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16. ABSTRACT

From page 9:

In setting out to develop a Strategic Plan, it was first important to identify the goals of the ACMS Task Force. The ACMS Strategic Plan is based on the following goals that promote the use and deployment of ACMS technologies.

* Facilitate the application of advanced technology to conventional construction and maintenance practices. This goal is directed towards applying technologies to the processes that are now used in construction and maintenance with the intent of making them more efficient, safer, and more effective.

* Influence intelligent transportation system design for optimal deployment and maintenance. This goal addresses the ITS systems themselves, to make their deployment and maintenance efficient and safe.

* Evolve and/or develop new equipment and methods to support the evolving construction, maintenance, and operations needs of a deployed ITS. This goal encourages the development of new equipment and methods that can be utilized in supporting deployed ITS technologies. With these new products, stakeholders will be prepared to support ITS in a manner that is simpler, safer, and less time consuming while also realizing improvements in accuracy and efficiency. Technologies will be targeted that allow quick deployment, safe operation and maintenance, reduced or no maintenance, improved accuracy, improved reliability, lower life-cycle costs, and improved energy efficiency.

These goals emcompass the entire technology environment as it relates to ACMS and ITS.

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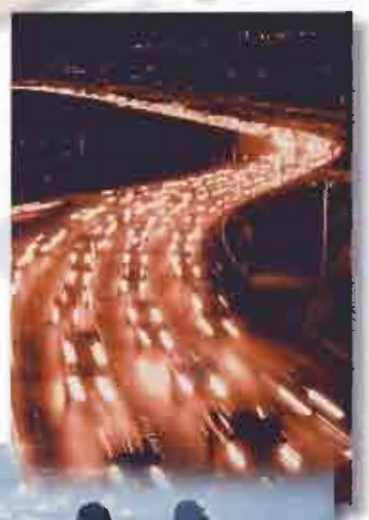

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Executive Summary

Within the variety and depth of Intelligent Transportation Systems (ITS) activities and plans, issues of construction and maintenance of facilities have not been addressed sufficiently. ITS deployments will eventually impact construction and maintenance requirements, and the stakeholders expected to support these improvements must have the tools and knowledge necessary to meet the challenge.

Currently, construction and maintenance workzones cause increased congestion in a traffic area, result in delays for travelers, and increase accident probabilities.[1] Making matters more urgent is the aging infrastructure; maintenance and rehabilitation operations will increase considerably in the coming years.[2] With the infrastructure aging, congestion limiting access times for construction and maintenance, and new challenges presented by ITS field elements, construction and maintenance of transportation facilities, particularly roadways, will become increasingly complex and pressured at the same time. Significantly more-advanced construction and maintenance operations, or Advanced Construction and Maintenance Systems (ACMS), will be required.

Introduction of sensitive electronics may require high accuracy for pavement markings or component installation, which indicates a need for more reliable, accurate, and repeatable methods, pointing towards automation for construction and maintenance. In addition, to assure continuing system performance, safety, and reliability, high-speed remote facility inspection will be required. If ITS implementation achieves the higher traffic volumes or at least the consistent traffic flow, intrusive construction and maintenance operations will become less acceptable; therefore, there will be fewer and shorter opportunities for on-road presence. Additionally, with the larger presence of electronic components, the construction and maintenance operations will become more complex and higher technology may be required to provide the level of service expected.

Technology and ITS can, and will, improve even the *current* workzone operation, safety, and efficiency. By using advanced technologies the potential exists to: conduct more highway work with the same number of workers, open a workzone lane to traffic faster, provide a higher level of service without increasing costs, and make it safer to work in, and drive by, a workzone. In the *future*, workzones must go high-tech in order to accommodate the increasing amount of traffic, allow ITS highways to be efficient with minimal workzone-related congestion, and to keep within the tight tolerance that intelligent vehicles (IV) may possibly require. An advanced

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[1] In a recent year, highway work zones experienced 52,000 property damage crashes, 24,000 injury crashes, and 700 fatalities (National Highway Traffic Safety Administration). The economic impact of these incidents is estimated at $2 billion in fatalities, $2.1 billion in injuries, and $300 million in property damage crashes (Federal Highway Administration).

[2] California Department of Transportation (Caltrans) plans to increase highway maintenance expenditures by 30% by the year 2003.

transportation system must be advanced in all facets in order to achieve its potential. Just as importantly, ITS needs to be designed and deployed in a construction and maintenance-friendly manner.

These changes will be essential to successful wide-scale deployment of ITS. For these technologies to be available to the key stakeholders in a timely and standardized manner, more support and increased activity nationwide is needed. Advanced workzones should be mainstreamed within TRB and ITS structures and other relevant funding programs, including the Intelligent Transportation Society of America (ITS America) Strategic Plan and Research Agenda. The stakeholders need national standards and coordinated Research and Development.

In national ITS plans, information-needs are outlined, communication methods are standardized, user needs are identified, vehicle needs are defined, and even infrastructure modifications are considered. In those plans, the average driver, the commercial vehicle such as heavy trucks, and emergency response vehicles are considered "the users." Their common needs such as driver information, navigation, and fleet management are developed in detail in the national plans. However, the same must be done for another crucial set of users, including the infrastructure-service vehicles, and the people and organizations that will build and maintain the future advanced transportation system.

With effective representation of ACMS in the ITS America Strategic Plan and Research Agenda, infrastructure providers may become equipped with the knowledge, support, and tools necessary to support an advanced transportation system. Construction and maintenance technology and abilities will develop at the same rate as other transportation system improvements such that the average driver experiences an overall improvement in service. *Without* providing the tools and support needed to increase safety and efficiency with technology, a future ITS will not provide the projected benefits in service. Additionally, public entities may be reluctant to fully adopt an ITS if they are not prepared to maintain it within available budget, manpower, and supporting technologies.

In June 1998, ITS America recognized the need by forming the ITS America ACMS Task Force. The need to elevate the infrastructure care issues to a more active level within the ITS community was, in fact, expressly described as "the missing link" in the progress to efficient and successful ITS deployment. A Maintenance and Construction User Service is currently under consideration by the ITS America Architecture Committee. Throughout the year 2000, this National ACMS Strategic Plan was developed to help set a common direction of progress toward bridging the gap between ITS and Maintenance perspectives.

This document outlines ACMS strategies focused on addressing the needs common to the nation's surface transportation system caretakers. In general, the goals are represented by a trilogy of perspectives.

- Facilitate the application of advanced technology to conventional construction and maintenance practices.
- Influence intelligent transportation system design for optimal deployment and maintenance.
- Evolve and/or develop new equipment and methods to support the evolving construction, maintenance and operational needs of a deployed ITS.

The stakeholder audience includes, but is certainly not limited to, the United States Department of Transportation (USDOT) and its administrations, State DOTs, Local DOTs, contractors, equipment manufacturers, construction industry, and travel advisory services. It is recommended that USDOT undertake the coordination, direction and/or financial support of the strategies as soon as possible. The responsibility for participation and actual conduct of the strategic initiatives falls upon a variety of organizations, with the ACMS Committee (currently the "Task Force") acting as a core source of interaction and leadership.

To set the stage for the strategic analyses, the Vision Section (2) presents the underlying ACMS principles and goals. Next, in order to allow the reader to understand the analysis that led to the recommended strategies, the supporting information is presented in logical order in the Gap Analysis Section (3). Indeed, the evaluation of current events and expressed needs leads to the understanding of the gap between 'here' and 'there.' The heart of this document, the Strategies and Supporting Initiatives, is presented in the next section, Section 4. In this section, the four essential Strategies to achieve the goals of ACMS, and the Initiatives designed to support the Strategies, are described. These Strategies were formulated only after thoroughly analyzing the current environment of ACMS activity, learning the key stakeholder needs and issues, and then discerning the difference, or the gap, between this, essentially, 'supply' and 'demand.' A Conclusion is provided in Section 5. Finally, the specific examples of current activities gathered and expressed to the team during the development of this plan are documented in the Existing Environment Appendix (1), along with a Literature Survey Appendix (2).

Much of the future success of ACMS is contingent upon organizing current projects and communicating prior achievements in order to create awareness and the capability to respond to expressed interests. Establishing an ACMS committee that participates in the transportation community and ITS events, identifies funding sources, and acts as a media target for information about ACMS will centralize the marketing efforts of ACMS.

Outlined within this strategic plan are several ACMS solutions that have been developed, implemented, and well received by individual highway agencies. These solutions have applications well beyond the individual agency that developed, tested, and implemented the approach. This strategic plan outlines an approach that emphasizes the importance of ACMS partnerships to further progress.

Additionally, the strategic plan describes a general inventory of existing projects and identifying needs and issues as expressed by stakeholders throughout the United States. Although these are not exhaustive, the examples demonstrate the value of ACMS to the transportation community.

The development of the strategic plan began with the formation of a project team and conference steering committee made up of roadway transportation professionals throughout the United States. Research was conducted through individual interviews, literature review, as well as a one-day public conference in conjunction with the Annual ITS America Conference in Boston. The project team, steering committee, and other leaders in the ITS community, acted as a sounding board and gave direction to the Deloitte Consulting/PB Farradyne team.

Input from the conference was an extremely critical element of the development process, as initial research and direction were discussed and new concepts and ideas were incorporated. Review of the strategies will continue with the steering committee, as well as the existing ACMS Task Force, as action plans are created for implementing the strategies.

The strategic initiatives are meant to provide direction to the ACMS community as a whole, as well as the ITS America ACMS Task Force. The strategies are not outlined sequentially, but serve as a dynamic set of processes and initiatives to attain the identified goals. The strategies include the following.

- ***Develop ACMS Partnerships and Network*** – This initiative was identified as a means of reducing shared costs and raising awareness of ACMS issues. Actions designed to achieve this initiative include:
  - Mainstream ACMS activities;
  - Participate in key industry events;
  - Provide a forum for information exchange; and
  - Provide funding opportunities.

- ***Promote ACMS*** – This strategy is meant to capitalize on the public and media interest in ACMS activities in order to promote political and financial support. It will increase the quantity and quality of information regarding ACMS

available to the ITS community, agency officials, the media and public. Means of implementing this initiative include:

- Develop an ACMS Traveling Showcase;
- Cultivate ACMS Champions; and
- Coordinate Media Campaigns.

- ***ACMS Research and Development*** – Identifying productive and profitable targets for research and development remains a time consuming and costly task. By setting this objective to be completed by a united effort, successful products and solutions will result. Actions to reach these results include:

  - Prepare and publicize research plans;
  - Cultivate research and development funding;
  - Identify and develop research teams; and
  - Encourage international research and development cooperation.

- ***Deployment of ACMS*** – An expansion of ACMS deployments will increase visibility and offer further validation of ACMS products and solutions. Further exposure will enable economic efficiencies as well as further encourage investment in ACMS services. Initiatives to support this strategy include the following:

  - Develop existing and emerging ACMS solutions;
  - Measure effectiveness of deployment; and
  - Develop ACMS Training Program.

These recommended actions build upon current ACMS efforts to centralize research and development, marketing, funding and deployment. A centralized approach will maximize efficiency and reduce duplication of efforts by independent agencies. A key strategic initiative outlined in the plan is the development of a ten year Research and Development Agenda for the advancement of ACMS technologies.

The challenge will be to continually organize the needs and work to be accomplished in a focused manner that ends with tangible results for field implementations. User group coordination is key to advancing many of the ACMS objectives. Similarly, agencies will need to work with the private sector to develop standardized equipment specifications to ease procurement processes and ensure equipment compatibility/interoperability.

Beyond the needs of specific stakeholders in construction and maintenance, ACMS activities are recommended to dovetail with the larger framework of the National ITS Architecture. The National ITS Architecture was developed with an extensive outreach effort to national stakeholders—travelers, commercial vehicle operators, and information service providers.

Section 1 – ACMS Goals and Guiding Principles

In approaching the ACMS Strategic Plan, the ACMS Task Force developed a clear vision, goals, and guiding principles to frame the ACMS Plan strategies. These goals and guiding principals are aligned with the strategies proposed in this Plan (contained in Section 3).

Goals

In setting out to develop a Strategic Plan, it was first important to identify the goals of the ACMS Task Force. The ACMS Strategic Plan is based on the following goals that promote the use and deployment of ACMS technologies.

- ***Facilitate the application of advanced technology to conventional construction and maintenance practices.*** This goal is directed towards applying technologies to the processes that are now used in construction and maintenance with the intent of making them more efficient, safer, and more effective.
- ***Influence intelligent transportation system design for optimal deployment and maintenance.*** This goal addresses the ITS systems themselves, to make their deployment and maintenance efficient and safe.
- ***Evolve and/or develop new equipment and methods to support the evolving construction, maintenance, and operations needs of a deployed ITS.*** This goal encourages the development of new equipment and methods that can be utilized in supporting deployed ITS technologies. With these new products, stakeholders will be prepared to support ITS in a manner that is simpler, safer, and less time consuming while also realizing improvements in accuracy and efficiency. Technologies will be targeted that allow quick deployment, safe operation and maintenance, reduced or no maintenance, improved accuracy, improved reliability, lower life-cycle costs, and improved energy efficiency.

These goals encompass the entire technology environment as it relates to ACMS and ITS.

Guiding Principles

The following Guiding Principles help communicate the ACMS Strategic Plan's underlying values and recommended initiatives. These Guiding Principles can be used by the ACMS Committee to help select projects and actions that they will support. These statements are intended to clarify the purpose of the Plan's proposed strategies.

Safety

Safety improvements can be realized for both work crews and system users through the deployment of appropriate technologies. Improved safety is one benefit that will be realized when technology is utilized to reduce the length of time that work crews are exposed to active traffic lanes. Technology can also improve safety by enabling workers to work out of harm's way while normal maintenance activities are being performed. Utilization of technologies to disseminate real-time roadwork information will produce safety benefits by improving user awareness of approaching roadway conditions and activities.

Efficiency and Costs

Through the application of technology, improvements will be realized in both operational efficiency and reduced construction and maintenance costs. Improvements in operational efficiency resulting from technology deployment may also simultaneously provide improvements in worker safety due to reduced worker exposure, and improved user satisfaction due to a reduction in the duration of traffic flow disruptions. New materials and methodologies will enhance efficiencies and reduce costs while improved inspection and testing methods will also result in the same improvements. Emphasis will be placed on approaches and systems that are attractive to the private sector to ensure that ACMS products are made available to the broadest possible market as soon as possible, including the development of key standards that allow for interoperability of deployed solutions.

Customer Satisfaction

Customers, in this case the traveling public and other roadway users, will benefit from the implementation of technologies that result in improved safety, shorter travel times, and timely dissemination of roadway information. With improved efficiency, maintenance operations will be accomplished in less time and result in a reduction in the time that traffic flow is impacted. Technologies that provide information through a variety of methods will assist drivers in planning their travel while other technologies that disseminate real-time information will allow the driver to modify travel plans enroute. Advanced traffic control systems will provide improved traffic flow. These benefits and improvements will enhance the driving experience and result in gains in customer satisfaction.

Section 2 – Stakeholder Needs and Issues

This section of the ACMS National Strategic Plan outlines ACMS needs identified by the stakeholder community, and the known gaps between those needs and currently available technology and deployment approaches.

Stakeholder Needs

To assess the key needs of ACMS stakeholders, the project team conducted interviews with construction and maintenance program managers and related roles from a representative group of state highways agencies, municipal governments, academic organizations, and the private sector. In addition to the interviews, a workshop was conducted during the ITS America Conference on May 1, 2000, in Boston, Massachusetts. Collectively, the group surveyed is representative of the diverse set of stakeholders with needs for ACMS technologies.

Based upon these discussions, it is clear that the needs in the ACMS arena are varied throughout the country, in many cases driven by geographic and climatic variations. However, there are many common threads that can be addressed within the maintenance and construction community as a whole. In general, these can be broken down into the following distinct categories.

A. Safety
B. New materials
C. Inspection and testing methods
D. Maintenance of ITS infrastructure
E. Workforce development
F. Influencing ITS deployment decisions

Each of these key stakeholder needs can be strongly supported by the pragmatic application of ACMS Technologies.

A. Safety

Highway and worker safety are the most important drivers for the expansion of ACMS research and deployment. Within the ACMS community it is worker safety that drives much of the research and development. In addition, traveler safety in and around work zones is identified as a key need that ACMS technologies can meet.

Despite advances in road construction, everyday preservation and maintenance activities often place highway workers extremely close to active traffic lanes. Despite

methods of separating workers from this danger, there continues to be incidents of injury and death to highway workers and ongoing dangers to drivers. The ACMS community is seeking to develop technologies that allow for maintenance activities to take place in a manner that does not endanger the worker. Currently the only means of accomplishing the desired level of safety is a complete closure, which is frequently not operationally feasible.

Several safety specific needs for ACMS technologies were identified, including applications that:

- Reduce rear-end collisions between traffic and slow moving construction vehicles in moving work zones;
- Reduce exposure of workers to hazards;
- Warn workers and drivers of imminent intrusion to work zone;
- Report maintenance activities and lane closures in order to increase driver awareness and potentially redirect traffic flow; and
- Share operational information across all stakeholders (highway patrol, operations, traffic management).

B. New Materials

The development of new materials, whether for construction or maintenance of facilities is often driven by the outside influences of nature and are often clustered around regional issues. However, there remain many applications that are common throughout the country. New materials for roadway surface, adhesion of pavement markings, paints, and chemicals for vegetation control have surfaced as consistent needs throughout the ACMS community. The need for new materials is emphasized as the development of automated maintenance equipment may require materials that behave differently than those currently in use. An example of this need is crack sealant material for use in automated crack sealing machines. Because of the way sealant material is carried and applied in automated sealing operations, it may be required to behave differently than traditional sealing compounds.

The development of new materials, unlike maintenance processes, is primarily a research function left to the private sector. The market for these materials, however, can drive the research in the direction of the need. Therefore, the identification of the need for advances in these areas is a critical element in the development process.

C. Inspection and Testing

Inspection and testing methods, while presenting major challenges in the field, continue to rely on old technology which requires workers to be located in harms way – whether dangerously close to active traffic lanes or on elevated structures. As

infrastructure continues to age, inspection will become increasingly important and frequent.

Alternatives, which might utilize remote surveillance equipment, robotics, smart structures, and Supervisory Control and Data Acquisition (SCADA), could have a significant impact on the quality and the frequency of inspections and tests.

D. Maintenance of ITS Infrastructure

The maintenance of ITS infrastructure is a growing challenge in state highway organizations. Due to the technical nature of most of the devices deployed, it is difficult for the traditional maintenance and operations organization to have responsibility for maintaining this infrastructure. It is equally challenging for agency information technology staff to take responsibility for maintaining ITS infrastructure, as information technology staff are not typically assigned to the field. The establishment of a "best practices" based organizational and funding model for the ideal ITS maintenance function is a growing need in the ITS arena.

ACMS technologies, themselves an element of ITS infrastructure, can potentially be used to detect operational irregularities in devices such as closed circuit television cameras, traffic detectors, traffic signal systems, dynamic message signs, communications infrastructure, and supporting hardware and software.

In addition to detecting operational irregularities or deficiencies, there is a key need for ACMS technologies to support the repair of ITS infrastructure. For example, automated support for the repair of highway sensors and incident detection loops would help remove the worker from the highway and increase efficiency of operations.

Several other specific needs were identified, including:

- Planning for ITS Maintenance funding;
- Need for better data to monitor the value of ITS; and
- Develop tools for planning ITS maintenance.

E. Workforce Development

The training of a skilled workforce to develop, use, and maintain ACMS technologies is a key stakeholder need. As ACMS tools increase the precision with which workers need to execute maintenance activities and traditional tools are replaced with sophisticated and expensive devices, it will be necessary to retrain workers so that the value of the new technologies can be maximized. Training of this nature needs to be proactively incorporated into any plans for deploying ACMS devices. In addition, new types of workers may need to be recruited to meet the specific skill requirements for

the efficient operation of ACMS technologies, creating new challenges in recruiting and job definition.

F. Influencing ITS Deployment Decisions

In considering the deployment of all ITS infrastructure, it is increasingly important for ACMS to be incorporated into overall deployment plans. To take best advantage of ACMS' potential, ACMS needs to be considered in light of the overall National ITS Architecture. This approach will foster long-term interoperability and maintainability of all ITS infrastructure.

Stakeholder Issues and Barriers

Although ACMS deployment has shown promise, stakeholders identified several issues that they have encountered or foresee encountering in developing and deploying ACMS technologies. Several gaps were identified during the course of the stakeholder interviews and the stakeholder workshop. In general the issues and barriers can be categorized as follows.

A. Funding
B. Institutional Relations
C. Workforce Development
D. Research and Development
E. Deployment
F. Procurement

These categories of stakeholder issues and barriers also provide a framework for identifying the gaps, discussed later in this section.

A. Funding

Many stakeholders identified funding as a key barrier to furthering the development of ACMS technologies. Currently, many maintenance and operations budgets are strained by day-to-day needs and have limited resources to support research and development activities.

As a solution to the funding issue, stakeholders suggested that proactive planning and budgeting for ITS maintenance was necessary to more clearly identify and plan for the funding needs. As well, many stakeholders identified the need for ITS maintenance to be eligible for categorical federal funding. Lastly, some suggested that given current constraints on funding sources, it would be necessary to pursue.

The following key issues need to be resolved in order to address the barriers associated with ACMS funding.

- A national advocacy for ACMS that will help bring awareness and support for ACMS.
- Well-developed marketing strategies to aid stakeholders and developers in seeking additional funding for ACMS projects.
- Effective media campaigns to raise awareness and support among decision makers, the industry, and the public.
- Promoting ACMS success stories and publicizing studies that clearly show benefits of ITS and ACMS products and solutions.

B. Institutional Relations

Institutional and organizational issues were identified as barriers to the use of ACMS technologies. The issues identified include sharing of information within an organization, sharing of information between organizations, inter-jurisdictional cooperation, and cooperation between the public and private sectors.

Approaches to overcoming these barriers include the establishment of an ACMS industry forum for the regular exchange of information, education of agency partners as to the goals and objectives of an ACMS program, and documentation of best practice partnership models.

ACMS can enjoy greater support and a broader deployment base if it has a strong institutional foundation. The following are items that will strengthen ACMS and help to overcome institutional barriers.

- A national advocacy for ACMS that will engage stakeholders by identifying needs, issues, and barriers, and help develop solutions to satisfy the needs.
- Increased collaboration and communication among stakeholders, including, but not limited to:
  - Industry / Private Sector
    - Construction Industry Manufacturers Association (CIMA)
    - Association of General Contractors (AGC)
    - Heavy vehicle manufacturers
    - Electronic manufacturers
    - Communications companies
    - Business and engineering consultants
    - Highway Users Federation for Safety and Mobility
  - Academic Sector
    - University Transportation Research Centers Program (UTRCP)
    - Universities and Colleges

  - Public Sector
    - AASHTO Members
    - TRB Members
    - Institute of Transportation Engineers (ITE)
    - Regional Council Associations or Transportation Planning Agencies
    - Metropolitan Planning Organizations (MPOs)

- A strong support for the FHWA and the ITSA's development of an ITS Operations and Maintenance User Service.
- A concerted effort to inform stakeholders, the industry, and the public of ACMS products, solutions, and benefits.
- A national cooperative effort in support of ACMS funding, development, and deployment.
- Active participation in transportation planning efforts to mainstream ITS construction and maintenance elements in the national and state plans.

C. Workforce Development

As discussed earlier, workforce development is both a key stakeholder need and issue. As new technologies become available it will be important to incorporate technology awareness and training for the maintenance workforce. The successful use of these technologies is largely dependent on the users' ability to install, maintain and/or use the devices or equipment. Because these technologies have not been widely implemented, most construction and maintenance personnel are unfamiliar with their use. As the technologies become increasingly sophisticated, the need for training will become commensurately important.

Similarly, if organizations pursue design, build, and operate (DBO) strategies that include ITS infrastructure (or for the deployment of ITS infrastructure itself) it is increasingly necessary to train maintenance workers so that they can efficiently maintain the new technologies.

The influx of new technologies, materials, and methods for ITS construction and maintenance poses unprecedented challenges to the workforce now and into the future. To ensure successful ITS and ACMS deployment, the workforce needs to acquire new skill sets and new paradigms. Most ACMS stakeholders are not prepared to deal with such drastic increases in training and workforce development. The following are some of the needs to be addressed.

- Improved workforce computer, information systems, and other technical skills to effectively install and maintain ITS devices and systems.
- Emphasis on user-friendliness in ACMS research and development to ensure a smooth technical transfer to deployment.

- Development of a sign and symbol system to aid the workforce in effectively deploying ACMS.
- Continued training and development programs to keep the workforce abreast of significant advances in ACMS technologies, materials and methods.

D. Research and Development (R&D)

Research and development activities supporting ACMS require multidisciplinary teams and broad collaboration in order to develop new technologies that best meet the needs of the construction and maintenance communities. Coordinated and collaborative research and development initiatives across public, private and academic organizations face barriers related to funding mechanisms, ownership of resultant intellectual property, and anti-trust. Some of these barriers also become issues in the procurement of technologies and services (discussed below). These issues provide barriers to the collaborative approach required to accelerate the development and eventual deployment of products.

There are significant gaps in research and development that require investment and focus in the coming years. The following outlines the prominent gaps needing attention.

- Improved methods and equipment to install and maintain ITS assets, especially communications and field devices that minimize workers' exposure to traffic and road closures, i.e., more effective use of non-intrusive traffic detectors that are easy to install, calibrate, and maintain over time.
- Utilize more maintainable ITS field elements, such as easily installed, non-intrusive traffic detectors.
- Better materials and repair methods to improve the performance of existing ITS assets particularly in loop detectors.
- New materials and technologies that extend the maintenance cycle well beyond current ITS products such as signal lights, field control devices, and dynamic message signs. LED technology, for example, has shown promise in reducing both traffic signal capital costs as well as increasing the maintenance cycle time to 3 times the current average. However, LED applications in other areas need more development.
- ITS construction and maintenance standards to foster quality control and reliability across manufacturer and product lines. Standards can also facilitate rapid procurement and deployment of ITS devices.
- Improved installation and maintenance methods for safety devices such as guard rails, lane delineations, and roadside and pavement markers.
- Improved snow and ice management tools such as automated snow removal, deicing, and maintenance database for management decision aid.

- Improved materials, equipment, and methods for safety and efficiency in nighttime construction and maintenance.
- Better use of communication media to protect workers in work zones, and to inform travelers of potential construction and maintenance related delays, e.g., telematics, real-time message signs, pre-trip planning via the internet.
- Coordinated R&D efforts, teams, and agenda. Publicized research and development plans are also needed.
- Elevate the importance to commercialize.
- Develop benefit-to-cost analysis for ACMS initiatives.

E. Deployment

In evaluating potential issues and barriers related to the deployment of ACMS, the stakeholder groups identified several issues. In many ways, these issues are linked to many others identified in this section. Barriers to deployment include the following.

- Lack of communications and available information regarding ACMS technologies available and best practices employed.
- Lack of sponsorship from Federal agencies.
- Lack of training materials and proven training approaches for ACMS.
- Lack of standards that foster interoperability.

Stakeholders identified several gaps between their deployment needs and what is currently available to increase the breadth and success of ACMS deployment. Gaps identified include needs for the following.

- Better Federal participation in this important area and more effective communications to stakeholders.
- Before/after studies to measure successes of current and future ITS deployment. This will serve as a tool to aid funding and deployment of existing and emerging ACMS products and solutions.
- Clearinghouse database of ACMS products and solutions as well as decision support assistance for those seeking to deploy them.
- Development of an ACMS best-practices document.
- Training materials and equipment to aid in effective deployment of ACMS.
- Deployment partnerships to develop synergy among ACMS users as well as to encourage market competition.

- A national (and perhaps international) sign and symbol system to aid workforce in deploying ACMS effectively.

F. Procurement

As government organizations, state and local highway agencies have a responsibility to follow a structured procurement process that provides for fairness and accountability in the purchasing cycle. However, due to the status of current ACMS development and the interdisciplinary nature of the ACMS technologies, traditional procurement models may inadvertently create barriers. Some specific issues identified by stakeholders include the following.

- Commercialization partnerships create a "single source" situation, which can constitute a procurement risk and violate state procurement regulations.
- Procurement of high technology items as part of "low-technology" installations or construction projects.
- Inclusion of specifications for maintenance in construction design.
- Investigate procurement of a "total maintenance package" as an integral part of construction procurement. This includes both roadway devices/ instrumentation and maintenance vehicles/special equipment/retrofit kits.

Many stakeholders cited rigid procurement mechanisms as having a significant impact on the outcome of any ACMS projects.

- Streamlined procurement processes to expedite ITS and ACMS deployments.
- Concentrated effort to develop standards for ITS components.
- Sharing of information in procuring of ITS components among stakeholders.
- Commercially viable approach to resolution of intellectual property and anti-trust issues.
- Procurement approaches that encourage competition and innovation, but that provide for the purchase of viable technology and successful deployment initiatives.

In order for ACMS technologies to be interoperable and viable long-term, it is important to develop standards for the technologies and include those standards in the procurement documents used to acquire new technologies. This approach has been documented in the National ITS Architecture and is vital to develop for the acceleration of ACMS technologies. Standards assist in the creation of coherent markets (volumes and standardized systems) to aid in commercialization and assist in the development of a trained workforce. Currently, standards for ACMS have not been documented.

Summary of Needs and Issues

Despite the progress in recent years, as described in current projects and deployments, many ACMS stakeholder needs in traditional and ITS construction and maintenance are still not met. To assess why certain technologies and initiatives have moved forward earlier and faster than others, a session was held at the 2000 ITS America annual meeting that asked a broad cross-section of stakeholders to evaluate the factors that lead to an ACMS project success. In addition, the critical application gaps were assessed. The results of that session are outlined below in the categories of funding, institutional relations, workforce development, research and development, deployment, and procurement that need to be addressed if ACMS is to succeed and meet stakeholder needs. This outline is intended to be a point of departure where in-depth discussion on future stakeholder needs, issues and barriers can begin. This list outlines today's gaps, and should be revisited in the future, and as more stakeholder voices are heard.

Many of the stakeholder needs, issues and barriers, and gaps identified by the ACMS stakeholders are inter-related. In order to best address these needs and gaps, it is necessary to develop strategies that approach these issues comprehensively. The next section of the strategic plan details the strategies developed by the ACMS Task Force.

Section 3 – Strategies

This section of the ACMS National Strategic Plan discusses key strategies and initiatives designed to enable the ACMS stakeholders to overcome issues and barriers in developing and deploying ACMS products and solutions. These strategies are designed to address the stakeholder needs and issues outlined in the previous section. In general, the following needs and issues were identified through previous stakeholder analysis.

Funding limitations and the need for alternative approaches to funding ACMS including partnership arrangements.

Institutional and organizational barriers that impede information sharing, technology transfer, and inter-agency cooperation.

Critical need for **w**orkforce development to satisfy the need for personnel with new skill sets to properly construct and maintain ITS infrastructure, and advanced construction and maintenance technologies.

The need for robust support and a coordinated agenda for **r**esearch and development efforts to further ACMS technologies.

The lack of ACMS technical standards for data and communications protocols to foster rapid and widespread **d**eployment of ACMS products and solutions.

Various **p**rocurement procedures that do not work well in a dynamic and sometimes experimental environment such as the ACMS market.

Each strategy includes supporting initiatives designed to address specific needs and issues identified above. The icons reappear with the strategies to show which needs are addressed by each strategy and its supporting initiatives.

The strategy and supporting initiatives detailed in this section, when implemented collectively and effectively, are expected to yield the following results that will aid stakeholders in accomplishing the vision and goals described in Section 2.

- Creation of an ACMS organization and network, that leverages off the existing ACMS Task Force, for the purpose of building and sustaining ACMS cooperative partnerships.

- Funding and procurement mechanisms and assistance available to ACMS developers and users.
- Coordinated and accelerated ACMS research and development guided by stakeholder needs.
- Workforce development and training.
- Set technical standards.
- Proliferated and commercialized ACMS products and solutions.

Action items are identified for each strategy and supporting initiative and special considerations are listed where appropriate. It should be noted that, due to the dynamics in the ITS and ACMS arenas, these initiatives should be regularly reviewed and refreshed annually. Some key tasks may require specific review cycles as identified in the strategies.

It should also be noted that these initiatives are intended to set the course for coordinated national ACMS efforts. Although the existing ACMS Task Force will act as the catalyst and leader of the initiatives, the results will be accomplished through the collective efforts of the entire ACMS community including the FHWA, the ITSA, public agencies, academia, and the private sector.

Strategies and Supporting Initiatives

There are four broad strategies outlined in this plan.

Strategy A:	Develop ACMS Partnerships and Network
Strategy B:	Promote ACMS to the ITS community, agency officials, the media, and the public to gain political and financial support
Strategy C:	Research and develop ACMS products and solutions
Strategy D:	Deploy ACMS products to save lives, time and money

Each of these strategies has a specific desired outcome. However, for ACMS development and deployment to proceed at a pace that meets user needs, the supporting initiatives must be considered as a broad program of activities that should be undertaken concurrently in order to achieve desired results.

The following quick list summarizes the initiatives suggested in this Strategic Plan to support the four strategies. Each strategy and supporting initiatives are discussed in detail in the sections that follow.

ACMS Strategies and Supporting Initiatives

A. Develop ACMS Partnerships and Network	B. Promote ACMS to ITS Community	C. Research and develop ACMS products and solutions	D. Deploy ACMS products
➢ Mainstream ACMS ➢ Participate in key industry events ➢ Provide information exchange opportunities ➢ Provide funding opportunities	➢ Develop ACMS Traveling Showcase ➢ Cultivate ACMS Champions ➢ Coordinate Media Campaign	➢ Prepare and publicize research plans ➢ Cultivate R&D Funding ➢ Identify and develop research teams ➢ International R&D Cooperation	➢ Deploy existing and emerging ACMS solutions ➢ Measure effectiveness of deployment ➢ Develop ACMS Best Practices Document ➢ Develop ACMS Training Program

Strategy A: Develop ACMS Partnerships and Network

Although construction and maintenance are prominent functions in conventional transportation agencies, new technologies for enhancing construction and maintenance operations have not been adopted at the same rate as technologies in other facets of the transportation community. While traditional construction and maintenance functions have an established nationwide network of policy and decision makers, ACMS development and solutions have been kept almost entirely local. Only a few agencies have consistently invested in ACMS. Fewer yet have built partnerships and synergies with ACMS developers or users in the private sector or academia. Although the Federal Highway Administration (FHWA) and ITSA have begun to take initiatives in advanced construction and maintenance solutions in response to the proliferations of ITS systems across the nation, there is still an absence in national leadership in ACMS. There has been a lack of a forum for dialogue, consensus building, and coordinated efforts among transportation officials when it comes to developing and adopting ACMS solutions.

ACMS can and should be a national (and perhaps international) effort because all transportation agencies share construction and maintenance needs and concerns. Partnerships and networks reduce costs, facilitate sharing of information, and accelerate time to deployment. The recommended strategies are designed to create and maintain national partnerships and foster a network for ACMS through a national advocacy organization attached to ITSA, participation in transportation and ITS forums to raise the awareness of construction and maintenance issues, and to serve as an information and cooperation clearinghouse for members of the ACMS community.

The process of establishing the national advocacy as described in this initiative will involve a careful evolution of existing entities including the ACMS Task Force under ITS America. For ease of reference in this document, the term ACMS Committee refers to the national organization either in its existing form or as the future national committee under ITS America.

Strategy A: Develop ACMS Partnerships and Network (cont'd)

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Initiative A1: Mainstream ACMS

Through this initiative, ACMS will be explicitly integrated with mainstream transportation and ITS planning, standards, and implementation activities. There has been a great deal of interest and support demonstrated by stakeholders and national associations since the formation of the ACMS Task Force. A logical development for the ACMS Task Force would be to evolve into an ITSA committee and continue advocating their needs on a permanent basis.

The nucleus of this ACMS Committee will consist of members of the current ACMS Task Force. It will also serve as the focal point for uniting public agencies, private industry and academia within the ACMS community. Additional members gained through outreach may include representatives of State ITS Chapters not yet present in the Task Force, academia, other organizations involved in road and bridge construction and maintenance, private sector equipment, construction and maintenance companies, and those engaged in ITS. The ACMS Committee will, among its duties, oversee the execution of the ACMS Strategic Plan, monitor progress, and make adjustments and updates as necessary.

The Committee will give ACMS a voice in the transportation and ITS communities by advocating advanced construction and maintenance solutions as a part of transportation planning, design, and operational considerations. The Committee will assist the FHWA and the ITSA in mainstreaming by developing and promoting the ITS-A Maintenance and Construction User Service, developing links/identity within the ITS Architecture, encouraging consideration of ACMS issues in national transportation planning and strategy documents, and conducting strategic actions identified in this plan.

Action Items:

1. Establish Committee
2. Develop User Service
3. Integrate with ITS Architecture and Planning Tools

Considerations:

1. Committee Operations
2. Travel
3. Committee Support

Strategy A: Develop ACMS Partnerships and Network (cont'd)

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Initiative A2: Participate in and present ACMS achievements at major transportation community and ITS events

For the ACMS community to have a presence in, and to be recognized by the transportation and ITS community, the ACMS messages must be heard and discussed by transportation and ITS professionals. Reaching out to stakeholders in prominent professional gatherings such as the ITSA annual meetings, ITS World Congress meetings, State ITS Chapter meetings, Transportation Research Board (TRB), AASHTO, ATSSA, and ITE conferences will raise awareness among key decision makers as well as promote interest in the national ACMS forum.

The ACMS Committee will seek to solicit, encourage, and coordinate ACMS topics at the abovementioned gatherings. Initially, the ACMS Committee will develop presentations on general issues related to the needs for ACMS and the cost/benefit analysis of applying ACMS solutions as opposed to conventional methods. As audiences become more in tune with this new practice area, transportation agencies, researchers, and private equipment vendors will conduct more specific technical discussions of ACMS solutions.

ITS stakeholders are drawn to topics that address their needs and concerns such as how to best manage a traffic network and how to fund ITS projects. ACMS topics that may be big draws include the following.

- Solutions to construction and maintenance challenges on roadways, roadsides, structures, and in work zones.
- Attracting and retaining qualified and skilled ITS construction and maintenance staff.
- Funding and procuring ACMS.
- Planning for and maintaining ITS systems.
- Meeting public expectations.

Action Items:

1. ACMS sessions on technical tracks at relevant professional conferences, such as ITSA Annual Meeting, World Congress, TRB, AASHTO, ATSSA, ITE, and others

Considerations:

1. Presentation Coordination and Development
2. Travel

Strategy A: Develop ACMS Partnerships and Network (cont'd)

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Initiative A3: Provide opportunities for members to exchange ideas, solutions, and experiences

While there is a great wealth of information on ACMS and its solutions to various construction and maintenance challenges, this information is not readily available to those seeking solutions. Providing the most current ACMS information to users will be a significant service to the community of ACMS users and developers as well as an essential step for building a strong network of those who share like interests. Many organizations including ITSA have been successfully attracting and retaining professionals in various fields such as Traffic Operations. The ITSA Traffic Operations Forum has attracted a constant flow of web-based dialogue of traffic operations practitioners worldwide. It is a very powerful, cost-effective tool for building partnerships and networking. This tool will be explored and developed to promote ACMS. Newsletters will also be published on the Internet on a regular basis to focus on issues and products of interest to the members. Regularly scheduled open forums will be hosted by the Committee on selected subjects or in conjunction with product rollouts.

Action Items:

1. Enhancing ACMS Forum on ITSA website
2. Beginning ACMS Newsletter
3. Hosting on-line forums

Considerations:

1. One-time setup cost for the website
2. Contents costs
3. On-line hosting

Strategy A: Develop ACMS Partnerships and Network (cont'd)

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Initiative A4: Provide funding opportunities and encouragements for ACMS developers

One of the most significant challenges encountered by the ACMS community is securing adequate funding for the research, design, and development of ACMS products and solutions. Like most entities associated with ITS in the otherwise traditional transportation agencies, ACMS must overcome typical funding and cultural hurdles. Many ACMS pioneers have been frustrated by limited funding sources for ACMS projects. The future of ACMS depends largely on its ability to secure funding at the federal, state, and local levels.

The ACMS Committee will assist the FHWA and committee members in developing funding sources and partnerships. It will help develop both short-term and long-term strategies to enable a steady flow of ACMS funding.

In the short-term, the Committee will encourage the development of funding awareness tools such as information packages targeting transportation agencies and private construction and maintenance industries. Information packages may include fact sheets, brochures and videotape describing ACMS benefits, technologies and products. The transportation agencies package should focus on informing transportation policy, planning and funding officials of cost effectiveness, safety, and improved services to the travelers. The industries package should focus on the opportunity for product and market development as well as partnerships with public agencies and academia. These packages would be made available for general consumption, group presentations, and one-on-one briefings.

In addition, the Committee will assist the FHWA in identifying ACMS educational opportunities as part of the ITS Professional Capacity Building series.

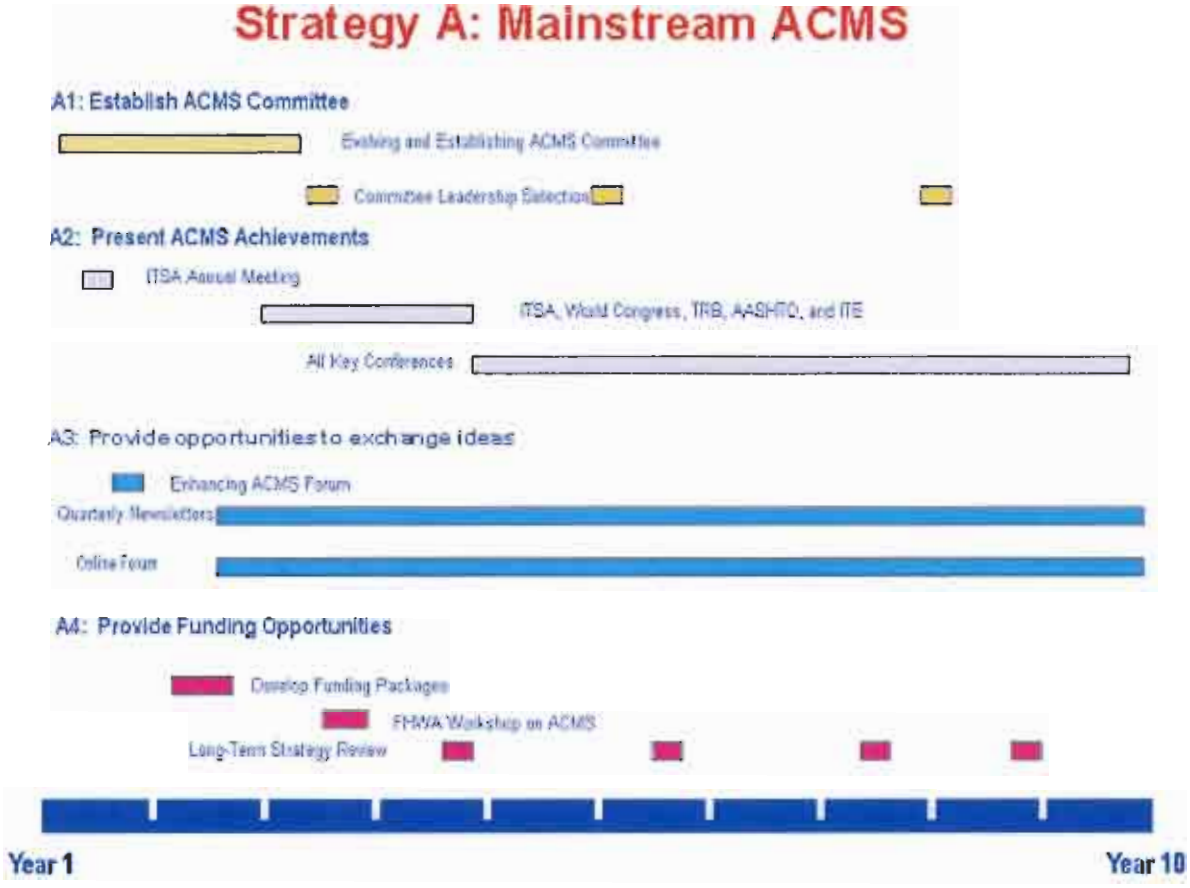
The long-term strategy may include establishing other innovative approaches to broker ACMS and funding sources to help expedite product development and deployments. This strategy needs to be further explored as a function of the short-term success.

Action Items:

1. Encourage short-term funding info packages
2. Package review and update
3. FHWA Workshop on ACMS
4. Long-term strategy review

Considerations:

1. State and Federal budget processes
2. Private sector funding implications
3. Multi-year funding



Strategy B: Promote ACMS to the ITS Community, Agency Officials, the Media, Industry, and the Public

A significant challenge for ACMS is the widely held notion that ACMS deals strictly with concrete and steel and, therefore, does not belong in the ITS realm. This perception needs to be addressed if ACMS is to be embraced and accepted as viable solutions to various ITS construction and maintenance issues. For the public and elected officials to support ITS deployments, they need to be assured that ITS investments can be protected by viable and affordable construction and maintenance. Furthermore, the highway construction and maintenance industry needs to be informed of the benefits of investing in ITS and ACMS.

Coordinated and consistent efforts to promote research, development, and deployments of ACMS products and solutions are needed. The media and the public have shown great interest in ACMS when given the opportunity. This is evident in the positive media and public response to the automated maintenance equipment deployed in California, the pavement faultmeter in Georgia, and other advanced pavement maintenance products demonstrated by the FHWA.

These examples represent compelling reasons to excite stakeholders: safety and cost savings for agency officials, potential products and established customers for equipment vendors, good visual excitement for the media, better service and shorter delay for the traveling public, and spin-offs of ITS technologies. Coordinated and consistent information on successes such as these is key to effective ACMS promotion.

The following strategies aim at providing timely and useful information to the ITS community, agency officials, the media and the public related to ACMS and its direct benefits to each of these groups. The objectives of these strategies are to raise awareness, acceptance, and support for ACMS politically and financially.

Strategy B: Promote ACMS to the ITS Community, Agency Officials, the Media, Industry, and the Public (cont'd)

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Initiative B1: Develop an ACMS Showcase

The ACMS Committee will encourage the development of an ACMS Traveling Showcase to promote workforce development, foster cooperation among stakeholders, and encourage procurement and deployment of ACMS products and solutions. The showcase will provide a valuable, hands-on communications tool for the transportation community. The showcase will be equipped with selected products aimed at specific segments of audiences. This showcase will visit important gatherings of agency officials and industry forums to give the audiences the first-hand experience of ACMS. Private and small group presentations for key officials and decision makers can be arranged. Appropriate information packets will be made available to enhance the experience. Careful consideration will also be given to maximum media coverage at all visits to optimize each opportunity. Where possible, schools, universities, and the public should be invited to share the ACMS experience.

The showcase should be equipped with products, displays, and materials provided by agencies and equipment developers and may include presentation and training space. Capital funding for the showcase may come from FHWA and ITSA. Funding for the operation of the showcase will be derived through the value of exposing vendors to potential customers. A dedicated crew, augmented by volunteers from agencies and vendors, may operate the showcase.

The ACMS showcase should be mounted on an appropriate vehicle capable of safely transporting the Showcase. It should also be properly secured to protect valuable products. Additionally, the showcase may contain presentation and training space. Presentations and training courses may be given as appropriate.

Action Items:

1. Showcase Planning
2. Showcase design and development
3. Showcase production
4. Showcase update

Considerations:

1. One-time design and development
2. One-time platform and production
3. Operations

Strategy B: Promote ACMS to the ITS Community, Agency Officials, the Media, Industry, and the Public (cont'd)

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Initiative B2: Identify and cultivate a strong group of agency and industry leaders who will champion ACMS

A strong circle of ACMS champions will help sustain and energize the ACMS community. Champions are agency and industry leaders who have strong interest in ACMS and are willing to help guide, promote and nurture ACMS. These champions may also help overcome institutional barriers, develop workforce, encourage deployment and procurement of ACMS in their agencies and others. These champions should be selected to represent a cross section of transportation and ITS concerns. This group of highly skilled and knowledgeable individuals may help publicize ITS, lobby legislatures, and attract funding during the incubative years.

The ACMS Committee will identify and cultivate the group of ACMS champions, and actively find ways of involving these individuals in events and meetings. The Committee will frequently seek advice, support, and assistance from the circle of champions in matters ranging from strategy, funding, to legislative support. The Committee will regularly meet with champions to solicit input on stakeholder needs and map those against the ACMS initiatives. It will also set a goal to expand the group each year until 2010.

Action Items:

1. Identify and initiate champions
2. Champion meetings
3. Champion review and membership drive

Considerations:

1. Communication and information materials
2. Travel costs

Strategy B: Promote ACMS to the ITS Community, Agency Officials, the Media, Industry, and the Public (cont'd)

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Initiative B3: Target major media outlets for mass promotions

To effectively convey information on ACMS to broad local and national audiences, major media outlets will be targeted for regular and timely promotions. News releases will be developed in conjunction with product demonstrations and presentation in states with strong ACMS potential or heavy investments in transportation construction and maintenance.

National news outlets such as CNN and *USA Today* have shown interest in previous ACMS products and have covered some local deployments and demonstrations. These outlets will be regularly informed and provided with the most current information on ACMS. These materials would also be available, upon request, for local promotion. The ACMS Committee will also develop contacts and working relationships with key journalists in national and local media to enable consistent and coordinated information dissemination.

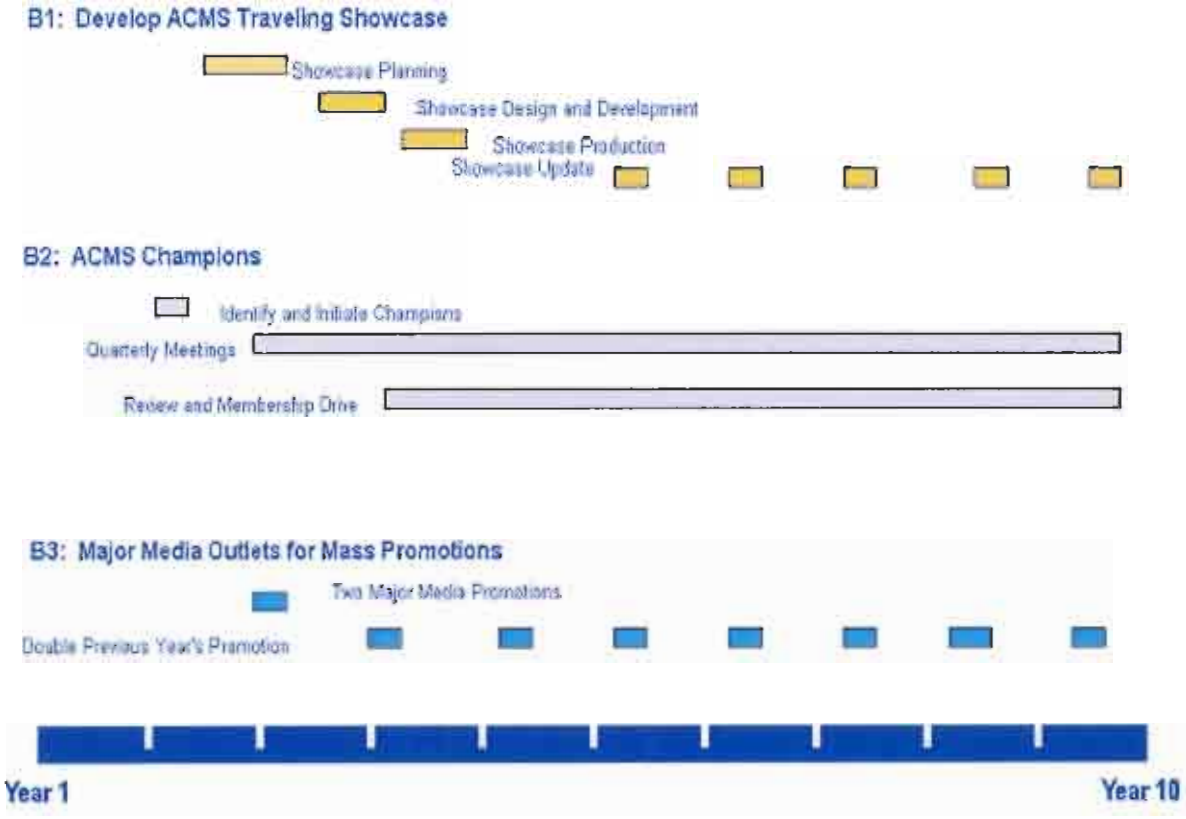
Action Items:

1. At least two major media promotions
2. Double previous year's promotion

Considerations:

1. Demo Video production
2. Press Releases

Strategy B: Promote ACMS



Strategy C: Research and Develop ACMS Products and Solutions

Extensive outreach and stakeholder interviews revealed a broad range of stakeholder needs requiring intensive and coordinated research and development. In general, stakeholders identify the following as prominent research and development needs:

- Construction and maintenance methods and systems that keep workers and the public out of harm's way, thereby improving safety for both workers and the traveling public.
- New materials to enhance the return on ITS investment.
- Improved inspection and testing methods and tools.
- Better ITS maintenance to keep pace with the proliferation of new technologies.
- New personnel skill sets to effectively construct, maintain, and manage ITS assets.

Construction and maintenance operations are potentially hazardous, time-consuming, and costly. There is ample evidence that ACMS can help improve safety while reducing congestion and costs. ACMS research and development is a perfect arena for public agencies, private industries, and academia to join forces and produce deployable solutions. Successful use of products and solutions will enhance ACMS promotion and strengthen the community.

As ITS deployments grow across the country, agencies are experiencing the urgent need for advanced construction and maintenance methods that maximize efficiency while minimizing traffic impacts. ITS elements such as traffic control systems, field components, and telecommunications need to be installed with little or no traffic closure. Remote diagnostics and corrections are becoming a necessity in the ITS arena. Although some solutions are now available, more research and development in this area will be required in years to come.

The following initiatives address research needs, prioritize them, set attainable goals, and develop necessary funding and personnel development to assure success. These initiatives will also pave the way for national and international ACMS cooperation in research and development to build synergy and take advantage of the resources worldwide. It is expected that the results of these research efforts will have far-reaching impacts on the ACMS community in ways never before realized.

Strategy C: Research and Develop ACMS Products and Solutions (cont'd)

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Initiative C1: Prepare and publicize a research and development agenda

The ACMS Committee will take an inventory of current ACMS research and development, map it against transportation and ITS construction and maintenance needs nationwide, and determine additional needed initiatives. Appendix 1 of this document is a start of this task.

Once research and development needs are identified, they may be prioritized according to categories, such as:

- Attributes such as safety, pertinent to ITS agenda, technical feasibility, and expected returns on investment;
- Research topology such as roadway, roadside, snow and ice, structure, work zone, telecommunications, and field elements; and
- Urgency such as immediate, needed short term (2-5 years), and long term (5-10 years).

Detailed plans, schedules, and milestones for the highest priority projects will be set for each year until 2010. These plans will be made part of promotion materials.

The development of a Research and Development Agenda is critical to the advancement of ACMS deployment. A coordinated national Research and Development Agenda will clarify and prioritize funding opportunities, reduce the duplicative effort and expenditures, and establish a clear roadmap for the ACMS community.

Action Items:

1. Develop Research and Development Agenda
2. Update Research and Development Agenda

Considerations:

1. Development costs
2. Production and distribution costs

Strategy C: Research and Develop ACMS Products and Solutions (cont'd)

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Initiative C2: Identify and cultivate funding for research projects

As in other research and development (R&D) efforts, ACMS projects require a steady and adequate flow of funding to maintain progress. ACMS has faced funding challenges due to lack of awareness among agency officials and the industry. This situation will begin to change as a result of consistent and coordinated dissemination of information on ACMS, the use of a network and circle of champions, and the pressure on transportation agencies and the ITS community as transportation and ITS assets' age and maintenance needs increase.

Currently, funding for ACMS research and development is segmented by the entity undertaking the R&D effort. State-specific initiatives, university sponsored research, and private sector sponsored product development are the typical funding mechanisms available. Although there is some collaboration in the community, R&D funds are not being pooled to accelerate progress.

The ACMS Committee will assist the stakeholders in developing an ACMS Research and Development Agenda. This agenda will clearly define goals, objectives, roles, responsibilities, funding and personnel development needed, and resultant ownership. In addition the agenda will be a tool for soliciting federal, state, academic and private funds. The funding rationale and the business plan should be reviewed and updated annually to ensure effectiveness and timeliness.

The ACMS Research and Development Agenda will assist in coordinating efforts and focusing funding on those initiatives most likely to yield significant benefits. In addition to typical federal and state funding, new funding sources will be sought, developed, and nurtured. The ACMS Task Force will foster the pooling of public agency funds in order to accelerate the ACMS Research and Development. Private sector investment will be encouraged through licensing and commercialization programs.

Action Items:

1. Develop funding drive plan
2. Execute funding drive plan
3. Select research project for funding
4. Develop partnership agreements

Considerations:

1. Execute funding drive
2. Business plan and partnership agreements

Strategy C: Research and Develop ACMS Products and Solutions (cont'd)

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Initiative C3: Identify and Establish Regional Research Teams

Individual ACMS research programs around the country have amassed knowledge and experience that can benefit others who are seeking new approaches to construction and maintenance. When partnerships and teams are formed, they can create greater synergy and personnel development opportunities that can accelerate ACMS research and development efforts.

Regional research and development teams should be created to enable experts in various agencies, academia, and private companies to join forces. Key regions will include Eastern, Midwest, Southern, and Western states. Establishment of regional teams will allow participants with similar geographic or climatic issues to work together on relevant solutions.

Each region may form its own structure and memberships, but is guided by the ACMS strategic plan. A Steering Committee, consisting of one representative from each region and chaired by the ACMS Committee Chair will meet regularly to exchange ideas, findings, and support. Annual meetings hosted by each region on a rotational basis will be held to showcase significant progress as well as highlighting product rollout. These meetings will also serve as media and public events.

Action Items:

1. Form regional Steering Committees

Considerations:

1. Team support
2. Annual meeting
3. Travel costs
4. Coordination of teams

Strategy C: Research and Develop ACMS Products and Solutions (cont'd)

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Initiative C4: Develop cooperative research and development efforts with international teams

The need for advanced transportation construction and maintenance is not unique to the United States. Transportation leaders in Europe and Asia have developed products similar to those needed in the U.S. For example, a French company developed a traffic cone placer over a decade ago. Similarly, the Japanese Ministry of Transport has developed sophisticated work zone safety systems using proximity detectors and wireless warning devices.

Historically, European and Japanese transportation officials have been interested in cooperative efforts with the United States. International ACMS efforts increase the probability of success, while also adding legitimacy and excitement to the projects. Furthermore, exposure to such a diverse environment creates synergy and excellent personnel development opportunities.

Between 1994 and 1997, many European and Japanese companies participated in the Automated Highway System (AHS) program sponsored by FHWA. The companies contributed funds and resources to demonstrate the feasibility of AHS technologies in partnerships with U.S. agencies, academia, and private corporations. This experience proved that European and Japanese governments and companies would be interested in meaningful partnerships with the U.S. when mutual benefits are clearly defined. ACMS offers such partnership opportunities.

The ACMS Committee will initiate discussions with appropriate foreign officials to solicit participation and cooperation on strategic ACMS projects. Detailed plans and milestones will be jointly developed. Regular coordination meetings will be held similar to those of the regional teams.

International ACMS teams should be formed by 2004. An international ACMS product demonstration and showcase will be held in 2006, and every two years thereafter, hosted by team members on a rotational basis.

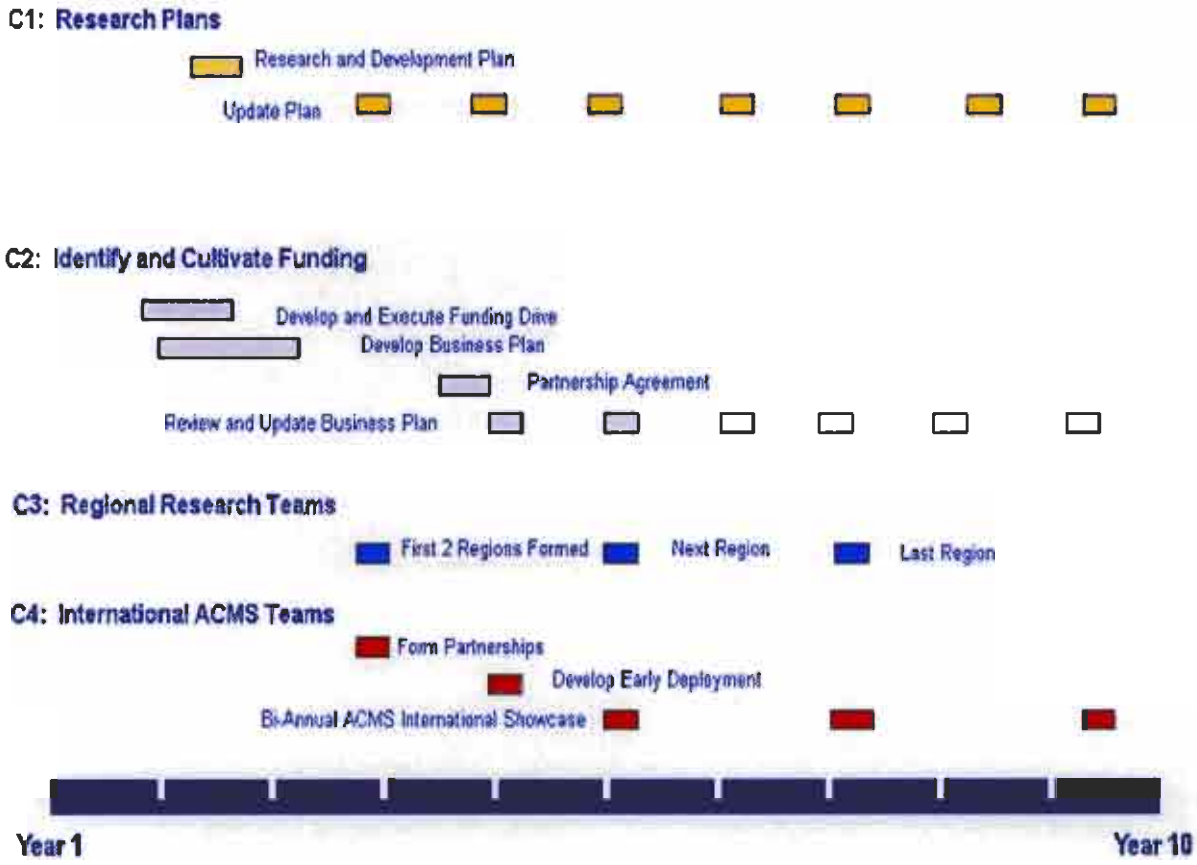
Action Items:

1. Solicit interest and form partnerships
2. Develop early deployment projects
3. First international ACMS Showcase
4. Bi-annual ACMS Showcase

Considerations:

1. Communications and Direct Costs
2. Travel
3. Showcase development

Strategy C: ACMS Research and Development



Strategy D: Deploy ACMS Products to Save Lives, Time, and Money

There are many ACMS products and solutions that can be, or have been, deployed successfully. They should be made available for widespread deployment by agencies seeking solutions for their transportation challenges. Furthermore, matured products should be slated for commercialization in order to bring down the costs while improving quality and rate of innovation.

ACMS will not be fully embraced by the ITS community unless it offers mainstream solutions that drive measurable benefits. Proliferation of ACMS products and solutions will also raise support and funding for additional research and development needed to sustain continuing growth and advances in ACMS, especially if deployment initiatives are carefully selected prior to implementation and carefully evaluated when in operation.

By applying the "design once - deploy many" principle to ACMS, it is possible to achieve economies of scale, maximize returns on investment, and minimize funding obstacles. Emphasis will be given to expanding deployment into mainstream ITS applications such as signal control diagnostics and surveillance, communications, vehicle telematics and incident management as a key part of maintenance activities.

In order to foster deployment, the following Strategic Initiatives have been identified to enhance the sharing of information via a deployment and best practice database, multi-organization cooperation in selecting initiatives for deployment, effectiveness evaluation, and agency staff training.

Strategy D: Deploy ACMS Products to Save Lives, Time, and Money (cont'd)

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Initiative D1: Create opportunities for deploying existing and emerging ACMS products and solutions

There is a wealth of ACMS products that can be proliferated. The ACMS Committee will be the catalyst for widespread deployments by providing information, brokering developers and users, and assisting in project funding.

An inventory of existing and emerging ACMS products and solutions, sorted by ACMS topology, will be posted on the ACMS website and be available to the public. Much of the dissemination of deployment data will be done through presentations at conferences, regional workshops, and elements of other initiatives discussed previously. In addition, the ACMS Committee meetings will continue to focus on educating its membership about the latest product deployments. The ACMS Committee will also assist the FHWA and product developers in transferring and licensing products and solutions to private equipment builders and construction and maintenance companies. This will accelerate procurement and deployment of existing and emerging ACMS products and solutions.

The Committee will track progress of these deployments and update the database on a regular basis.

Action Items:

1. Establish deployment database and post on website
2. Target deployment candidates
3. Track deployment and update database

Considerations:

1. Deployment database
2. Database maintenance
3. Deployment assistance
4. Travel costs

Strategy D: Deploy ACMS Products to Save Lives, Time, and Money (cont'd)

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Initiative D2: Develop before/after studies to measure effectiveness

An important aspect of ACMS deployment is the measure of effectiveness. Deployments must be supported by substantial improvement and benefits offered by a new approach to transportation construction and maintenance.

The ACMS Committee will encourage studies that measure deployment effectiveness to ensure that they meet or exceed there stated desired objectives. Evaluation and assessments will be both quantitative and qualitative. Quantitative measures may include cost savings, timesavings, safety improvements, congestion reduction, and product lifecycle. Qualitative measures may include worker's job satisfaction, and public acceptance of the results. Independent academia and consultants may be engaged to assist in the before and after studies. The results of the studies will be posted on the website as well as distributed to interested parties. The results may be used to enhance and justify future project funding, workforce development, procurement, and deployment.

Funding for the studies may be built into each deployment budget.

Action Items:

1. Perform evaluations

Considerations:

1. Fund studies

Strategy D: Deploy ACMS Products to Save Lives, Time and Money (cont'd)

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Initiative D3: Develop ACMS Best Practices Document

In order to collect and document best practices in the development and deployment of ACMS technologies, it is necessary to develop an ACMS Best Practices Document. Once developed and distributed to the ACMS community, this document will provide a point of reference for new agencies and departments pursuing new ACMS-related initiatives. Best practices collected and documented in the document will include proven approaches for the following.

- Funding
- Research and Development
- Workforce Development
- Deployment Planning and System Design
- Procurement
- Deployment
- Maintenance

This initiative will leverage the information collected as part of Initiative D1, Create opportunities for deploying existing and emerging ACMS products and solutions. The database to be developed during that initiative will serve as the central repository for all know deployment activities. Through a process of developing criteria and assessing the broad range of ACMS deployment initiatives against these criteria to determine which areas represent best practices.

Traditionally, documents that collect best practices are best designed as a "living document," with a schedule for regular updates, based upon advancements in the community.

Action Items:

1. Review information in Deployment Database
2. Determine Best Practices Criteria
3. Develop ACMS Best Practices Document
4. Publish ACMS Best Practices Document
5. Scheduled Updates of ACMS Best Practices Document

Considerations:

1. Timely development of Deployment Database
2. Responsibility/Ownership of ACMS Best Practices Document
3. Schedule for Updates of the ACMS Best Practices Document

Strategy D: Deploy ACMS Products to Save Lives, Time and Money (cont'd)

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Initiative D4: Workforce training program on how to deploy and maintain ACMS/ITS

ACMS cannot be successful without trained and informed personnel behind it. One of the challenges of ACMS is to match workforce training and expertise with the skill set requirements of ITS. The introduction of a wide variety of new and advanced technologies will require new skill sets amongst those responsible for deploying and maintaining these systems.

Construction, maintenance, and operations staff (workforce) will need to be modified in light of the changing responsibilities. Personnel must have the ability to address performance problems within short periods of time. The staff must have the skills and knowledge to understand the systems' purpose and limitations in order to provide a fully efficient ITS. This workforce update can occur through recruitment, training, or, in some cases, contracting (some agencies may determine that contracting the new responsibilities is more effective). The staffing structures may be adjusted to a level appropriate to new distributions of responsibility, and new personnel classifications will likely be introduced to the workforce. New training programs and materials will be necessary for the current majority of the workforce. In some cases, product manufacturers will provide training courses. Some industries, such as telecommunications and optical fiber, have offered free training to public agencies as a part of market development. To minimize learning curves and needs for new classifications, product developers should design products with simple training and operation in mind. For instance, new equipment can be designed so that average construction or maintenance personnel can comfortably operate it within hours of training and practicing.

Some agencies have already taken action to develop training programs and materials covering procurement, deployment, maintenance, and management of ITS products. The Committee will work with these agencies to advocate ACMS stakeholder needs. Some of these courses and materials should be accessible commercially, and through the Internet (including the internet site created by Initiative A3.) The Committee will regularly monitor training needs among the users and take steps to help users meet their needs.

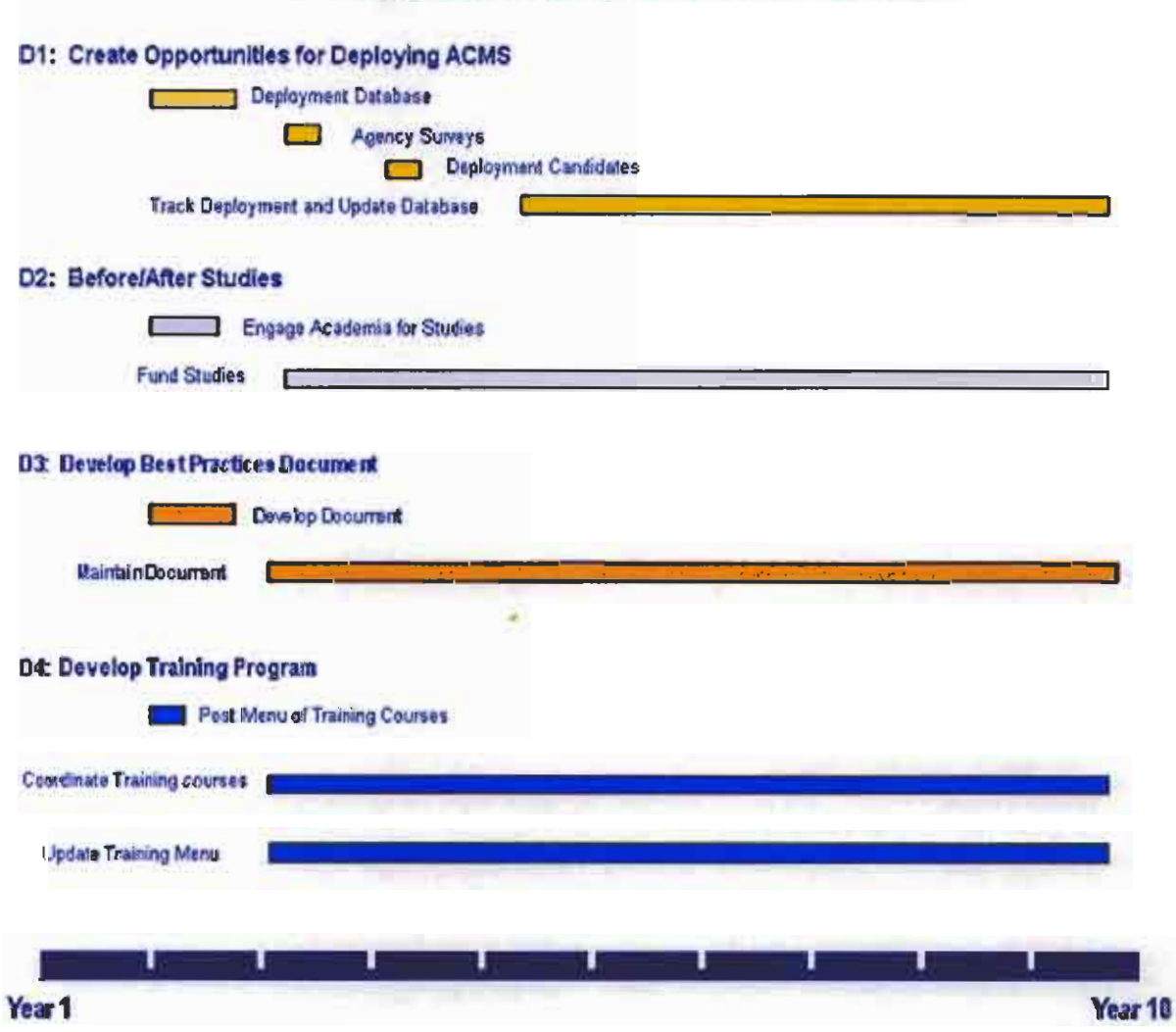
Action Items:

1. Post a menu of training courses on website
2. Coordinate training courses
3. Update training menu
4. Publish training materials

Considerations:

1. Website and coordination costs

Strategy D: Deploy ACMS Products



Section 4 – Conclusions

The information and strategies presented here focus on the point that ACMS offers strong possibilities for addressing issues related to modern highway construction and maintenance activities. The challenge will be to continually organize the needs and work to be accomplished in a focused manner that ends with tangible results for field implementations. As discussed, coordination of user groups is key to advancing many of the ACMS objectives in the future. Similarly, agencies will need to work with the private sector to develop standardized equipment specifications to ease procurement processes and ensure equipment compatibility/interoperability.

The construction and maintenance community have historically been at the "fringe" of ITS developments, and are only now beginning a more proactive approach to ITS, as evidenced by the development of this strategic plan. To meet the objectives, this plan has focused not only on research, development, and deployment of new technologies, but also on institutional issues and needs that need to be addressed in order to further ACMS deployment initiatives. The coordination of user groups mentioned above was evidenced throughout the development of this plan and only underscores the need for this unified coordination of ideas.

Key components of the plan include short and long term strategies and supporting initiatives that the ACMS Committee will be undertaking. These strategic initiatives attempt to address the stakeholder needs and barriers, and the gaps, identified by the ACMS Task Force in developing this plan. The four strategies include:

Strategy A: Develop ACMS Partnerships and Network.

Strategy B: Promote ACMS to the ITS community, agency officials, the media, and the public to gain political and financial support.

Strategy C: Research and develop ACMS products and solutions.

Strategy D: Deploy ACMS products to save lives, time and money.

Beyond the needs of specific stakeholders in construction and maintenance, ACMS activities have been recommended to dovetail with the larger framework of the National ITS Architecture. The National ITS Architecture was developed with an extensive outreach effort to national stakeholders—travelers, commercial vehicle operators, and information service providers. This plan continues that work including participation of the user groups that maintain and build these systems and facilities.

This ACMS Strategic Plan supplements the National ITS Architecture while providing the type of program benefits that have been so important to the development of other ITS user services. The development of the Maintenance and Construction Operations User Service is a key mechanism for enabling interoperability of ACMS technologies with the National Architecture.

An important next step for the ACMS Committee will be to publish a National Research and Development Agenda. A coordinated, national, ACMS research and development agenda will provide a framework that will research and development efforts so that duplicative efforts are avoided, and time to deployment is accelerated.

Appendix 1 – Overview of the Existing Environment

This section of the ACMS National Strategic Plan provides a sample overview of the existing environment in which current ACMS development and deployment are taking place, including examples of current projects and initiatives. In general, components of ACMS are in development, testing, and operation throughout the world. ACMS, a subset of ITS, is building a constituency throughout highway construction and maintenance agencies, as well as within transportation research organizations, institutions of higher learning, and the private sector.

Although construction and maintenance users have not been historically involved in the ITS arena, the critical need to protect roadway workers, the advancement of technology, and the desire to more efficiently maintain highway assets is elevating interest in the use of ACMS technologies amongst construction and maintenance programs. As a result, many organizations have pursued the development and deployment of ACMS technologies on a limited basis, focused mostly in maintenance functions.

ACMS projects - from visioning to prototyping to operational deployment – are beginning to build momentum in state transportation agencies nationwide. Many agencies have undertaken these initiatives through individual efforts, partnerships, and other creative means. Although there has not been a coordinated approach to research and deployment to date, the projects that have been undertaken have demonstrated the significant potential benefits that ACMS technologies offer. Descriptions of sample current activities and initiatives (including partnerships, cooperative efforts, and industry dialogue) and an overview of specific projects and deployment initiatives undertaken to date are presented below.

This overview is not intended to be an exhaustive list of all projects undertaken or in progress, but rather to provide an understanding of the type of initiatives and projects that have taken place.

As mentioned above, much of the activity in this area has been undertaken on an ad hoc basis by individual agencies.

Current Projects and Deployment Activities

Due to the interdisciplinary nature of many of these efforts, innovative public-private-academic partnerships have been formed to accelerate research and development in this area. Examples of initiatives in this area include:

- In February 1998, the American Road and Transportation Builders Association formed a partnership with the Federal Highway Administration to improve safety in highway work zones. They created the National Work Zone Safety Information Clearinghouse to provide information and referrals to government agencies, public and private organizations, and the general public concerning the safe and effective operation of traffic work zones.
- The AHMCT Research Center in California teamed with Lockheed-Martin Corporation in the NAHSC activities to build an Infrastructure Diagnostic Vehicle (IDV), which was successfully demonstrated in 1997, at the San Diego NAHSC Feasibility Demonstration. The IDV used a vision system to autonomously guide the in-lane positioning of the vehicle as it proceeded down the highway inspecting facility qualities such as pavement and AHS component condition. The GPS, voice recognition and computerized mapping technologies assisted in location tracking and event logging. (1997)
- An Automated Crack Sealing Machine was built under the Strategic Highway Research Program (SHRP) that integrated various technologies for crack detection (vision and laser), vehicle tracking, path planning, crack preparation, and robotic sealing of an identified crack. (1993)

Due to the interdisciplinary nature of ACMS technologies, the type of partnerships that created the successes noted above have been beneficial in furthering research and development activities. Academic and industry involvement provide auxiliary resources that may not be available inside a traditional public sector highway organization. In addition, both academic organizations and industry realize long term benefits from involvement in these types of partnerships.

The data is organized into the following functional areas of highway construction and maintenance.

- Resource Planning and Management
- Roadway
- Roadside
- Structure
- Snow and Ice Control
- Work zone safety/traffic control

It is important to note that some technologies can apply to more than one of these functional areas.

Resource Planning and Management

Although not typically included in the discussion of ITS, Resource Planning and Management Software applications have been used to enhance the management of agency resources. Many states have been using Pavement Management Systems and Bridge Management Systems to assemble condition assessment reports, and develop maintenance budgets. Recently, several states – including Virginia and California – have pursued fully integrated maintenance management systems to further support the maintenance operations on an enterprise-wide basis. These new generation systems integrate asset inventory tracking, work order generation, and condition assessment, and budgeting.

Fortunately, maintenance management solutions are not being developed in a vacuum. In fact, Integrated Maintenance Management Systems (IMMS) including bridge, pavement, equipment, financial and materials management are being developed. Recently, funding and organizational barriers that previously prohibited IMMS deployment have begun to be addressed as the technology becomes more affordable and the benefits across the enterprise are recognized. This systematic management approach may improve the development of work programs, the allocation of budget, work scheduling, and the evaluation of performance and cost.

For example, the Maintenance Division of the Virginia DOT is in the preliminary planning stage of an Integrated Maintenance Management Program (IMMP). The program consists of several subsystems, including inventory and condition assessment, pavement management, bridge management, integrated maintenance management systems, and a Virginia Operational Information System (VOIS). The IMMP will use GPS data to inventory the location and condition of all roadway assets under the Virginia DOT control. The integration of the system will allow managers to evaluate different investment strategies, improve budgeting, track performance and schedule maintenance activities.

In addition, integrated maintenance management applications can be used to assist in the tracking and management of ITS devices and can potentially be used as a repository for information gathered from a variety of structural and roadway condition monitoring devices.

Roadway

Roadway maintenance is generally defined as preservation activities for the roadway surface, shoulder, and drainage systems, as well as pavement markings for the purpose of traffic control. Effective roadway maintenance involves detailed planning and strategy of cost-effective treatments that preserve the system, retard future deterioration, and maintain or improve the functional condition of the system (without increasing its carrying capacity).

The following table provides an outline of several key components, characteristics and activities associated with roadway maintenance.

Component	Characteristics	Maintenance Activity
Flexible Pavement	Composed of mixes of aggregate and bituminous materials (generally, asphalt)	– Sand sealing – Chip sealing – Slurry sealing – Thin asphaltic concrete overlays – Viscous asphalt liquid crack sealer – Surface planing and milling
Rigid Pavement	Portland cement concrete base, frequently with flexible surface	– Partial depth patching – Full depth patching, joint and crack sealing – Grouting, jacking and under sealing – Grinding, grooving and milling – Expansion joint sealing
Shoulders	Earth, aggregate, flexible or rigid pavements	– Leveling of drop off – Defect repair
Drainage	Impervious surface to keep water out, a crown to run water to the edge, a ditch to take it to a collection point, a outtake ditch to discharge collected water, and a cutoff trench or drain tile to intercept subsurface flow	– Ditch cleaning – Vegetation removal – Correction of defects in drainage structures – Erosion control.
Pavement Markings	Include lines, symbols, words and patterns painted or applied to pavements and adjacent appurtenance to regulate traffic flow and provide guidance information to drivers. Markers include paint with glass beads for reflectivity, thermoplastic, cold plastic, tape, ceramic markers, raised markers, dry thermo powder, and polyester material.	– Cleaning – Reapplication – Repair or replacement of markers – Removal for changing traffic patterns

These roadway maintenance activities are prime candidates for advanced technology systems that improve safety, productivity, and quality. ACMS technologies deliver benefits by enabling productivity improvement and reduction of congestion in work

zones. Worker exposure is reduced or eliminated, and work zone duration is reduced. In addition, ACMS technologies may deliver longer lasting materials in a more economical manner. Besides conducting the required maintenance activities, improved sensing and diagnostic techniques can also improve maintenance programs by collecting real-time data regarding the condition of roadway assets.

ACMS for Roadway Maintenance

Several ACMS projects have been pursued in the Roadway Maintenance area.

Pavement Diagnostic Technology

The Georgia DOT has developed a digital ***faultmeter*** for inexpensive, quick, and safe measurement of the degree of vertical displacement in joint faults in Portland cement concrete pavements and lane-to-shoulder drop-offs. Changes in both measurements over time are important when evaluating pavement performance. Traditional methods of measuring faults and drop-offs put inspectors at risk – pavement inspectors previously knelt on the road to measure the fault and document the result.

The faultmeter developed by the Georgia DOT offers two major improvements. The first is a handle that allows the user to stand while he or she measures a fault. The second is a digital readout of the fault or drop-off. The faultmeter "freezes" this reading, allowing the user to move to the roadside before recording the measurement. This reading, recorded in millimeters, takes only seconds to obtain.

The ***impact-echo device*** detects cracks, voids, and poor consolidation in concrete. Due to its lightweight portable design and construction, the device can be used on-site to detect problems in plain and reinforced slabs, beams, and columns. This device sends a low-frequency stress pulse (sound wave) into the concrete. The pulse travels until it reaches either the other side of the concrete or an internal flaw, at which point the pulse is reflected back to the surface. A transducer on the concrete surface measures the surface displacement and sends the information to a portable computer, where it's converted into a frequency spectrum. The results, displayed on a computer screen, pinpoint the location of any defects.

This application of technology replaces core sampling, which is time consuming, invasive, labor intensive, and expensive. The device is also a useful tool for controlling quality in new construction; by measuring the thickness of a concrete pavement, the highway agency can quickly determine if a just-placed pavement meets the job specification.

Pavement Repair Technology

Asphalt mixes consist of two components—aggregate, which provides the structure for the mix, and asphalt, which binds the mix together. FHWA, SHRP and private manufacturers have developed some similar technologies for pothole, and even larger, defects, where complete resurfacing is not warranted.

The technology solution uses spray-injection of aggregate and asphalt binder. The asphalt and aggregate are mixed as they travel, under pressure, through the machine's spray hose; the mix is sprayed into the pothole, filling it. A layer of aggregate is then placed on top of the patched area. With the proper equipment, one person from the cab of the truck can perform the entire process.
More advanced equipment is available for larger repairs. One self-contained vehicle features portable excavating and compacting equipment for complete preparation and finishing of large patches. Another manufacturer offers equipment that delivers a patented polymer blend for pavement repair on high volume, high-speed roadways.

These new technologies are fast, simple, and more efficient than conventional patching processes. Work crews spend less time on the roadway, improving safety; and motorists spend less time waiting for the patch to be applied. Most of these technologies allow the pavement to be opened to traffic almost immediately after patching.

Pavement Maintenance Technology

The AHMCT and Caltrans have jointly designed and tested the Longitudinal Crack Sealing Machine (LCSM). This solution seals longitudinal pavement cracks between lanes and along shoulders. The LCSM can work at speeds up to three miles an hour – a significant productivity improvement – while at the same time removing workers from the roadway. The LCSM consists of a dual steering truck and a trailer containing a sealant kettle. The operator drives the truck and positions a mechanical arm containing the sealant nozzle over the crack to seal. The operator has a hand control to run the sealing process and a visual display screen indicating the status of the equipment. A support worker re-supplies the kettle and controls its temperature and operation.

The AHMCT, Caltrans, and SHRP have also developed an Automated Crack Sealing Machine (ACSM) that automatically identifies, prepares, and seals random pavement cracks. The main project (ACSM: Automated Crack Sealing Machine) from 1991, which Caltrans/AHMCT did for SHRP resulted in a super-machine, which evolved into two less-complicated, but more effective machines:

1. A Longitudinal Crack Sealing Machine deployed in San Diego. This design seals/fills the straight crack or construction joint that can be seen

between lanes or between the slow-lane and the shoulder. Commercialization and full deployment should happen by 2002.

2. An Operator Controlled Crack Sealing Machine (OCCSM) for sealing the random cracks within the lanes. The computer processes a video of the crack scene, and the operator uses a touch screen to control robotic sealing. A prototype has been built and installed on a truck. Limited FOT will take place in 2000-2001.

The ACSM consists of a three-axle truck with a machine vision system on the front and a robot positioning system mounted on the rear. Computer and peripheral support systems complete the integrated package. As the truck moves forward, the video sensing system detects the position and orientation of pavement cracks. The position of the vehicle is monitored by a dead-reckoning system. Crack location data is fed to a path planning system, which determines the order in which cracks are sealed. Finally, the path-planning system sends crack configuration data to a robot positioning system, which then follows the crack and applies sealant.

Roadside

Roadside maintenance includes the entire work zone stretching from the outside edge of the shoulder to the right-of-way line. Unpaved medians are included in the "roadside" definition, as their maintenance is generally identical to the outer roadside. Roadside maintenance contributes to safe travel and operation of the transportation facility, as well as enhancing the appearance to motorists and individuals living adjacent to the facility.

Component	Characteristics	Maintenance Activity
Vegetation Management and Pest Control	– Roadside weed, brush and other vegetation	– Mowing – Chemical application
Drainage	– Impervious surface to keep water out, a crown to run water to the edge, a ditch to take it to a collection point, a outtake ditch to discharge collected water, and a cutoff trench or drain tile to intercept subsurface flow	– Ditch cleaning – Vegetation removal – Correction of defects in drainage structures – Erosion control
Guardrails/Traffic Barriers Impact Attenuators Fencing		– Inspection – Alignment – Repair of impact damage – Erosion

Component	Characteristics	Maintenance Activity
Curb		
Traffic Control Signs	– Automated and static signage	– Inspection – Replacement of damaged/deteriorated signs – Placement of new signage
Highway Illumination Systems	– Street-lights – High-mast, high intensity lighting – Illumination of control signs	– Inspections – Electrical maintenance-Replacement of consumable components (light-bulbs, fuses)
Facilities (rest area, etc.)	– Travel Info – Lighting – Signage – Roadside Assistance	– Inspection – Electrical maintenance – Replacement of consumable components – Communication system maintenance

ACMS for Roadside Maintenance

Many roadside maintenance operations are labor intensive. While not technically difficult, roadside operations require manual manipulation of machinery and equipment in order to complete the maintenance and repair processes. Therefore, much of the research and advancement in roadside maintenance has been in the use of tele-operation and robotics.

Tele-operated Machines for Roadside Maintenance

Earth moving equipment such as front-end loaders, backhoes, and bulldozers are an integral part of highway construction and maintenance activities. Often, these machines work in hazardous environments, such as working to clear landslides. Also, some earth moving tasks for major construction sites are repetitive. Remotely controlled machines can perform many of the required jobs and reduce worker exposure to dangerous conditions.

The following institutions are working to develop technologies for the remote control of earth moving equipment:

- ***Construction Automation and Robotics Laboratory (North Carolina State University).*** North Carolina State University has developed an

automated system for robotic excavation and pipe installation. Trenching operations are historically dangerous and expensive, with workers in the trench placing concrete pipe and conduit, and labor-intensive shoring to prevent the collapse of the earthen sidewalls. The system is a backhoe excavator with pipe handling attachment, joystick control of hydraulic actuators, data acquisition/processing, CAD interface, and automatic as-built plan generation. The system removes the need for workers in the trench thus increasing safety and productivity.

- ***National Robotics Engineering Consortium (Carnegie-Mellon University).*** The National Robotics Engineering Consortium has developed two projects for the advancement of tele-operation. The first is a remote control Caterpillar bulldozer, similar to the AHMCT prototype, for studying human factors in tele-operation. The ultimate objective is to compare the performance of direct human control with remote operated control. The consortium has also developed an Autonomous Loading System for repetitive backhoe operations. The goal is to improve the productivity and reduce the cost of mass excavation projects, which may be applicable in many highway construction or landslide scenarios.

- **AHMCT Research Center *(University of California-Davis).*** The AHMCT Research Center has designed and constructed a tele-operation system (the TAMER) to operate a Case front-end loader remotely. Several semi-automatic functions such as "return to dig" and "travel height" were implemented to speed up operations of repetitive work. The system allows for direct operator control in addition to the remote operation that is used if the work involves hazardous slopes or materials. The tele-operated front-end loader has been integrated with a three-dimensional color video/audio feedback system. The feedback system consists of a camera subsystem on the loader, a viewing system that is mounted on the remote operating station, and an additional radio frequency communication link. The video/audio feedback system enables the operator to regain the major senses, as to the status of the vehicle and position of the vehicle relative to the points of operation, which are lost during remote operation from a distance greater than 200 feet. This system is now commercially available from Unmanned Solutions, and represents an early success in ACMS technology transfer from academia to industry.

Vegetation Management

In 1996, the Texas DOT unveiled an herbicide spray vehicle incorporating state-of-the art components with the design process. The vehicle is outfitted with a variable sprayer controller that adjusts the rate at which herbicides are applied in response to changing vehicle speeds resulting in a constant flow rate regardless of

vehicle speed. Texas DOT officials estimate that this innovation could result in a 25 - 30 percent reduction in application costs.

The AHMCT Research Center has developed an herbicide applicator truck with a vision sensing system to detect plant materials requiring spraying. The system will allow Caltrans to reduce the total amount of herbicide that must be used for vegetation control. The system uses vision sensing to detect green plants, image processing to identify the exact plant location and a speed adjusted control system to regulate spray force and trajectory for vehicle speed. The system should reduce over-spray and herbicide use, improve productivity, and improve the working conditions for vegetation management crews.

In the State of Iowa, the Clinton County Conservation Board deployed an Integrated Roadside Vegetation Management System based on GPS guided spray trucks to produce real-time records of what chemicals are being applied, their volume and concentration, what truck is being used, the crew which is operating it, and providing alerts to environmentally sensitive areas not to be sprayed. The Iowa Living Roadway Trust Fund funded the project. This system integrated data from years of mapping and identifies spray areas that required special treatment. The result was increased crew efficiency and more accurate application of herbicides.

Another example of an automated vegetation management system that has been recently deployed is the commercially available Patchen WeedSeeker®. The Patchen WeedSeeker® is a chlorophyll-identifying selective spray system adaptable to any type of boom sprayer. The system, which employs LED light sources and optical detectors connected to electronically controlled solenoid valves, rapidly controls the operation of each individual boom nozzle. Nozzles only operate when "something green" is detected. The system is ideal for spraying large areas with low-weed densities, such as airfield pavements and roadways. WeedSeekers are currently being used for roadside vegetation control, ditch bank weed control, and railroad right-of-way control. Herbicide use reductions of 40-50 percent are common when using the WeedSeeker. Besides being adaptable to existing spray systems, WeedSeekers also provide real-time recording of herbicide use, and the systems can be used at night when herbiciding will interfere less with operations and traffic.

Structure

Bridge and structure maintenance activities are typically accomplished by dedicated or specialized work units, which bring the skills and equipment necessary to monitor structures and carry out their maintenance and repair. Many structure maintenance activities are related to roadway maintenance, as described above. However, structural maintenance does require specialized skills and tools for structure inspection and repair. Recent literature indicates that far more technology applications are being developed for non-destructive testing of concrete and steel, as

opposed to advanced equipment and machinery for structure maintenance and repair. Some concrete testing methods can also be used for rigid pavement, but are only addressed in this section.

Also, many of the technology advances in structure construction and maintenance is centered in material technology. These advances have implications for construction and maintenance, however, these materials are early in the development process and an adequate assessment of their long-term performance, much less maintenance requirements, would be premature.

ACMS for Structures

Several ACMS projects have been pursued for Structures.

Real-time Stress and Strain Monitoring

Recent developments in fiber-optic based detection technologies have enabled low-cost, long-term monitoring of strains, temperatures, and chemistry during construction and operation of the structure. During construction, fiber-optic strain gauge systems are placed to monitor pre-stress during and after casting of the structural members, as well as concrete temperature history and shrinkage in both pre-cast and cast-in-place members. Once construction has been completed, the system can be used to measure deformations under load testing to verify design calculations. These fiber-optic systems can also remain in place to meet other operational needs, such as weigh-in-motion, incident detection, and overall structural monitoring. Described below are some examples of real-time stress and strain monitoring systems projects:

- FHWA led the development of a system that leveraged a large number of sensors placed on a single fiber, reducing both the physical space required for cabling as well as the labor costs for installation. The sensors are also highly durable and are not subject to drift or electromagnetic interference. Prototype fiber-optic sensor systems consisting of up to 64 sensors have been embedded in several concrete bridges in the United States and abroad and have experienced good performance. The sensors can be embedded directly in the concrete or can be attached to reinforcements before the concrete is placed. FHWA sponsored a wireless bridge monitoring system in attempt to create low cost, remote-monitoring capabilities. It consists of a number of battery powered, sensor/transponder modules, which communicate via spread spectrum radio to a local controller. Modules measure strain, rotation, and displacement.

- A laser system has been developed to detect deflections in the shape of structures. The Coherent Laser Radar (CLR) is a portable laser scanning system, which can quickly measure the deflected shape of a bridge with sub-millimeter accuracy. The system was developed, demonstrated in the

field, and delivered to FHWA in February 1996. The system has undergone extensive laboratory and field-testing since then, with good results, and is now commercially available.

Deck Inspection

Dual Band Infrared Thermograph Imaging looks at bridge decks using two different infrared wavelengths simultaneously for detection and quantification of de-laminations. A fully operational mobile infrared imaging system was delivered to FHWA in February 1996. It has been undergoing field-testing to more fully evaluate the benefits of the system.

Structure Inspection (Steel)

High-resolution thermograph imaging systems are available to detect surface breaking fatigue cracks. The method, known as coating tolerant thermography, uses active heating of the bridge surface with a high wattage light to detect cracks. The pattern of hot and cold regions on the steel bridge is mapped using a thermograph imaging system, which provides the operator with an image of heat flow patterns. A crack is detected by a characteristic pattern in the readout.

Electromagnetic acoustic transducers are being used to generate and detect high frequency stress waves in steel using electromagnetic fields. The system can measure the strain in steel members by detecting the change in travel time of stress waves. The advantage of this system is that it attaches magnetically to the steel bridge, so little surface preparation is required, and dynamic stress measurements can be taken quickly.

Structure Inspection (Concrete)

FHWA and the Lawrence Livermore National Laboratory (LLNL) developed two engineering prototypes of ground-penetrating radar for bridge deck inspection. The systems use radar and sophisticated signal processing and imaging algorithms to image a two-meter width of a bridge deck at one time. Using frequency based diffusion tomography, the system produces images of the internal structure of reinforced concrete bridge decks. Two prototypes were delivered to FHWA in 1997 and 1998, with one licensed for commercial development by LLNL.

For large structures, a precision differential GPS (DGPS) system integrates commercially available DGPS technology, digital spread spectrum radio telemetry and standard data acquisition systems into a bridge monitoring system which can measure the movement of strategic points on a large bridge to within one millimeter accuracy.

Another concrete structure analysis task is testing for corrosion of reinforcement steel within the structure. The FHWA is now field-testing a magnetic based system that detects and quantifies corrosion and strand failure in pre-stressed concrete components. The system consists of a strong magnet, sensor array, position encoder, and a wireless communications unit. The portable unit is used to scan concrete girders and beams, and relay the information to a portable PC for analysis, with results displayed as an image for rapid anomaly identification.

Other Monitoring Technology

The Bridge Scour Section of the Alabama Maintenance Bureau uses post-processed and real-time DGPS to routinely monitor major water crossings to assist in the bridge inspection program. These surveys create contour maps that are used to monitor degradation as well as lateral migration of bridge foundation soils. In addition, GPS is used to collect field data for various flood analyses as well as to check for any scour or migration that may have occurred after high water events.

Snow and Ice Control

Effective snow and ice control is a critical maintenance mission for many highway agencies. Practices in this area tend to vary depending on the severity of the climate and characteristics of the geography. In climatic zones where snow and ice events are infrequent, snow and ice control practices might call for passive measures such as traveler advisory warnings. At the other extreme, maintenance departments in northern climates might have a snow and ice control policy with the objective of bare pavement for all paved roadways. Climate is a key driver of a maintenance department's commitment to snow and ice control budgeting, workforce, equipment, and willingness to develop advanced technologies.

There are two direct snow and ice removal methods: physical plowing of the traveled roadway surface and chemical treatment to hasten the rate of melt. Sand or grit is also applied to aid vehicle traction while other control measures take effect. Often, trucks are equipped for both plowing and chemical/abrasive applicators.

Physical removal or displacement of snow and ice is typically accomplished through front-mounted plows, wing plows, belly plows, rotary blowers, or motor graders. In areas of restricted right of way such as urban freeways, limited storage space makes it necessary to physically remove snow using front-end loaders or conveyor loaders.

The chemicals used for snow and ice control are sodium chloride, magnesium chloride, and calcium chloride. These chemicals carry consequences associated with environmental impacts and the corrosion of steel highway structures, so their use is controlled. In addition, agencies are practicing liquid applications of chlorides, pre-

wetting of chloride-grit mixes and application of other chemicals to reduce the negative impacts of chloride application. Spreaders mounted on dump trucks apply chemicals and grit to the roadway surface; calibration of the flow rate is important to ensure the proper amount of material is being applied for roadway conditions. In addition, proper calibration ensures minimum environmental impact of chloride applications.

ACMS Systems for Snow and Ice Control

Winter maintenance activities have received some of the most focused attention of ACMS research. Technologies such as roadway weather information systems, automated weather observing systems and thermal mapping enhance the effectiveness of snow and ice control by providing real time information of roadway surface conditions. The goal of these technologies has been to provide for the more efficient deployment of work crews, enhanced guidance of snowplows, and communication of roadway conditions in the agency and to the public to allow for more informed and safe travel.

Weather information systems can help an agency estimate the onset of road surface ice so they can apply material before storm or ice events. The vehicle itself has become a platform for technology that monitors surface conditions, reports on production, and guides the vehicle to avoid obstacles.

GPS use for Planning and Scheduling Winter Maintenance

Among the computer technology utilized by maintenance agencies are GPS to document, plan, and schedule their activities. Working with integrated maintenance management software applications, the use of on vehicle and remote detection devices can enhance the overall effectiveness of winter maintenance programs. In a recent TRB survey, several agencies cited the use of GIS in their daily activities.

Indiana DOT uses a computer aided routing system for designing efficient snow and ice removal routes. Computer Aided Snow Plow Efficiency Routing (CASPER) was designed to improve routing to achieve the most efficient utilization of human resources, equipment, and material.

The Virginia DOT has equipped 80 snowplows in Northern Virginia with GPS. The system will indicate to highway supervisors in Fairfax County the location of the plows, down to a level of detail indicating the lane of traffic they are in, whether they are plowing, spreading salt or chemicals, or not operating. If the GPS-based system works as expected, Virginia DOT crews will be able to report the roadways that have been plowed, which are closed, and how long it will be before a road is cleared.

With the South East Michigan Snow and Ice Removal Management system, advanced techniques are being used to coordinate snow and ice removal and road condition status across jurisdictional boundaries. GPS and data communications are employed on the plow trucks, and GIS and computer networking allows snow centers in all jurisdictions to understand the total regional picture during a snowstorm, with the ability to also feed this information to cable TV and the media.

Snowplow guidance based on magnetic roadway reference markings has been successfully tested in both California and Minnesota. Testing is also underway in Arizona. These systems keep plows on the road and out of the ditch in low visibility conditions, and prevent damage to roadside hardware from plow blade hits. The advanced snowplows also utilize radar technology to provide advanced warning to the operator of potential or eminent collision. 3M has commercialized its Lane Awareness System (since discontinued), which consists of magnetic road marking tape, a sensor bar installed on an appropriate place on the plow truck, and a driver interface.

Roadway Weather Information Systems (RWIS)

Roadway Weather Information Systems are roadside-based networks of data gathering systems, involving pavement sensors and weather stations with communication links to central monitoring locations. These systems provide information on weather and pavement conditions that can be processed at a central site. Maintenance engineers can track changing weather conditions and allocate materials, equipment, and human resources where most needed. A TRB survey found significant cost savings when these systems were used for resource deployment. For example, the New Jersey DOT reported that their system has the potential to reduce snow and ice control costs by 10 to 25 percent.

Weather Information Processing

Although many agencies and businesses collect and distribute weather information, it has been only recently that this information has been targeted to travelers. The Washington State DOT has begun a program to collect and disseminate real-time and predictive statewide road and weather information. It is called rWeather (road-Weather/"Our" weather). The program will gather data from a variety of sources and will provide statewide weather and road-condition reports and forecasts via a comprehensive Web site.

The system consists of data collection, weather prediction, roadway condition prediction, and information dissemination. rWeather combines information from a variety of sources across Washington State, including agricultural monitoring networks, air pollution sensing stations, and even television station weather

networks, as well as the resources of the National Weather Service Advanced Surface Observation Sites and the Federal Aviation Administration. A high-resolution weather prediction system generates detailed weather forecasts throughout the state, and road condition prediction models combine observed and forecast atmospheric data.

Washington State DOT maintenance officials identified many potential benefits of the rWeather program, rWeather Web site, and data for maintenance departments across the state. rWeather will provide weather details for specific locations instead of generic forecasts. As maintenance has evolved in procedures and techniques, site-specific weather forecasts are growing in importance. For example, site-specific forecasts allow more accurate coverage of snow and ice chemicals, with positive productivity and budget implications.

The rWeather program will be most useful for winter weather maintenance, but there are potential maintenance applications in other operations. For example, maintenance crews cannot apply pavement markings in rainy weather. Thus, maintenance crews, which often have to travel miles from a central facility, can be aware of storms and schedule their operation accordingly. There are also some paving operations that need the surface temperature to reach a certain level before paving can proceed, and rWeather data would allow paving at the right time.

Work Zone Safety and Traffic Control

With most of the nation's highway system built out, construction and maintenance activities will be carried out in an environment where traffic must traverse in close proximity to workers and equipment. This situation results in work zones being high-hazard areas, with nearly 52,000 property damage crashes, 24,000 injury crashes, and 700 fatalities annually.

A work zone is defined as a segment of the roadway marked to indicate that construction, maintenance, or utility work is being performed. Work zones are as varied as maintenance activities – their size, location, and duration all depend on the type of construction or maintenance being performed. Because of the hazardous environment that work zones create, engineering judgment must be used to ensure that temporary safety and traffic control devices are effectively deployed for the safest possible environment for construction workers and motorists alike.

Work zone traffic control principles are outlined in the *Manual of Uniform Traffic Control Devices,* Part VI, or its state-adopted equivalent. Work crews or private contractors must have the proper warning devices on their trucks and equipment when they set out to perform their work; if the assigned maintenance or construction activity is so complex that warning devices will not provide reasonable safety, then barricades, warning signs, flaggers, flashers, or temporary regulatory signs should be considered.

Work zone traffic control has six basic requirements.

1. It must fit the need of the unique setting
2. Command attention
3. Convey clear and simple meaning
4. Command respect
5. Give adequate time for proper response
6. Provide protection for workers and travelers

Warning device design should be consistent with state practices, devices should be placed within the drivers normal line of sight, device operation/application should meet the traffic requirements of the location, devices should be properly maintained for visibility-functionality, and they should be used uniformly.

ACMS for Work Zone Safety and Traffic Control

Traffic Management and Traveler Information

At least two manufacturers and a number of transportation agencies have developed traffic management/traveler information systems for work zones. For the most part, these systems are unique in their mobility – i.e., they perform the traffic surveillance and management functions of traffic operations centers, but are mobile and/or temporary in their deployment. Thus, they provide focused traffic management services in areas where normal traffic management devices are disrupted by the construction itself.

- ***Caltrans Mobile Surveillance:*** Caltrans is conducting a field operational test of a mobile traffic control system for work zones. The project involves self-powered mobile surveillance trailers for traffic detection and video imaging. Data is transmitted to an existing transportation management center via wireless communication (spread spectrum). The application is able to transmit video images and traffic data (speed, volume, and occupancy) to the TMC for locations without surveillance. The trailers can also control ramp meters that may have had their surveillance disabled during a construction phase. This mobile surveillance technology takes the place of traffic sensing that might be disrupted due to the construction project. In addition, it can provide temporary traffic monitoring for temporal high-hazard areas, notably work zones but also special events such as sporting events, entertainment, and large conventions.

- ***Indiana Smart Work Zone:*** Indiana DOT is conducting a test as part of the I-65 design/build project. Indiana has used a variety of technologies including dynamic message signs, Indiana lane merge system, 2/10 reference markers, tow truck service, ambulance service, closed circuit TV, and smiley-face signs. A unique feature of this application is Highway Advisory Radio, which is incorporated into the construction project and remains operational after construction to become part of the state system.
- ***Maryland: Condition-Responsive Work Zone Traffic Control System:*** this is a portable system designed to provide highway customers with real time traffic information in a work zone. The system utilizes queue detectors, portable sensors, dynamic message signs, and highway advisory radio. These components are controlled by a central computer, which analyzes traffic volumes and speeds and displays traffic delay information to the motorist. Dynamic message signs may suggest an alternate route to take or the message may display the amount of travel delay to expect. The system has been deployed two times for short periods of testing and evaluation and is scheduled to undergo a more comprehensive implementation.
- ***Minnesota DOT Portable Traffic Management System:*** Minnesota DOT has experimented with the Portable Traffic Management System or Smart Work Zone for the past two years. The system utilizes traffic detection cameras and a series of changeable message signs in and around the work zone area to manage traffic and can be fully deployed and operational within four hours. This system is now commercially available.
- ***Missouri: Portable ITS for Work Zones:*** portable ITS technologies such as dynamic message signs, highway advisory radio, and queue length detectors have been utilized on various construction projects in Missouri. The queue length detector technology was used and evaluated on an I-70 Missouri River Bridge rehabilitation project in 1995 near Rocheport, Missouri. The use of video imaging for developing traffic management plans is under consideration, as well as the use of traveler information systems in construction zones.
- ***Automated Data Acquisition and Processing of Traffic Information in Real-time:*** a system that senses and processes data relating to current traffic conditions and automatically provides travelers with appropriate speed control, lane control, delay and diversion advisory messages via variable message signs, and highway advisory radio. Maryland DOT is currently using this system on an experimental basis.
- ***Automated Shadow Vehicle:*** a computerized truck which utilizes a triple sensor system to follow a lead maintenance vehicle. California DOT and Minnesota DOT funded the development of this driverless shadow vehicle (adapted from the Minnesota-developed Remotely Driven Vehicle) to allow a workzone to be protected by a shadow vehicle without exposing a

driver to the potential of a crash. The ASV system uses GPS, vision, and radar sensors and a neural-network to control the steering, braking, and throttle and follow the lead vehicle at a distance set by the operator. Also, there is a communication and control link between the lead vehicle and ASV.

Appendix 2 - ACMS Literature Survey

An extensive literature review was conducted for this document. The main focus of the literature review was "technology" – its current, emerging and potential uses in highway construction and maintenance activities. Key areas of literature search included work zone safety, work zone traffic management, winter maintenance, roadway and roadside maintenance, materials testing technology, and emerging trends in building smart structures.

The literature search was conducted by using TRB's Transportation Research Information Service (TRIS), the FHWA's ITS Joint Program Office Electronic Document Library, and other sources such as the Internet.

Review materials included TRB publications, ITS America publications, NCHRP reports, proceedings of conferences, ITE and ASCE journals, trade magazines (such as ITS World, Engineering News-Record, Traffic Technology International, etc.), and reports available in Electronic Document Library (EDL). In addition to published documents, the literature review included electronic information available through various web sites on the Internet. A bibliography of literature reviewed for this study is provided below, alpha by article/publication title.

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