Implementing Next-Generation Maintenance Vehicle Technology

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Transportation agencies are facing ever-increasing demands from the customers they serve for safer, faster, and more reliable transportation systems. This is especially true for highway transportation because nearly all trips begin and end using the roadway. To add to the challenge, most public agencies are being asked to downsize, improve efficiency and effectiveness, and provide real-time status of the roadway system so that the motoring public can make better travel plans and decisions. The progress is described that three Midwest states are making on improving the efficiency and effectiveness of snow and ice control operations with improved equipment, road/weather forecasting, and interfacing with the National Intelligent Transportation System Architecture for improved customer communication.

The mission of the Iowa Department of Transportation's Maintenance Division is to manage the preservation and operation of Iowa's transportation system to deliver transportation services that support the economic, environmental, and social needs of its customers. This mission is particularly challenging to Snow Belt states during the perils of a winter season. Just-in-time goods deliveries, a key ingredient in any state's economic vitality, place an ever-increasing importance on reliable year-round transportation. These increasing transportation demands are coming at a time when most states are being asked to downsize their maintenance operations work force. The application of advanced snow and ice control technologies and their integration with intelligent transportation systems (ITS) offer excellent potential for increasing operational efficiency and effectiveness as well as improving winter mobility and driver safety. In 1995, the state departments of transportation (DOTs) of Iowa, Michigan, and Minnesota formed a consortium to define and develop the next-generation highway maintenance vehicle that would use the latest maintenance operational technologies and interface with ITS. Focus groups consisting of each DOT's internal and external customers revealed that, although all maintenance operations could benefit from creating this new-generation vehicle, ice and snow operations were the most complex and would benefit greatly from improvements in state-of-the-art vehicle navigation systems, onboard computer applications, and enhanced safety systems. This advanced-technology highway maintenance vehicle functions as both an operational truck and a mobile data-gathering platform. Sensors mounted on the vehicle record air and roadway surface temperature, roadway surface condition, and roadway surface friction characteristics. This information is Global Positioning System–correlated and is used in maintenance operational decision making. The information eventually will be interfaced with the ITS technology in the Traffic Management and Information Service Provider Centers Subsystems of the National ITS Architecture.

The advanced-technology highway maintenance vehicle performs an important role in the FHWA's Weather Information for Surface Transportation ITS Field Operational Test being conducted by the Foretell Consortium.

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The vehicle operates as a mobile environmental sensor station gathering real-time pavement thermal profiles and air-temperature data for input to the Foretell microscale models.

Each consortium state has built and operated an advanced-technology highway maintenance vehicle in its daily maintenance operations for 3 years. Each vehicle and its advanced concept technologies have passed proof-of-concept tests. Each technology is now being evaluated to determine what benefits have been realized and to calculate their respective benefit/cost ratio. Emerging technologies are also being tested on the concept vehicle. First-generation concept technologies are being redesigned to improve their reliability and reduce complexity and cost. For example, a roadway friction-measuring device has been redesigned to make it smaller, less complex, and more durable, and the cost has been reduced by 65 percent. Reduced cost is especially important because each state will need several hundred friction-measuring units to adequately meet the need that rural ITS must accurately determine and predict the winter condition of road surfaces and its impact on braking and driving traction.

In recognition of the potential for using advanced methods and ITS technologies for highway maintenance activities, a four-phase study, shown in Figure 1, was initiated to define the desired vehicle and equipment capabilities for the next-generation highway vehicle, develop and evaluate prototype vehicles, conduct benefit/cost analysis, and produce maintenance vehicles for fleet applications. The initial focus is on maintenance operations that are most visible to the public. Transportation agency operations and ITS surveys have shown that safety and winter mobility rank high in customers' concerns and expectations. Winter snow and ice control operations, therefore, are receiving first consideration for technology applications in developing the next-generation highway maintenance vehicle.

FOUR-PHASE RESEARCH IN PROCESS

Phase I

The objective of Phase I was to develop the functionality that the concept vehicle will provide and to enlist private-sector partners to provide the functionality. This phase began with a literature review of materials related to winter highway maintenance activities. One hundred five articles were collected that pertained to state-of-the-art equipment, technologies, and research related to winter highway maintenance activities.

The ideal capabilities of a winter maintenance vehicle were identified through focus groups. Five focus groups were formed. They included representation from equipment operators and managers, mechanics, resident and central maintenance office engineers, area supervisors, law enforcement, and emergency responders. Focus group meetings were held in the three consortium states generating more than 600 ideas. These were later combined and organized into a list of 181 desired capabilities for the highway maintenance concept vehicle. The final prototype design for the three prototype vehicles provided the following desired capabilities identified by the focus groups:

- Sense roadway surface temperatures,
- Sense roadway surface friction conditions,
- Record and download vehicle activities,
- Improve fuel economy,
- Provide adequate horsepower for the vehicle,
- Carry and distribute multiple types of materials,
- Provide removable salt/salt brine dispensing system, and
- Provide backup sensors/monitors.

Private-sector equipment and technology providers were introduced to the study and asked to join the effort. These private partners committed to providing equipment and expertise for the study's duration. Phase I is complete, and a more detailed discussion can be found in *Concept Highway Maintenance Vehicle, Final Report Phase I*, dated April 1997, Iowa State University, Ames, Iowa. The report is also on the Iowa State University Center for Transportation Research and Education (CTRE) website at http://www.ctre.iastate.edu/Research/conceptv/index.htm.

Phase II

The objectives of Phase II were to build three prototype concept vehicles, integrating the subsystems into a working system; conduct proof of concept; and prepare for field evaluations of three prototype vehicles in Phase III. Proof of concept was conducted for each of the functional areas integrated into the prototype vehicles. Proof of concept for Phase II was defined as conducting "end-to-end" processing, observing the success of the "end-to-end" processing, and observing if the data were reasonable. Proof of concept is not a rigorous, statistically valid field test. A data collection and observation plan was developed to conduct proof of concept while operating the prototype vehicles during the winter of 1998–1999.

In addition, telephone interviews were conducted with the prototype vehicle operators to ascertain equipment performance. The interviews and documentation of equipment performance led to guidelines for the desired equip-

Foundation Statements:

1. "The solutions must be selected and recommended based on a benefit/cost analysis and a reasonably short time to implementation."
2 " The application of solutions must be described in terms that related to improving *service to customers*."

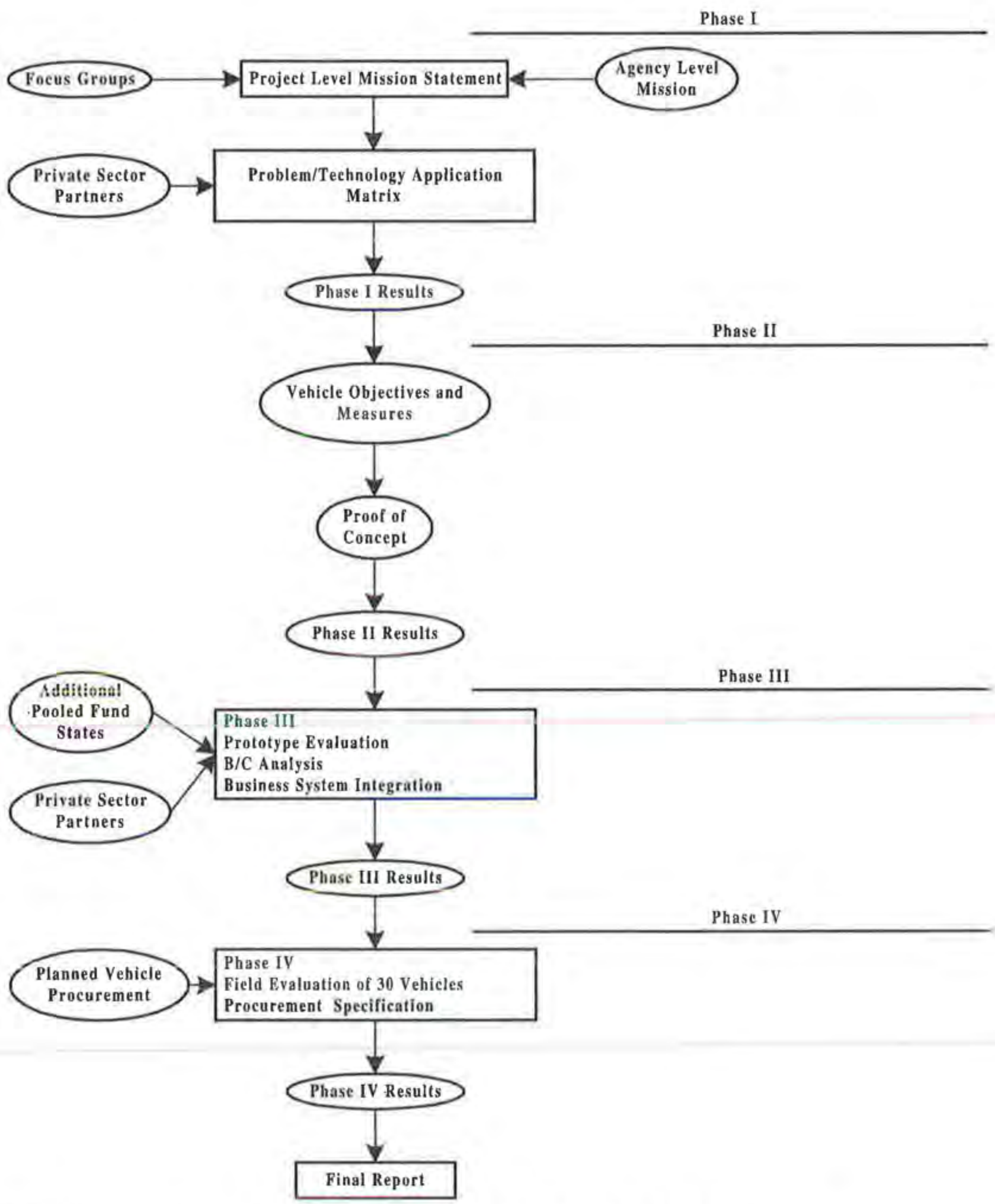

FIGURE 1 Next-generation maintenance vehicle technology: the four-phase approach.

ment capabilities for the Phase III prototype vehicle. Phase II is complete, and the final report, *Concept Highway Maintenance Vehicle, Final Report Phase II,* is on the Iowa State University CTRE website at http://www.ctre.iastate.edu/Research/conceptv/index.htm.

Phase III

The general objectives of Phase III to be achieved in 1999–2000 are to perform proof of concept on newly discovered technologies, establish the functionality of each technology to be implemented, conduct a benefit/cost analysis for each technology, estimate the time to implementation, conduct field evaluation, produce data flow and decision process maps to integrate the concept vehicle functionality in management and ITS systems, and develop draft vehicle specifications for each consortium state.

Phase III will answer these questions:

- Which technologies should be implemented?
- What are the benefits and costs of each technology?
- What is the expected time to implementation?

Sensing roadway surface conditions is being attempted by Norsemeter of Norway using a device called Saltar. The Saltar design is an outgrowth of the evaluation done in Phase II and has been tested at Wallops Island, Virginia, and North Bay, Ontario. Both tests are sponsored by the National Aeronautics and Space Administration and attended by several manufacturers of surface friction measuring devices. The Saltar device did function as expected. The report will be placed on the Iowa State University CTRE website.

Benefit/cost analysis is currently being conducted on the pavement-surface temperature measuring technology. Benefits will be based on estimating the difference between materials distributed knowing the pavement-surface temperature at the vehicle's location and materials distributed based on the pavement temperature measured at a remote road weather information system (RWIS) site. Data are being collected based on interviews with field staff and from databases generated by the vehicle and the RWIS site. Analysis is currently under way.

Phase III also includes conducting proof-of-concept evaluation on a pavement-surface freezing point sensing system. CTRE is currently bench testing the system, supplied by Enator of Sweden.

Phase IV

The objectives of Phase IV are to

- Equip 10 vehicles per state with selected advanced technologies, and
- Conduct field evaluation.

Interfacing with ITS

National ITS Architecture

The Iowa Department of Transportation envisions the concept vehicle functionality fitting into the National ITS Architecture Subsystem and Communications architecture very smoothly. Figure 2 illustrates the placement of the functionality.

Road and Weather Model Interface

As part of the Weather Information for Surface Transportation ITS Field Operational Test, the Iowa prototype maintenance vehicle provided air and pavement temperatures to the Foretell Consortium to assist in the calibration of a new road and weather forecast model. This interface is depicted in Figure 3. It is envisioned that the 10 advanced-technology maintenance vehicles in Phase IV of this research will serve as Foretell's mobile platforms. The vehicles will use National Transportation Communications for ITS environmental sensor station protocol standards to radio air temperatures, wind speeds, pavement data, and maintenance operations reports in real time to Foretell ITS service centers. These service centers will provide the interface between ITS and ITS users, allowing progressive deployment of weather, roadway, and other ITS applications throughout the service center area.

Conclusions

The four-phase research project to develop a new-generation, advanced-technology highway maintenance vehicle began in 1995. The vision was to develop a concept vehicle that would support equipment operators and fleet managers in making more informed and cost-effective decisions based on emerging ITS technology. The approach was to bring technology applications from other industries to the concept vehicle. The customer was brought into the planning process at the very beginning, which is one of the reasons the project has been successful in field testing. The advanced-technology applications have withstood the severity of snow and ice control operations for two winters with only minor problems. Field operators and managers feel the new technology has made their efforts more efficient and effective. The information these vehicles provide to the ITS community is an incidental benefit to the main snow and ice control mission and is used by both the Department of Transportation in its operations management and the ITS service centers.

As new technologies emerge, they will be evaluated and tested using the model developed for this research project.

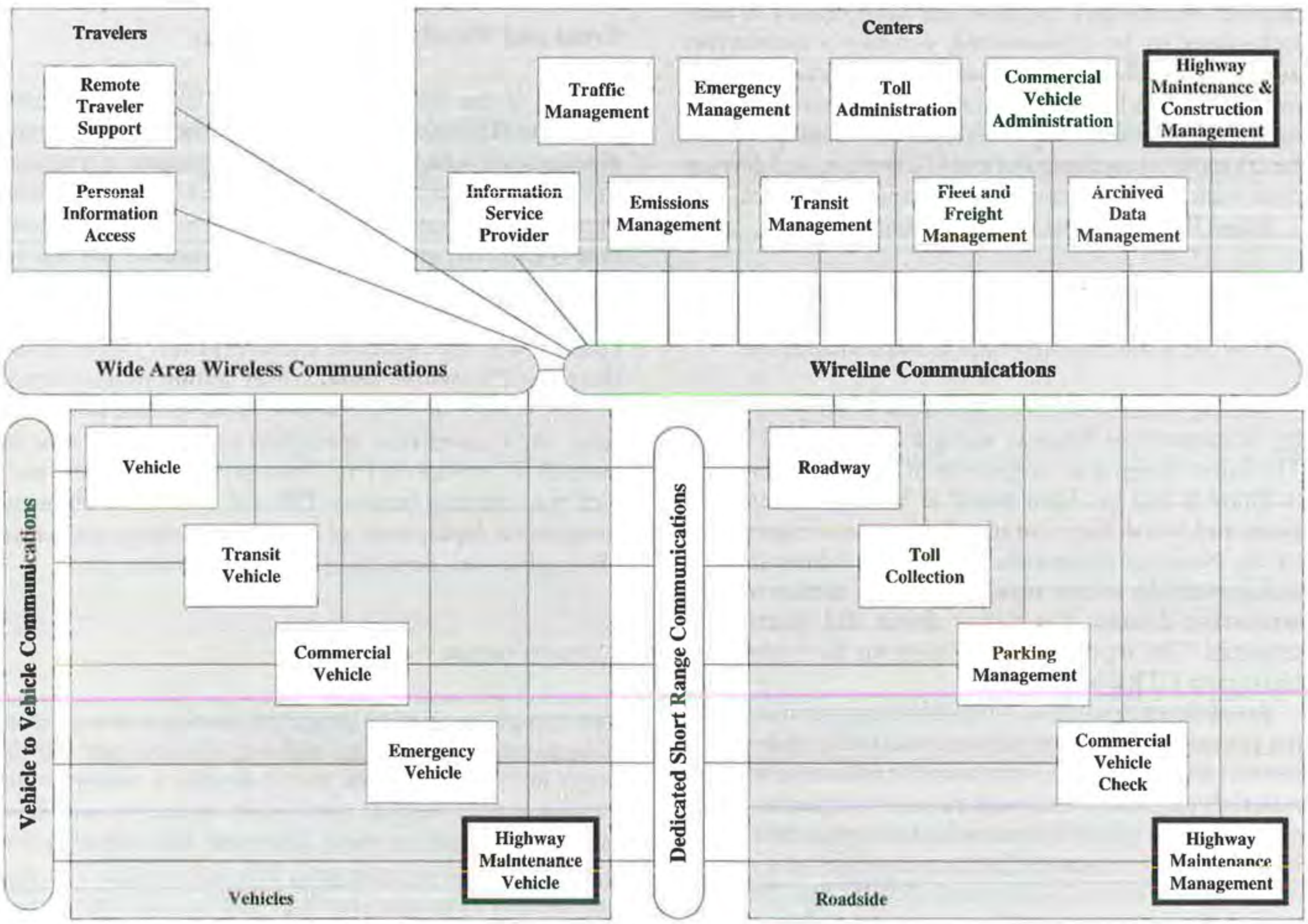

FIGURE 2 National ITS Architecture interface.

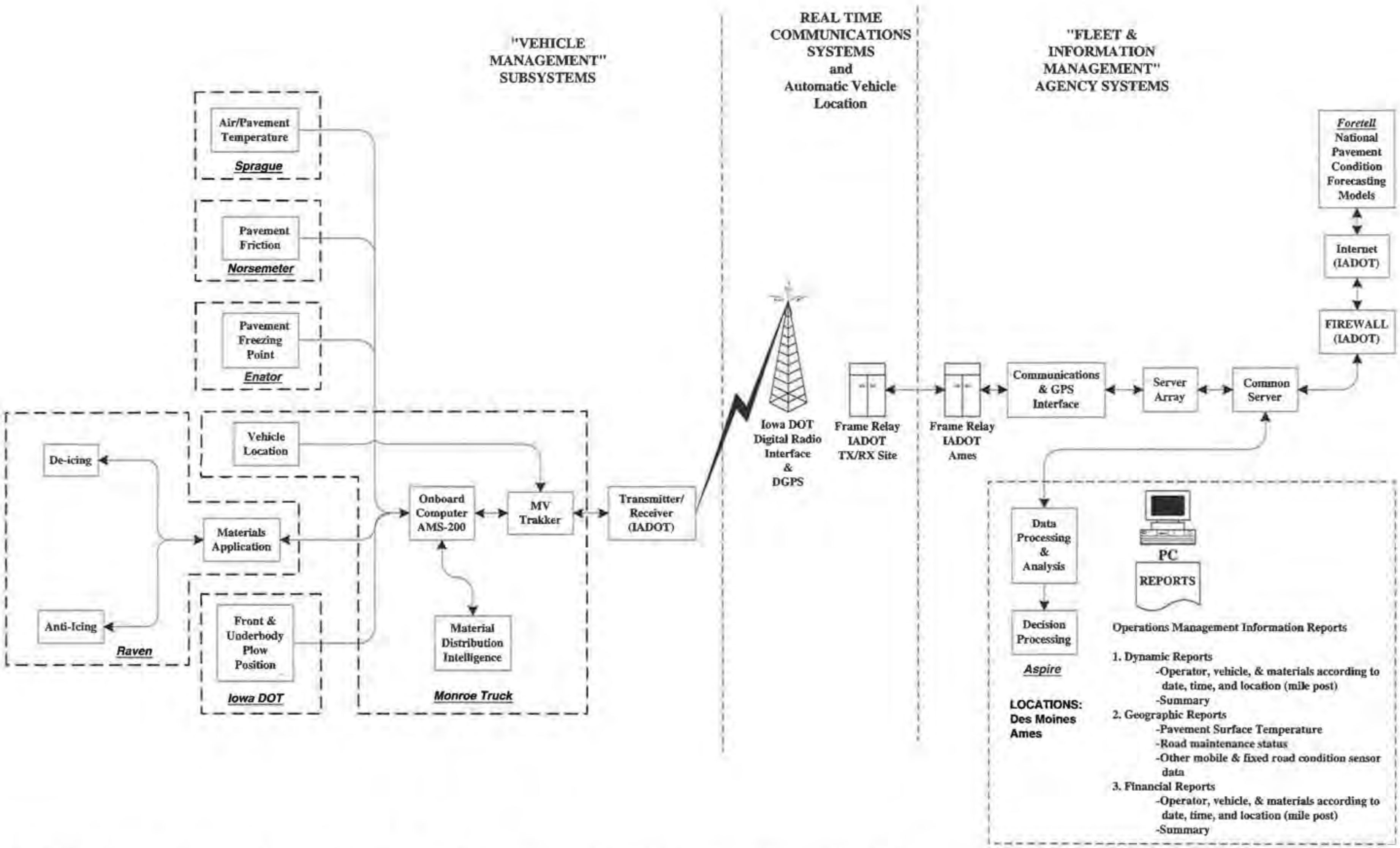

FIGURE 3 Iowa Technologies Network diagram, Phase III concept vehicle (work in progress). Source: Iowa DOT.