the MDSS prototype design effort and will serve as the backbone for all subsequent development regardless of the final MDSS prototype design. These development efforts will be conducted prior to the Technical Panel's approval of the prototype design (Task 6) in order to expedite the completion of the prototype MDSS. The sub-tasks 7.1 and 7.2 below are in reference to the development of these foundation development efforts.

7.1 Review and recommend early MDSS foundation elements for development

Meridian will review the essential foundation elements of any subsequent MDSS software platform and identify code development efforts that will be required regardless of a final prototype design. Where appropriate the information from Task 1 through Task 6 will be included in this review. Upon completion of this review a prioritized list of code development efforts shall be forwarded to the Technical Panel for their approval.

STATUS: In process

The design diagrams in Task 6.1 lay out the coherent components of the MDSS architecture. As indicated in that section the MDSS may be viewed as five separate functions (weather processing, surface condition analyses, maintenance support information, user interface, and the decision processor). The MDSS FP developed a complete code set to create an operational model. Meridian has evaluated the software design and, in fact, had to delve deeply into the code to assure we could make the software components work as advertised. The design is well documented. Meridian has also built better than half of the MDSS design to support its 511 and maintenance forecasting contracts. Both approaches use sets of code to execute specific functions within MDSS or road weather forecasting. Both of these sets have been developed for efficiency and therefore their design tends to merge the separate functional components of the MDSS design.

Following our ad hoc Technical Panel discussions in Des Moines, the Meridian development team refocused the design effort toward the discrete architectural approach of the National ITS Architecture to assure that the pooled fund study design met the architectural integrity requested by the member states. The emphasis was placed on developing the software within the framework of the national architecture. Task 6.2 addresses this design effort and defines the structural components and data flows in considerable detail. This hierarchal design approach works from a general overview approach through ever increasing layers of structural complexity. The design approach is applicable to any MDSS software development and provides the characterization of the essential design elements of MDSS. This design format and the data flows is an important agenda item for the July 10 Technical Panel meeting.

7.2 Develop MDSS foundation elements and provide tracking information on the software development effort

With the approval of the Technical Panel, Meridian will proceed with software development efforts as recommended in the previous sub-task. Progress on the software development will be provided through routine progress updates provided via the project's email reflector and/or the project's website. Where appropriate functional elements will be provided to Technical Panel members, or their designee, for review and testing.

STATUS: On hold pending results of July 10, 2003 Technical Panel meeting.

During the software development current documentation will be maintained of the software through the periodic collection of development notes made during the software development. These development notes will be a part of the revision control system that is used at Meridian for software development (Concurrent Version System or CVS). These notes will be incorporated into an accepted software documentation standard. The standard used in this project will be based upon the Institute of Electrical and Electronics Engineers (IEEE) standard for Software User Documentation (ANSI/IEEE standard 1063-1987). Using the IEEE standard the software documentation will be organized to provide a high-level system descriptions followed by detailed descriptions of each system component. The detailed descriptions are presented as software processes covering process type, purpose, function, dependencies, and interfaces.

7.3 Construct prototype MDSS software modules

Upon approval of the prototype MDSS recommended in sub-task 6.7 Meridian will implement a design program to complete the MDSS prototype. Software development tracking, as provided in the previous sub-task, will be maintained for all MDSS software modules developed. Testing and review will be made as appropriate as listed above. As this final prototype development effort will not be completed prior to the end of Phase I, a summary report of the percentage completion of all modules under development at the end of Phase I will be provided at the end of the Phase I period.

STATUS: On hold pending results of July 10, 2003 Technical Panel meeting.

7.4 Release and distribute the software

[THIS SUB-TASK IS BEYOND PHASE I AND IS INCLUDED FOR PLANNING PURPOSES ONLY]

Meridian will create a software upgrade program to distribute the newest version of the software to participants in the MDSS evaluation. Meridian will track the distribution and installation of the new revisions in order to monitor the user interaction with these software enhancements.

7.5 Collect feedback on the new revisions

[THIS SUB-TASK IS BEYOND PHASE I AND IS INCLUDED FOR PLANNING PURPOSES ONLY]

Meridian will routinely contact users to assess the response of the users to the enhancements. This interaction will follow the guidelines developed in Tasks 3, 4, and 5 for evaluation procedures. In addition, Meridian will provide a method for participants to notify Meridian if the participants discover an issue with the software or the user interface.

7.6 Correct any software inconsistencies in the new revision and issue an update following the tracking procedures defined for Sub-task 4

[THIS SUB-TASK IS BEYOND PHASE I AND IS INCLUDED FOR PLANNING PURPOSES ONLY]

When users discover deficiencies in the software that preclude the software from correctly executing the feature designated in the new release, Meridian will modify the software and issue an update to the revision. Meridian will release updates as needed and track them in the same manner as described in sub-task 7.4. If the issue raised by the state DOT participant is not a software processing issue but rather an issue with the software's ability to appropriately satisfy a user's expectations related to the feature, Meridian will assess whether the issue should be addressed as an update or designated as a new feature in a future revision. Meridian will maintain a list of all issues raised in a general forum so all users can track issues raised by their peers in the program and determine how Meridian will address resolution of the issue.

TASK 10. DEVELOP AND TEST NEW SYSTEM COMPONENTS THAT SATISFY THOSE REQUIREMENTS REQUIRING FUNDAMENTAL RESEARCH, INCORPORATING ONGOING AND EMERGING TECHNOLOGY IMPROVEMENTS ASSOCIATED WITH WEATHER FORECASTING AND MAINTENANCE PRACTICES.

As part of Task 6, a list of recommended new system components will be provided to the technical panel for development consideration. After consultation and with approval of the technical panel, the prioritized new system components will undergo development. The selection of the new system components will be based upon the level of fundamental research required and the level of relevance to the overall MDSS deployment. These new system components will incorporate state-of-the-art and/or emerging technologies in weather forecasting, weather display, computational and logistical decision-making, information technology, and maintenance practices. As this effort will require a sustained commitment to complete, Meridian will provide the technical panel monthly *updates of the development progress and development milestones leading to completion of the development and testing. Meridian will meet with the technical panel every quarter during the development to review project progress.*

SUB-TASKS

Certain technologies valuable to the MDSS will require a sustained long-term development effort. Sub-tasks 10.1 and 10.2 attempt to identify these tasks and to begin their development at an early stage of the MDSS project such that the technology may become available in time for incorporation in the prototype MDSS deployment.

10.1 Identification, prioritization and development recommendation of fundamental operational research needs supporting MDSS

Working with the Technical Panel, Meridian will assess additional research needs that are important to the development of an effective MDSS, which do not presently exist in an operational capability, and require a long time for development than other MDSS components. Information from federal and academic researchers will be sought to assess the feasibility of the technologies and the amount of further work required to bring the technologies into an operational environment. A list of needed technologies will be prepared including an assessment of the technologies' timeframe of availability and a recommended prioritization of importance to the present MDSS prototype development. Along with the list of technologies Meridian will submit a recommendation for technology development leading to inclusion within the MDSS prototype.

STATUS: In process

Members of the Meridian team have discussed a number of issues that will eventually need better simulation or computation processes within a MDSS. Here is a partial list of research needs and a rough estimate of its priority in the development of an operational decision support system. For comparison purposes a priority rating of 1 indicates an important factor that needs attention immediately while a priority rating of 10 is low.

RESEARCH NEEDS	PRIORITY
Chemical concentration – Freeze point computation Computation of chemical concentration of the liquid component of slush for all routinely used chemicals and chemical admixtures. Module needs to compute the freeze point of the mixture of chemicals.	1
Percent ice in slush mixture Computation of the ice percent of the mixture of ice and dissolved chemical solution for all routinely used chemicals and chemical admixtures	1
Chemical migration/dissolution in slush Develop a simulation process that mimics the movement of	5

chemical through a contaminant layer and approximates the process of chemical dissolving and/or mixing in a snow or slush layer	
Latent heat effects of chemical application Develop a simulation of the heat of fusion required as salt induces the state change from ice to water over time and how this heat flux affects the pavement temperature; output from this simulation needs to loop back into freeze point and percent ice computation modules	3
Chemical mixing as a function of traffic volumes Develop a simulation of traffic's effect on the contaminant layer at varying degrees of slush consistency; part of the module should also determine how much material is removed from the contaminant layer at different traffic volumes and speeds	5
Chemical residue Create a simulation of the bonding process of different chemicals or chemical admixtures on various types of pavement as the solvent (water) evaporates from the highway surface; simulate the residual bond over time for different traffic volumes and speeds; simulate the dissolution of this bonded chemical once moisture is added to contaminant layer due to dew, frost, absorption, or some form of precipitation	3
Grit migration Simulate the positioning and movement of grit materials within the contaminant layer; simulate the amount of residual grit material over time and determine where and how it migrates under different traffic situations	6
Traction index Develop an index based upon the "effective" coefficient of friction caused by the state of the contaminant layer	2
Traffic simulation Create a simulation model that estimates the traffic volume and speeds as a function of time and special events; simulation should estimate the same traffic flows under varying weather and contaminant layer situations; output from the simulation becomes input into nearly all modules addressing contaminant layer values	7
Plowing techniques Simulate the plowing action of the spectrum of plow types with the intent to output the residual material after plowing is complete; consider the effects of different road surface types and their interaction with the plow action	3
Contaminant layer composition during precipitation Simulate the state of the contaminant layer during precipitation events such as snowfall; determine how snow melt occurs and how the concentration changes with time through the layer	8
Research the bonding of snow to pavement surfaces Develop and understanding of the bonding process and determine what conditions are needed at the threshold point and how the process occurs as conditions change; evaluate the	7

influence of different types of pavement and characterize the critical bonding conditions	
Blowing snow Simulate the effects of blowing snow due to topography, local wind patterns, construction factors, vegetative cover, and snow fences; simulate the amount of snow within the contaminant layer caused by a variety of wind conditions under differing snow densities; simulate the effect of traffic on the snow blowing or moving across the highway	3
Road condition reporting Develop a module to capture and transmit road conditions along a stretch of highway and relatively short time intervals (on the order of once an hour or less); module needs to store and display road conditions along any segment of highway	4
Material application estimator For each type of material spreader, create an algorithm or simulation package to determine the effective amount of material placed on the road surface	4
Long wave radiation balance Perform research to determine what factors impact the energy balance equations in the long wave portion of the spectrum; observations indicate the temperature of the lower atmosphere influences the net long wave radiation; this parameter is not currently considered in the long wave radiation flux	6
Frost Develop an improved model to simulate the formation of frost on bridges or highways	3

There are additional topics tied up in the design of the MDSS. Meridian has addressed a number of these as integral components of the core MDSS processing scheme. Some of these processing components may be more complex than originally envisioned and are likely to generate more issues. Some of the potential development efforts are tied to the discussion of the architecture which will be reviewed at the upcoming technical panel meeting. Meridian intends to use the feedback from the discussions with the technical panel to adjust this list and reset priorities.

10.2 Development of components requiring new technology development

Upon approval of the Technical Panel, development of component technologies based upon emerging and evolving research will commence. Meridian personnel will work with the Technical Panel to discuss issues related to the technology development to ensure that the development remains relevant to the project's needs. As code development occurs it will be monitored and reported in a manner consistent with other code development identified in this workplan. Testing and review will be made as appropriate. As this development effort is not anticipated to be completed prior to the end of Phase I, a summary report of the percentage *completion of all modules under development at the end of Phase I will be provided at the end of the Phase I period.*

STATUS: Recommendation to be provided to Technical Panel on July 10, 2003

10.3 Integrate new component technology with MDSS prototype

[THIS SUB-TASK IS BEYOND PHASE I AND IS INCLUDED FOR PLANNING PURPOSES ONLY]

As new component technology becomes available, the components will be integrated into the MDSS prototype and tested. Upon successful testing the updated software will be distributed to MDSS evaluation participants.

10.4 Collect feedback on the new revisions

[THIS SUB-TASK IS BEYOND PHASE I AND IS INCLUDED FOR PLANNING PURPOSES ONLY]

Meridian will routinely contact users to assess the response of the users to the enhancements. This interaction will follow the guidelines developed in Tasks 3, 4, and 5 for evaluation procedures. In addition, Meridian will provide a method for participants to notify Meridian if the participants discover an issue with the software or the user interface.

10.5 Correct any software inconsistencies in the new revision and issue an update following the tracking procedures defined for Sub-task 4

[THIS SUB-TASK IS BEYOND PHASE I AND IS INCLUDED FOR PLANNING PURPOSES ONLY]

When users discover deficiencies in the software that preclude the software from correctly executing the feature designated in the new release, Meridian will modify the software and issue an update to the revision. Meridian will release updates as needed and track them in the same manner as described in sub-task 7.4. If the issue raised by the state DOT participant is not a software processing issue but rather an issue with the software's ability to appropriately satisfy a user's expectations related to the feature, Meridian will assess whether the issue should be addressed as an update or designated as a new feature in a future revision. Meridian will maintain a list of all issues raised in a general forum so all users can track issues raised by their peers in the program and determine how Meridian will address resolution of the issue.

APPENDIX A

TASK 1.1

Study Objectives

Development of Maintenance Decision Support System
SD2002-18

Task 1.1

Determine Extent of Study Population

Objective:

The objectives are to define three basic components of the MDSS project and get consensus amongst the Technical Panel on the definitions. The three components under consideration in this sub-task are: MDSS Objectives, MDSS Personnel Categories, and MDSS Personnel Resources.

Process:

Meridian has prepared this draft list of items within each of the three categories and now submits the Phase 1 list to the MDSS Technical Panel. Members of the Technical Panel should review the list and make recommendations on additions, deletions, or modifications to the lists. Any revisions may be returned via the MDSS reflector site or directly to the principal investigator at Meridian (bobhart@meridian-enviro.com). Meridian will make the necessary revisions to a master file and redistribute the modified Phase 2 file for further review. Based upon the response to the second distribution, Meridian will either modify the document again and redistribute the revision, or send a notification stating the MDSS Technical Panel members are in agreement as to the wording of the document. The document will then become part of the documentation for the Final Report.

Technical Panel Involvement:

The Technical Panel members need to review the entire Task 1.1 document and provide input on each of the three categories. Input should include recommended additions, deletions, and modifications. To permit open dialog, Technical Panel members should include an editorial comment after each change, unless the change is merely a grammatical or word change. These editorial comments may be embedded in the document using either the Tracking or Comment feature in Microsoft Word or some highlighted addition inserted in the text. In the Personnel section following the Information Resources section, Technical Panel members should indicate personnel under each of the Technical Resource classes.

Milestone Dates:

End of Input Phase 1 .... March 14, 2003
Distribution of Modification 1 .... March 17, 2003
End of Input Phase 2 .... March 24, 2003
Decision on Release of Modification 2 .... March 25, 2003

MDSS OBJECTIVES

1. **Document the background that lead to the requirement for a Maintenance Decision Support System approach to augmenting the operational response to maintenance obligations.**

   Documentation of the background provides an understanding of the needs that generated predecessor products/services such as RWIS and the discovery of limitations in the information resources provided by these predecessor services. MDSS is not an exclusive innovation but an evolution in an evolving technological approach to maintenance. This understanding is necessary to grasp the vision of MDSS in the broader maintenance perspective and will help assess whether current and proposed development approaches truly address the evolving maintenance vision.

2. **Fully describe the MDSS architecture, alternative approaches to the architecture, and provide justification for the infrastructure chosen for this development effort.**

   It is essential that a Maintenance Decision Support System satisfy the requirements of its name. The system must be designed to serve the decision support function for maintenance. Although we have conceptualized the MDSS development effort for a decision support system for winter maintenance, it is important that the design be cognizant of the broader set of maintenance requirements. Maintenance decisions are not limited to nor totally driven by response scenarios to meteorological conditions. The architecture must revolve around the decision support function and the design needs to integrate input from meteorological, logistical, and resource subsystems. The architecture must also consider interactions with ancillary programs such as inventory control, equipment management, human resource management, homeland security, traveler advisory services, and communications services.

3. **Establish a baseline of current operational procedures that are key components of the MDSS architecture or are fundamental processes in the maintenance decision process.**

   The baseline is needed to help us understand what components of the MDSS will require the most development effort. The proposed architecture requires some enhanced capabilities that may exceed existing programs. We need to establish where we are at the beginning of the project in order to get a better handle on the development direction and level of effort. We also have an obligation to those who fiscally support the program to clearly document what we plan to do at project inception, why we expend the effort we do, and what incremental change we will accomplish. A baseline is necessary to support this documentation process, while future discussion will indicate what MDSS can provide in the way of expanded support as well as those needs it cannot enhance.

4. **Define the maintenance needs that serve as fundamental requirements for the development of an MDSS and which must be partially or fully satisfied in order to create a successful MDSS design.**

   This objective defines a fundamental approach to this pooled fund study. It is imperative that we fully document and understand the operational needs of maintenance. This is fundamental to set the direction of the project and determine modifications in the architecture to wholly or partially satisfy specific DOT needs. Designing solutions without understanding the needs that must be fulfilled is folly.

5. **Gain an understanding of the perception of MDSS within the states at various levels within the agencies and determine potential approaches to overcome sources of resistance.**

   Technological change often only comes with sociological or attitudinal change. For MDSS to be successful, it is essential that it be accepted amongst field personnel as an effective tool that does not threaten their security. We must understand up front what potential barriers we may face and use this understanding to create an effective implementation program that minimizes the sociological barriers.

6. **Agree upon the MDSS design, a phased development and implementation program to build the MDSS infrastructure, and a test program to evaluate the performance of the evolving MDSS program.**

   The eventual MDSS design should be a successful integration of the information we gain by accomplishing the tasks associated with objectives 1 through 5. Once we have done our homework and laid out a strong argument for our development effort we should be able to develop a game plan that achieves the expectations derived from user needs and our existing capabilities.

7. **Enhance, further develop, and integrate the initial modules of the MDSS to provide a framework for evaluation of the MDSS concept and subsequent guidance on the direction of the development effort.**

   Growth and progress come from a cyclical process that includes new development, evaluation, feedback, reassessment, design modification, and an agreement on a refined work plan. The objective is to evolve the MDSS design into an effective maintenance support tool. It will be important to have an effective instrument to guide and direct our ongoing efforts.

MDSS INFORMATION CATEGORIES

1. **History of RWIS Program**
   The review should start with the initial operational need that engendered the RWIS program and discuss what information was needed to fulfill the operational need. The history should discuss the original RWIS design and the development of the original sensors. The discussion should follow the evolution of the RWIS design and the change in the approach and maturation of the pavement sensors and meteorological instrumentation. Other areas that need to be included in the discussion include pavement specific forecasting, energy and mass balance models, user interfaces, user acceptance, and ancillary uses of RWIS (e.g., bridge spray systems). Finally, there needs to be documentation of the known barriers to effective utilization of the RWIS tools and the identification of deficiencies perceived within RWIS implementations.

2. **Maintenance Needs – Fundamental Requirements for Operation**
   Based upon the needs assessment objective (Objective 4) develop a list of fundamental issues that the DOTs have to address on a routine basis. Some of these items can be extracted from the Surface Transportation Weather Decision Support Requirements (STWDSR) document, others can be taken from the policies and practices documents, and the entire list needs to be clarified based upon the interview process.

3. **Maintenance Needs – Information Resources to Support Operations**
   Based upon the requirements for a needs assessment, develop a list of existing or proposed resources to support operations. These are the pieces of information that aid in the deployment and utilization of equipment and manpower to accomplish the operational requirements outlined in item 2. It includes such items as pavement conditions, weather data, status of equipment, status of workforce, materials inventory, location of equipment, etc. The data resource should also consider how the information is managed and how it is transferred from its storage location to the user when needed in the decision process.

4. **Maintenance Needs – Decision Tools to Support Operations**
   This is the list of rules and the logic required to make maintenance decisions. This logic should derive from two separate sources. One source should be the maintenance staff and should be a compilation of situations and how users would respond based upon experience or state policies. It is anticipated that this input will be quite varied and reflect needs of a diverse community of stakeholders. Another source should be the physical and

chemical rules to transform the state of the contaminant layer (surface layer of water, ice, snow, chemical, grit, etc.) from one state to a different, more desirable state.

5. **Maintenance Needs – Ancillary Support Services (materials inventory, equipment status, availability of labor)**

   The decision support system isn't just about how to respond to adverse winter maintenance situations. There are numerous related decision processes that are just as important to maintainers as direct maintenance of the roadways that can be just as time consuming. The maintenance decision process should be coupled with these associated management service modules. A partial list includes materials inventory and procurement, vehicle maintenance and replacement planning, management and tracking of peripheral equipment (plows, spreaders, feeders, storage facilities, brine makers, etc.). There is also an extensive list of services needed as input into the decision module of the MDSS. Some of the services include staffing and current availability, shift management, equipment availability and current status, vehicle tracking, materials application tracking, plowing history, and road condition reports. The list undoubtedly needs to cover a multitude of other associated services that are necessary to effectively perform routine maintenance activities.

6. **Characterization of FHWA MDSS Functional Prototype program**

   The detail that comes out of the analysis of the FHWA MDSS FP in Task 2 of the Phase 1 Workplan needs to be stored for reference for the development of the pooled fund MDSS.

7. **Baseline analysis of current maintenance operations (practices, policies, procedures, support services, road condition reporting)**

   This is a distillation of the documentation of current practices and policies plus a complete list of services that the DOTs currently use or provide as part of their maintenance program.

8. **Baseline analysis of DOT communications infrastructure**

   The communication of information within the DOT is maintained within an information technology or communications division within the various states. This infrastructure covers a broad spectrum of components which includes radio, phone, fiber, voice processing centers, digital networks, digital processing centers, and user interface devices. Communications has such a tremendous impact on the transfer of data necessary for the decision support process that we must have a fairly detailed understanding of the communications infrastructure within each state and the policies that determine how information can be moved within this infrastructure and how it can be exchanged into and out of the state infrastructure.

9. Sociological Perspective of MDSS

This is the output of Task 5 in the MDSS Detailed Phase 1 Workplan.

10. MDSS architecture

This is result of the effort defined within Task 6 of the Phase 1 Workplan.

11. MDSS processing techniques

The processes go hand-in-hand with the architecture defined within Task 6.

12. MDSS data structures

This is the result of the effort defined within Task 6 and becomes an important consideration in the design of an open system architecture.

13. MDSS data exchange protocols

This is the result of the effort defined within Task 6 and is essential in the movement of data in an open systems design construct.

14. MDSS communications protocols

This is the result of the effort defined within Task 6 and will address the communications issues that can potentially delay implementation in a state if the interface issues are not resolved with the communications group.

15. Required research

The proposed MDSS stretches the technological expertise of several areas of the architecture. A number of these efforts are associated with the pavement model or forecasting techniques. Others are associated with the fundamental methods of risk management in a decision support system environment. Additional effort will also be needed in techniques to collect and telemeter operational information from the field to a processing center.

MDSS PERSONNEL RESOURCES

1. **Technical panel**

   The technical panel is comprised of those individuals within the member states participating in this pooled fund study who have the responsibility to monitor and guide all phases of the development of the MDSS, both in its general evolution and its involvement within their state. Membership on the panel also includes members of the FHWA who have been involved with RWIS and 511 programs at the national and regional levels. The current membership includes:

Jon Becker	SDDOT Research
Dennis Belter	INDOT Program Support
Dennis Burkheimer	IADOT
John Forman	SDDOT Operations Support
Jerry Horner	NDDOT Maintenance
David Huft	SDDOT Research
Bruce Hunt	FHWA
Larry Kirschenman	SDDOT Yankton
Tony McClellan	INDOT Operations Support
Curt Pape	Mn/DOT Maintenance
Paul Pasano	FHWA
Rudy Persaud	FHWA
Ed Ryen	NDDOT Maintenance

2. **State champions**

   Preferably, there should be several MDSS champions in each state. These individuals see new technology as a way to get their jobs done more efficiently and effectively and are willing to evaluate new approaches to maintenance. Members of the technical panel should select the champions within their respective states, get the individuals permission to participate, and provide the contact information. The list of champions may include members of the Technical Panel. It is anticipated that the champions will participate in the interviews, be directly involved in the field tests, or serve in an advisory capacity regarding all or part of the components of the MDSS development effort. The Technical Panel shall determine whether these champions become part of the MDSS reflector site or whether the project needs to keep them informed in some other manner.

3. **Research support personnel**

   The MDSS effort will require interactions with a number of DOT personnel in capacities not directly related to maintenance. The group is not explicitly defined but it is anticipated that the project will either need resources from or need to interact with individuals in communications, data processing, internal DOT networks, and possibly ITS departments. Members of the Technical Panel will likely need to provide points of contact for the required resources within their states.

4. **Field supervisors in test area**
   Field supervisors are those individuals in Operations who have the responsibility to oversee and monitor aspects of the MDSS test in the field. The nomenclature reflects their responsibility in the MDSS test and not necessarily their designated capacity in the DOT. However, in most cases the individual selected will most likely be the local individual with supervisory responsibilities for that area. It is anticipated that the Technical Panel will select the individuals within this category and the individuals chosen will participate in the MDSS development effort from the initial interviews through the actual test area field evaluations.

5. **Field supervisors interested in MDSS**
   There are a number of individuals within each state that have an interest, or at least curiosity, in the MDSS program and desire to participate or remain informed about the progress of the project. Because the decision support logic needs to address the diversity across each of the states, it is important to provide a mechanism for these individuals to critique the development process and provide input regarding factors that may not be important in the chosen test areas. The Technical Panel in consort with Meridian needs to define the composition of this group, the communications process, and methods to involve these individuals in the evaluation.

6. **Other field representatives**
   There may be other individuals who hold field positions that are not supervisory in capacity but who have an interest in the MDSS project and could become important resources in the design of MDSS or eventual champions of the program. There needs to be a mechanism for their participation. The Technical Panel and Meridian need to define the structure to permit their involvement.

7. **Contract administrators**
   Administrative concerns are always a component of any contractual agreement and it will be necessary to address these concerns through the contract administrators. David Huft, SDDOT, will serve as the lead liaison concerning contract administrative issues.

8. RWIS service representative(s)

Data from the Road Weather Information Systems will play an integral part in the development of the MDSS. The project will need to address both access to the RWIS data and the quality of the data. This will require interaction with the individuals tasked with managing the data processing components and servicing the field components. Members of the Technical Panel need to specify the points of contact in their respective states.

PERSONNEL/POINTS OF CONTACT

Where possible please enter the name, title, phone number, and e-mail address of each recommendation. As a minimum for now, please provide names of those individuals you recommend for each category. If all e-mail extensions in your state addresses are the same, you may enter the extension once and merely enter the name portion of the address in the E-MAIL cell in the table.
E-mail extension = ________________________ (e.g., DOT.STATE.yy.US)

2. State champions

NAME	TITLE	PHONE	E-MAIL

3. Research support personnel

NAME	TITLE	PHONE	E-MAIL

4. Field supervisors in test area

NAME	TITLE	PHONE	E-MAIL

5. **Field supervisors interested in MDSS**

NAME	TITLE	PHONE	E-MAIL

6. **Other field representatives**

NAME	TITLE	PHONE	E-MAIL

7. **Contract administrators**

NAME	TITLE	PHONE	E-MAIL

8. **RWIS service representatives**

NAME	TITLE	PHONE	E-MAIL

APPENDIX B

TASK 1.2

Study Objectives

Development of Maintenance Decision Support System
SD2002-18

Task 1.2
Determine Modes of Investigation

Objective:
The objective is to define the forms of investigation necessary to transfer the knowledge base of the DOT personnel into the knowledge base of the MDSS study knowledge base.

Process:
Meridian will list the potential modes of investigation and provide the strengths and weaknesses of each approach as it relates to the collection of information needed to support the development of the Maintenance Decision Support System. Meridian will distribute the document to the Technical Panel for review. Members of the Technical Panel need to review the discussion and make recommendations on modifications or alternative approaches. Any revisions may be returned via the MDSS reflector site or directly to the principal investigator at Meridian (bobhart@meridian-enviro.com). Meridian will formulate these recommendations into a revised Task 1.2 document and distribute a second time. Once the Technical Panel agrees that the modes are an appropriate methodology, Meridian will compose a final document for distribution. The document will then become part of the Final Report.

Technical Panel Involvement:
The Technical Panel members need to review the entire Task 1.2 document and provide recommendations. To permit open dialog, Technical Panel members should include an editorial comment after each change, unless the change is merely a grammatical or word change. These editorial comments may be embedded in the document using either the Tracking or Comment feature in Microsoft Word or some highlighted addition inserted in the text.

Milestone Dates:
End of Input Phase 1 .... March 21, 2003
Distribution of Modification 1 .... March 24, 2003
End of Input Phase 2 .... March 28, 2003
Decision on Release of Modification 2 .... March 31, 2003

OBJECTIVES OF INVESTIGATION

The objectives of the investigation were delineated in three primary tasks of the Detailed Phase 1 Work Plan. These objectives and their respective tasks in the Work Plan are:

1. Identify and Prioritize the Needs for Maintenance Support Functionality (Task 3)

2. Assess Capabilities for Road Condition Reporting and Tracking Maintenance Activities (Task 4)

3. Assess Institutional Receptivity to MDSS (Task 5)

POTENTIAL MDSS MODES OF INVESTIGATION

8. Face-to-Face Interviews

Face-to-face interviews are a formatted dialog structured around a set of questions that have the joint approval of the Technical Panel and Meridian. The questions form the base, or thread, of a modified free-form discussion. The predefined questions are essential to assure continuity in the interview process and derive responses that may be evaluated in a statistical manner. However, the interview should be relatively spontaneous and the interviewee should not sense that the interviewer is merely going down a list of questions and that the process is really a verbal questionnaire. The objectives are to raise key issues, elicit a response on the required query, and then allow the respondent to elaborate or even digress into issues the interviewee feels are important to the MDSS process or to his/her operational needs. Meridian anticipates they will conduct the interview with a minimum of two participants; one individual will serve as the primary interviewer and the other(s) will take notes. Unless objected to by the interviewee, all interviews will be audio recorded to capture details of the conversations that may be difficult to record in writing during the meeting. All audio recordings will be destroyed after review for relevant content. In this manner, Meridian expects to capture most of the input provided by the DOT participant(s). Meridian requests that meeting sizes be kept to a small number of DOT participants to permit maximum interaction with each interviewee. It is hoped that the maximum number of DOT members involved in a given interview will be three or less.

Strengths

- Permits collection of answers to fundamental questions within the project
- Permits elaboration on issues associated with the fundamental questions
- Permits the interviewee to digress into topics that are of importance to the interviewee and may provide ideas or facts that a regular question set would not address

- Allows the interviewer to interpret answers based upon other body language factors
- Exchange builds a rapport between the interview team and the participants that can pay dividends later in the project
- Allows Meridian personnel to focus on issues most important to DOT personnel involved in different levels of the maintenance organization
- Allows Meridian personnel to learn what issues are the key “hot buttons” in field operations and which items are most likely to benefit DOT maintenance and in what way

Weaknesses

- Takes considerable time for both the interviewing team and those participating in the interview
- Creates considerable scheduling challenges
- Can reach an impasse if there are personality conflicts or the interviewee is reticent about the program and the interview process
- Discussions can concentrate on certain areas too extensively and limit or even preclude discussing some of the issues

9. Phone Interviews

Phone interviews follow the same format as the face-to-face interviews but they are done over the phone. To involve multiple individuals at the same time, Meridian will use speakerphones or conference calls to include multiple parties in the conversation.

Strengths

- Permits collection of answers to fundamental questions within the project
- Permits elaboration on issues associated with the fundamental questions
- Permits the interviewee to digress into topics that are of importance to the interviewee and may provide ideas or facts that a regular question set would not address
- Exchange aids the development of a rapport between the interview team and the participants that can pay dividends later in the project
- Allows Meridian personnel to focus on issues most important to DOT personnel involved in different levels of the maintenance organization
- Allows Meridian personnel to learn what issues are the key “hot buttons” in field operations and which items are most likely to benefit DOT maintenance and in what way

Weaknesses

- Requires considerable time commitment from both the interviewing team and those participating in the interview
- Requires some scheduling effort
- Is prone to interruptions

- Can reach an impasse if there are personality conflicts or the interviewee is reticent about the program and the interview process
- Discussions can concentrate on certain areas too extensively and limit or even preclude discussing some of the issues

10. Survey Questionnaire

A survey questionnaire is an excellent mechanism to receive responses from a broad audience rather than a focused group of individuals. The survey is limited to a couple of pages and should take no more than 5 to 10 minutes to complete answer. The question format is typically "**Yes/No"** or **multiple choice** questions. In this study, the survey questionnaire may be appropriate for feedback on the perception of the MDSS program and its anticipated impact on maintenance operations. This feedback is part of the requirement for Task 5 of the Detailed Phase 1 Work Plan. The design of the questionnaire should permit easy conversion of the answers to metrics and should not contain questions that could have ambiguous interpretations.

Strengths

- Permits collection of answers to fundamental questions within the project
- Is easy to administer to a large number of people
- Takes minimal time after questions are developed
- Is organized to permit easy calculation of metrics
- Takes minimal time on the part of person answering the questionnaire

Weaknesses

- Percentage of participants may be limited
- Input is limited to direct response to questions in questionnaire

11. Detailed Questionnaire

Detailed questionnaires are designed to extract complete, complex responses from the person answering the questionnaire. The set of questions may contain "**Yes/No"**, **multiple choice**, **fill-in-the-blank**, or **free-form** responses. Meridian anticipates that some form of detailed inquiry will be needed to obtain the detailed feedback needed to design the MDSS program. Much of the value of the MDSS will come from the integration of detailed information inherent in experience of DOT personnel. As the development effort evolves it will become more important to go back and inquire about specifics regarding certain, relatively narrow areas within maintenance operations. The detailed survey is an effective instrument to capture answers regarding specific issues or eliciting discussions that highlight unique operations. It also permits the DOT respondent to describe examples that may be pertinent.

Strengths

- Permits collection of answers to fundamental questions within the project

- Permits DOT users to share a substantial amount of information via the detailed responses
- Is easy to administer to a large number of people
- Takes less time than direct interviews once the questions are developed
- Can be organized to permit easy calculation of metrics
- Outcome may direct investigators to redirect their efforts or inquiry process to clarify specific issues

Weaknesses

- Percentage of participants may be limited
- Requires a more significant time commitment on behalf of DOT personnel than survey questionnaires, which may serve to reduce the number of responses
- Input may be limited to direct responses to questions in questionnaire
- Legibility of handwriting may be an issue in some instances

12. Time-Study Analyses

Time-study analyses allow a third party evaluator to assess the routine operations from an external viewpoint. The purpose of the time-study in this project is to educate the evaluator in the routine practices of the DOT maintenance operator or supervisor. It is not to evaluate the efficiency of the actual operational procedures and make recommendations on modifications to increase performance, although it may permit Meridian to develop MDSS tools intended to address certain perceived needs that may be apparent from this process. Meridian feels it will be extremely beneficial for a number of its development staff to see the actual operational procedures associated with winter maintenance activities in the member states.

Strengths

- Permits investigator an opportunity to see operational response to environmental situations
- Permits investigator to learn the procedures necessary to perform maintenance tasks
- Permits the investigator to understand the detail involved in the decision support logic and how these decisions affect response scenarios
- Allows the investigator and DOT participants to build a rapport that can pay dividends later in the project
- Allows Meridian personnel to learn firsthand what issues are most important to DOT personnel involved in different levels of the maintenance organization
- Allows Meridian personnel to learn what issues are the key “hot buttons” in field operations and which items are most likely to benefit DOT maintenance and in what way

- Permits investigator to ask specific questions to clarify key points regarding particular maintenance procedures

Weaknesses

- Takes considerable investigator time
- Time limitation may limit experience to a small subset of the possible maintenance response scenarios
- Practices seen in one time study may be indigenous to that location and procedures at another location may be different

13. Feedback on Interface Prototypes

As part of Task 3 of the Detailed Phase 1 Work Plan, Meridian proposed to develop a prototype for the interface anticipated with the MDSS operational program. This prototype and the feedback from users regarding the test interface will be instrumental in developing a user interface that is acceptable to the dominant user community. It is anticipated that the interface will need to address a broad spectrum of user capabilities and the instrument to capture the feedback will need to address this. The entire interface development effort will need to be an iterative process requiring some degree of trial and error.

Strengths

- Gives direct feedback on user interface
- Allows users to relate to tangible features of the MDSS
- Allows Meridian personnel to learn what issues are most important to DOT personnel
- Allows DOT personnel an opportunity to indicate which components of the display are important to them and which are superfluous
- Permits Meridian to assess whether the interface needs to be flexible and possibly separated into different interfaces or different interface levels
- Can redirect the interface development effort at all stages of development, thereby minimizing the amount of time lost developing unsatisfactory tools

Weaknesses

- Takes considerable time to develop the interface
- Feedback is generally limited to the interface and not the decision support logic behind the interface

14. Unstructured Discussions

Much of the exchange of information will occur through discussions concerning specific issues within the MDSS development effort. These discussions may occur during any of the processes defined above. Many will be digressions from the primary topic and will occur when a key word or topic is brought up in a discussion or when an idea or topic of importance pops into one’s head. Much of the unstructured discussions will occur during phone conversations between one of the Meridian development team and a member of the DOT resource team.

Strengths

- Permits elaboration on issues associated with the fundamental issues within the study
- Permits the investigator to concentrate on a single topic or area of the study in order to develop a detailed understanding of the DOT need and how DOT personnel respond to this need in specific situations
- Allows the DOT participant to not only answer the specific inquiry but also raise associated concerns or decisions
- Allows Meridian personnel to learn what issues are most important to DOT personnel involved in different levels of the maintenance organization
- Allows Meridian personnel to learn what issues are the key “hot buttons” in field operations and which items are most likely to benefit DOT maintenance and in what way
- Permits an excellent opportunity to develop a good transfer of information from the operational approach to the technological approach to maintenance
- Allows both parties to see where further investigation is necessary

Weaknesses

- Takes considerable time on the part of the investigator and the DOT people involved
- The level of exchange may be impacted by the personalities involved
- Discussions can concentrate on certain areas too extensively or get off on tangents that may be of little value to the study
- Cannot be planned, although they can be facilitated by maximizing the informal conversation time between the MDSS users and the MDSS development team

APPROACH TO INTEGRATION OF INVESTIGATION METHODS

The Study would benefit from the use of all or most of these approaches in the execution of Phase 1. Based upon the tasks defined in Phase 1 and the timeframe for the execution of Phase 1, Meridian proposes the following plan to utilize the majority of the modes of investigation discussed above.

- Use of a ***survey questionnaire*** to assess the receptivity of the MDSS in a DOT-wide distribution of the survey (Task 5 of the Detailed Phase 1 Work Plan)
- Development of a detailed question set and the use of this question set as the basis for the ***face-to-face interviews*** (Task 3 and part of Task 4 of the Detailed Phase 1 Work Plan)

- The responses from the interviews will be used to modify the question set in the ***detailed questionnaire***
- The revised questions in the ***modified detailed questionnaire*** may be used in two ways:
    - 1) As a ***detailed questionnaire*** to be filled out by the champions and lead supervisors
    - 2) Integration into a dialog as part of a set of follow-up ***phone interviews*** with the individuals who participated in the ***face-to-face interviews***
- The ***interviews*** and ***questionnaires*** will likely create a new set of questions or expose areas where the Meridian investigators need additional information. The primary source of the information will come from ***unstructured discussions*** with key contacts in the DOTs or experts regarding the particular area of uncertainty. If the unresolved issue may be addressed differently across individual agencies or states, Meridian may have to use the ***interview*** and ***questionnaire*** approaches once more.
- Time-study and GUI feedback mechanisms will depend upon the schedule beyond phase 1.

APPENDIX C

TASKS 3.1 & 3.2

MDSS GRAPHICAL USER INTERFACE GUIDELINES

MDSS Graphical User Interface Design Guidelines.

Introduction

The construction of a highly functional graphical user interface will be a critical part of a successful MDSS system. While the graphical user interface (GUI) by itself will have little functional role other than directing information to and from the decision support elements in the MDSS, it is the interface that the maintenance user will encounter and will likely be assumed to "be the MDSS". Therefore, developing this functional interface carefully is important to meet the expectations of the MDSS outcomes. As the interface will involve numerous individuals in the development and design level, both at Meridian and at the respective state DOTs, it is important that all parties involved have an understanding of expectations and limitations of GUIs. This guideline document is meant to serve both as an overview of graphical user interfaces and as a design guideline to be used throughout the development process of all MDSS GUIs. Following this guideline will help to ensure that consistency in purpose and construction is attained.

Overview of Graphical User Interfaces and Their Design

Graphical user interfaces (GUIs) have become the user interface of choice found on desktop computers. Yet despite the GUI's popularity, surprisingly few programs exhibit good interface design. Moreover, finding information explaining what constitutes a good and intuitive interface is exceedingly difficult. The guideline documents that follow results from reviews of existing literature on GUI design, discussions with computer scientists in academia and industry who focus on GUI design methods, insight from cognitive psychology literature on methods in decision making and from personal experiences by Meridian staff in effective GUI applications. This summary document identifies the basic rules for good interface design that are recommended for adoption by the MDSS Technical Panel.

Before beginning a discussion of elements constituting a good design of graphical user interfaces, it is important to first describe various causes a bad design. In this way, the personnel involved in designing and evaluating the MDSS GUI design will understand better that beginning down wrong paths can lead to poor design and poor user effectiveness.

A major cardinal sin in GUI design is attributable to developers often designing for what they know, not what the users know. This age old problem occurs in many other areas of software development, such as testing, documentation, and the like. It is even more pernicious in the interface because it immediately makes the user feel incapable of using the MDSS client software. Because of this it is important that the development of effective GUIs focus on the user and their desires for the end product and not a perception by the developers as to what they believe the user should see. Furthermore, with the premise that naturalistic decision-making (Zsambok and Klein, 1997) (the way people use their experience to make decisions in the context of a job or task) embodies the principle elements of the present MDSS project, it is important to understand the methods of cognition as part of the decision making and to impart as much of this effort to the GUI as possible.

This topic is central to the field of human-computer interaction (HCI), which is concerned with interface design and its highly interdisciplinary nature. Complete understanding of the processes involved requires the use of research findings and methods from psychology, computer science, information science, engineering, education, and communications. A central concern of HCI research is to determine the effects of human physical, cognitive, and affective characteristics on the interactions between users and computers for specific tasks. Thus, HCI researchers develop models of human activity and use these models in designing new interfaces (Dix, et. al., 1998).

The information-processing model of cognition prevalent in cognitive psychology provides a foundation for interface design. This model establishes that: (1) humans have a working memory limited to five to seven "chunks" of information; (2) humans must have their attention refreshed frequently; and (3) recalling information requires more cognitive effort than recognizing information. Computer interface styles consistent with this model include menus, query-by-example, and direct manipulation. Novices and casual users prefer menus to command languages because recognizing an appropriate option is easier than remembering a command. Direct manipulation interfaces (such as touch panels in information kiosks, in-maintenance vehicle input devices and graphic displays in of complex weather images) overcome many psychological limitations because they share the "load" between physical and cognitive activity. In addition, their immediate feedback and ease in reversibility invite user application.

GUI designers’ predilection for control is evident in applications that continually attempt to control user navigation by graying and blackening menu items or controls within an application or limiting their ability to adjust the level of detail afforded the user in the interface. Controlling the user is completely contradictory to the event driven design in which the user rather than the software dictates what events will occur (Reisner, 1981). As GUI development occurs, if a lot of time is being spent dynamically graying and blackening controls, then the design approach must be re-examined as to whether too much is being blocked from the user or being made too complex to obtain. With the plug-and-play design concept being promoted for the MDSS client, there will no doubt be numerous new elements added to the maintenance decision support system over time. As these changes occur at a faster pace, flexibility in user interfaces will become a key enabler for providing these changes without the ongoing need to ‘re-invent’ the GUI. Allowing the maintenance personnel to access the client-side applications in ways not initially anticipated is indeed intimidating for the MDSS developers, but will ultimately be satisfying to both the developers and users as the development evolves into a greater overall acceptance and empowerment for the maintenance user.

Likewise the GUI design should ensure that features used frequently are readily available. The design must avoid the temptation to put everything on the first screen or load the toolbar(s) with rarely used buttons. It will be important to do the extra analysis with maintenance personnel to find out what features can go behind the panel instead of on the faceplate.

ELEMENTS IN SUCCESSFUL GUI DESIGN

Successful GUIs share many common characteristics. Most importantly, good GUIs are more intuitive than their character base counterparts. One way to achieve this is to use real-world metaphors found either within maintenance operations or common to the maintenance personnel's frequently used computer desktop environment whenever possible. Another important characteristic of good GUIs is speed or more specifically, responsiveness. Many speed issues are handled via the design of the GUI, not the hardware. Depending on the type of application, speed can be the make-or-break factor in determining MDSS projects acceptability by the maintenance community. Experience has shown that slow performance will quickly result in users of any computer-based application wanting to abandon the system.

However, it is important to understand that most applications in the MDSS software system will involve sophisticated calculations, access to distant data sources and/or the generation of complex graphics.   Thus, it will often be necessary to develop a perception of speed when periods of slow response are unavoidable. Fortunately, there are a number of ways to proceed. Avoid repainting the screen unless it is absolutely necessary. Another method is to have all field validation's occur on a whole screen bases, instead of a field-by-field bases. Also, depending upon the skills of the user, it may be possible to design features into a GUI that give the "power user" the capability to enter more complex commands that reduce the mining downward through multiple menus. Such features include mnemonics accelerator keys and toolbar buttons with meaningful icons, all of which allow the speed user to control the GUI and rate/type of display generation.

The ultimate goal is to develop the best possible MDSS GUI that provides a long-term framework and consistency for maintenance personnel. The following sections list specific design principles to be used in the MDSS GUI design and development.

Understand Maintenance Personnel

Above all, the GUI applications must reflect the perspectives and behaviors of maintenance personnel and their manner of computer usage. To understand these characteristics fully, Meridian must first understand what commonalities in characteristics exist between all maintenance personnel beyond their computer experience i.e., understand them as people. Cognitive psychology stresses that people learn more easily by recognition than by recall (O'Neil, T, 2003). By breaking down the complex decision making process into smaller communication pieces between the system and the user provides the modularity that will enable the construction of recognition paths that permit the user to make more informed inputs to the decision making process. The expression of these smaller communication pieces as visual event grammars permits the algorithm construction of the GUI modules (Reisner, P., 1981; Berstel et.al, 2001). Therefore, it is important to always attempt to provide a list of data values to select from rather than have the users key in values from memory. The average person can recall about 2000 to 3000 words, yet can recognize more than 50,000 words.

Be Careful Of Different Perspectives

Many GUI designers unwittingly fall into the perspective trap when it comes to icon/symbol design or the overall behavior of the application (Mandel, 1997). Often these designers will apply too much artistic creativity to the development of icons where simplicity would serve an equal purpose. Further, designers may apply a faulty perception to the meaning of an icon for a given application that often leads to confusion and misperception by the user. To eliminate these problems, it is important to have a reserved set of icons or symbols containing standard approved icons and symbols used within the maintenance community. In addition, depending upon the computer experience of the maintenance personnel selected icons found within standard computer-based word processing environments and desktop applications should be used in a non-ambiguous manner within the display environment.

Design for Clarity

GUI applications often are not clear to end-users. One effective way to increase the clarity of MDSS applications is to develop and use a list of reserved words. A common complaint among by application software users is that certain terms are not clear or consistent. This lack of clarity can be found in semantic differences between what the developer believes are the appropriate term for a button or menu and what the maintenance personnel believe is appropriate. There may also be debates among maintenance personnel, either between states or within a single state, as to what the appropriate meaning should be. An example of this might be the meaning of "item" versus the meaning of "product". Neither may be the most appropriate and the use of either could lead to confusion. This lack of consistency, ultimately leads to confusion and frustration for users.

Table 1 gives an example of a list of reserved words, and application development group might completely expanded table with additional reserve words.

Text	Meaning & Behavior	On Button?	On Menu?	Mnemonic Keystrokes	Shortcut Keystrokes
OK	Accept data entered or acknowledge information presented and remove the window	Yes	No	None	<Return> or <Enter>
Cancel	Do not accept data entered and remove the window	Yes	No	None	Esc
Close	Close the current task and continue working with the application; close view of data	Yes	Yes	Alt+C	None
Exit	Quit the application	No	Yes	Alt+X	Alt+F4
Help	Invoke the application's Help facility	Yes	Yes	Alt+H	F1
File	Invoke drop down menu presenting base program operations	No	Yes	None	None
Open	Invoke file selection dialog	No	Yes	Alt+O	Ctl+O
Save	Save data or configuration entered and stay in current window	Yes	Yes	Alt+S	Shift+F12
Save As	Save the data or configuration entered with a new name	No	Yes	Alt+A	F12
View	Invoke drop down menu presenting viewport options	No	Yes	Alt+V	None
Tools	Invoke drop down menu presenting optional data/window applications	No	Yes	Alt+T	None
Properties	Display and modify general GUI configuration preferences	No	Yes	Alt+I	None

Table 1. Standard reserved words common in most graphical user interface systems.

Design for Consistency

Good GUIs apply consistent behavior throughout the application and build upon the user's prior knowledge of other successful applications (Smith and Mosier, 1986). When writing software GUI interfaces for MDSS applications it is important to provide as many consistent behaviors for each level of maintenance personnel and/or maintenance personnel between state DOTs as possible. For example, each of the participating state DOTs has or will have road condition reporting systems available for MDSS activities. However, the database structures and possible content will vary for each state and will result in differing ability to display certain information. Defining a GUI that hides the dissimilarity in these databases will be important to provide a similar look-and-feel across all states. Further, this uniformity in design will provide for more stability in GUI software maintenance for the future.

Provide Visual Feedback

As mentioned earlier, the calculations involved in completing a maintenance decision support activity will be lengthy at times. Furthermore, the inconsistency in processor speeds within the participating MDSS DOT maintenance community, even within a given state or within a maintenance unit, may lead to significant variation in desktop performance. This will result in a great variation in time needed to complete a given application transaction. When delays occur, unless there are visual cues provided to indicate the status of the activity occurring, user frustration will likely develop that will potentially reduce user acceptance of the MDSS application. Users greatly appreciate knowing how much longer a given operation will take. As a general rule, most users like to have a message dialog box with a progress indicator displayed when operations are going to take longer than seven to 10 seconds. This number is highly variable based on the type of user in overall characteristics of the application. Capabilities must be designed in the MDSS GUI to inform the maintenance user of the status of pending operations and special notices when certain activities are to take extended time to complete.

Provide Audible Feedback Judiciously

Audible feedback, on systems capable of supporting this feature, can be useful in cases where the client's application needs to warn the user of an impending serious problem. Such a problem might be one in which further activity by the user could cause loss of data or software or an application may abort. It will be important to allow users to enable/disable audio feedback, except in cases where a significant error must be addressed. The GUI must avoid excessive use of audio feedback as it can sensitized the users to the effective use of audio and it can become a source of annoyance not only to the user, but to those in the workspace around the user.

Keep Text Clear

Developers often try to make textual feedback clear by adding a lot of words. However, they ultimately make the message less clear. The MDSS GUI must use concise wording of text labels, user error messages, and online help messages, which is often challenging to accomplish. Textual feedback will be most effectively accomplished after conducting user feedback surveys and working with the Technical Panel to assure that wording meets the approval of experienced maintenance personnel.

Provide Traceable Paths

It will be critical to prevent maintenance user comments such as "I don't know how I got to this window, and now that I'm here, I don't know how to get out". To prevent this, it is important to provide traceable (or retraceable) paths (Preece, et.al., 2002). Providing a traceable path is harder than it sounds. It starts with an intuitive menu structure from which to launch specific features.

To assist in minimizing the path lengths to perform an activity, the GUI design must identify areas where menu structure can be flattened. It is necessary to avoid more than two levels of cascading menus. For each menu and/or dialog box there must be a descriptive title bar provided to remind the user what menu items or buttons were pressed to bring them to the window now in focus.

Provide Keyboard Support

Keyboards are a common fixture on computer desktops and provide efficient means to enter text and data. With the introduction of GUI applications, it is often assumed that computer users will embrace a mouse as the primary interactive device. However, mouse inputs are serial and do not provide convenient methods to circumvent a chain of serial inputs. This can become time-consuming and inefficient when too many mouse clicks are required to enter a request. As the maintenance user becomes more accustomed to the GUI interface and the applications desired, the use of a mouse may actually detract from the efficiency and effectiveness of the GUI.

Where practical, keyboard accelerators can provide efficient ways for users to access specific menu items and/or control application execution within the client window. The accelerators used should be easy to access and limited to one or two keys (such as F3 or Ctrl-P). However, keyboards have limitations in the GUI world, such as when trying to implement a direct manipulation task like drag-and-drop, pointing, and resizing.

In contrast, some users find difficulty with typing on keyboards and prefer an exclusive use of a mouse for all operations. The result is that it is necessary to provide complete, and equal, keyboard and mouse support for all menu and window operations.

Watch the Presentation Model

A critical aspect that ties all facets of the interface together is the interface’s look and feel. The look and feel must be from one screen to the next. On the basis of the maintenance user’s experiences with one screen or one dialog box, they should have some sense of how to interact with the next screen or control.

Searching the interface model for good design continuity is most important. The model should involve careful decisions, such as whether the application will have a single (such as found with the FP MDSS) or a multiple document interface (such as commonly found with word processing software applications). The model also will validate how users perform their main task within the application.

Identifying the appropriate presentation for the application early in the design development phase of the GUI will greatly facilitate the subsequent windows being developed, since they will have a common framework in which to reside. On the other hand, if the presentation model is not defined early in the design of the MDSS GUI, late changes to the look and feel of the application will be much more costly and time-consuming because nearly every window may be affected.

Modal vs. Modeless Dialogs

When input is needed from the user the information is often entered through the use of a modal dialog box. GUI developers have largely shunned using modal dialogs asserting they are too constraining on the user. However modal dialogs do have many uses in complex applications, since most people only work on one window at a time. Hence, when a finite task exists, the use of modal dialogs is encouraged. For tasks with no fixed duration, modeless dialogs will normally be the preferable choice with a major caveat: try to keep the user working in no more than three modeless windows at any one time. Go beyond this magical number and the level of window confusion increases rapidly and the availability of computer resources may become critically short. Table 2 provides guidelines to determine the appropriate use of dialog boxes and windows.

Type	Description	Use	Example
Modal	Dialog Box	Presentation of a finite task.	File Open dialog box
Modeless	Dialog Box	Presentation of an ongoing task.	Search dialog box Task List dialog box
Application Window	Window frame with document (child) windows contained within	Presentation of multiple instances of an object. Presentation of data within two or more windows.	Word Processor Spreadsheet
Document Window	Modeless dialog box or document window contained within and managed by the application window	Presentation of multiple parts of an application.	Multiple views of data (sheets) i.e., view of displays from multiple weather radars.
Secondary Window	Primary window of a secondary application.	Presentation of another application called from parent.	Invoke Help within an application. Display of treatment scenarios.

Table 2. Guidelines for appropriate use of dialog boxes and windows.

Control Design

Controls are the visual elements that let the user interact with the application. GUI designs are faced with an unending array of controls to choose from. Each new control brings with it expected behaviors and characteristics. Hence, choosing the appropriate control for each user task will result in higher productivity, lower error rates, and higher overall user satisfaction. Figure four includes a guideline for control usage in screens. It is important to try to keep the basic behavior and placement of these controls consistent throughout the MDSS GUI application. If attention is not placed on consistency, the maintenance user will possibly become confused when the behavior of the controls change. Table 3 provides some standard guidelines on using controls.

Control	Number of Choices in Domain Shown	Types of Controls
Menu Bar	Maximum 10 items	Static action
Pull-Down Menu	Maximum 12 items	Static action
Cascading Menu	Maximum 5 items, 1 cascade deep	Static action
Pop-up Menu	Maximum 10 items	Static action
Push button	1 for each button, maximum of 6 per dialog box	Static action
Check Box	1 for each box, maximum of 10 to 12 per group	Static set/select value
Radio Button	1 for each button, maximum of 6 per group box	Static set/select value
List Box	50 in list, display 8 to 10 rows	Dynamic set/select value
Drop-down List Box	Display 1 selection in control at a time, up to 20 in a drop-down box	Dynamic set/select value
Combination List Box	Display 1 selection in control at a time in standard format up to 20 in a drop-down box	Dynamic set/select single value; add value to list
Spin Button	Maximum 10 values	Static set/select value
Slider	Dependent on data displayed	State set/select value in range

Table 3. Guidelines on window control standards.

APPLYING DESIGN PRINCIPLES

Understanding the principles behind good GUI design and correctly applying them to the MDSS GUI will be a challenge requiring considerable time and effort by not only the Meridian developers, but also a commitment to review by maintenance personnel and the Technical Panel. Attention to the following checklist of items in an application will result in improved interface acceptance:

Workflow Guidelines.

- Be consistent.
- The user should always know where they are.
- It should take a very small number of clicks to get anywhere.
- The high frequency windows take the smallest number of clicks to get too.
- GUI applications involving an extended series of workflow steps are expressed by a logical series of windows. As many as possible of these windows are also used in other applications (often referred to in the literature as use cases).
- Provide useful defaults.
- Always validate all user input. Do this as close to the time of entry as possible. This smoothes out the user’s habitual workflow.
- Use Wizards when the workflow needs active guidance.

Window Guidelines.

- Be consistent.
- The window must be easily understood at the first glance.
- Use a small collection of standard widgets. Follow industry standards.
- Use a standard window layout. For example, put the most important data at the upper left, the buttons at the bottom, and a close button at the lower right. Follow industry standards.
- Clearly label everything.
- Don't put too much on a window unless it's for a highly skilled user. Avoid too many buttons or menus on a window.
- Avoid inventing cool new widgets, clever layout and snazzy effects.
- Put the user in a "look and choose" mindset, not "remember to enter". Strive for symmetry in window layouts.
- Right click context menus are a form of "hidden choices". The simplest GUIs don't use them. If you do start to use them, you must uniformly provide them everywhere.
- Everything should be able to be done without the mouse.
- Allow expert users to sail through a window fast, such as without the mouse.
- Always follow the principle of "Least user astonishment".

Complexity Guidelines.

- Be consistent.
- A huge problem for products with complex requirements is how to make the product appear simple to the user. Address this large risk early.
- Hide complex areas from the casual user, such as with an Advanced button, lower window expansion (show detail button) or user types. Different user types cause the system to reveal different types of behavior.
- Organize the workflow so complex areas are not accidentally encountered.
- Provide online "how to do it assistance" in a variety of levels, such as tool tips, F1 use, and a User's Guide. Each level has progressively more assistance.

- Have a sophisticated workflow for all complex applications. Make the hard stuff easy.
- In some cases offer alternate paths to accomplish something. For example, for the average user offer a Wizard, but for the expert offer raw data and application commands. The first is easy but slow, the second requires more skill, but is fast.

The limits of GUI design

Constructing the perfect GUI is impossible; albeit it is the goal to which to strive in the current project. Understanding that there are limits to be found in GUI design are important concepts to be understood by Meridian developers and the maintenance personnel it is attempting to serve. An early awareness and acceptance of this premise will go far to balance the design development process into achieving the best possible functionality without becoming a sinkhole for time and effort. However, having a good initial design built upon a framework that permits routine design maintenance and adaptation to new modularity and functionality will be important.

The following items should be kept in mind as something akin to Murphy's Law of GUI design:

- Do not rely solely on GUI standards and general style guides …..
  - Most users do not know the standards; they have their own way of operation. (Customization)

- Do not expect the users to follow the specifications ……
  - Most users do not know your way of thinking. Remember, you are not the user. (User Focus)

- Do not expect usability practitioners to guarantee the product usability …..
  - Common usability practices target only a subset of the usability needs. (Uniqueness)

- Good design does not guarantee usability . . . . .
  - Users are always unpredictable!! Even the best GUI designers cannot think the way many different users do. And, some of the user unexpected actions are really costly. (The Unknown)

GUI Design and Implementation

Following the guidelines and standards discussed above will enable an orderly development of the MDSS graphical user interface. To achieve the final design and GUI implementation will require strong teamwork between Meridian and the state DOT maintenance personnel. The following steps are general industry accepted standards to follow for development and implementation of a new GUI design (Rubin, 1994):

1. Determine the top objectives of the product from the maintenance user's viewpoint.
2. Organize these objectives into a single top-level window.
3. List the window GUI applications, data input/output and displays. Rank by frequency of use (collectively referred to as the use cases).
4. Organize these use cases into a logical, easy-to-use window workflow model.
5. Do a mockup of each window with a design tool (Meridian uses Smart Draw).
6. Validate the mockup model with user exercises and expert reviews.
7. Fine tune the models.
8. Get final feedback and approval.

It may be necessary to repeat this process several times at various stages of this list.

Conclusion

Designing a good graphical user interface is a challenging task requiring insight, vision and expertise; they don't happen by accident. Good GUIs require the development team to learn and apply basic principles, including making the design something the end user will accept and work with everyday. For this to occur the maintenance personnel using the MDSS GUI must find value in efficiency and effectiveness towards completing their job tasks.

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APPENDIX D

TASK 3.4

STWDSR Classification of Needs

Table 6.1.1: Winter Road Maintenance Needs, V2.0

DM#		#	ID	Micro-Scale Warning	Meso/Synoptic Operational	Synoptic/Climatic Planning
1.0	Infrastructure Operators					
1.1	Highway maintainer (winter)					
		1	1.1	control spreader/sprayer application		
		2	1.2	program treatment control		
		3	1.3	control plow		
		4	1.4	control static (bridge) anti-icer		
		5	1.5	observe/report		
		6	1.6	navigate spreader/plow truck		
		7	1.7	select chemicals		
		8	1.8	actuate traffic control messages (e.g., sign on truck)		
		9	2.1		become aware of weather threat	
		10	2.2		monitor weather threat	
		11	2.3		identify weather threat occurrence	
		12	2.4		assess sufficiency of staff, equipment and consumables	
		13	2.5		replenish consumable stocks	
		14	2.6		check readiness of staff, equipment and consumables	
		15	2.7		mix expendables	
		16	2.8		repair/PM equipment to augment fleet	
		17	2.9		check staffing availability	
		18	2.10		assign minimum staff to monitor and manage	
		19	2.11		select event-treatment strategy	
		20	2.12		assign crews to shifts, schedules	
		21	2.13		disseminate important weather information to field staff	
		22	2.14		forward-place equipment and stocks	
		23	2.15		put supervisory staff on event schedule	
		24	2.16		alert supervisory staff to monitor/prepare	
		25	2.17		confirm strategy-plan in place	
		26	2.18		alert crews (flexible plan)	
		27	2.19		split crew shifts	
		28	2.20		call in crews	
		29	2.21		select treatment expendables	
		30	2.22		dress and load equipment	
		31	2.23		dispatch patrols	
		32	2.24		dispatch crews to wait at routes	
		33	2.25		dispatch crews to treat (anti-ice)	
		34	2.26		program treatment control	

DM#	#	ID	Warning	Operational	Planning
	35	2.27		dispatch crews to treat (plow/spread)	
	36	2.28		dispatch crews to treat (plow cake, deice)	
	37	2.29		dispatch crews to treat (bulk removal)	
	38	2.30		dispatch crews to treat (ice-spot treatment)	
	39	2.31		dispatch crews to treat (drifting)	
	40	2.32		alert contractors	
	41	2.33		call in contractors	
	42	2.34		request out-of-jurisdiction resources	
	43	2.35		coordinate: traffic mgt.	
	44	2.36		coordinate: emergency mgt.	
	45	2.37		coordinate: public (traveler) information	
	46	2.38		manage incidents	
	47	2.39		close roads	
	48	2.40		monitor crew working time and conditions	
	49	2.41		rest crews	
	50	2.42		reevaluate storm intensity and duration	
	51	2.43		identify threat end	
	52	2.44		determine that level-of-service goal is reached	
	53	2.45		plan for cleanup	
	54	2.46		dispatch snow cleanup (push back banks)	
	55	2.47		dispatch snow cleanup (phase 2, turnouts and bridges)	
	56	2.48		open roads	
	57	2.49		dispatch damage repair (facilities, trees, power lines etc.)	
	58	2.50		assign cleanup (equipment & yard)	
	59	2.51		dispatch abrasives cleanup	
	60	2.52		release crews	
	61	2.53		return to normal procedure	
	62	3.1			locate facilities
	63	3.2			establish organization
	64	3.3			specify equipment/services
	65	3.4			devise/revise response plan
	66	3.5			define level-of-service goals
	67	3.6			hire staff
	68	3.7			train staff
	69	3.8			buy equipment/services
	70	3.9			stock stores and consumables
	71	3.10			budget

72

DM#			#	ID	Warning	Operational	Planning
			72	3.11			schedule seasonal tasks (incl. end-season abrasives cleanup)
			73	3.12			calibrate treatment controls
			74	3.13			check seasonal readiness (equipment, consumables, staff)
			75	3.14			repair/adjust/PM of equipment
			76	3.15			forward-place equipment and stocks
			77	3.16			confirm plans in place
			78	3.17			evaluate performance

This table gives the decisions (equivalent to management actions) that define the user needs to be served by decision support. The planning and warning scales are included but only the operational scale decisions, with the 2.x indexing, are considered here. There are 78 decisions represented in total, 53 of operational scale. The decisions capture all the variations stated by the STWDSR stakeholders that could be put in uniform phrases. It was recognized that the list of 53 operational decisions was too varied for a general operational concept. Also, a simpler scheme was desired to define the lead time and confidence parameters of decision groups. By looking at how the decisions groups in lead time, the decision clusters were defined. These are tabulated below with their constituent decisions.

Table 6.1.2: Decision Cluster Definitions

ID	Decisions	Ct.	Avg.	Cluster ID, Name
2.2 2.1 2.3	monitor weather threat become aware of weather threat identify weather threat occurrence	4.00	1.00	2.A Monitor Conditions* *Note: this will include monitoring of all relevant conditions–traffic, incidents, weather etc.
2.6 2.9 2.4	check readiness of (staff,)* equipment and consumables check staffing availability assess sufficiency of (staff,)* equipment and consumables * staff may defer to cluster 2.F	4.00	1.00	2.B Prepare
2.18 2.13 2.10 2.14 2.16	alert crews (flexible plan) disseminate important weather information to field staff assign minimum staff to monitor and manage forward-place equipment and stocks alert supervisory staff to monitor/prepare	9.00	1.67	2.C Get Ready
2.7 2.21 2.5	mix expendables select treatment expendables replenish consumable stocks	6.00	2.17	2.D Prepare Expendables
2.11 2.17	select event-treatment strategy confirm strategy-plan in place	4.00	2.50	2.E Select Strategy

ID	Decisions	Ct.	Avg.	Cluster ID, Name
2.12	assign crews to shifts, schedules (cancel leaves)	10.0	2.80	2.F Assign Crews
2.22	dress and load equipment	18.0	3.00	2.G Prepare Equipment
2.20 2.19 2.15	call in crews split crew shifts put supervisory staff on event schedule	4.00 10.0	3.00 3.30	2.H Activate Staff
2.25 2.23 2.35	dispatch crews to treat (anti-ice) dispatch patrols coordinate: traffic mgt.	16.0	4.19	2.I Initial Dispatching
2.33 2.32 2.24	call in contractors alert contractors dispatch crews to wait at routes* (* variable sequencing)	3.00	4.67	2.J Contracting
2.27 2.26 2.8	dispatch crews to treat (plow/spread) program treatment control repair/PM equipment to augment fleet	22.0	4.91	2.K Primary Dispatching
2.28	dispatch crews to treat (plow cake, deice)	3.00	5.67	2.L Remedial Dispatching
2.34 2.30 2.42 2.44 2.41 2.36 2.37 2.38 2.39 2.40	request out-of-jurisdiction resources dispatch crews to treat (ice-spot treat) reevaluate storm intensity and duration determine that level-of-service goal is reached rest crews coordinate: emergency mgt. coordinate: public (traveler) information manage incidents close roads monitor crew working time and condition	4.00	6.25	2.M Mid-Storm Management
2.29 2.31 2.47 2.49	dispatch crews to treat (bulk removal) dispatch crews to treat (drifting) dispatch snow cleanup (phase 2, turnouts and bridges) dispatch damage repair (facilities, trees, power lines etc.)	4.00	7.00	2.N Discretionary Dispatching
2.52 2.43 2.53 2.45 2.48	release crews identify threat end return to normal procedure plan for cleanup open roads	7.00	7.00	2.O Termination
2.46 2.50 2.51	dispatch snow cleanup (push back banks) assign cleanup (equipment and yard) dispatch abrasives cleanup	10.0	7.10	2.P Cleanup

The "Ct." measure is the count of mentions of decisions in the cluster from the STWDSR response forms. The "Avg." measure is the average ordinal position of the decision when it was mentioned among a general set of decisions and the order in which they are typically made. The numerical values for confidence and time lead for the clusters given in a previous figure are from data on responses to specific weather scenarios. The decisions were assigned to clusters based on their homogeneity of order and time lead.

Table 6.1.3: Information Desired for Cluster Decisions

Actions and Triggers for Scenarios		
Clusters	**Categories**	**Info Desired**
2.A Monitor		
Monitor	(sub)pavement temp (5)	RWIS data
	start/end time (1)	Pavement temp/thermal map
		RWIS data
		subsurface probes
		check shaded areas/RWIS
		start/end time
2.B Prepare		
Alert crew/flexible plan	(sub)pavement temp (3)	Surf temp, snow start/end, rate
	start/end time (8)	start/end time, snow amount
	rate (3)	start time
	amount (2)	Start time, rate, duration
	NWS discussion (1)	Rate of snow fall
	track (1)	more definite timelines
		NWS discussions
		RWIS, VAMS
		surf. Temp models/RWIS
Activate district ops center		event timing
Loaders at remote stockpile		start time, rate of movement
		Timing, amount, duration
2.C Get Ready		
Check readiness	winds (1)	Start time, intensity
	start/end time (2)	Start time, rate, duration
	rate (3)	wind speeds, jetstream
	amount (1)	forecast
	NWS discussion (1)	duration, intensity
		NWS discussions
2.D Prepare Expendables		
Mix chemicals/abrasives	start/end time (2)	Timing, amount, duration
Stir liquids	rate (1)	Start/end time, accumulation rate
	amount (1)	
2.G Prepare Equipment		
Dress/load equipment	start/end time (5)	start time, rate of movement
	rate (1)	start time
	track(1)	precip window (time)
	temp (1)	Start/end time, accumulation rate
		event timing
		forecast
		temp FR and SAT

2.H Activate Staff		
Split Crews	start/end time (10)	start time, rate of movement
	rate (2)	Time to precip start
	track(1)	wind speed
	(sub)pavement temp (2)	forecast
	winds(2)	duration, intensity
	NWS Discussion (1)	NWS discussion
	what happening elsewhere (1)	what happening elsewhere
	amount (2)	pavement temp,
		actual start and end of storm
		amount and duration
Mobilize/Dispatch crews		start time
		start time
		end time
		duration, intensity
		rate of snow fall
		Timing, amount, duration
		Duration
		wet pavement, low temp
Partial crew report		storm start
2.I Initial Dispatching		
Do anticing/pretreat	start/end time (8)	Surf temp, snow start/end, rate
	rate (5)	snowfall rate
	(sub)pavement temp (3)	Pavement temp/thermal map
	winds (1)	precip start
	what happening elsewhere (1)	Start/end time, snow amount
	amount (1)	start time
	area affected (1)	Start time and intensity
		How other districts hit
		intensity, duration
		detail on pavement temps, area affected, precip rates, timing
		snow end time, winds
2.J Contracting		
Call contractors	start/end time (2)	start time
		precip window (time)
2.K Primary Dispatching		
Plow/spread	start/end time (4)	storm end time, temp
	rate (1)	visual obs
	(sub)pavement temp (3)	storm end time, temp
	winds (1)	snow rate forecast
	temp (1)	Duration
	visual obs (2)	
		snow end time, winds
Salt/deice		RWIS, patrol obs.
Other		
Traffic management	next event (2)	snow rate forecast
Spot treatment	rate (1)	
Clean up snow/ice	(sub)pavement temp (3)	future warming, rising temps
Clean up sand	RH (1)	
Plan for Cleanup	temp (1)	temps, RH, next event expected
Terminate response	visual obs (1)	road pavement temp
	NWS discussion (1)	RWIS, crew obs
Road closure		NWS discussion

APPENDIX E

TASK 3.7

GUIDELINE QUESTIONS FOR MAINTENANCE INTERVIEWS

QUESTIONS FOR THE MDSS INTERVIEW SESSIONS

INTRODUCTIONS

1. What is your current position with the DOT?
2. What are your responsibilities in that position?
3. How many years have you been with the DOT?
4. What different experiences have you had with the DOT?
5. Did you have any additional training/education prior to joining the DOT?
6. Have you had specific training as a DOT employee that you use in making routine winter maintenance decisions?
7. What do you consider the important lessons learned during your DOT experience?

LEVEL OF SERVICE

1. What are the level of service guidelines you follow?
2. How does LOS vary over different road classes?
3. How does LOS vary based upon public expectations?

MATERIALS

1. What materials do you use during winter maintenance operations?
2. What are the DOT guidelines on the use of these materials?
3. Do you adjust the guidelines to fit specific needs within your local jurisdiction?
4. Do you use liquid chemical applications in your operations?
5. Do you pre-wet solids as part of your maintenance program?
6. If so, what chemicals do you use?
7. What's your normal application rate?
8. What changes do you make to application rates based upon specific weather conditions, such as temperature ranges, precipitation rates, drifting snow?
9. If you use grit what are the guidelines for the grit sizing?
10. Does the type of grit used change as the weather conditions change?
11. What are your application rate guidelines?
12. Do you have a requirement for cleanup at the end of the season? At other intervals during the winter?

EQUIPMENT

1. What type of vehicles do you use for winter maintenance?
2. What type of equipment do you use for application of chemicals? Grit?
3. Do you have the ability to adjust the application rates?
4. Can these adjustments be done from the cab?
5. What is the range of adjustment?

6. Can you monitor the application rates from the cab?
7. What type of other monitoring devices do you have in the cab?
8. Do the operating features of your spreaders cause variability in the spreading rates and spread patterns during normal operation?
9. What types of problems do you experience with your spreading equipment?
10. What type of plows do you normally use for snow and ice removal?
11. What type of plow configurations do you use?
12. Do you use different plows or plow configurations for different winter maintenance situation?
13. When do you configure your equipment for winter maintenance?
14. Do you change the equipment configurations during normal operations?
15. Are there particular issues you have with specific types of plows and/or plow configurations?

ROAD REPORTING

1. What mechanism do you have in place to officially report road conditions?
2. What measures do you take in maintenance operations to report road conditions?
3. How does the existing knowledge of road conditions affect your response along specific routes?
4. Does existing knowledge of road conditions along one route alter your operational response plans within the entire crew? If so, how?
5. Do you record the amount of material that is applied to a specific route?
6. How do you report or record what snow/ice removal actions that have taken place?

SCHEDULING

1. What are the policies that impact the use of personnel within your operations?
2. When there is the potential for a major winter storm lasting more than 24 hours, how do you adjust your scheduling of personnel to fight the storm continually?
3. Please describe your planning process from the first indication of a winter storm through the mop up action at the end of the storm. Are there distinct phases in your decision making process?

WEATHER

1. What weather elements are most critical in your decision process?
2. Do the important weather elements change with different situations?
3. Is the weather information available to you adequate to support your decision process?
4. Do you use the information from the Road Weather Information System sensors? In what way?
5. What other sources do you use to get weather information other than NWS, RWIS, and other data available over the Internet?

WINTER SCENARIOS

1. Explain your decision process during a major winter storm.
2. Explain your decision process during a period of snow squalls and variable snows of an inch or less.
3. Explain your decision process during blowing snow situations.
4. Explain your decision process during freezing rain situations.
5. Explain your decision process during frost situations.
6. Explain your decision process during refreeze situations.

SUMMARY

1. Are there issues that affect your decision process that we have not addressed in this discussion?

APPENDIX F

TASK 5.2

Survey

MAINTENANCE DECISION SUPPORT SYSTEMS

An authorized survey project of the
Indiana, Iowa, Minnesota, North Dakota, South Dakota DOT
MDSS Pooled-Fund Study

1. Based on your experience and expertise, how would you rate the usefulness of your Department's current "published" policies and procedures for winter maintenance activities (rate on a scale of 1 to 10)?

Not at All Usefull	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Extremely Useful**

2. Do you generally follow your Department's formal winter maintenance policies and procedures or do you modify them to address local maintenance issues (rate on a scale of 1 to 10)?

Follow Exactly	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Modify Considerably**

3. How receptive is your organization to suggestions for improvements to current methods and systems (rate on a scale of 1 to 10)?

Not at All Receptive	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Very Receptive**

4. Please indicate your level of comfort with desktop computer technology (rate on a scale of 1 to 10).

No Experience	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Very Comfortable**

5. Please indicate the level of winter maintenance coordination between your shop or office and surrounding shops or offices (rate on a scale of 1 to 10).

No Contact	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Constant Contact**

6. How would you rate the <u>quality</u> of information you receive to help you make decisions to do your job in winter maintenance (rate on a scale of 1 to 10)?

Very Poor	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Excellent Quality**

7. How would you rate the <u>timeliness</u> of information you receive to help you make decisions to do your job in winter maintenance (rate on a scale of 1 to 10)?

Very Late	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Very Timely**

8. Considering recent developments in technology in the transportation industry, how helpful do you think technology could be assist your decisions in winter maintenance (rate on a scale of 1 to 10)?

Not at All Helpful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Extremely Helpful**

9. Are you aware of work being done on the development of Maintenance Decision Support Systems for winter maintenance in your Department of Transportation? (circle one) Yes No

10. From the list below, please indicate which decisions you are personally authorized to make in winter maintenance (check Yes or No for each Decision Type):

Decision Type	**Yes**	**No**
When to start operations		
When to stop operations		
When to suspend operations (for example, because of severe conditions)		
When to resume operations		
Whether to schedule more than one shift per day		
What personnel to assign to highway routes		
What treatment (plowing, chemical, sanding, etc) to use		
What rate of treatment to apply (for example, gallons or pounds per mile)		

11. From the list below, please rate the importance of each type of information you use to make decisions for winter maintenance (check one box for each Information Type):

Information Type	Not at All Important	Not Very Important	Somewhat Important	Very Important	Absolutely Essential
Road/Weather Information Systems (RWIS)					
General weather forecasts					
Maintenance-specific weather forecasts					
Road condition reports from DOT					
Road condition reports from Highway Patrol					
Complaints from the public					
Availability of personnel					
Skill levels of personnel					
Availability of materials (chemicals, sand, etc)					
Availability of equipment					
DOT Maintenance policies and procedures					
Other (please specify):					
Other (please specify):					

12. Do you use the Internet or Intranet at the office? (circle one) Yes No

13. If you use the Internet or Intranet at the office, please describe your type of connection (check one):

Check One	Connection Type
	Low-speed dial-up modem
	High speed phone (DSL, ISDN, etc)
	High speed cable
	High-speed local- or wide-area network
	Other (please specify):

14. Which of the following limit your use of the Internet or Intranet at the office (check "Yes" or "No" for each Limitation)?

Limitation	Yes	No
I am not authorized to use the Internet or Intranet		
Slow communication line		
I need training to use the Internet or Intranet		
Restrictions on access to certain web sites		
Poor screen resolution on monitor		
I don't have access to a computer		
I don't have time to use the computer		
Other (please specify):		

15. On a scale of 1 to 10, how severely do these limitations to using the Internet or Intranet affect your ability to do your job?

Not at All 1 2 3 4 5 6 7 8 9 10 Severely

16. Please list up to five of the most important pieces of information you use to set crew schedules for winter maintenance (1=most important, 5=least important):

Rank	***Information Type***
1	
2	
3	
4	
5	

17. If you would like to comment on any of your responses to help clarify your response, please enter the question number and your comments (continue on back if you need more space):

Question #	**Comment**

18. Job Title: ______________________________________
19. Age: _________
20. Years of DOT experience: _____________

Please return by **July 7, 2003** to:
MDSS Survey
PO Box 14178
Grand Forks, ND 58208-4178

APPENDIX H

TASK 6.1

Functional Infrastructure

An Extended White Paper
for a
Project to Develop and Deploy
a
Maintenance Decision Support System

Submitted by
Meridian Environmental Technology, Inc.

February 5, 2002

BACKGROUND

From its inception around 1970 the Road/Runway Weather Information System (RWIS) program has offered the prospect of reduced maintenance costs on both the nation's highways and airfields. RWIS monitoring devices (both weather instruments and in-pavement sensors) supplied weather and pavement information along the highway corridor that had been unavailable previously. These highway observation platforms known as Environmental Sensing Systems (ESS) provided informative insight into existing conditions or recent trends but failed to project pavement conditions forward into the decision time frame of roadway maintainers. Starting in 1985 this limitation was resolved with the introduction of pavement temperature and surface condition forecasts.

The combination of an ESS observation network in the field and pavement specific weather forecasts promised to provide substantial reductions in operational maintenance costs. Research done as part of the Strategic Highway Research Program during the period of 1991 –1993 argued potential reductions of up to 20% of the $2.1B cost of winter maintenance in North America [SHRP-H-350]. Several states have documented savings of 1% to 6% associated with their RWIS programs but none approaching the magnitude suggested by the SHRP research. In the period from 1990 - 1995 RWIS programs expanded rapidly in many states and RWIS program managers were attempting to determine why they were not able to get the savings and benefit/cost payback they had anticipated. This concern was raised in and amongst the states involved in RWIS and most of forums dedicated to winter maintenance issues, such as the AASHTO Winter Maintenance Committee, the AASHTO Snow and Ice Cooperative Program, the Aurora consortium, NACE conferences, the Multi-state RWIS meetings, and FHWA sponsored conferences. Agencies using RWIS found the information of considerable value, but discovered that the information resource had the following limitations:

- The volume of information was overwhelming and more than most decision makers had time to assimilate prior to making an operational decision

- The readings from the pavement sensors were inconsistent and unreliable in too many situations, especially relating to chemical concentrations
- Effective use of the RWIS data and forecasts required a meteorological background that maintainers did not have nor desired to obtain
- The detailed information showed interactions of precipitation or moisture with chemicals atop highway surfaces is a very complex environment
- Weather forecasts were seen as being more important in making RWIS decisions; thus the accuracy of existing forecast services was insufficient to meet user's expectations

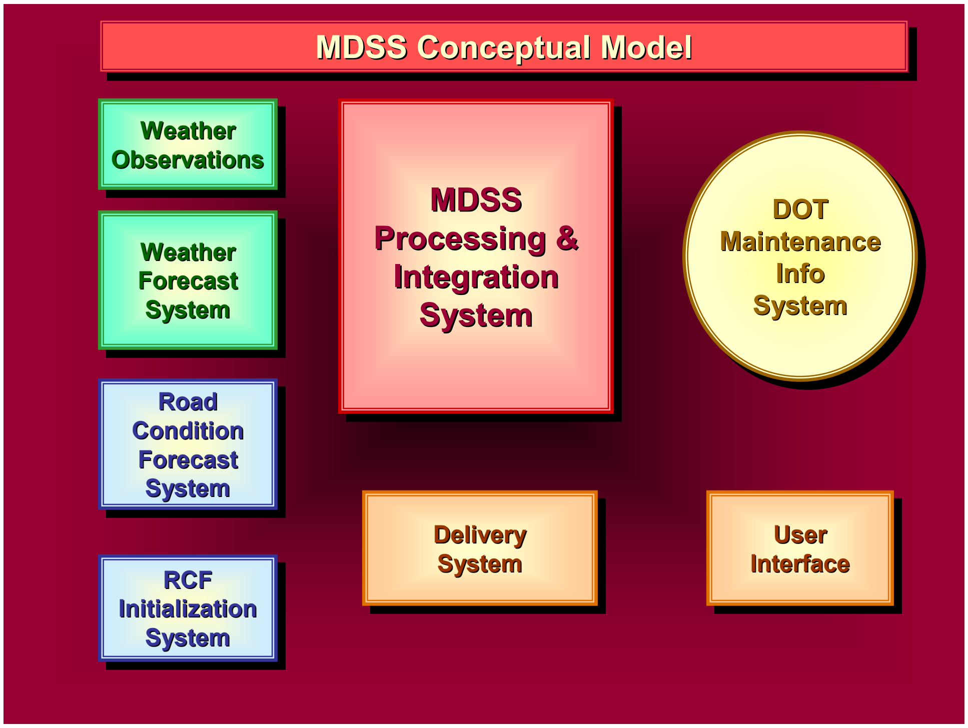
It was out of these meetings that the state DOTs discussed the development of the next phase of the RWIS program, the development of a Maintenance Decision Support System. The FHWA became aware of the discussions and opted to demonstrate the feasibility of a maintenance decision support system commencing in 1999. The three-year plan was to develop an operational MDSS prototype utilizing the resources of the six federal labs involved in weather research. As the end of the three-year program nears, the prototype is far from complete and it appears that funding is not likely for the continuation of the program with the expectation that completion of the federal program will be accomplished by the private sector.

The MDSS Development Plan

Based upon the desire to see the MDSS program reach fruition, representatives from the Departments of Transportation from the States of Minnesota, North Dakota, and South Dakota met with representatives from Meridian Environmental Technology, Inc. of Grand Forks, North Dakota on January 3, 2002 to determine the feasibility of developing an operational Maintenance Design Support System outside of the FHWA program. Subsequent to this meeting the Indiana Department of Transportation indicated interest in joining the project. The four agencies involved in the initial meeting agreed to have Meridian present a proposal outlining the development effort necessary to create an operational MDSS. This paper is the result of that mutual understanding.

A Maintenance Design Support System is a complex integration of several independent, but inter-related components. From a functional perspective the MDSS design may be viewed as five basic components:

- The Weather System
- The Pavement Forecast System
- The DOT Operations and Control System
- The MDSS Decision Logic System
- The Delivery and Display System



The Weather System is further partitioned into a module that handles current and past weather observations and a module that generates and updates the high resolution weather forecast needed for the MDSS. The Pavement Forecast System is also separated into an Initialization module and the actual Road Condition Forecast System. The Delivery and Display System is functionally separated but in the final design it is most likely that the two components will appear as one to the user.

Meridian has already invested over fifteen man-years in the development and refinement of the Weather System, the Pavement Forecast System, and the Delivery and Display System. Some additional enhancements are needed in each of these components to meet the specific MDSS requirements, but Meridian will be able to utilize this infrastructure as part of the conduit to input weather and pavement guidance into the MDSS Decision Logic System and deliver the resulting MDSS products to the MDSS user. Thus three of the five components are estimated as better than two-thirds complete. Even so, the heart of the MDSS lies in the two remaining components, the DOT Operations and Control System and the MDSS Decision Logic System. This is where the bulk of further development will be needed.

The MDSS User Interface

The objective of the development effort is the creation of an interactive tool that delivers the desired solutions to meet currently unmet needs. In the background section there are five limitations listed that prompted consideration of an MDSS.

The proposed MDSS addresses all five of these issues plus all of the items raised by the three states at the January 3rd planning meeting. In addition, it incorporates the years of experience Meridian employees have working with and designing RWIS and weather display graphical user interfaces.

The features of the MDSS fit into the same design structure addressed in the federal MDSS Development Plan. Each of the features planned for the MDSS are listed by their primary category. As the technology for some of the features will require more time to establish than others, selected features are separated into a first, second, or third phase of development. Where not specified, the listed items will require identification of phase of development desired. This will be determined through consultation and coordination with the participating DOTs during the final proposal development. However, much of the non-phase designated items are expected to become available during the first two years of development.

Weather Information

1. Climatological weather data
    a. Presentation of data in two-dimensional map, table, or meteogram format
    b. Daily values or means of primary weather parameters
    c. User may select a map area and control the looping of the image sequence to view the change of a weather parameter over time
2. Current and recent weather data
    a. Site specific hour-by-hour observations from any location, either direct instrument reading or a derived value
    b. Presentation of data in a table, meteogram, or two-dimensional map format
    c. Presentation of multiple parameters in one display
    d. On the two-dimensional maps user may loop images such as radar, satellite, temperatures, winds, etc.
    e. Complete alarm and alerting with criteria and location controlled by user; alert delivery available over all possible communications devices
3. Short term-weather forecast – 0 to 36 hours
    a. Forecasts delivered as a table, meteogram, or a two-dimensional map
    b. Two-dimensional maps contain hourly graphic representations of one or two major forecast weather parameters per display image
    c. User may select a map area and control the looping of the image sequence to view the progress of a weather event over time
    d. Parameters: air temperature, dew point temperature, relative humidity, wind speed and direction, wind gusts, precipitation rate and accumulation, precipitation type, precipitation coverage and probability, snow rate and accumulation, future radar color coded for precipitation type, cloudiness, visibility (distance), obstructions to visibility (blowing snow, fog, etc.)
    e. Site specific forecasts for any point

    f. Complete alarm and alerting with criteria controlled by user; alert delivery over all possible communications devices
    g. Indication of confidence intervals on forecast parameters
4. Mid-term weather forecast – 36 – 120 hours
    a. Two-dimensional maps, tables, or meteograms with values at 12-hour intervals
    b. Parameters: max/min temp, winds, precipitation type, precipitation probability, hourly and storm accumulation of rain and snow, cloud cover
5. Long-term weather forecast 5 – 10 days
    a. Period averaged departures from normal for precipitation and temperature
    b. Potential storm tracks
6. Blowing / drifting snow
    a. Phase 1 – the potential for drifting based upon general landcover type plus wind direction and speed
    b. Phase 2 – the potential for drifting based upon local specific landcover and geographic terrain features plus wind direction and speed
7. Forecast verification
    a. Automatic statistical verification for sites with reliable verification source
    b. Side by side presentation of recent forecasts for easy visual comparison

<u>Pavement Information</u>

1. Historical road condition information
    a. Presentation of ESS data in user selectable raw or quality controlled format
    b. Modeling and presentation of virtual ESS data by road segment (hourly recommended)
    c. History of maintenance operations performed by road segment
    d. Presentation of data in two-dimensional map, table, or meteogram format
    e. Two-dimensional map display of all ESS conditions and maintenance operations by parameter with looping option
    f. Override option to replace computed surface condition with user-observed condition
2. Current road condition information
    a. Presentation of ESS data in user selectable raw or quality controlled format
    b. Modeling and presentation of virtual ESS data by road segment
    c. Parameters: pavement/deck temperature, surface condition, depth of contaminant, chemical concentrations, freeze point temperature, ice percentage
    d. Maintenance operations in progress

   e. Presentation of data in two-dimensional map, table, or meteogram format
   f. Two-dimensional map display of current ESS conditions and maintenance operations by parameter
   g. Road conditions in a continuous display using a combination of modeling techniques (output similar to thermal mapping presentations)
   h. Override option to replace computed surface condition with user-observed condition
   i. Complete alarm and alerting with criteria and location controlled by user; alert delivery available over all possible communications devices
3. Road Condition Forecast
   a. Forecast generated, starting from current pavement and road conditions at each segment, out to 24 hours and displayed alongside weather forecast parameters
   b. Parameters: forecasted pavement/deck temperature, surface condition, chemical concentrations, freeze point temperature, and ice percentage
   c. Display for a single point done as table or meteogram
   d. Two-dimensional map display of user selected pavement parameter in color encoded format over a user selected area (region, state, district, maintenance route) with ability to loop display over period of forecast
   e. Forecast updated hourly – current forecast is always available
   f. User may receive a forecast at specific times or retrieve a forecast only when needed
   g. Complete alarm and alerting with criteria and location controlled by user; alert delivery available over all possible communications devices

<u>Maintenance Decision Support System</u>

1. Phase 1: Generation of decision options based upon pre-defined treatment scenarios for given weather forecast/existing condition categories
2. Phase 2: Implementation of artificial intelligence techniques to simulate maintenance practices and rank most effective response for existing conditions
3. Phase 3: Integration of resource management tools (see description under DOT Operations and Control System section – may be third party package or software developed by MDSS team) into phase 2 techniques
4. Treatment Management
   a. User selects one or more response options and views the forecasted pavement condition responses
   b. User commits to one option and generates weather and pavement condition forecast

<u>DOT Operations and Control System</u>

1. Personnel Management
   a. Manage personnel capabilities
   b. Track hours and maintain work schedule

c. Manage routes and equipment utilization
d. Integrate forecast with resource allocation planning (split shifts, route modification for special situations, unavailable employee, etc.)
e. Provide cost analysis of each management scenario

APPENDIX I

TASK 6.2

Data Flow Diagrams

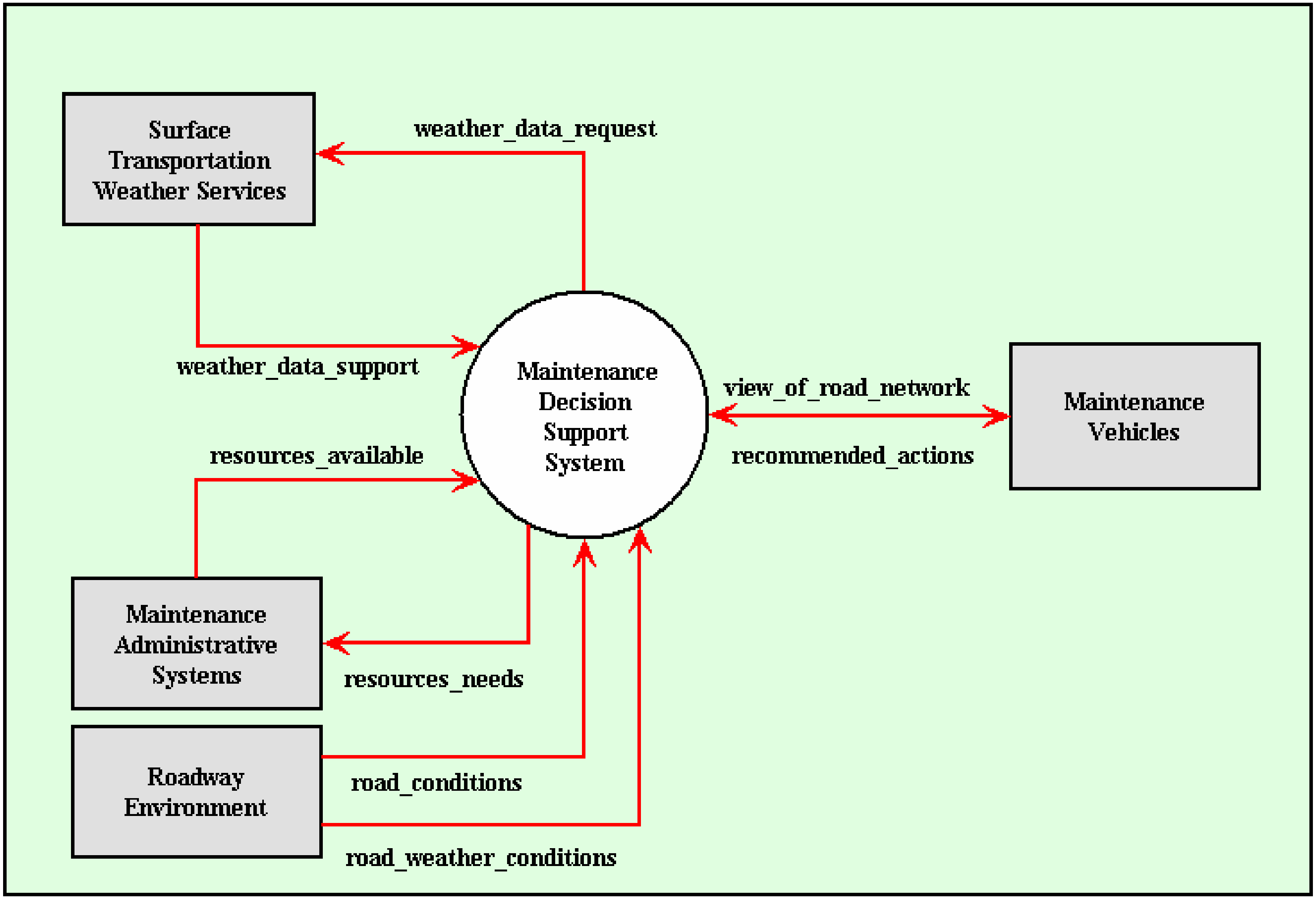


Figure I- 1. Pooled fund MDSS context diagram. Grayed boxes denote terminators. Data flow labels conform to NITSA conventions for MDSS.

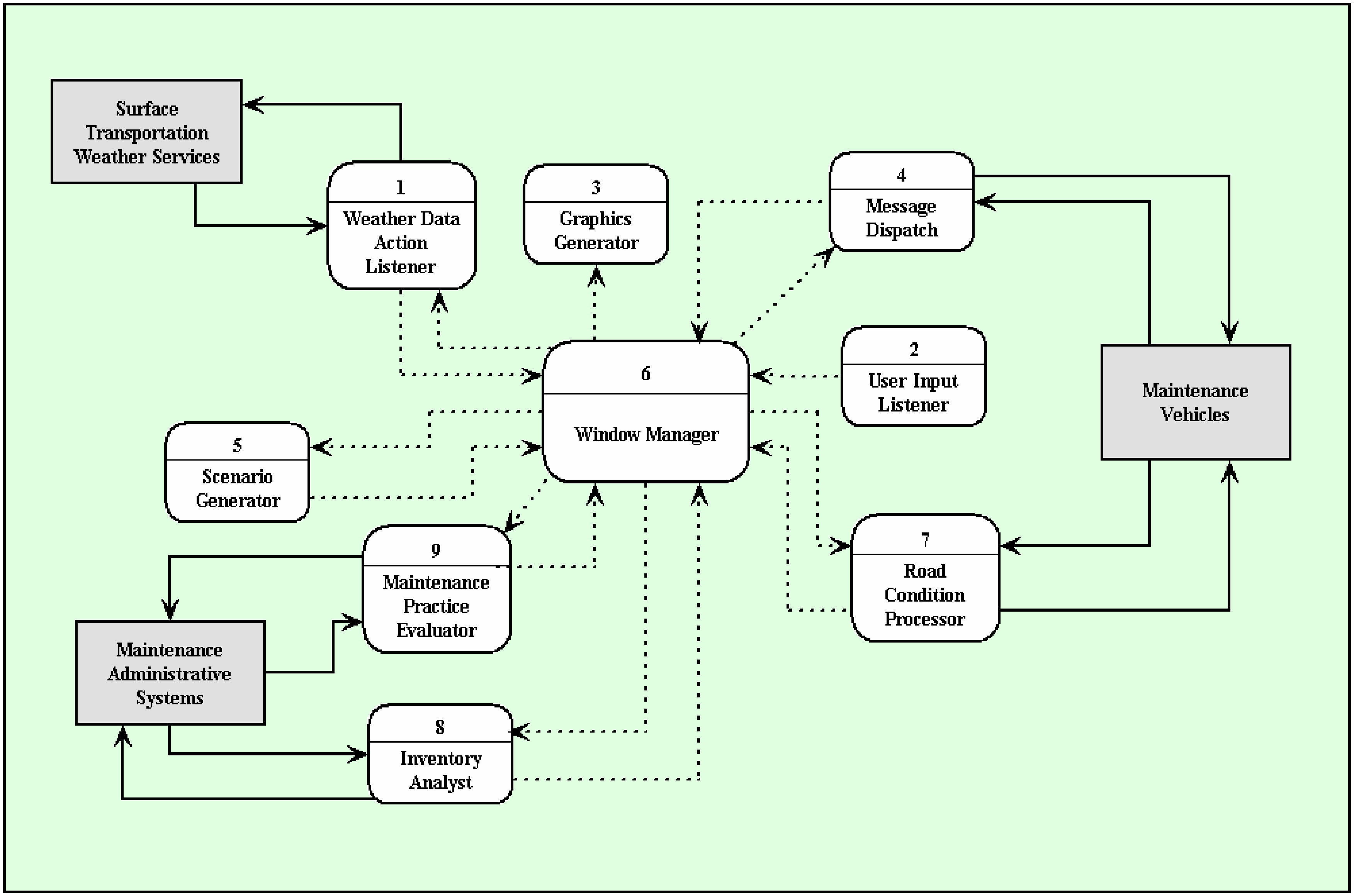


Figure I- 2. Pooled fund MDSS level 1 data flow diagram. Grayed boxes denote terminators. Rounded rectangle boxes are level 1 processes. Solid lines are data flows, dashed lines are controls.

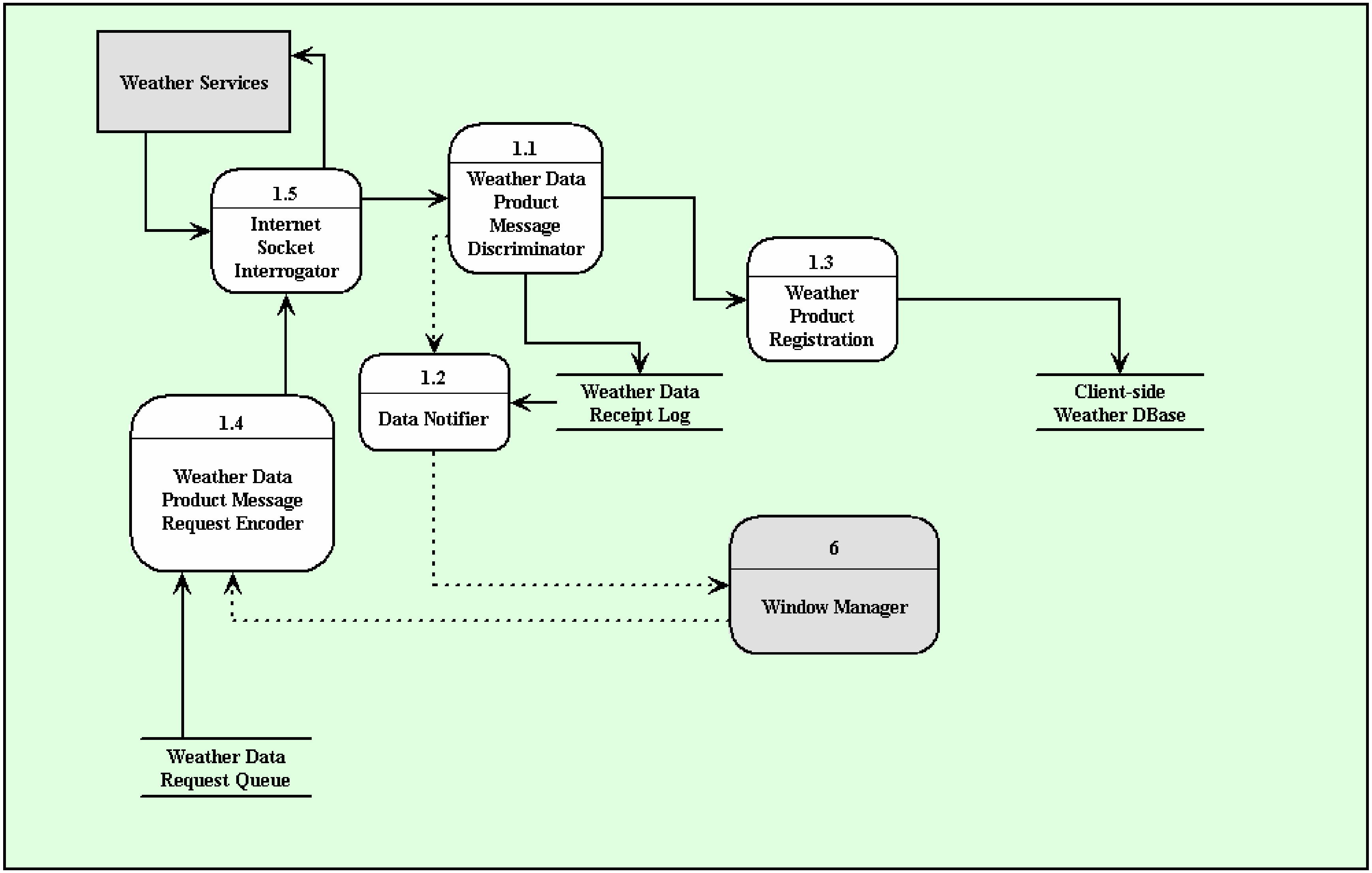


Figure I- 3. Pooled fund MDSS level 2 data flow diagram for the Weather Data Action Listener process. Grayed boxes denote processes/terminators external to the process. Solid lines denote data flows, dashed lines denote controls. Parallel horizontal lines are data stores.

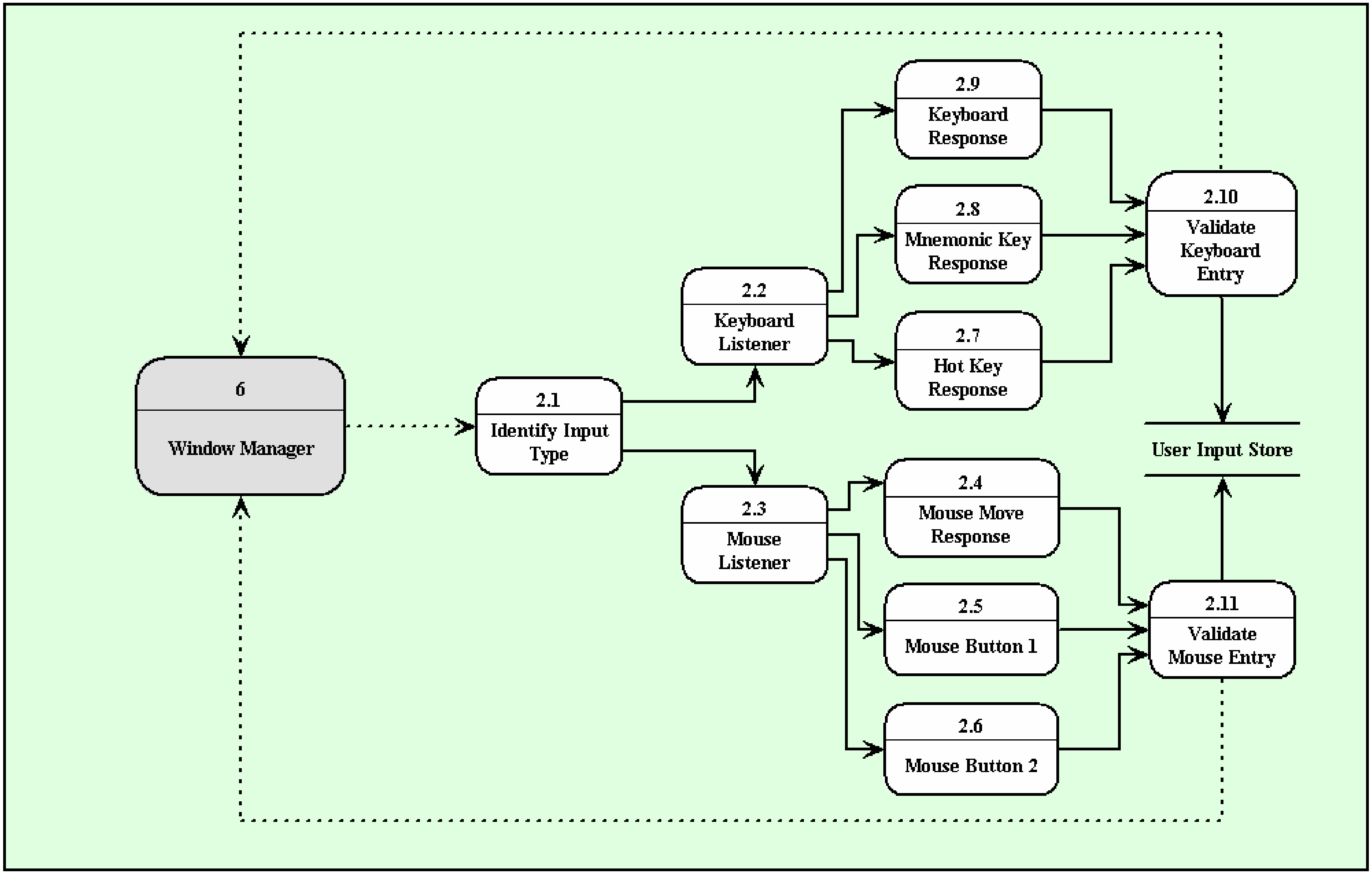


Figure I- 4. Pooled fund MDSS level 2 data flow diagram for the User Input Listener process. Grayed boxes denote processes/terminators external to the process. Solid lines denote data flows, dashed lines denote controls. Parallel horizontal lines are data stores.

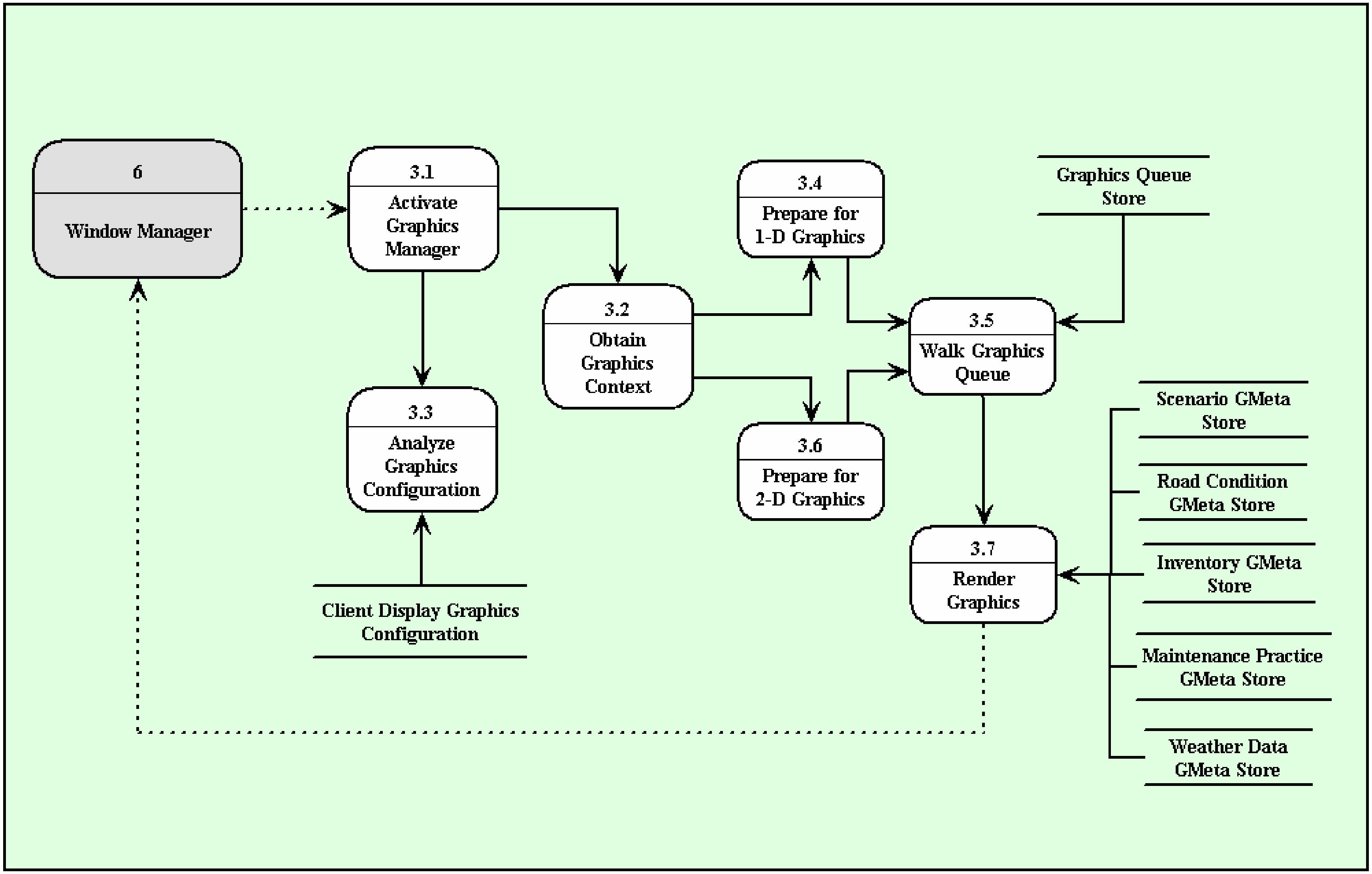


Figure I- 5. Pooled fund MDSS level 2 data flow diagram for the Graphics Generator. Grayed boxes denote processes/terminators external to the process. Solid lines denote data flows, dashed lines denote controls. Parallel horizontal lines are data stores.

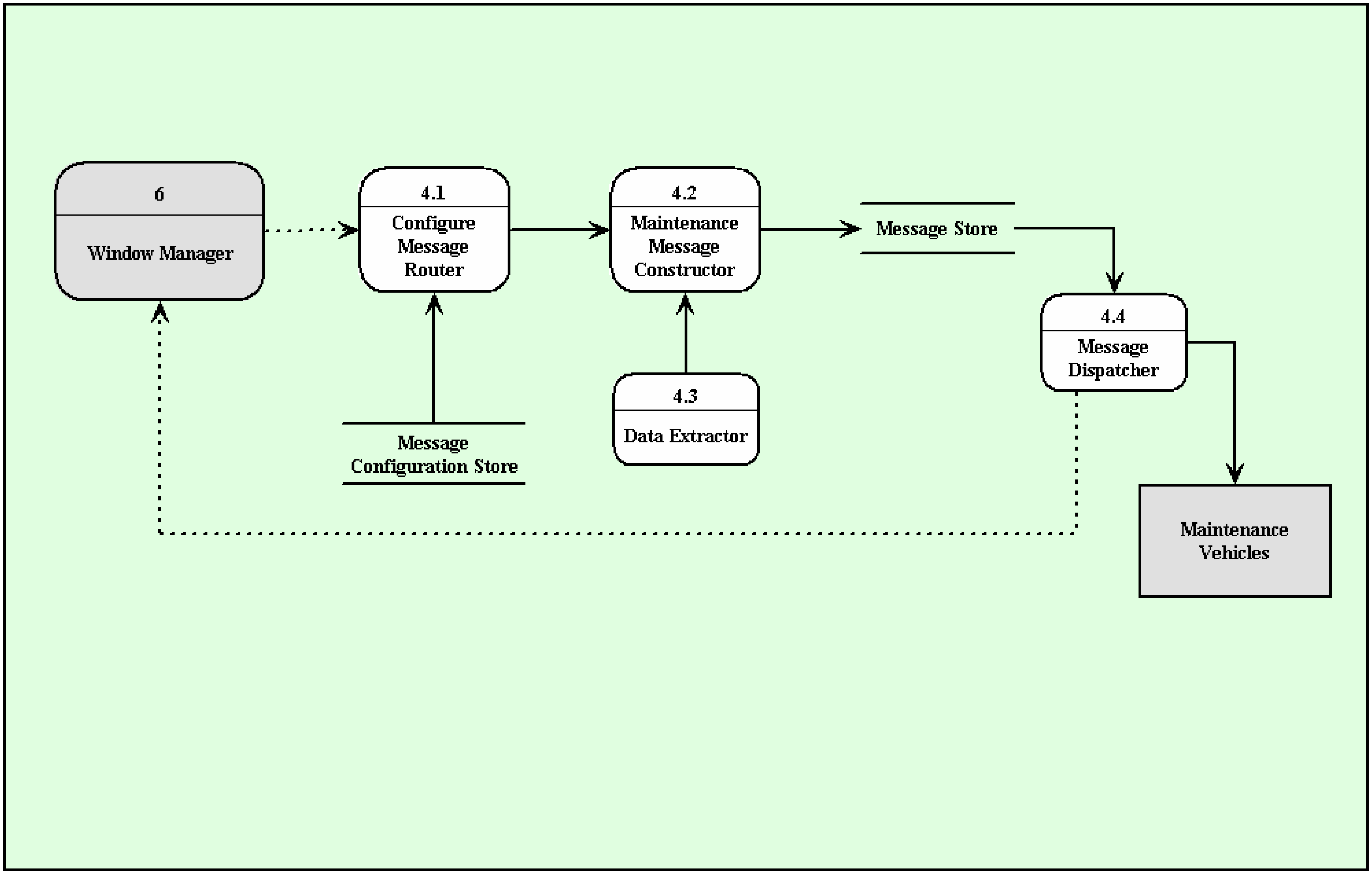


Figure I- 6. Pooled fund MDSS level 2 data flow diagram for the Message Dispatch. Grayed boxes denote processes/terminators external to the process. Solid lines denote data flows, dashed lines denote controls. Parallel horizontal lines are data stores.

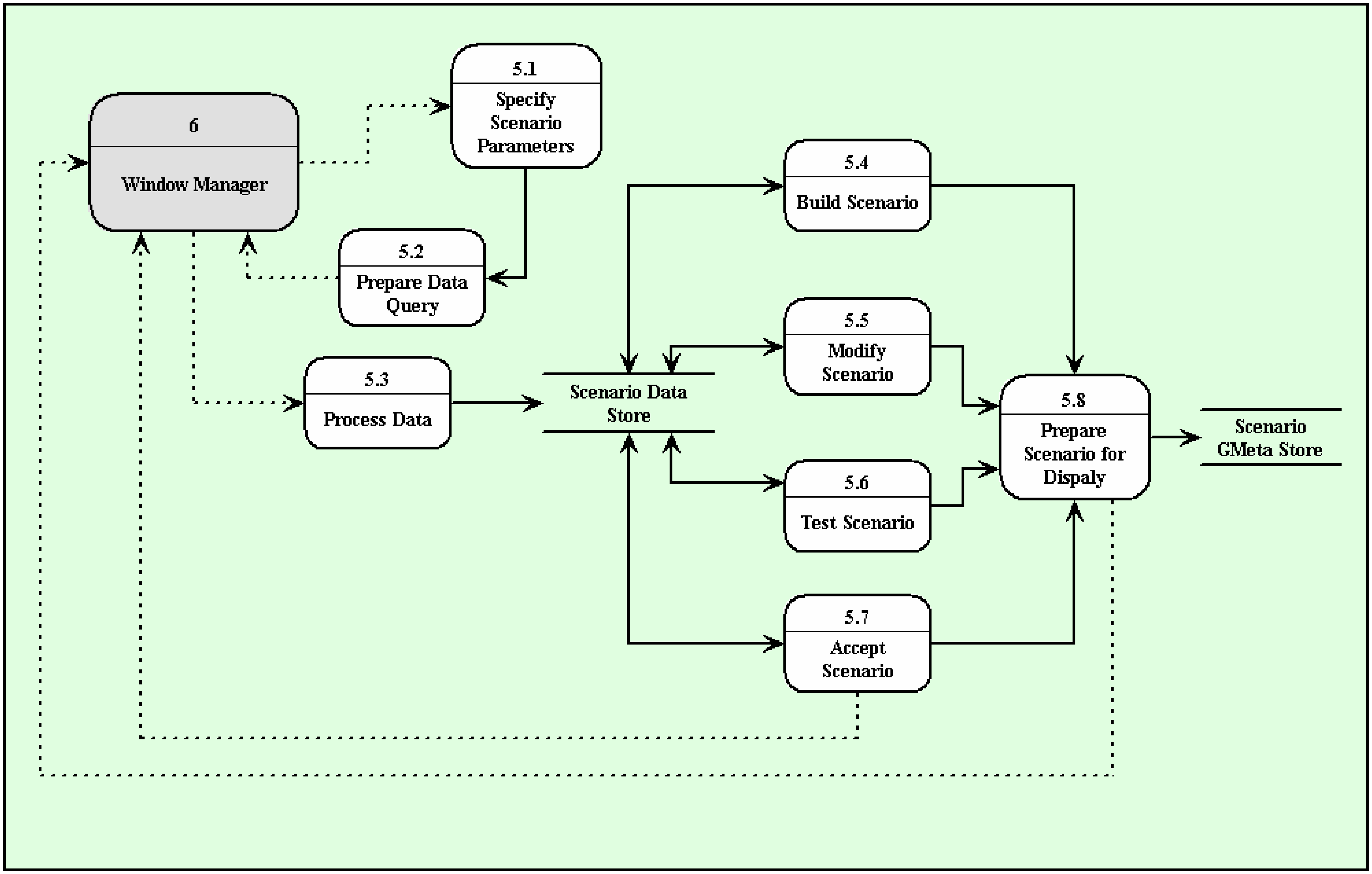


Figure I- 7. Pooled fund MDSS level 2 data flow diagram for the Scenario Generator process. Grayed boxes denote processes/terminators external to the process. Solid lines denote data flows, dashed lines denote controls. Parallel horizontal lines are data stores.

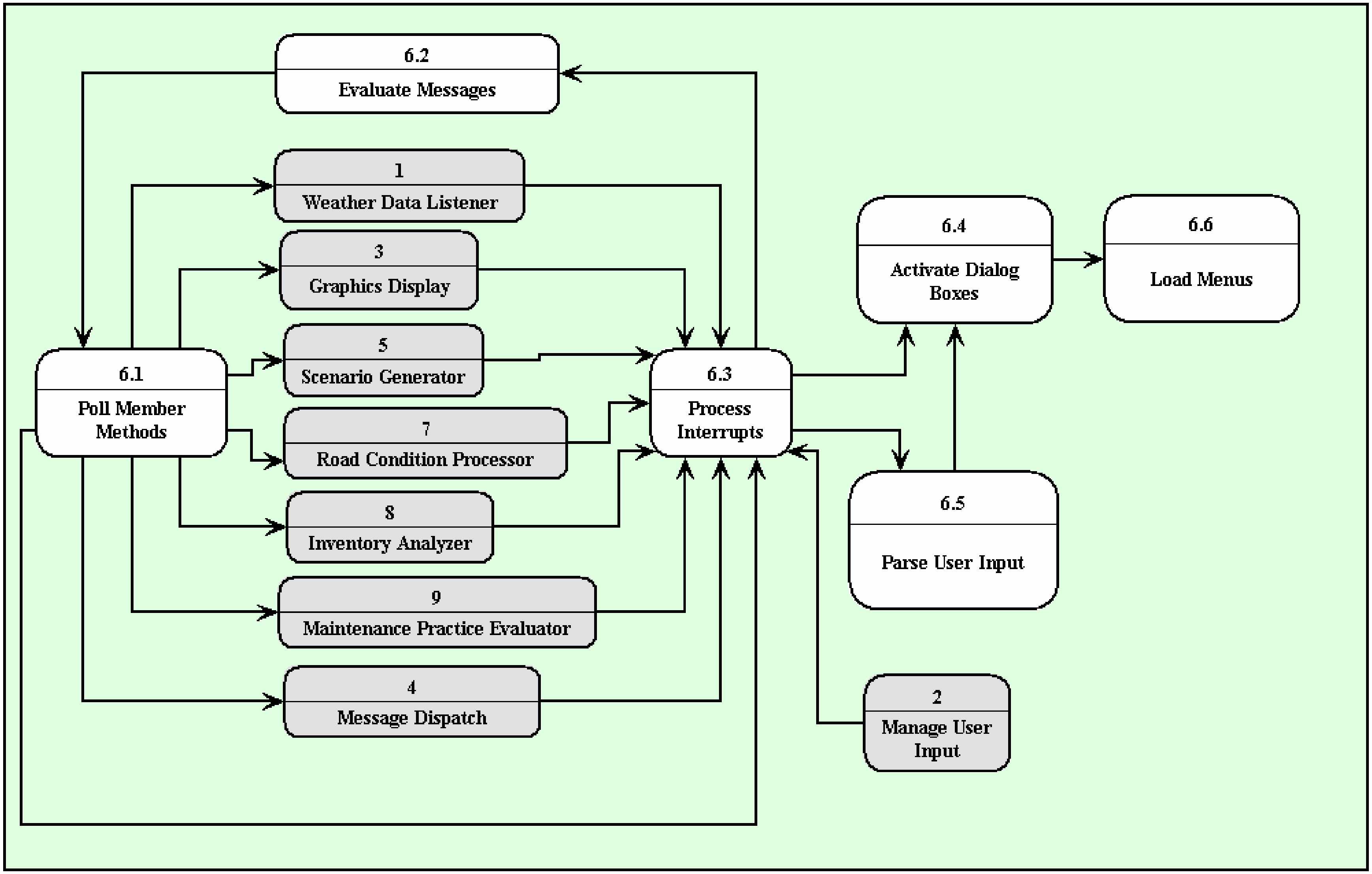


Figure I- 8. Pooled fund MDSS level 2 data flow diagram for the Window Manager process. Grayed boxes denote processes/terminators external to the process. Solid lines denote data flows, dashed lines denote controls. Parallel horizontal lines are data stores.

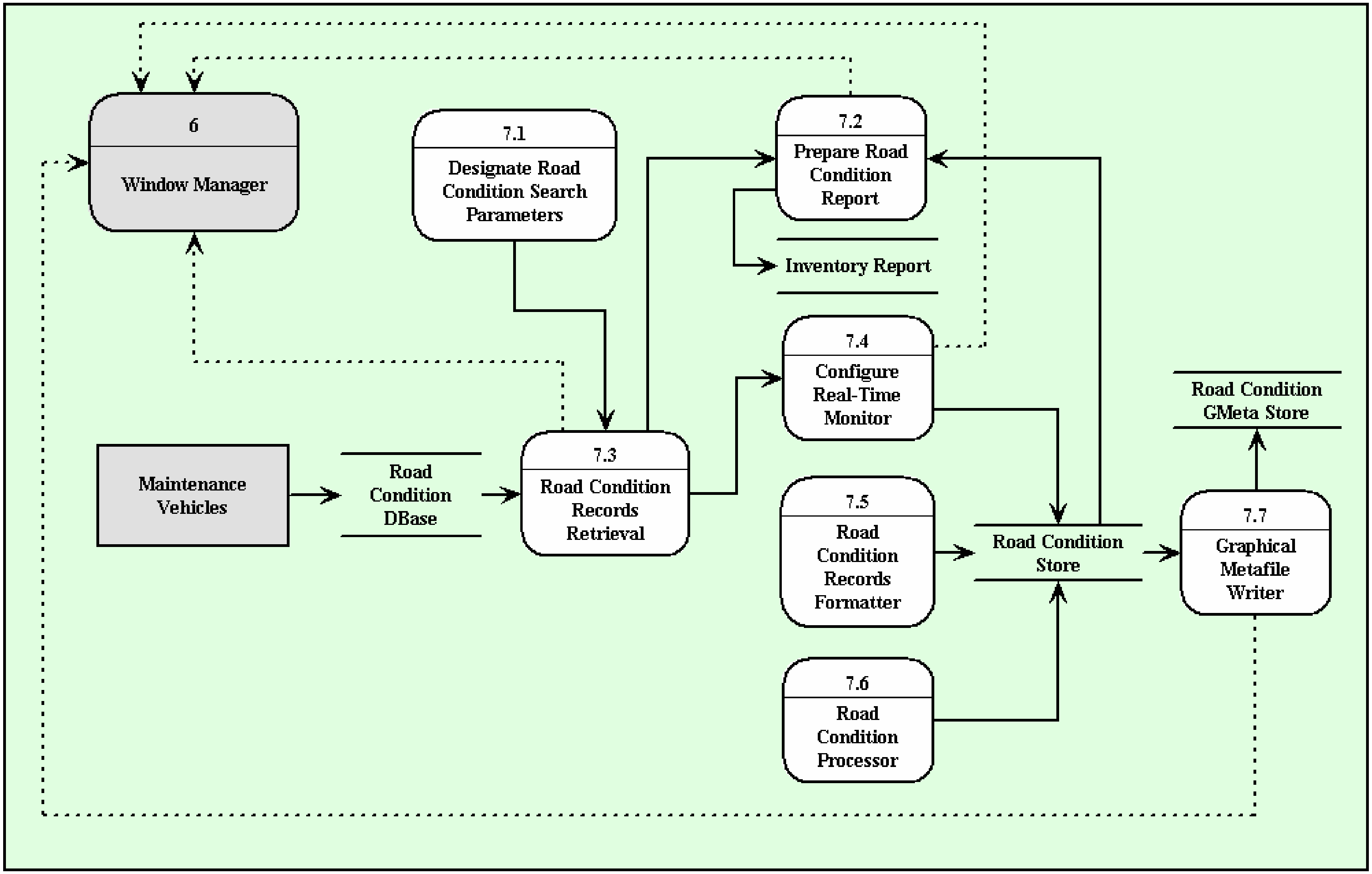


Figure I- 9. Pooled fund MDSS level 2 data flow diagram for the Road Condition Processor. Grayed boxes denote processes/terminators external to the process. Solid lines denote data flows, dashed lines denote controls. Parallel horizontal lines are data stores.

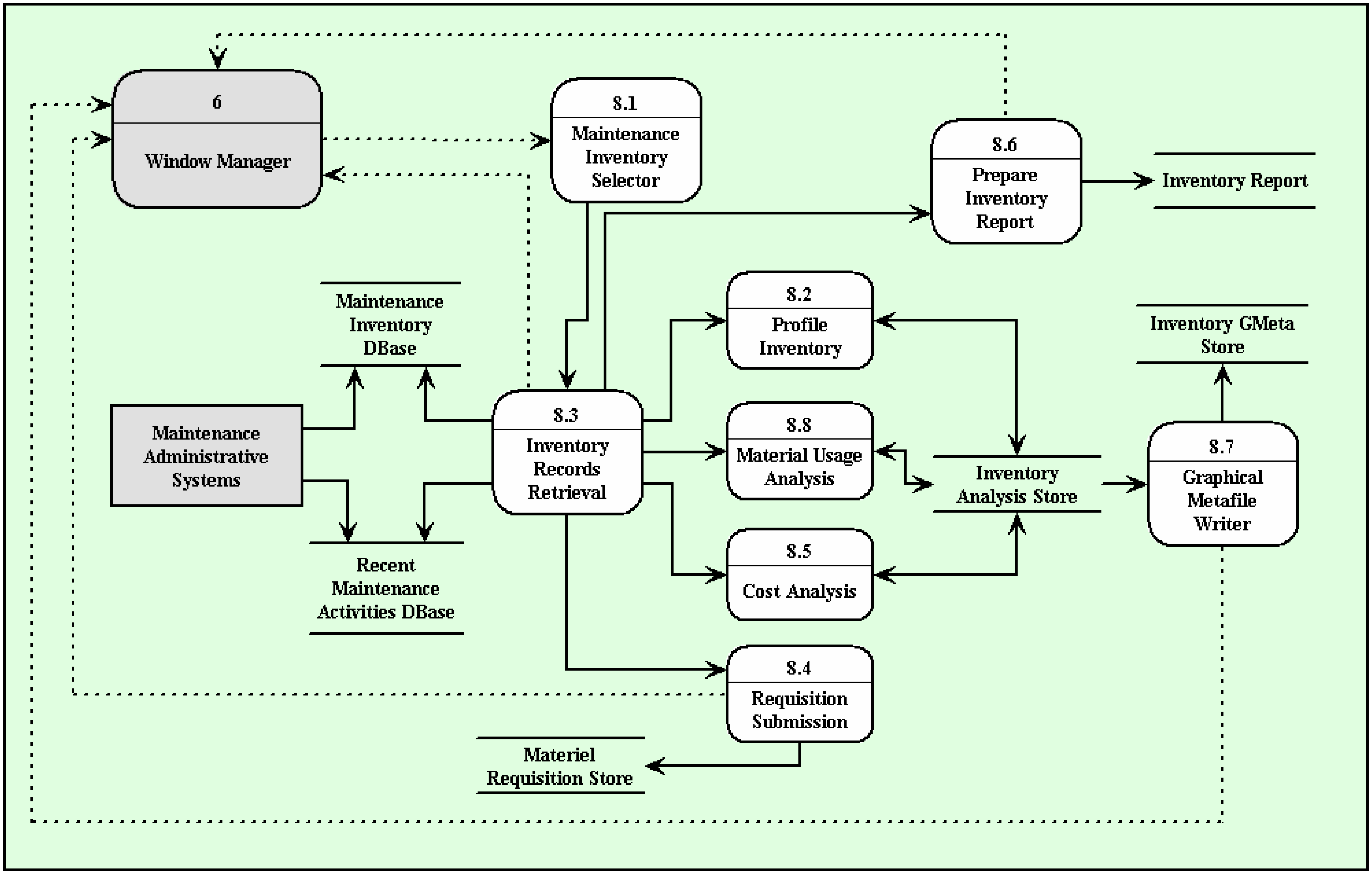


Figure I- 10. Pooled fund MDSS level 2 data flow diagram for the Inventory Analyst process. Grayed boxes denote processes/terminators external to the process. Solid lines denote data flows, dashed lines denote controls. Parallel horizontal lines are data stores.

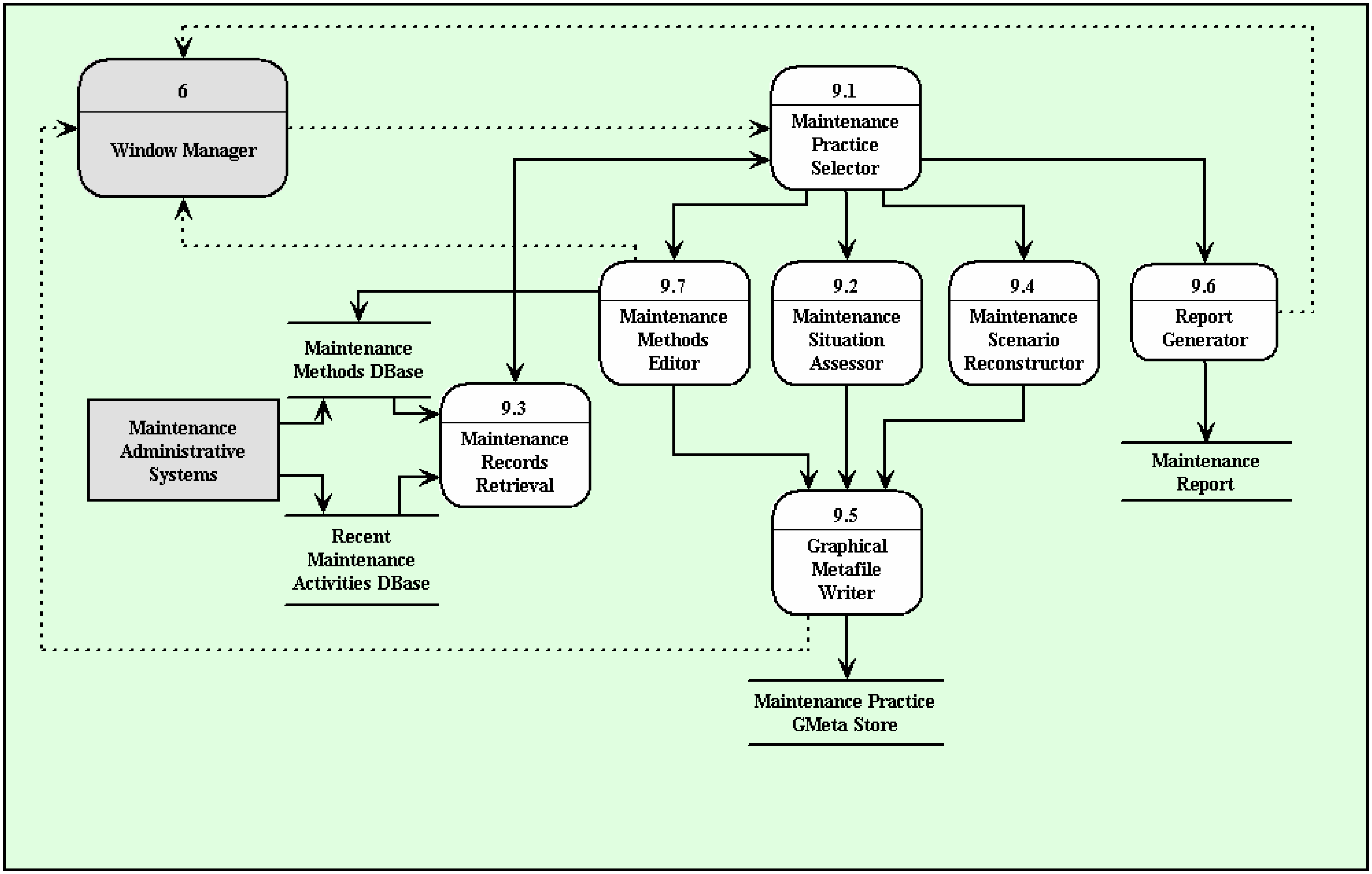


Figure I- 11. Pooled fund MDSS level 2 diagram for the Maintenance Practice Evaluator process. Grayed boxes denote processes/terminators external to the process. Solid lines denote data flows, dashed lines denote controls. Parallel horizontal lines are data stores.

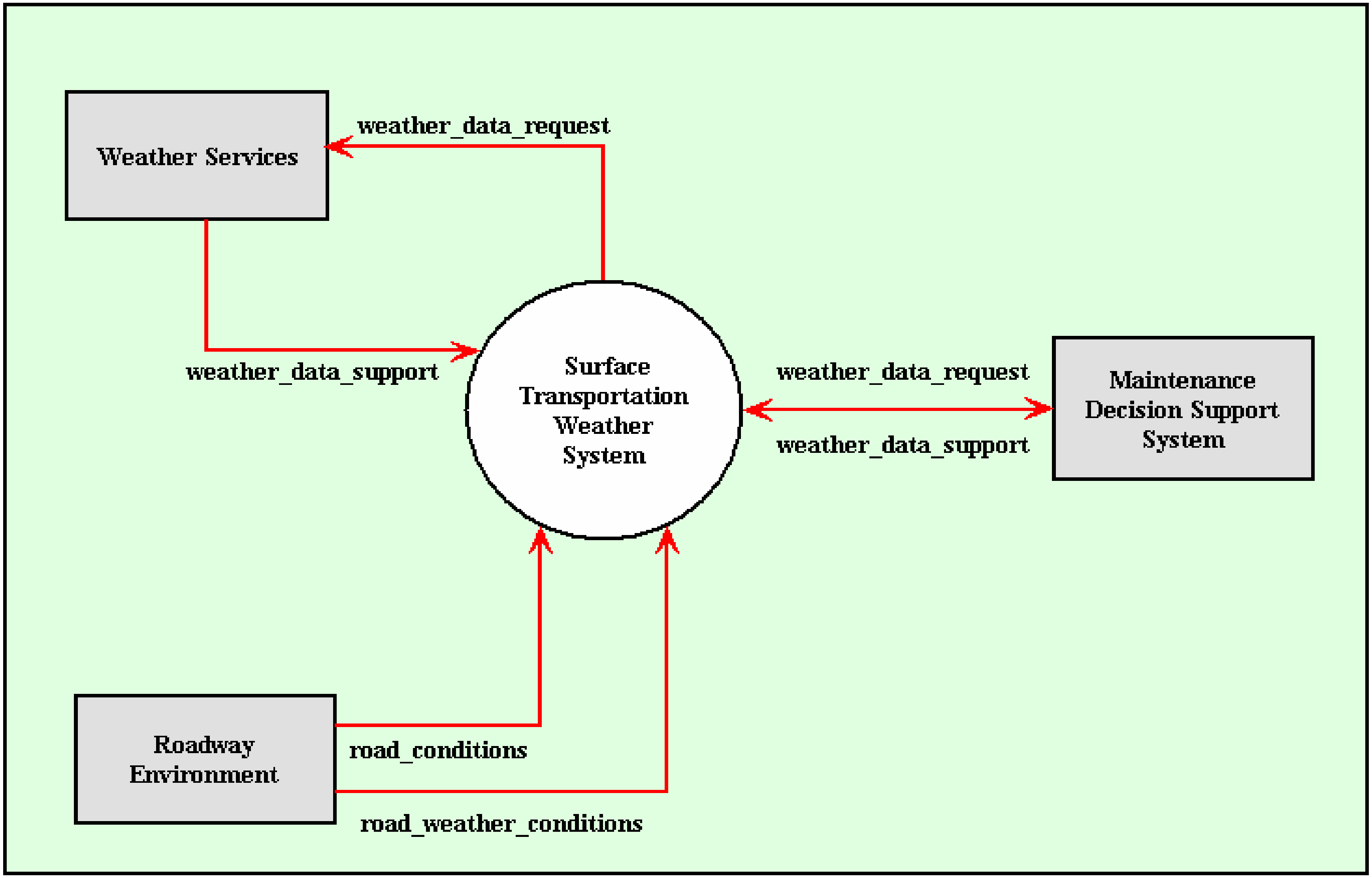


Figure I- 12. Pooled fund MDSS context diagram for the Surface Transportation Weather System (STWx). Grayed boxes denote terminators. Data flow labels conform to NITSA conventions.

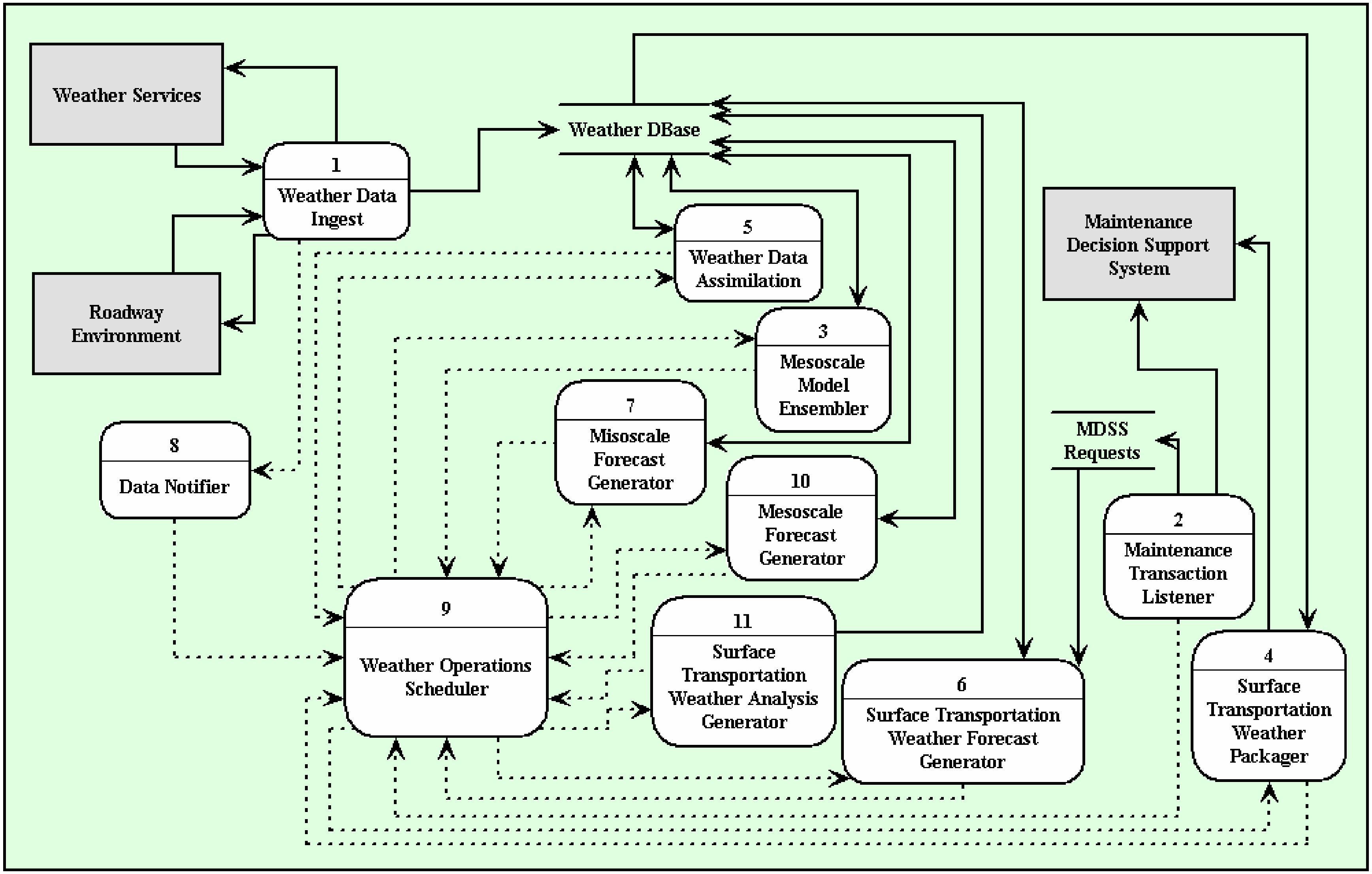


Figure I- 13. Pooled fund MDSS STWx level 1 data flow diagram. Grayed boxes denote terminators. Rounded rectangle boxes are level 1 processes. Solid lines are data flows, dashed lines are controls.

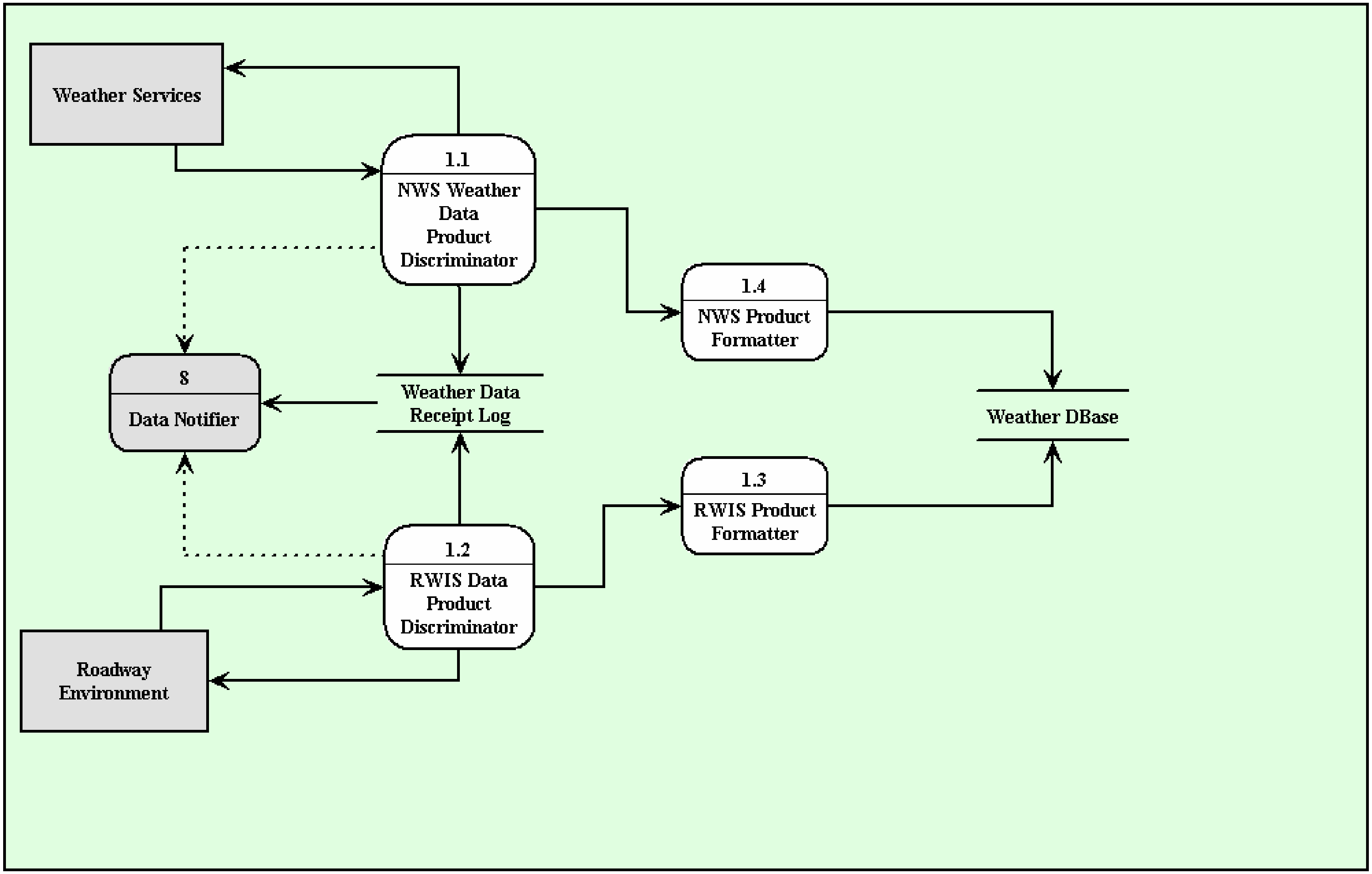


Figure I- 14. Pooled fund MDSS STWx level 2 data flow diagram for the Weather Data Ingest process. Grayed boxes denote processes/terminators external to the process. Solid lines denote data flows, dashed lines denote controls. Parallel horizontal lines are data stores.

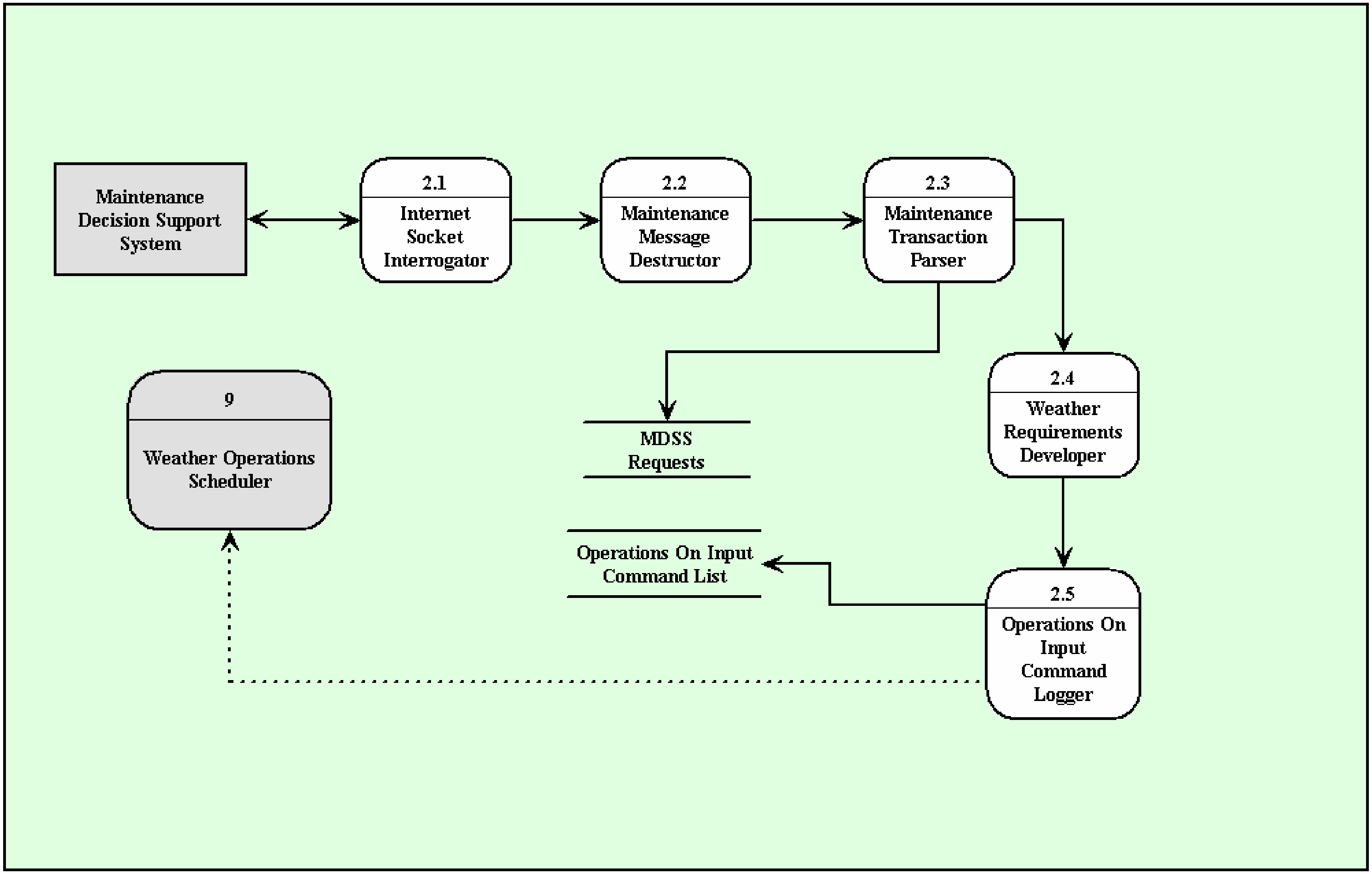


Figure I- 15. Pooled fund MDSS STWx level 2 data flow diagram for the Maintenance Transaction Listener. Grayed boxes denote processes/terminators external to the process. Solid lines denote data flows, dashed lines denote controls. Parallel horizontal lines are data stores.

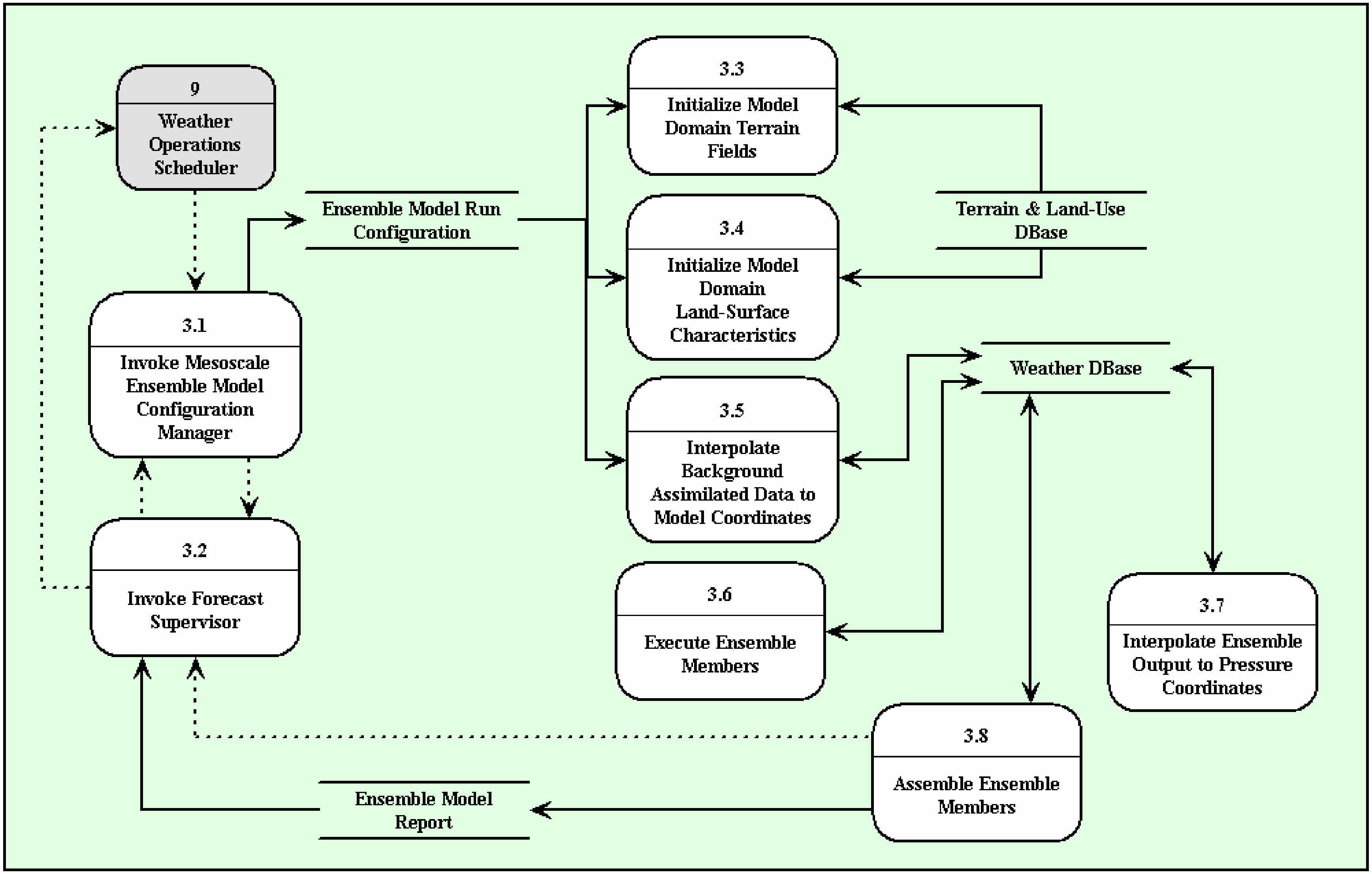


Figure I- 16. Pooled fund MDSS STWx level 2 data flow diagram for the Mesoscale Model Ensembler. Grayed boxes denote processes/terminators external to the process. Solid lines denote data flows, dashed lines denote controls. Parallel horizontal lines are data stores.

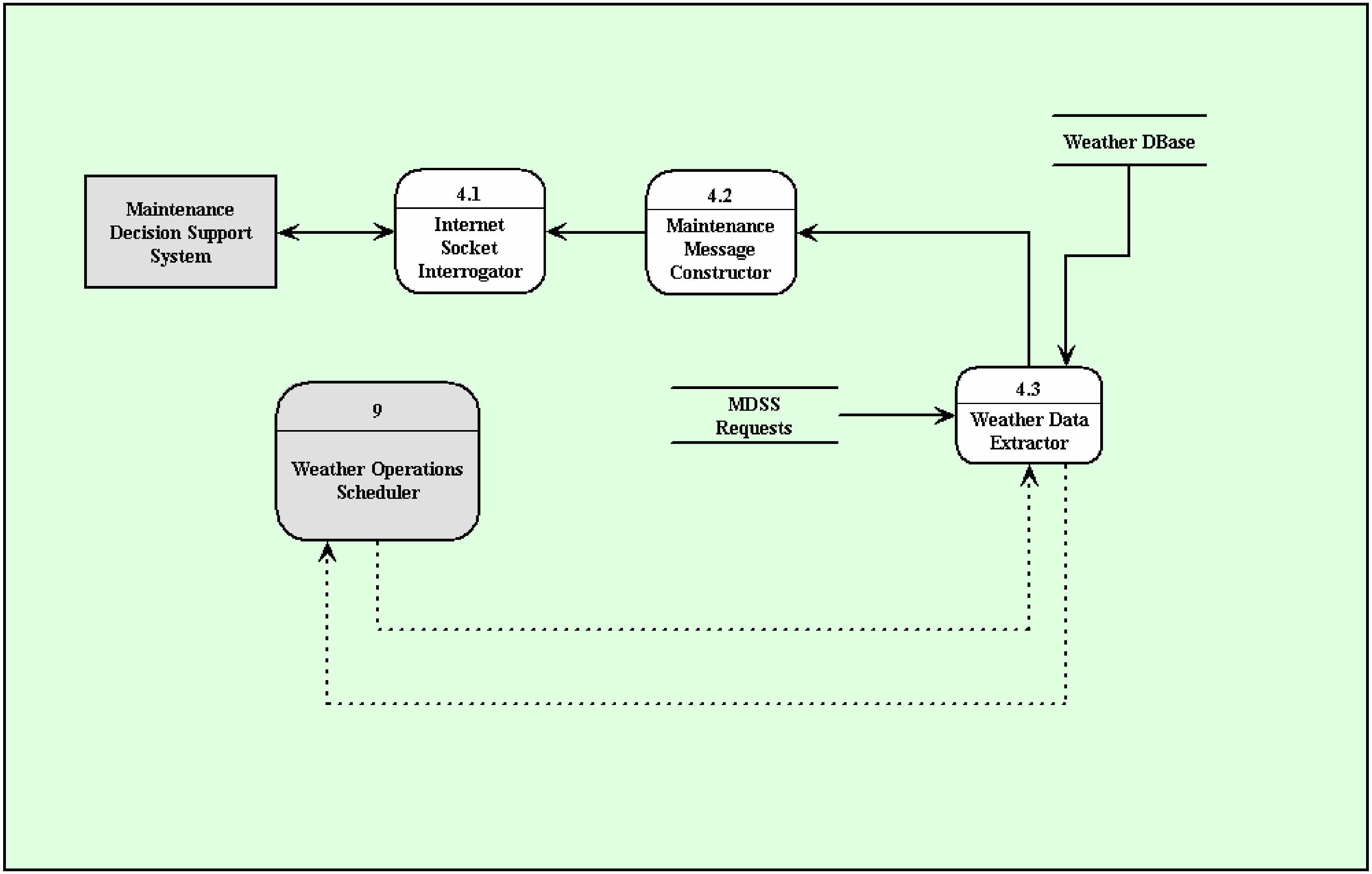


Figure I- 17. Pooled fund MDSS STWx level 2 data flow diagram for the Surface Transportation Weather Packager process. Grayed boxes denote processes/terminators external to the process. Solid lines denote data flows, dashed lines denote controls. Parallel horizontal lines are data stores.

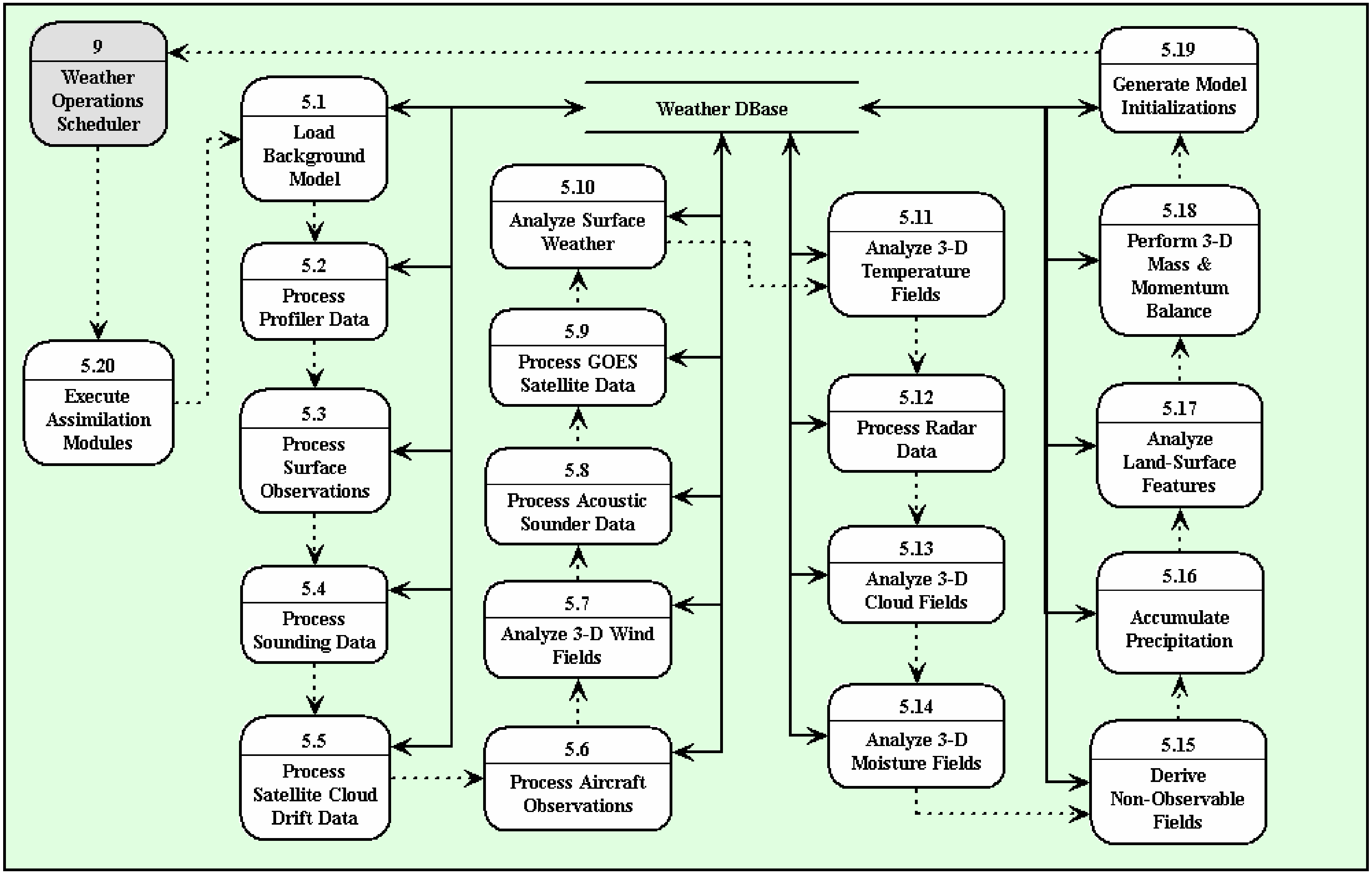


Figure I- 18. Pooled fund MDSS STWx level 2 data flow diagram for the Weather Data Assimilation process. Grayed boxes denote processes/terminators external to the process. Solid lines denote data flows, dashed lines denote controls. Parallel horizontal lines are data stores.

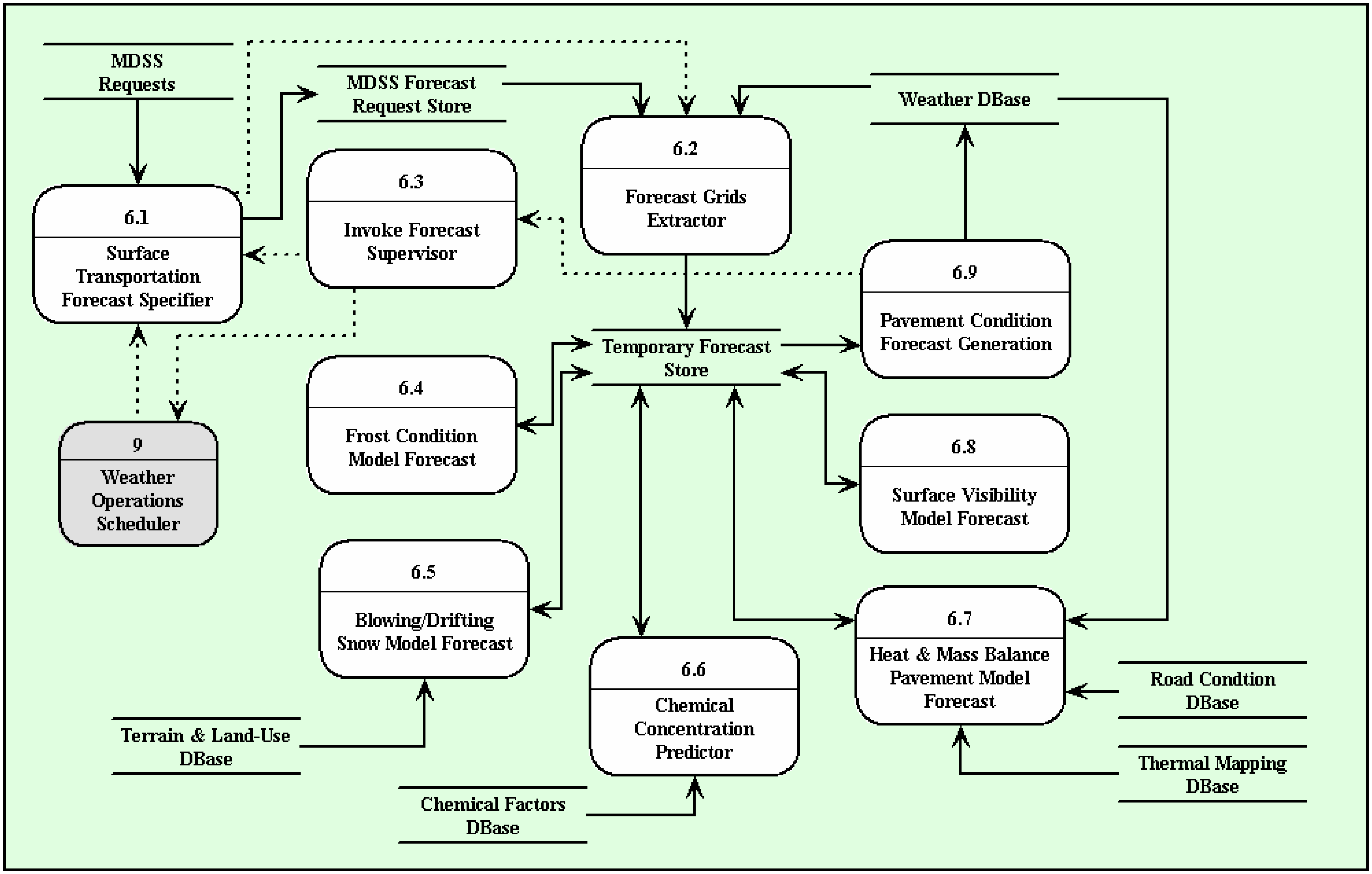


Figure I- 19. Pooled fund MDSS STWx level 2 data flow diagram for the Surface Transportation Forecast Generator process. Grayed boxes denote processes/terminators external to the process. Solid lines denote data flows, dashed lines denote controls. Parallel horizontal lines are data stores.

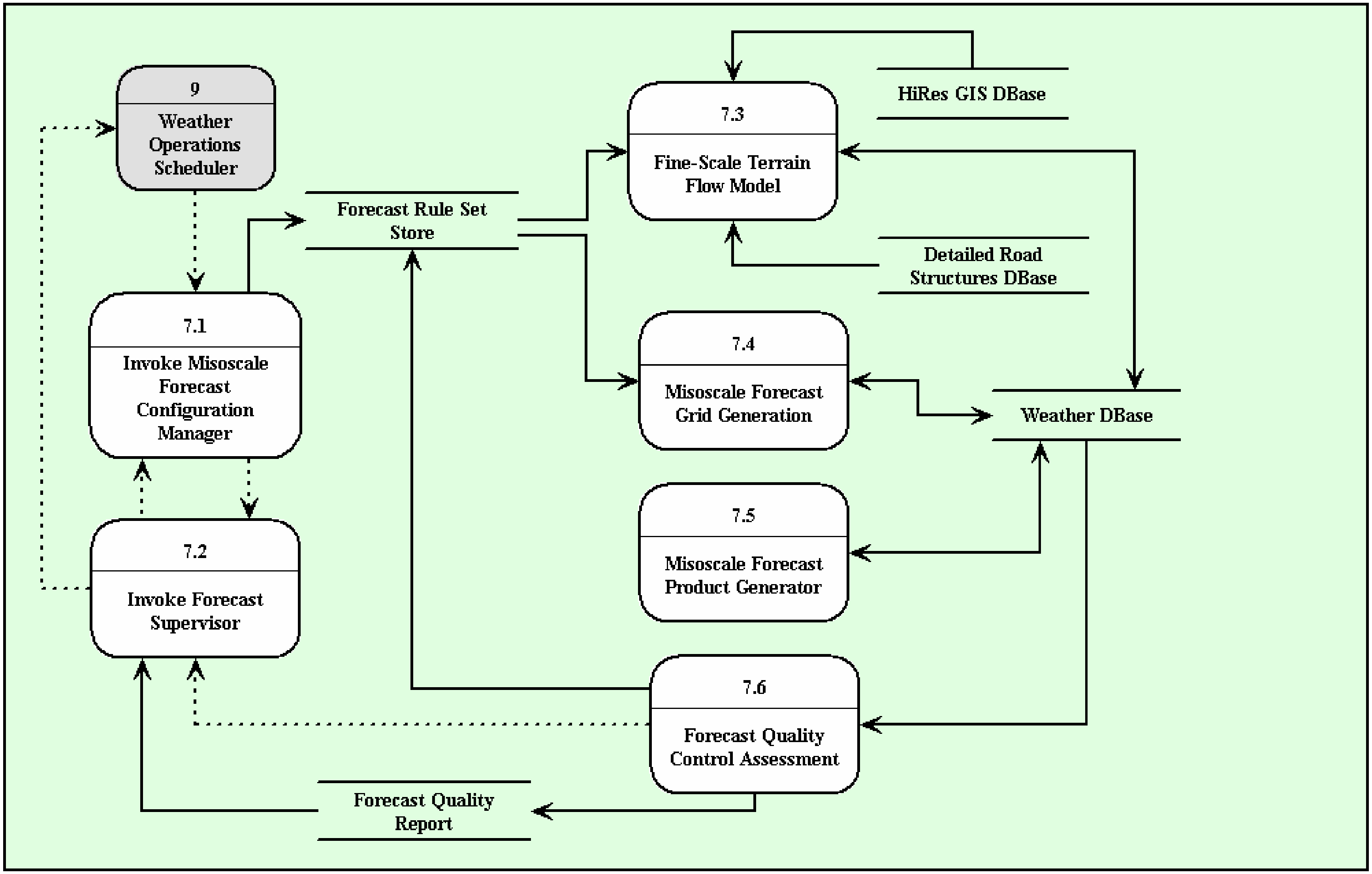


Figure I- 20. Pooled fund MDSS STWx level 2 data flow diagram for the Misoscale Forecast Generator process. Grayed boxes denote processes/terminators external to the process. Solid lines denote data flows, dashed lines denote controls. Parallel horizontal lines are data stores.

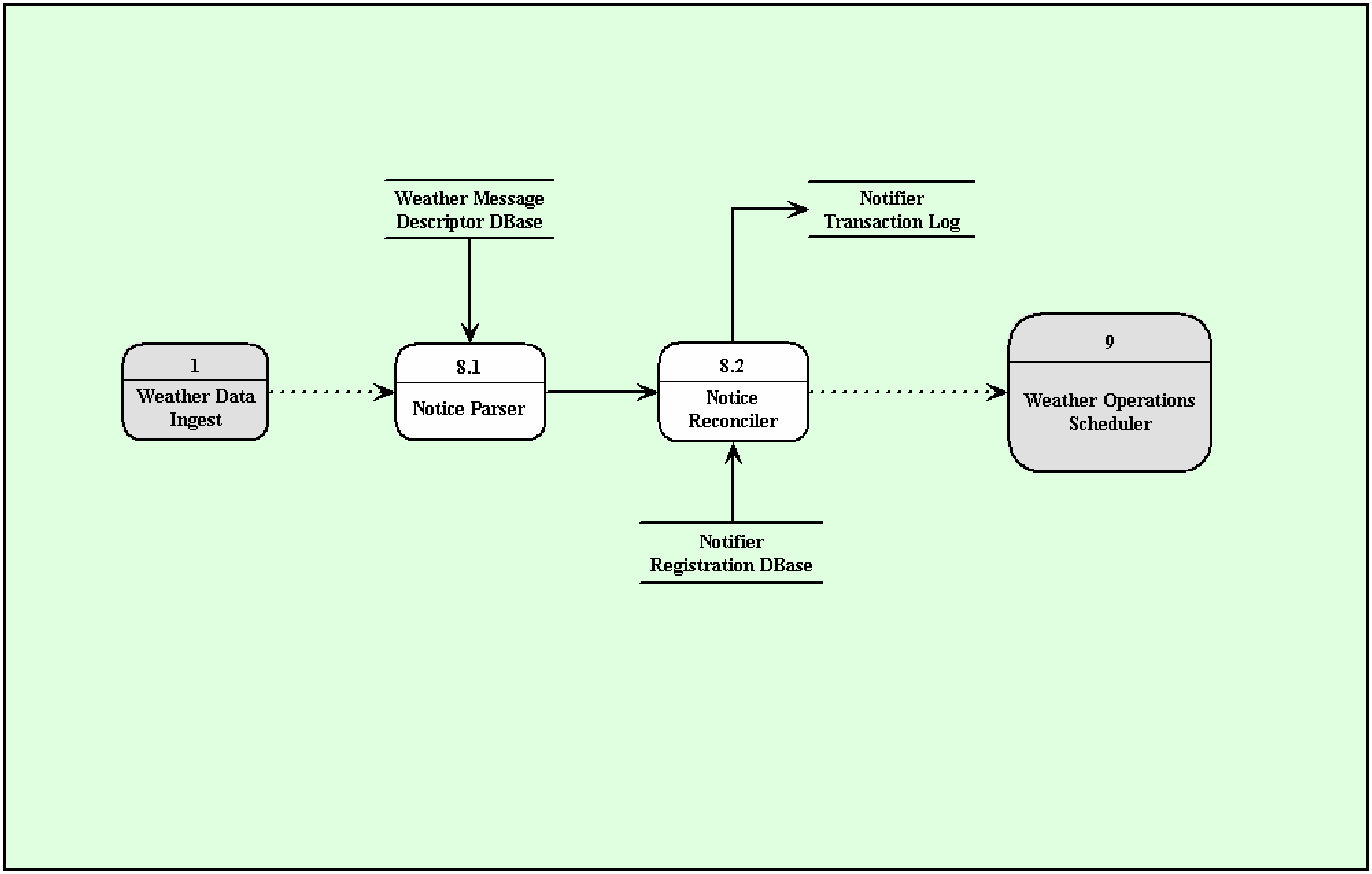


Figure I- 21. Pooled fund MDSS STWx level 2 data flow diagram for the Data Notifier process. Grayed boxes denote processes/terminators external to the process. Solid lines denote data flows, dashed lines denote controls. Parallel horizontal lines are data stores.

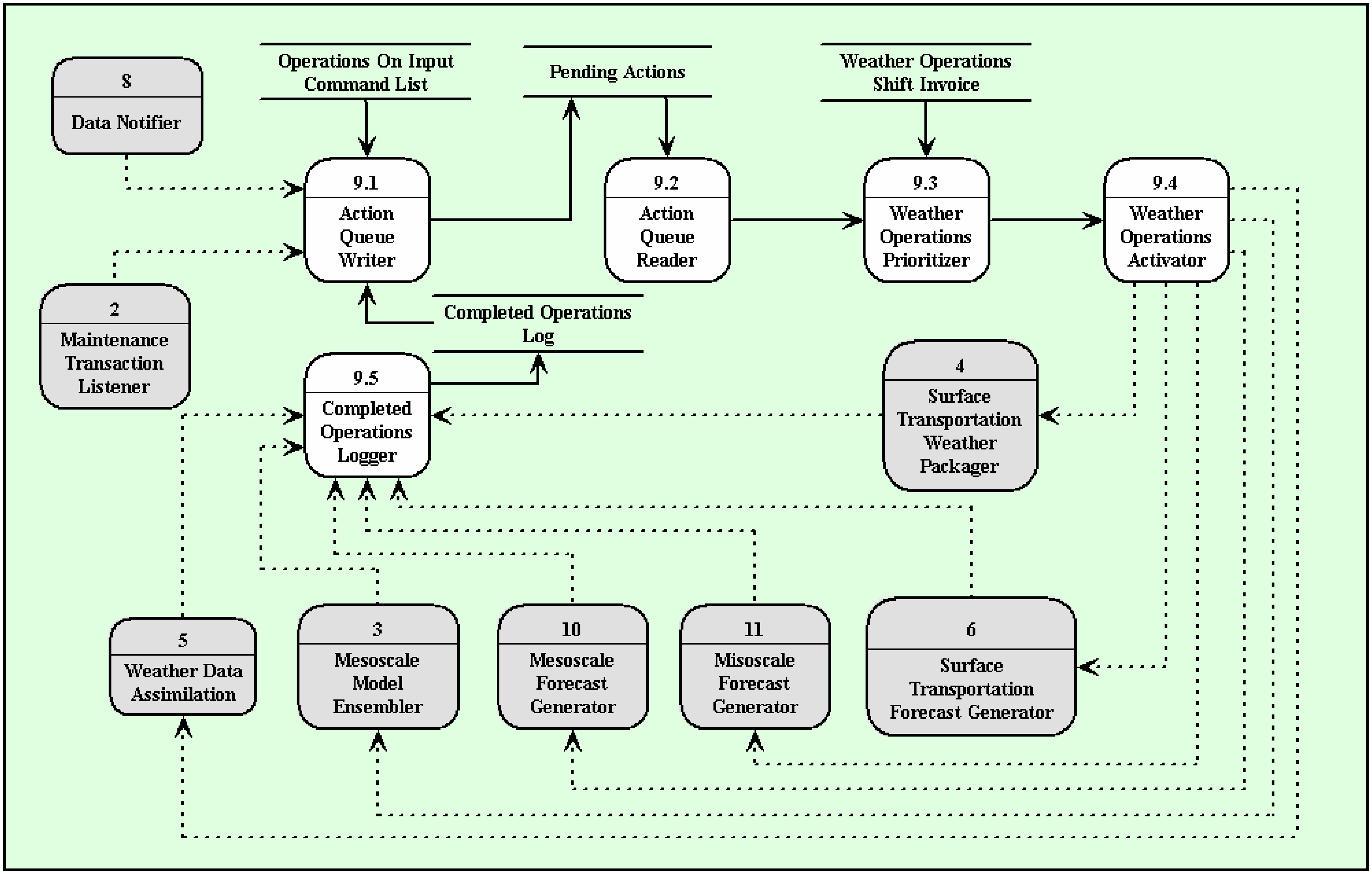


Figure I- 22. Pooled fund MDSS level 2 data flow diagram for the Weather Operations Scheduler process. Grayed boxes denote processes/terminators external to the process. Solid lines denote data flows, dashed lines denote controls. Parallel horizontal lines are data stores.

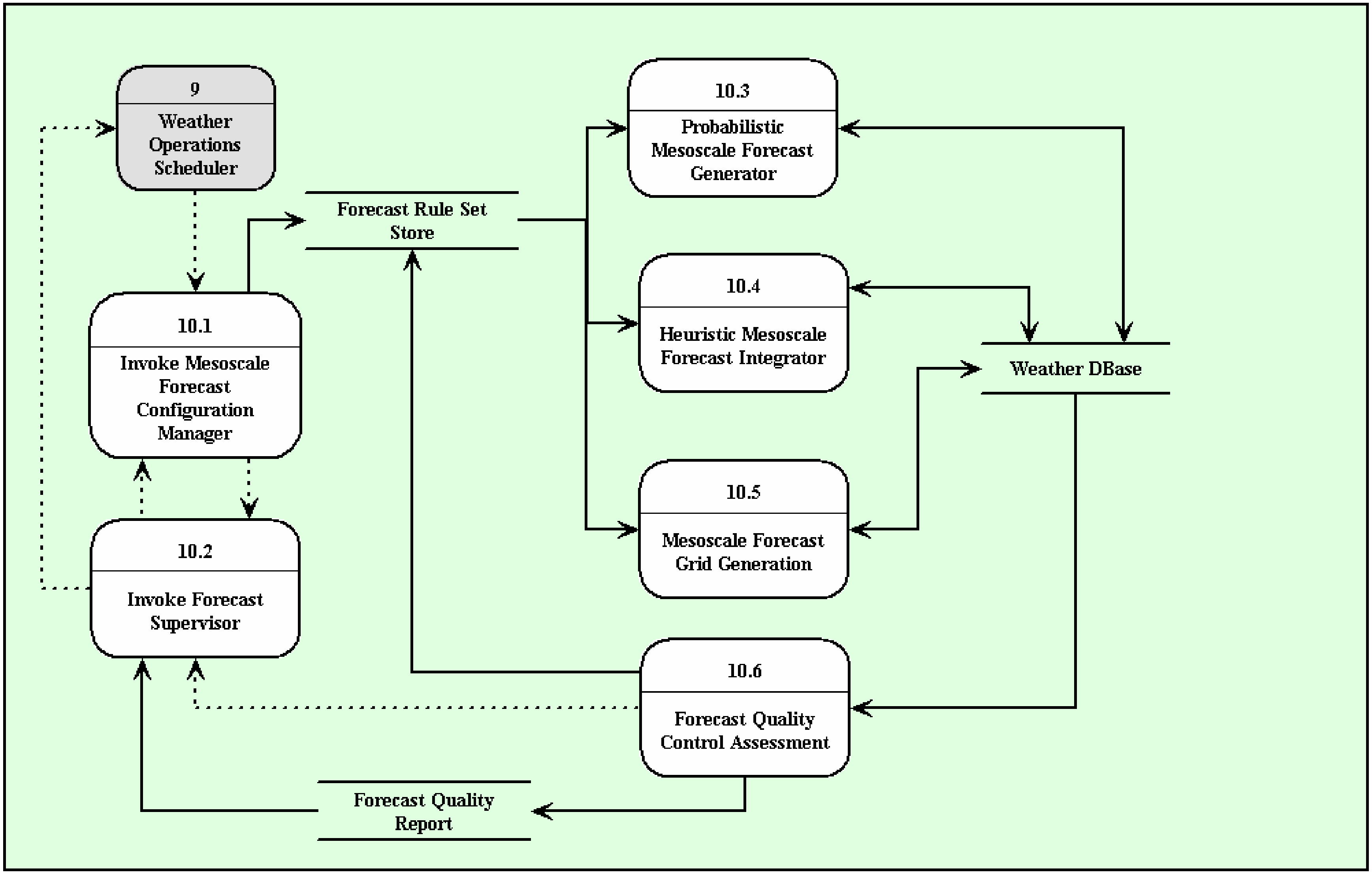


Figure I- 23. Pooled fund MDSS STWx level 2 data flow diagram for the Mesoscale Forecast Generator process. Grayed boxes denote processes/terminators external to the process. Solid lines denote data flows, dashed lines denote controls. Parallel horizontal lines are data stores.

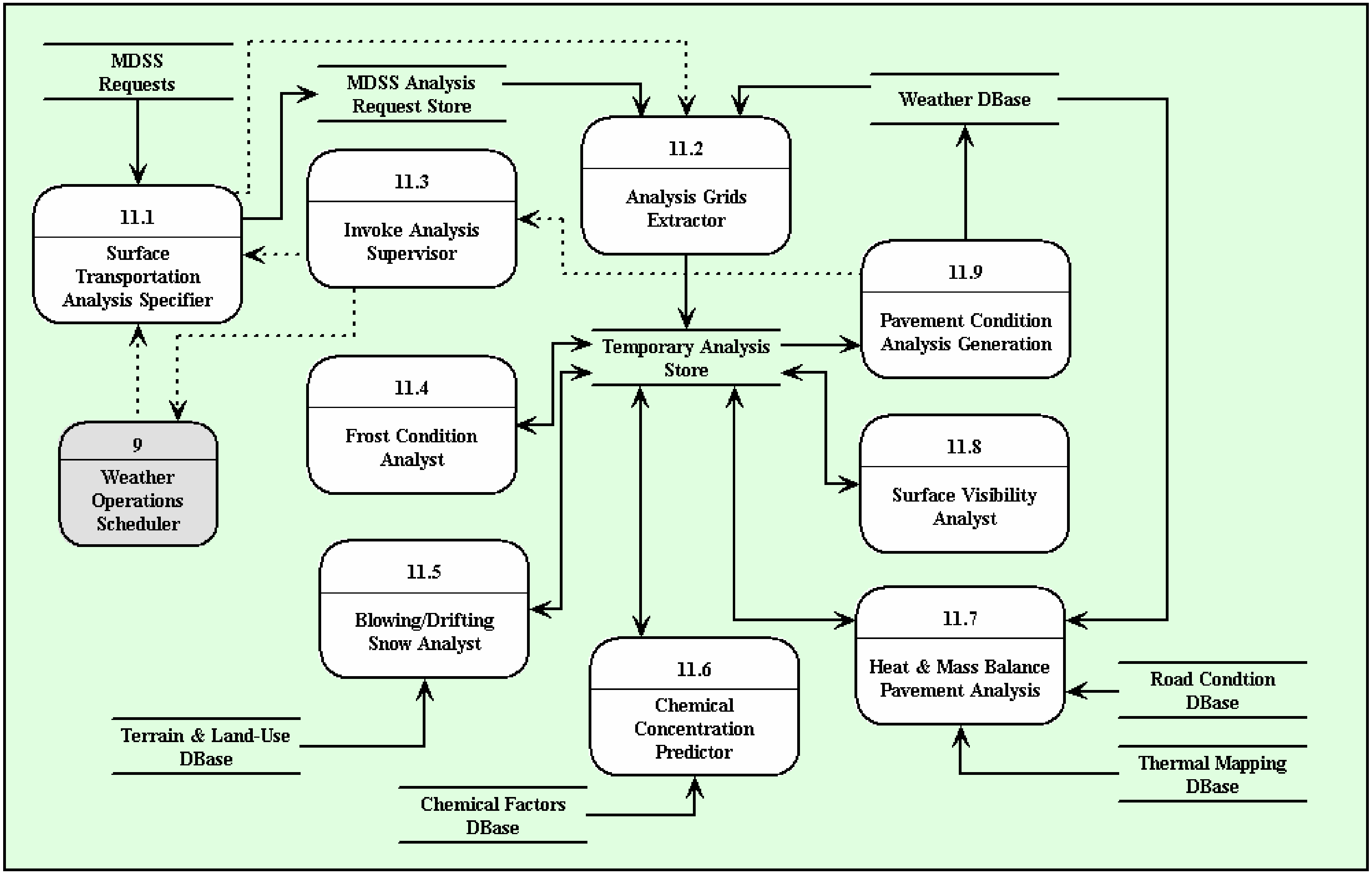


Figure I- 24. Pooled fund MDSS STWx level 2 data flow diagram for the Surface Transportation Analysis Generator process. Grayed boxes denote processes/terminators external to the process. Solid lines denote data flows, dashed lines denote controls. Parallel horizontal lines are data stores.