Statewide Advanced Transportation Management System (ATMS) Project Smartlink

Concept of Operations

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EXECUTIVE SUMMARY

The North Carolina Department of Transportation (NCDOT) currently has a large number of closed-circuit TV cameras and large electronic message signs that are controlled from different sites around the state. The control of these devices is typically through vendor supplied software that only works with that manufacturer's products. Exchange of information between control sites is limited to e-mail, fax and telephone calls; there is no way to gather performance data throughout the state to see how well NCDOT is managing the roads. Traffic is increasing on NC roads to the point where it is grid-locking in some major metropolitan areas; a safe comfortable drive is becoming a relic of the past. To solve this problem NCDOT is looking to implement a system to integrate the various field devices that serve as the tools to manage traffic. This will provide a single operator interface within the Regional Transportation Management Centers (RTMCs) and other existing and future facilities to operate existing and future Intelligent Transportation System (ITS) devices. A statewide software system owned by NCDOT that will be used to manage all of the field devices will be cost effective for the state because it will not cost anything to deploy additional copies of the software, and training on the system will be the same throughout the state. Consistent performance data collected by the software such as:

- how long it takes to restore a section of freeway to normal flow after an accident, and
- how long it took for an emergency responder to be notified,

will serve as key performance metrics that can be used to improve the efficiency and safety of the state's transportation network. To facilitate communications between sites, Center-to-Center (C2C) communications shall be developed using National Transportation Communications for ITS Protocol (NTCIP[1]), Traffic Management Data Dictionary (TMDD), and other related standards. The development team, including representatives from NCDOT's Information Technology (IT) Branch, the ITS Operations Units, and the ITS Design Section, have determined the requirements of the new system and have opted for a competitive proposal process to select a private company to provide the integrated statewide traffic management software system, known as Smartlink.

A functional system specification has been developed to be used in the competitive procurement that is derived from existing software system in use today. The Smartlink project is divided into three phases to be deployed over a two year period. Each phase will build on the previous phase adding more and more capability over time. Table 1 lists the capabilities of each phase of Smartlink and an estimated cost based on actual cost data from a similar system deployed in another state.

The Request For Proposal (RFP) will make it clear that NCDOT wants the most capable system for the lowest cost and, in order to achieve that, maximum reuse of existing systems will be encouraged. Furthermore, the bidders will be allowed to take exception to any of the requirements, propose alternate wording for a requirement or otherwise tailor the requirements to match the performance of what they already have developed. This should minimize overly costly development. Some significant costs should be expected even from

[1] See http://www.ntcip.org/ for protocol definitions and standards.

deployment of an existing system that already meets most of the requirements, because the system will need to be closely configured for operation in North Carolina.

Table 1 Smartlink Capability by Phases and Estimated Cost

Phase	Capabilities	Estimated Cost
1	Basic event management, DMS control, CCTV control, video wall control, TIMS interface, GIS map based GUI, secure web based view for authorized users, C2C, AMBER Alert messaging, emergency management links and performance measures reporting.	$2.8M – $3.9M
2	Phase 1 plus automatic incident detection based on traffic sensor data, speed, volume, occupancy, travel time calculation, evacuation route and status overlays, reversible lane control.	$1M - $ 1.4M
3	Phase 2 plus HAR, RWIS, ramp metering, Maintenance Management, IMAP dispatch and AVL tracking	$2 - $2.3M

1. Overview

The first section of the Concept of Operations (ConOps) provides four elements:

- system identification,
- overview of the ConOps document,
- high-level overview of the proposed system, and
- brief description of the scope of effort required to take the system from the current state to the final future state of deployment.

These elements are described in the following sections.

1.1 Identification

This document serves as the Concept of Operations (ConOps) for the North Carolina Department of Transportation (NCDOT) Statewide ATMS Smartlink (hereafter "Smartlink") software. The content of this document is based upon the IEEE Standard 1362-1988, IEEE Guide for Information Technology – System Definition – Concept of Operations (CONOPS) Document. The document control number for this document is contained in the document footer and the file name for the electronic rendition of the document is recorded in the table of contents for the document. This document is conceptual and is intended to provide a basis for the further development of operational procedures, response plans, and contact lists to be integrated with the Smartlink software for use by the Regional Transportation Management Centers (RTMCs) as well as other user agencies within and outside NCDOT. These derivative documents will support communications design, testing, training, maintenance, and configuration management of Smartlink. The ConOps is one of the baseline documents used to provide a general overview of operational objectives as well as management and support organizational structure envisioned for the operation of the system.

1.2 Document Overview

This document provides a ConOps for NCDOT's Smartlink software. The ConOps document is designed for system owners, users, developers, and providers. It describes the current system state, establishes the need for system change, and describes the proposed system in terms of features and functionality.

The remainder of this document consists of the following sections and content:

Section 2 (References and Contacts) provides relevant reference and contact information for the Smartlink project.

Section 3 (Current System or Situation) describes Smartlink's current situation with respect to the existing system (either automated or manual). When systems or functionality do not currently exist, the document describes the situation that motivates development of the proposed system.

Section 4 (Justification For and Nature of Changes) describes the justification for and nature of the proposed changes. This section identifies deficiencies of the existing situation and the benefits of change.

Section 5 (Concepts for the Proposed System) describes the proposed system resulting from the desired changes. This is a high-level description, indicating the operational features of the system when fully deployed. This represents a long-term vision, not a description of the initial deployment. Also included are estimates of the hardware and software cost to develop and deploy each phase of Smartlink and a schedule for each phase based on a hypothetical start date of February 2008.

Section 6 (Operational Scenarios) of the ConOps contains operational scenarios for the system. A scenario is a step-by-step description of how the proposed system might operate and interact with its users and its external interfaces under a given set of circumstances. The scenarios tie together all parts of the proposed system, users, and other entities by describing how they interact.

Section 7 (Summary of Impacts) of the document describes the operational impacts of the proposed system on the users, developers, and support and maintenance organizations. This section also identifies temporary impacts on participants in the deployment that are a direct impact of transition from the old system(s) to the new system.

CONOPS Appendix A - Definitions, Acronyms, and Abbreviations provides definitions for the terms, acronyms, and abbreviations used throughout the document.

1.3 System Overview

NCDOT has initiated a program to develop an integrated software system for use statewide to manage traffic more efficiently and improve the safety of its transportation system. The statewide software system is an Advanced Transportation Management System (ATMS) called Smartlink. The term currently encompasses NCDOT's ITS Traveler Information Management System (TIMS) including the NCDOT traveler information website. Smartlink will integrate with TIMS so that after development, Smartlink will represent an integrated Intelligent Transportation System (ITS) software comprised of ATMS and ATIS elements. For the purposes of this ConOps, the term Smartlink will refer to the ATMS element.

A phased deployment of the system is proposed to reduce risk and incorporate change more efficiently as the system gets widespread use throughout the state. The first phase deployed will automatically provide response plans, control signs and TV cameras and exchange information with various transportation agencies. The first phase of the system will also establish an interface between TIMS and Smartlink for incident reports, construction, and other traffic events. The interface between Smartlink and the State Highway Patrol (SHP) will be through TIMS using the existing interface TIMS has with the SHP.

Changes to the TIMS should be minimal; the most significant change will be to geo-locate all incidents so the Smartlink will be able to correctly display icons on the operator map to indicate where an incident is located. The physical interface with TIMS can either be through a local area network if a Smartlink system will be collocated with the TIMS server or through

a Center-to-Center (C2C) plug-in that TIMS would need to integrate with. The system specification leaves this open to design but depicts the interface through the "NCDOT communications infrastructure" which can be a wide area network using a SONET ring or similar technology. C2C operates on any communications protocol using TCP/IP so even a public internet connection will support Center-to-Center communications.

The project's goal is to provide a common software base that can be deployed throughout the State of North Carolina. There are ten diverse ITS regions that operate around the NCDOT's fourteen geographic Divisions. The 14 Divisions are shown in Figure 1-1 and ten ITS geographic regions defined by the state's ITS Strategic Deployment Plan are shown in Figure 1-2. NCDOT's ITS system manages approximately 300 miles of interstate routes with "ITS coverage" including some or all of incident detection / verification, incident response, and information dissemination. These functions are currently carried out using diverse software that does not allow for interoperability or transfer or command / control for remote management of devices. Using a single integrated software will facilitate device control, incident management, emergency management, special events management, traveler information dissemination, and the associated notifications and reporting via Smartlink operational checklists, procedures, and response plans. Furthermore, Smartlink enhancements will provide future system expandability and interoperability capabilities for other transportation management partners.

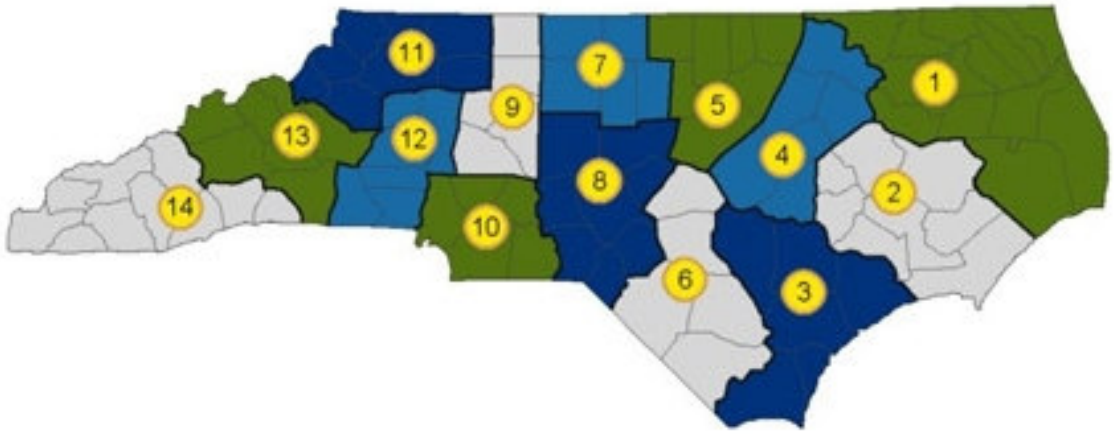

Figure 1-1 The Fourteen NCDOT Divisions in North Carolina

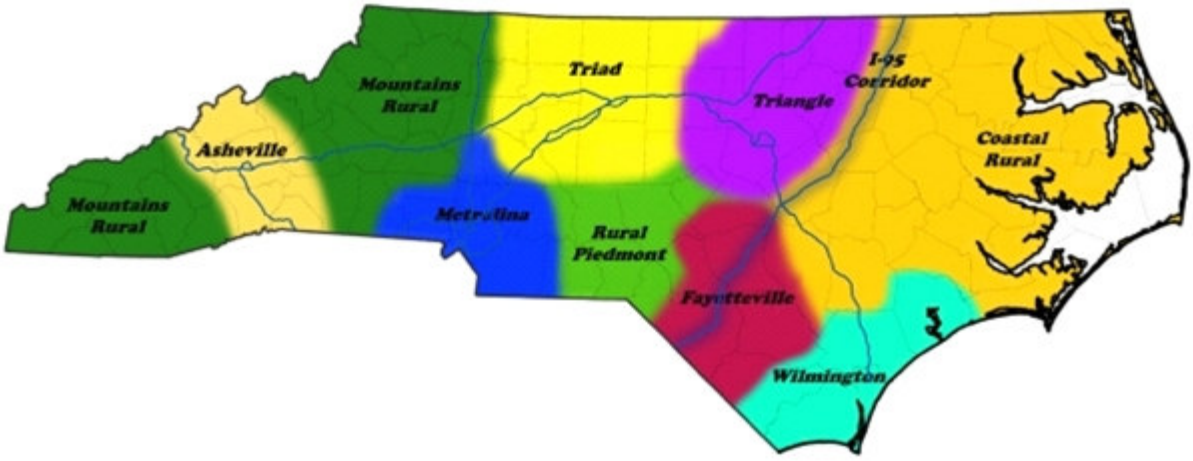

Figure 1-2 The Ten ITS Regions in North Carolina

The first phase of Smartlink software development effort is expected to span approximately one year, after which it will be deployed to various RTMCs, NCDOT Division offices, and other agencies while development of the second and third phase continues.

Figure 1-3 provides a graphical overview of the system to be developed. The system specification contains more detailed functional block diagrams and interface diagrams.

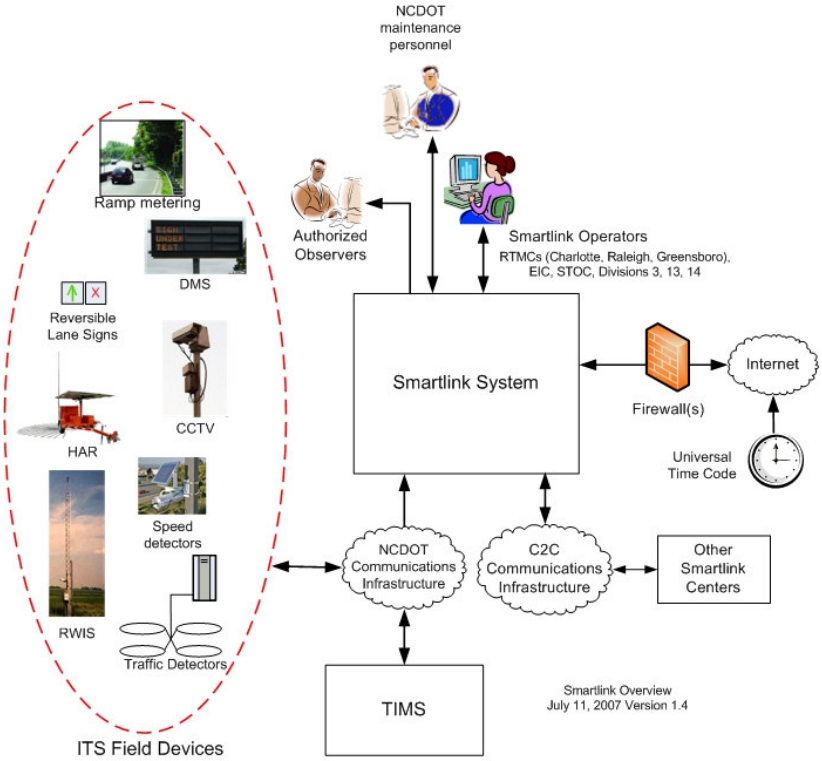

Figure 1-3 Overview of the System Interfaces

2. References and Contacts

2.1 Referenced Documents

The following documents, of the exact issue shown, form a part of this document to the extent specified herein. In the event of a conflict between the documents referenced herein and the contents of this document, this document shall be considered the superseding requirement.

Table 2-1 Referenced Documents

Statewide Advanced Transportation Management System (ATMS) and Advanced Traveler Information System (ATIS) Project Smartlink Functional Requirements Specification July 6, 2007 Draft Version 2.0	The Office of the State Chief Information Officer Enterprise Technology Strategies North Carolina Statewide Technical Architecture P.O. Box 17209 Raleigh North Carolina 27699-7209 Telephone (919) 981-5510 http://www.ncsta.gov/

2.2 Contacts

The following are contacts for the Smartlink project:

- David Alford, NCDOT IT Project Manager, email address: dmalford@dot.state.nc.us, phone: (919) 707-2224
- Jo Ann Oerter, NCDOT ITS Operations, email address: joerter@dot.state.nc.us, phone: (919) 233-9331 x230
- Tom Parker, NCDOT ITS Design, email address: tparker@dot.state.nc.us, phone: (919) 919-661-4834
- David Jones, PBS&J Project Manager, email address: djones@pbsj.com.
- John Bonds, PBS&J, Smartlink System Engineer, email address: jbonds@pbsj.com.
- Ingrid Birenbaum, PBS&J ATMS Operations Engineer, email address: ibirenbaum@pbsj.com.
- Alf Badgett, PBS&J, Field Operations Engineer, email address: habadgett@pbsj.com.
- Ben Morgan, PBS&J Test Specialist, email address: brmorgan@pbsj.com.

3. Current System or Situation

This section describes the current state of the practice in North Carolina.

3.1 Background, Objectives, and Scope

Within the State of North Carolina, a number of ITS elements have been developed and deployed. While these systems provide for the needs of the ITS regions that procured the systems, NCDOT desires to have a single software code base, owned by the State of North Carolina, that can be used and re-used by agencies throughout the state at no charge. The software would also provide C2C communications that do not currently exist but that are needed to provide a truly integrated statewide system.

The following regions have deployed significant ITS capabilities with RTMCs:

- Metrolina (Charlotte area)-serves Divisions 10 and 12.
- Triangle (Raleigh-Durham area) – serves Division 5
- Triad (Greensboro / Winston-Salem/High Point area) – serves Divisions 7 and 9

The remaining Divisions operate various permanent or portable ITS field devices either through an office in an NCDOT facility or in a satellite/mini-TMC. The variety and quantity of field devices includes DMS (portable and / or permanent), HAR, CCTV, video detection equipment, RWIS, and fog detection systems. They use a great variety of communications media for device control that includes; fiber, leased lines, dial-up telephone, and wireless data links.

Currently, North Carolina's TIMS is also branded as Smartlink. Website visitors can get real-time information for events that cause recurring and non-recurring congestion including roadway construction, major incidents, and severe weather. The term "Smartlink" will be expanded by this project to encompass a reusable software framework with a single source code base for development and maintenance for the Division offices, satellite TMCs, RTMCs, and NCDOT's Emergency Incident Command (EIC) center.

3.2 Operational Constraints

North Carolina's RTMCs and satellite TMCs are constrained with respect to hours and days of operation and staffing levels. They also do not uniformly share a common software base, share information and device command and control through integration, or have communications links. They therefore work with a fair amount of independence and isolation from partner TMCs that could provide redundancy and share incident data that extend across regional boundaries. They are also not fully integrated with local transportation entities such as the State Highway Patrol, other police departments, or other emergency response / rescue entities. In addition to potential communications issues, these constraints introduce an element of delay into emergency and incident response.

In order for the statewide approach to software development to work, it must be understood that not every region or organization will want to deploy the exact same software. There will be operational and equipment differences needed to accomplish the ITS goals of the region.

With these constraints in mind, it is important to establish a software framework that allows regions and other agencies to pick and choose software modules based upon their operational needs. With this approach, the State of North Carolina will leverage its development funds by developing software one time and deploying it multiple times. This will also provide a significant savings on software maintenance because a single code base will be maintained for all users.

3.3 Description of the Current System or Situation

This section describes the current status of ITS in North Carolina. The various TMCs and ITS devices provide service to a large portion of population of motorists in North Carolina.

3.3.1 Current System Description

NCDOT's ITS environment is comprised of several functional elements include the RTMCs with their workstation consoles and "back room" computer equipment areas that support the facilities. The operational environment includes the communications infrastructure for voice / data / video, software applications for major applications of TMC operating system software, and the field devices. Often device manufacturer software is used to communicate with and control specific types of field devices leaving the RTMC operator to deal with multiple software operator interfaces. Often the data collected by one set of software are not shared with other systems do the creation o a coordinated response plan to an incident is impossible. Using multiple vendor software packages can result in a stressful environment for the TMC operators that can lead to decreased efficiency in operations.

3.3.1.1 Regional Traffic Management Centers

The RTMCs have primary control of devices with full features and capabilities because the software servers are located on-site. Satellite TMCs have control of some local field devices but are significantly smaller in scale. Office locations that require ITS information will have viewing capability only. The ITS in the various TMCs is isolated from the NCDOT networks preventing interoperability and the sharing of information. Computers and servers in the TMCs are configured on only one local area network (ITS or the NCDOT administrative LAN).

CARAT (Congestion Avoidance and Reduction for Automobiles and Trucks) was deployed in the Charlotte area approximately in 1997 It includes an advanced RTMC and subscription-based traveler information that provides incident location, response, and consumer information to its users for the five county areas surrounding the city of Charlotte. The RTMC controls a system of cameras, microwave traffic detectors and changeable message signs on I-77, I-85 and portions of I-485. The RTMC is operated in three 8-hour shifts Monday through Friday and two 12-hour shifts Saturday and Sunday with a total of 8 operators. The Triangle RTMC currently also serves as the State Transportation Operations Center (STOC), which is separately staffed by contract labor.

The Triangle RTMC is deployed in the Raleigh-Durham area and controls ITS devices throughout four counties. A major service of the RTMC is motorist traveler information dissemination. The RTMC also controls a system of cameras and message signs along I-40, I-440, and I-85. The Triangle RTMC currently serves as the State Transportation Operations Center (STOC). The RTMC operates Monday through Friday from 6 am to 9 pm with one permanent and two temporary operators, one of whom works from a remote location.

The Triad Region encompasses five counties in the north-central part of the state near Greensboro and Winston-Salem. Major roadways include I-40 and I-85, providing vital roadway links to the two other major RTMCs in North Carolina. The RTMC operates Monday through Friday from 6 am to 9 pm with three permanent and two part-time operators.

The satellite TMCs are located in Divisions 3, 13, and 14. They operate a very small number of various field devices, predominantly during office hours, through a location in a highway department building using fiber, leased lines and wireless for communications.

3.3.1.1.1 Console Equipment

The following equipment exists in the TMC consoles with some variation between the three RTMCs:

- Monitors for video, GIS, GUIs, etc;
- CPU, keyboards, peripherals;
- Voice communications equipment
  - Telephone (landline and cell)
  - Radio (NCDOT and State Highway Patrol (SHP));
- Play-back recorders;
- Speakers;
- Joy sticks used at centers to control CCTVs;
- Video wall equipment; and
- Video switches

3.3.1.1.2 Back Room Equipment

The following equipment exists in the computer room areas of the TMCs with some variation between the regional centers:

- Fiber storage and termination panels
- Modems/transceivers
- Digital video recorders
- Encoders and decoders
- Media-installed equipment
- Servers
- Ethernet switches
- Routers
- Uninterruptible power supplies
- Firewalls
- Video distribution switches
- Multiplexers and demultiplexers

3.3.1.2 Communications

Communications media are needed to link the RTMCs with deployed field devices, other control centers, and other facilities / offices. There are varying degrees of connectivity between the ITS sites using a combination of fiber, cellular phone, leased telephone lines, radio, and wireless data communications to operate the data, voice, and video subsystems. There is a leased T-1 line connection between the Charlotte RTMC and the Raleigh RTMC. Data connectivity between other offices is accomplished over an intranet connection through a web server. Public access to traveler information furnished through TIMS is over a public internet connection. .

3.3.1.3 ITS Software

CARAT is the most complex ITS software within NCDOT's RTMCs, and the only software that can integrate devices of different manufacturers to a single interface. The CARAT software includes the following configuration items:

- INDM Incident Management
- INDD Incident Detection
- CMDM Congestion Detection and Management
- CMDA Changeable Message Sign Data Acquisition
- RSPM Response Plan Management
- STAM System Alarm Management
- EVLG Event Log
- CSDA Count Station Data Acquisition
- VDS Video Detection System
- DDHL Detector Data History Logger

Each software item listed above has its own operator interface called Graphical User Interface (GUI) screen. The software cannot automatically connect to incident response plans and provide contact lists specified by operational procedures. TMC operators have access to external databases to get roadway characteristics and aerial photo files. Operator workstations are linked to Windows-based servers through local area network based on the Ethernet communications standard.

3.3.1.4 Field Devices

NCDOT has a wide variety and number of ITS field devices for incident detection, verification, and response as well as information dissemination. Future and current projects will deploy more field devices that seek to standardize on NTCIP Center-to-Field communications protocol. Legacy devices already in the field have unique interfaces requiring the myriad of software previously mentioned. Table 3-1 shows NCDOT's current inventory of ITS field devices:

Table 3-1 Number and Type of ITS Field Devices by Division (early 2007)

Division	CCTV	Comm. Hub	Detection	DMS	Fog Detection	HAR	Portable HAR	Portable VMS	Reversible Lane Sys.	RWIS	Total
1	22	0	0	0	0	0	0	0	0	0	**22**
2	0	0	0	0	0	0	0	0	0	0	**0**
3	0	0	0	9	0	0	0	0	0	0	**9**
4	5	0	8	10	0	2	1	12	0	1	**39**
5	63	0	0	33	0	6	2	8	1	0	**113**
6	0	0	0	5	0	0	0	10	0	0	**15**
7	11	0	0	16	0	0	0	12	0	0	**39**
8	0	0	0	0	0	0	0	0	0	0	**0**
9	33	0	1	23	0	4	0	2	0	0	**63**
10	57	9	134	36	0	0	0	0	25	0	**261**
11	0	0	0	3	0	0	0	0	0	0	**3**
12	0	0	0	5	0	0	0	0	0	0	**5**
13	0	0	0	4	2	0	0	0	0	0	**6**
14	0	0	0	8	0	0	0	0	0	0	**8**
Total	**191**	**9**	**143**	**152**	**2**	**12**	**3**	**44**	**26**	**1**	**583**

3.3.2 Operational Characteristics

A primary objective for a RTMC is to manage traffic on the major roads in its region and a secondary objective if to provide operational coordination across jurisdictional lines. This is done through sharing information and coordination during incidents.

The RTMCs are responsible for operating the various ITS field devices within their region. They monitor conditions with CCTV cameras where they are available, and the video can be shared with other NCDOT offices over the Intranet. In all the RTMCs some of the video is made available to local TV stations. However, the media possess no ability to control the cameras and select the current images that best fit their current programming. Periodically NCDOT will block the dissemination of video to the TV stations during incidents that involve death or serious injury. However, the State Patrol, local law enforcement, and municipalities will always have access to the video feeds.

The RTMCs facilitate statewide incident coordination, messaging, and TIMS user support. Regional Emergency Operations Center (EOC) functions are generally handled in the Charlotte RTMC; however Mecklenburg County and the City of Charlotte have their own EOCs. Amber Alert coordination is handled by the STOC in the Raleigh-Durham RTMC.

When the TMCs are staffed, they dispatch roadside assistance patrols called Incident Management Assistance Patrol (IMAP). During hours when the RTMCs are closed, they are dispatched by SHP. The dispatch is handled differently at each location as follows:

- Asheville – dispatched from operations yard mini-TMC or the mini-TMC in Clyde,
- Charlotte – dispatched from the Metrolina RTMC,
- Greensboro - dispatched from Triad RTMC,
- Raleigh/Durham- dispatched from the Triangle RTMC/STOC.

Because the trucks do not have automatic location reporting (AVL), the TMC staff does not always know their exact locations. In more remote locations, IMAP drivers report roadway conditions back to the TMC when no other forms of detection are available. IMAP drivers in these locations also check the status of devices and radio their report back to the TMC.

The Metrolina RTMC has the only integrated central software package in the state. The development of that software package included drivers only for those devices used at the time of the initial installation. Since the initial installation, newer models of equipment have been implemented with newer more sophisticated protocols but the newer equipment has not been fully compatible with the software. This problem is most evident in the DMS sign control.

3.4 User Profiles

This section describes existing stakeholders for the various centers that comprise NCDOT's RTMCs including those that interact directly with the system as well as those who support its operational status.

3.4.1 Organizational Structure

The organization chart shown in Figure 3-1 shows the reporting structure for ITS within NCDOT. The dashed lines indicate working relationships with external entities such as the NC State Patrol.

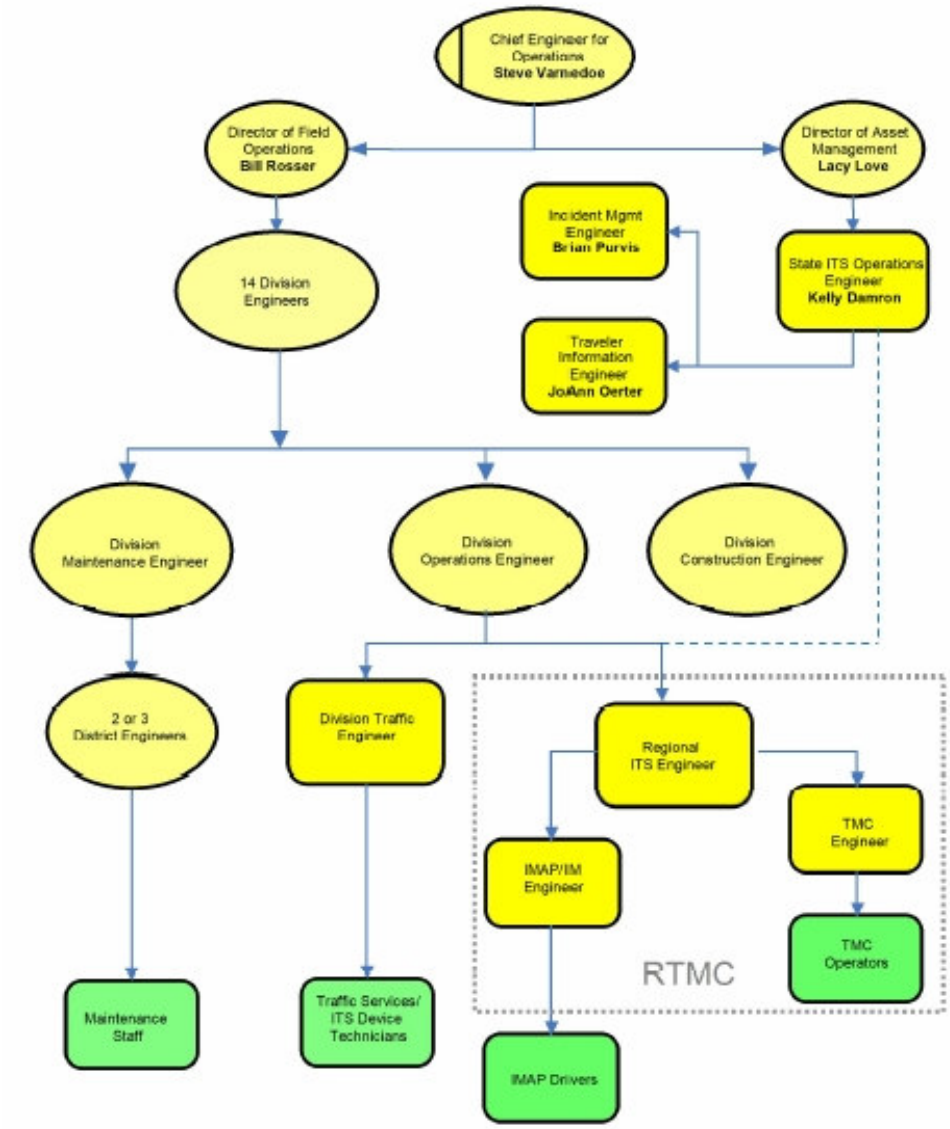

Figure 3-1 NCDOT ITS Organization Chart (circa 2006)

3.4.2 Profiles of User Classes

The following subsections describe the user classes for the various TMCs within North Carolina. While there are some differences within each TMC, the user classes are generalized to be applicable statewide unless noted otherwise. The descriptions include system responsibilities and interactions.

3.4.2.1 Management and Administrative

Management and administrative staff work in Raleigh within the ITS Operations office and include the State ITS Operations Engineer, the State Technology Implementation and Maintenance Engineer, and the State Incident Management Engineer. Responsibilities include:

- Establishing budgets;
- Develop statewide checklists for processes / procedures / reference guides;
- Developing statewide operations polices;
- Training on statewide processes / procedures;
- Monitoring TMC/ITS-related performance measures
- Managing the statewide 511 traveler information system;
- Providing program leadership, direction, and oversight; and
- Provide long range strategic planning for ITS and IM.

3.4.2.2 TMC Operations Management

TMC Operations staff includes personnel who manage TMC operations and communications. They have unrestricted access to TMC software and hardware. Their responsibilities include:

- Supervision and management of all TMC staff;
- Developing locally relevant checklists for processes / procedures / reference guides;
- Training on local processes / procedures;
- Scheduling maintenance activities;
- Oversight of TMC support contracts;
- Responding to customer requests;
- Liaison to other agencies;
- Equipment replacement and purchasing;
- Making equipment purchase requests and
- Management of IMAP resources (varies by site)

3.4.2.3 TMC Operator

TMC Operations staff includes personnel who operate the equipment and manage the traffic on the roads under their control. In many cases the operators are restricted in their access to TMC software and hardware depending upon their skills and responsibilities. Their responsibilities include:

- Monitor roads and control ITS field devices;
- Update TIMS including phone support requests from users (sometimes done externally from TMC in divisions with satellite centers by other NCDOT staff);
- Contact local traffic signal agencies when changes on local street system are needed because of major incidents;
- Posting AMBER Alerts when instructed by the STOC;
- Training new operators;
- Dispatching IMAP vehicles; and

- Call for support when problems with the hardware or software are detected or suspected.

3.4.2.4 ITS Technical Operations / Software Support

Technical operations and software support staff are responsible for TMC back-room functions. They operate and maintain individual servers, perform system backups, and ensure that TMC systems are functional. They have unrestricted access to TMC software and hardware. Currently such dedicated staff only exists in the Metropolitan RTMC in Charlotte.

3.4.2.5 Maintenance Staff

Maintenance staffs are responsible for ITS device and network communications infrastructure. They can also be responsible for contract oversight and inspection when maintenance activities are performed by contractors. They have restricted access (or no access) to TMC software and hardware.

3.4.2.6 Incident Management Engineer

Each Division has a designated person who supervises the Division's incident management response. If the Division has an IMAP operation, this also comes under this person's responsibilities. Depending on the Division, this person may have significant responsibilities outside incident management and ITS.

3.4.2.7 Incident Management Assistance Patrol (IMAP)

IMAP service patrols are trucks with trained drivers who provide motorist assistance, incident management, and preliminary traffic control during peak traffic hours and other heavily traveled times. Their responsibilities include:

- Removal of debris;
- Assistance for disabled vehicles;
- Interaction with law enforcement by providing lane closures during accident investigations and incidents;
- Special event traffic control;
- Communication with TMC regarding roadway conditions; and
- Reporting on traffic conditions including incidents.

3.4.2.8 Emergency Information Center (EIC)

NCDOT maintains a command center that is activated during emergencies. The center has a fiber cable connection to the STOC to receive video from those cameras connected to the STOC video switch. The EIC also has leased-line connections to other TMCs including Charlotte, Triad, Asheville, and city TMCs in Greenville and Wilmington. The EIC has its own video switch so they can control and select cameras that are connected to the video switch.

The EIC, with its direct connection the state TOC, can also share the video they receive by leased lines.

3.4.2.9 Other State Agencies

The North Carolina State Patrol (SHP) is the lead law enforcement agency on the roadways where ITS systems exist. The SHP, local city or county law enforcement typically receive the first report of an incident from the public, typically through a 911 call. At the same time, NCDOT IMAP patrols may be called to or discover through routine patrol the same incident. In either case, SHP and IMAP generally coordinate their activities by radio or in person on scene. Unless there is a fire or medical emergency, SHP is responsible for the scene and investigation. Since the IMAP trucks are equipped with both NCDOT and SHP radios, they can communicate directly.

The NC Emergency Management Division manages and operates the statewide EOC. The EOC is equipped to receive video from the State EIC. At the EOC, they can view certain cameras beyond those in Raleigh. The Emergency Management Division interacts with the TMCs only during events of regional and statewide importance. Their interaction is conducted through the NCDOT EIC in Raleigh and from there to the appropriate highway divisions.

3.4.2.10 Other Entities

Other entities such as cities and the news media have local arrangements with some RTMCs to share video. For those RTMCs sharing video with cities, the city agency usually has control of the cameras and typically shares video with NCDOT. The local agencies include transportation, emergency management and police. These systems are configured such the owner of the camera has priority for control over the “guest” user.

For the news media, each of the RTMCs has written agreements on sharing video that spell out the physical connection, cost and maintenance responsibilities. NCDOT reserves the right to block the video feed at any time. The media however do not have camera control.

3.5 Support Environment

The current systems rely on in-house and contracted staff to operate, support, and maintain the systems, including repair and replacement of facilities, equipment, and support for software / hardware. Each RTMC has its own set of site specific device drivers and software.

Various communications media are in place for information dissemination devices: fiber optic, dial up, and wireless / cellular. The different capacities of the communication links and their lack of redundancy impacts their reliability and timeliness for posting incident response messages on DMS and HAR.

Maintenance includes routine and preventative maintenance activities for facilities, communications media, and field devices. Some devices are changed out with spare equipment, and then the damaged devices are shipped out for repair. This requires stockpiling of some pieces of equipment. There is also a capital replacement cycle that allows equipment replacement once it exceeds its accepted usable life.

Software support varies from NCDOT resources to vendor's engineers. In most cases the software is licensed to the state annually and the vendor maintains and upgrades the software. At some sites the legacy software is no longer supported because the vendor has gone out of business or merged with another company and has dropped the product line.

4. Justification and Nature of the Changes

This section describes the shortcomings of the current state of ITS deployment that motivate development of the statewide Smartlink system and also describes the nature of the desired changes and assumptions for the proposed Smartlink ATMS.

4.1 Justification for Changes

An integrated statewide software system for managing traffic is needed because:

- Not all of the ITS software is owned or maintained by NCDOT resulting in costly dependence on vendors.
- Generally each Division has a set of unique software and hardware that require specialized support. Personnel who transfer to other Divisions often need retraining.
- Most TMCs cannot share information or control another Division's ITS devices so there are many opportunities for single site failure impacting an entire region during an emergency.
- Lack of a standardized software system results in inefficient operations and communications.
- There is no way to collect uniform statewide performance measures that can be used to identify operational problems and improve safety and efficiency of the state's transportation system.

4.2 Description of the Desired Changes

The proposed Smartlink ATMS will provide an integrated software system owned by NCDOT that:

- Provides command and control of new and legacy ITS field devices through a single operator interface;
- Provides control of video within each TMC;
- Provides a national standard communications interface between Smartlink sites that allow for command and control of ITS field devices at any site from any other site;
- Provides the ability to view the current state of the roads throughout the state at any Smartlink site;
- Collects uniform performance measures from each Smartlink site;
- Exchanges information with TIMS and the State Highway Patrol so that up to date incident information is available supporting coordinated response;
- Provides automatic incident detection and response plan generation reducing operator workload and reducing the chances for errors;

- Provides standardized DMS messaging so that drivers can expect the same message formatting across the state.
- Provides a centralized maintenance management system for tracking ITS assets at each Smartlink site;
- Provides access to emergency management information so coordinated traffic management evacuation plans can be optimized and employed;
- Allows any Smartlink site to control another TMC's ITS field devices so all regions can have 24/7 coverage even if local coverage is not possible;
- Provides a standard set of server hardware and software that is scalable to meet the requirements at each site;
- Provides a common training program so any Smartlink operator can work at any Smartlink site without the need for training;
- Provides a common software system that standardizes operations throughout the state leading to uniform performance measures data collection;
- Provides an integrated support environment reducing the number of licenses that need to be maintained;
- Provides for less costly maintenance through reduced cost for sparing due to commonality across the state.

4.3 Implementing Changes

The Smartlink system is specified to be deployed in three phases with each succeeding phase adding more capability. A phased approach was chosen to reduce the risk deploying a new software system statewide and to make it easier to transition between legacy systems and Smartlink. The first phase will support the immediate needs of NCDOT and interface with existing ITS devices and legacy systems. Later phases will implement additional functions as new ITS devices are added to the NCDOT inventory. Table 4-1 lists the functional capabilities of the first three phases of Smartlink and follow-on future phases.

Table 4-1 Smartlink Implementation Phases

Phase 1	Basic event management, DMS control, CCTV control, video wall control, TIMS interface, GIS map based GUI, secure web based view for authorized users, C2C, AMBER Alert messaging, emergency management links and performance measures reporting.
Phase 2	Phase 1 plus, automatic incident detection based on traffic sensor data, speed, volume, occupancy, travel time calculation, evacuation route and status overlays, reversible lane control.
Phase 3	Phase 2 plus HAR, RWIS, ramp metering, Maintenance Management, IMAP dispatch and AVL tracking
Phase 4 and beyond	Other capabilities to be specified by NCDOT in the future.

4.3.1 Phase 1

The first phase of Smartlink will meet the critical needs of the TMCs. Figure 4-1 depicts the functions that Smartlink phase 1 will provide.

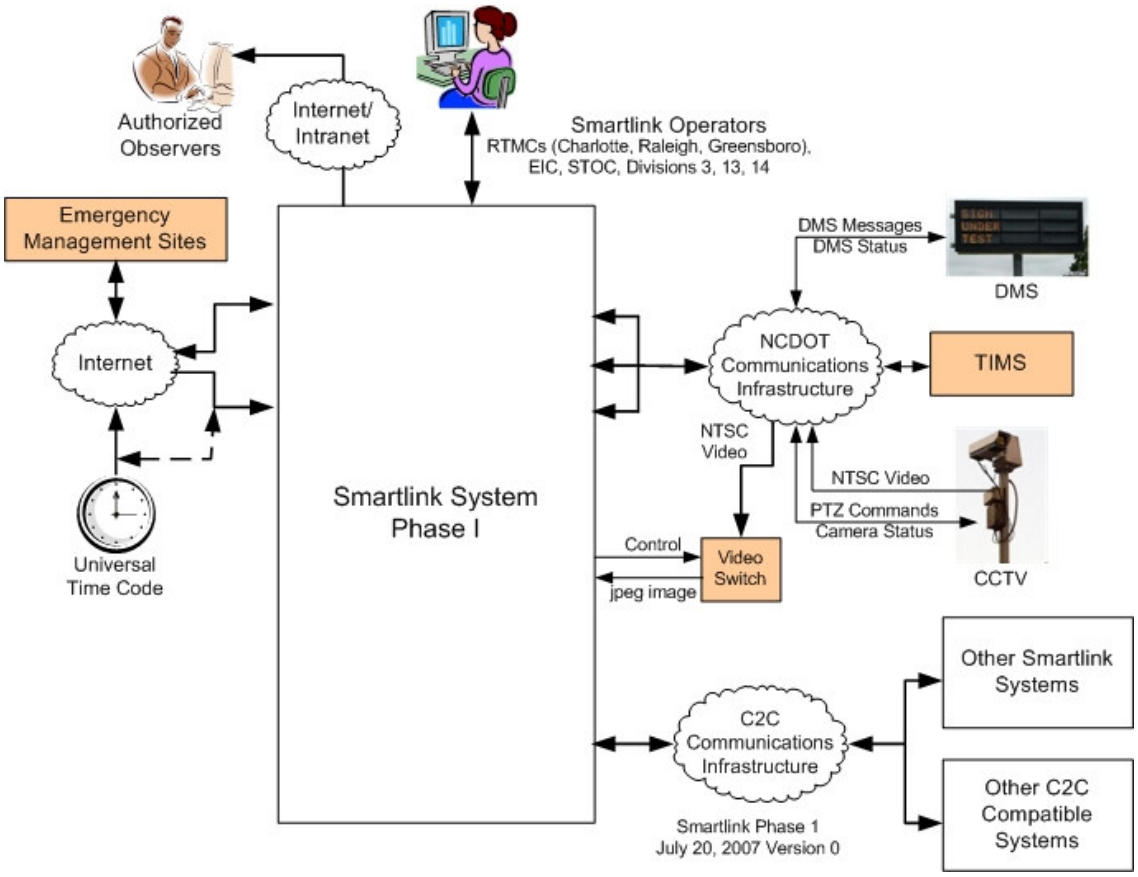

Figure 4-1 Smartlink Phase 1 Capabilities

Phase 1 will provide for command and control of DMS and CCTV cameras that include legacy systems with device specific drivers and newer signs that use the standard center-to-field NTCIP communications protocol and data set. TIMS will be modified by NCDOT to associate incidents with a latitude and longitude location so that Smartlink can accurately show the TIMS data on the Smartlink map. Smartlink will control the routing of video by controlling the video switches at each site. The TMCs that have video walls will be able to place any video source that goes through the video switch on any part of the video wall by using the Smartlink GUI. Smartlink will also be able to schedule a sequence of camera commands so that selected cameras are automatically pointed in operator specified directions according to a schedule developed by the operator.

Access to emergency management sites will be provided through access to the Internet so management of the roads can be coordinated during emergencies. The Internet will also provide a universal time code signal used to synchronize all the servers and workstations on the Smartlink network.

The national standard for Center-to-Center (C2C) communications will be implemented by Smartlink so it can communicate with any other site using the same standard. As other Smartlink sites are deployed, they will have command and control and data sharing capability with any other Smartlink site. The only requirement for C2C communications is to have a TCP/IP protocol so even a public Internet connection can be used. It is recommended that if an Internet connection is used that a Virtual Private Network (VPN) be established between Smartlink sites for C2C.

It is expected that Phase 1 will be deployed to the first TMC within one year after contract award depending on how much software reuse is possible. Subsequent deployments can be expected to occur at 2 to 3 week intervals depending on each site's readiness and availability.

The CCTV control will include the capability for the nearest camera to an incident to be identified on the operator's map and for that camera to automatically turn to point at where the incident is located.

Division offices and other authorized NCDOT personnel who do not need to control ITS devices will be able to access the local Smartlink site through a secure Internet connection. This interface will be through a browser but will provide the same capabilities as the Smartlink operator screen with the exception of not having command and control of ITS devices. This secure web site will allow authorized users to view data, generate reports, select cameras to view video and review response plans and see what messages are currently displayed on DMS and are being broadcast by the HAR.

Deploying a Smartlink with basic capabilities makes it easier for TMCs to transition to a new system and for them to gain operational experience with a relatively simple system. Further, if there are problems with the software that were not apparent during testing and acceptance, a basic system will be easier to find where the problems are and fix them.

4.3.2 Phase 2

The second phase integrates with traffic sensors to provide for automatic incident detection, automatic response plan generation and travel time calculations. Figure 4-2 depicts the additional capabilities of phase 2 that is expected to take about 8 months to deploy after Phase 1 is first installed.

The simple integration of traffic data into Smartlink provides for a significant increase in capabilities that will reduce the TMC operator's workload. Smartlink will detect when traffic is slower than normal on instrumented sections of roadway and will display an icon on the Smartlink map to indicate a possible incident. Smartlink will also alert the operator by flashing the icon and sounding an audible alarm at each workstation. The concept of incident ownership was introduced in Phase 1 that requires each active incident in the Smartlink system be owned by an operator. This provides for accountability and makes sure no incident goes unnoticed for any length of time. An operator must acknowledge an incident alert and take ownership of it and then confirm that the automated alert is an actual incident. The operator can do this using CCTV near the scene of the incident or rely on IMAP, TIMS or SHP reports through TIMS to confirm the incident.

Another feature of Smartlink Phase 2 is the ability to automatically generate response plans with recommended DMS messages on selected DMS signs based on the severity and location

of the incident. The operator can edit the messages as needed or just accept the response plan recommendations and post the messages to the signs. Since Smartlink fills in a lot of the incident data needed for a response plan, there is much less work needed to post meaningful messages on DMS signs to alert motorists.

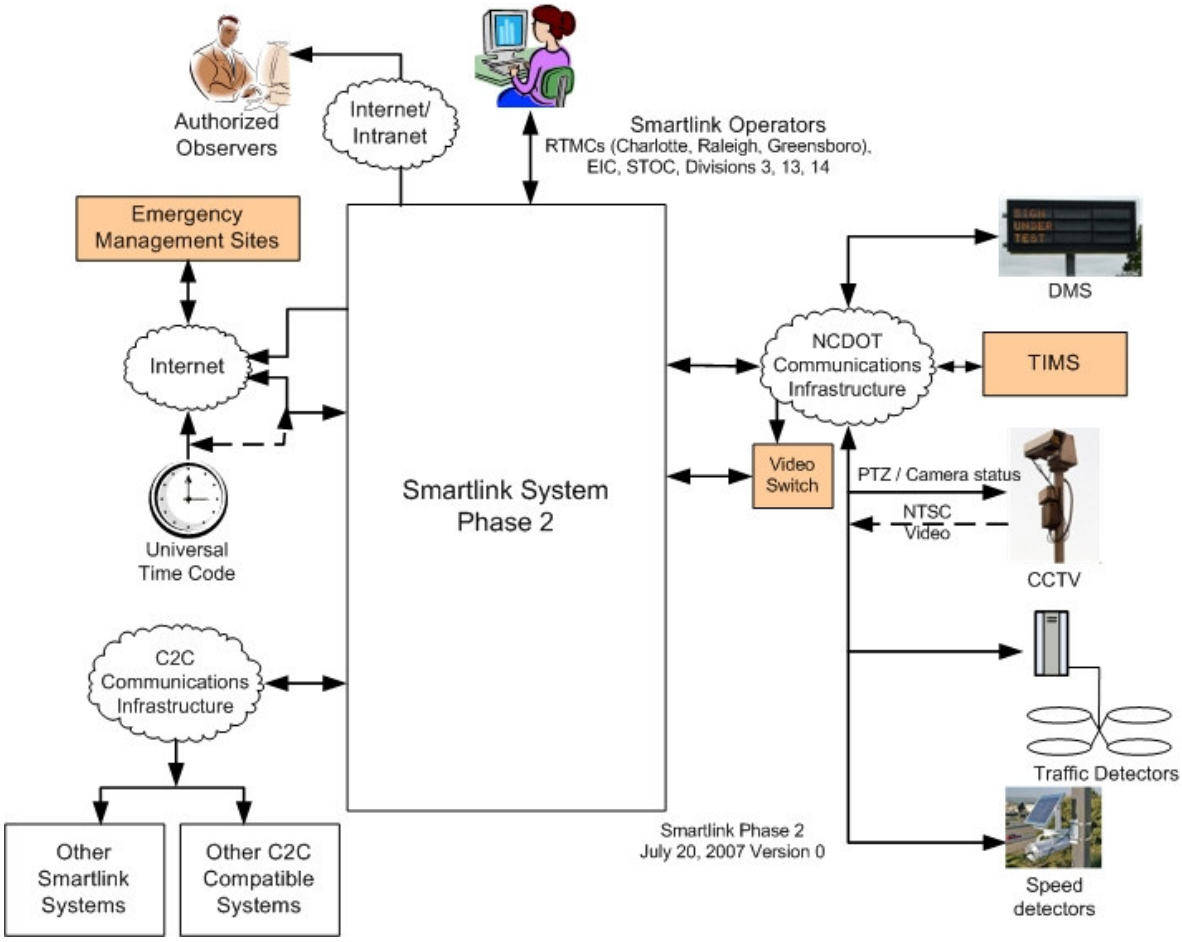

Figure 4-2 Smartlink Phase 2 Capabilities

4.3.3 Phase 3

The third and final phase specified by the Smartlink System Requirements Specification adds other ITS devices and capabilities shown in Figure 4-3. Significant new functions in Phase 3 include the integration with IMAP vehicles with automatic vehicle location and data communications to allow the Smartlink operator to dispatch and track IMAP vehicles. Other new functions are; ramp metering, control of reversible lane signs and integration with RWIS devices. Much of Phase 3 will be bid as priced options that can be implemented as money becomes available in later years. It is estimated that to develop and deploy Phase 3 as currently specified could take as much as 12 months after Phase 2 development is complete depending on how much Vendor software is able to be reused.

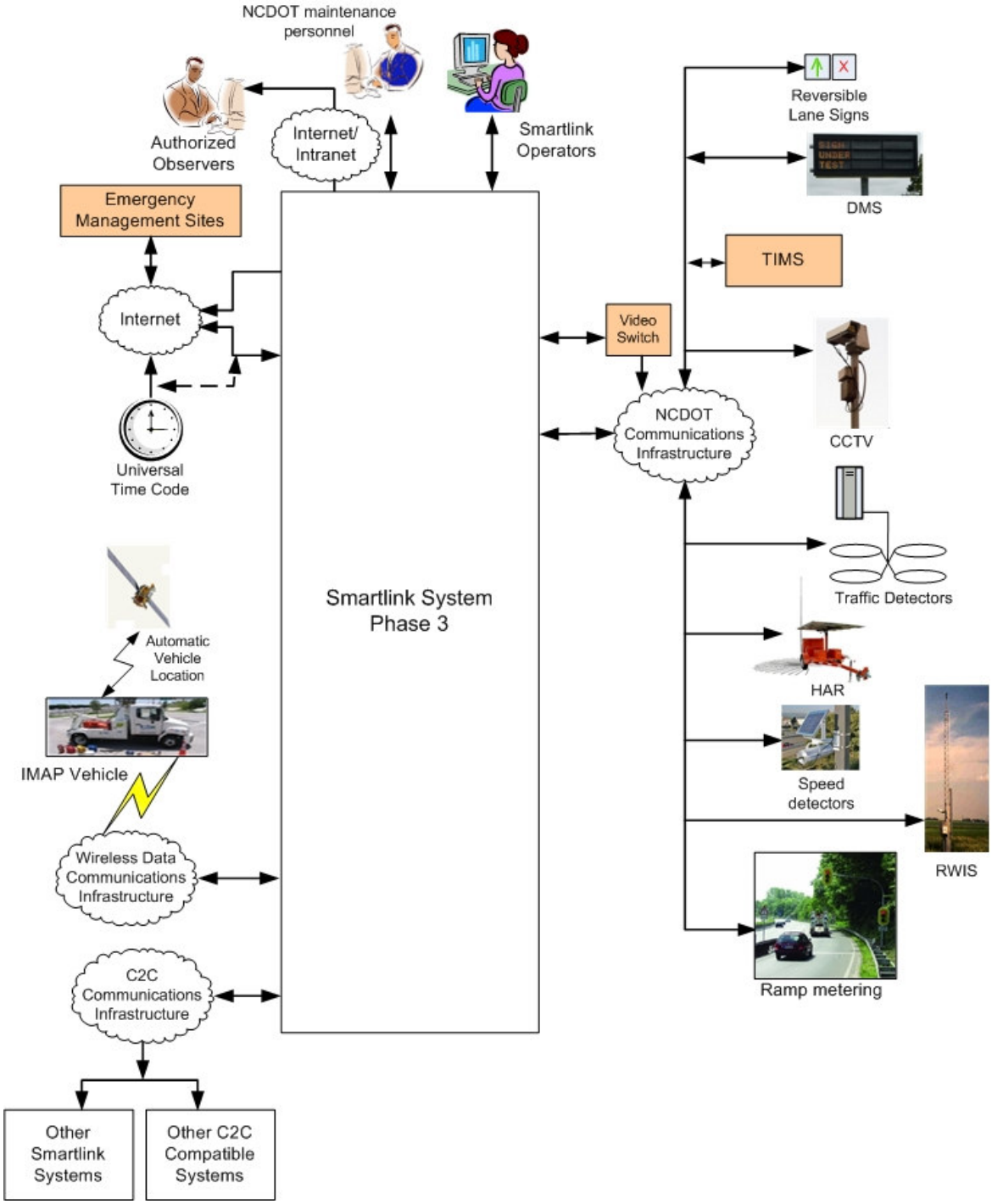

Figure 4-3 Smartlink Phase 3 Capabilities

4.4 Changes Considered But Not Included

There are three basic architectures that could be used for a statewide ATMS. The concept described in this document is considered a distributed network of Smartlink sites. Other possibilities are a central Smartlink site connected to ITS devices throughout the state and another is a non-integrated approach.

4.4.1 Centralized Processing Architecture

Figure 4-4 depicts the central processing architecture.

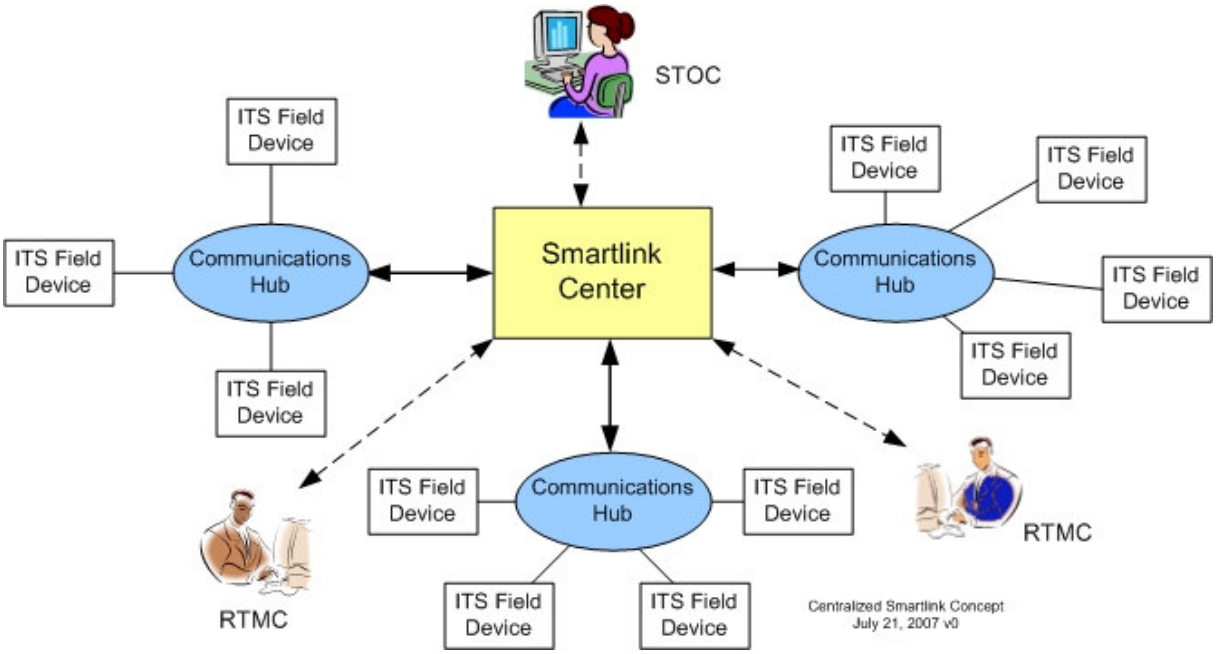

Figure 4-4 Alternate Centralized Processing Concept.

The centralized processing concept relies on being able to connect to all the ITS field devices from a central site in the state. Currently the ITS devices connect locally through a communications hub where the TMCs are located. The current operational concept is that each region controls its own field devices and manages the roads in their region. Coordination between regions is manual through telephone, fax or e-mail. The centralized concept will require that these communication hubs be connected with all their bandwidth intact to a central site in the state. The Smartlink servers would be installed at the central site and regional TMCs would remote in to the central site to access the ITS field devices. This architecture was discarded because:

- The physical communications links would need to be built and routed to a central site retaining all the bandwidth available at the local communications hubs.
- Any RTMC operator would theoretically have access to any of the states ITS devices so operations policies would need to be developed to managed access to the ITS field devices regionally or else conflicts will occur.
- A central server site is a single point of failure for the entire state.

- The time to deploy Smartlink is determined by the connectivity to the field devices that may require construction of additional fiber optic or microwave links back to the central site. Deploying new fiber cable takes a relatively long time statewide.
- Regional differences in operating policies and capabilities require software tailored to the region that could not be accomplished through a single central site.

4.4.2 Non-Integrated Architecture

The non-integrated architecture would provide a software system that used Center-to-Field and Center-to-Center standard communications for ITS field devices and sites that supported the protocol. For legacy systems that were non-NTCIP compliant, the existing software at each site would be accessed through the Smartlink operator interface but not integrated with Smartlink in the sense that data would be accessible through the Smartlink database. Figure 4-4 depicts the non-integrated architecture for a single site. The older Mark IV DMS signs are not compliant with NTCIP and the American Dynamics Ultra Dome 7 and 8 CCTV are not fully compliant. These are used only as examples of ITS field devices that are noncompliant. There are others in use by NCDOT that are not depicted for the sake of clarity in the drawing.

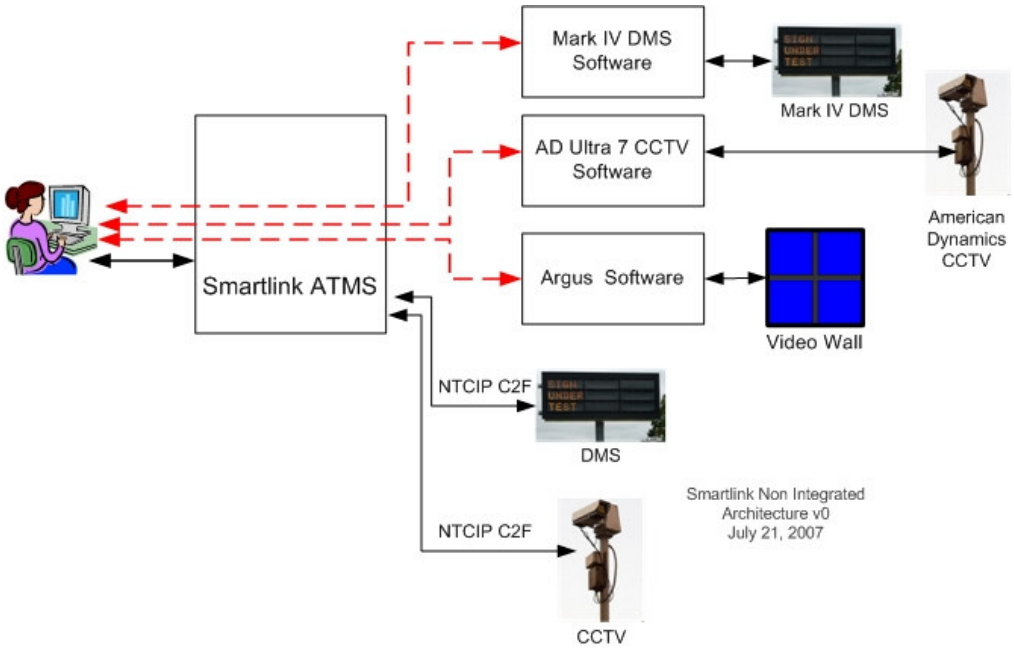

Figure 4-5 Non-Integrated Smartlink Alternative

The Smartlink operator would access a shortcut on the desktop of their workstation to open up the legacy software's operator interface. This architecture would be deployed at each TMC. This approach was discarded because:

- Data from the field devices could not be shared between applications
- No coordinated response plan could be generated
- Higher workload for the operators
- Slower system response time to incidents

- No ability to collect uniform performance measures.
- Operator training on separate multiple software systems would be required.
- Reliance on vendors for software maintenance and upgrades.
- Licenses would need to be maintained for legacy software adding to the cost to operate Smartlink annually.

4.5 Assumptions and Constraints

The Smartlink operational concept is based on relatively few assumptions and has a low development risk because the system functional requirements are derived from exiting traffic management systems already deployed. The following are the assumptions and operational constraints imposed by the Smartlink concept:

- Most major vendors of ATMS software have software that meets the requirements specified for Smartlink.
- NCDOT wants to collect a uniform set of performance measures statewide to improve operational efficiency and safety for the drivers.
- TIMS will be modified to geo-locate incidents.
- TIMS will either add Center-to-Center plug-ins or there will be an NCDOT communications interface that uses TCP/IP with TIMS from a Smartlink site.
- Vendors already have drivers for legacy ITS field devices or that Intelligent Devices Incorporated (IDI) has a hardware solution to translate from NTCIP protocol to native ITS device format.
- There is no single site in North Carolina that has access to all the ITS devices in the state but instead there are regions in the state where these communication links come together.

5. Concepts for the Proposed System

The function of Smartlink is to provide an integrated software system for the command and control of ITS devices to be used to promote safety on the NCDOT roadways and increase the efficiency of managing those roadways. An ancillary function is to provide information that can be used to inform travelers to help them plan trips and travel safely on NCDOT's roadways.

The underlying principle that Smartlink is built on is that the ITS devices[2] used to inform motorists and detect traffic and road surface conditions are controlled from regional sites that have software systems that can communicate to those device and control them. There is no single site in North Carolina that has access to all the ITS devices in the state but instead there are regions in the state where these communication links come together. These will be called Smartlink sites and the Smartlink software will be installed at each site so there will be many sites throughout North Carolina that operate Smartlink and use the same software. That means Smartlink will have the capability to operate or get data from every ITS device in the NCDOT inventory using standard protocols and data formats so that future devices can be purchased and deployed that work without modification to Smartlink.

Smartlink sites will be able to communicate with and control other Smartlink sites through a standard C2C interface that relies only on an Internet connection to work. The assumption is that the site controlling the ITS devices "owns" the devices and has the final say as to who can control the devices it owns so Smartlink is a permissions based system. Operator permissions to operate different subsystems and the extent to how much control they have over each ITS device type is based on permissions established by management.

Smartlink will be highly configurable so that the software can be easily configured at each center to support that center's need. Therefore, if a center had control of DMS but no CCTV cameras or road sensors, only the DMS subsystem would need to be installed. The Smartlink concept is for the subsystems to be able to be loaded or unloaded much the same way an operating system allows the user to activate or deactivate processes without having to shut down the software and restart it.

5.1 Overview of Smartlink

The statewide Smartlink system functional architecture is modular with data being exchanged in real time through messages between subsystems in accordance with the NCDOT Statewide Technical Architecture[3]. A standard message protocol such as XML is encouraged but such details are left to the designer. An overview of the major Smartlink functions and external interfaces is shown in 5-1 below; the functional requirements for Smartlink are provided in the System Functional Requirements Specification.

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[2] Primarily CCTV cameras and Dynamic Message Signs.

[3] STA: Conceptual Architecture. March 11, 2004 version 1.0.1

The core of Smartlink is the Incident Management subsystem that supports the management of incidents occurring on the roadways for which the local NCDOT entity is responsible for. Incident management allows the NCDOT staff to alert drivers through dynamic message signs, view current road conditions through closed circuit television cameras and eventually dispatch IMAP vehicles to expedite event clearance and to restore free flow operation on the roadways. The Incident Management function will collect performance measures such as the time an incident was first reported, when the incident was cleared and when the roadway returned to free-flow operation. A reporting subsystem will extract the performance data collected through the Incident Management subsystem and store the data in the Database subsystem for later reporting.

In the first phase of the project the Smartlink operator will be responsible for identifying incidents and locating them in the system through a geographical information system map based graphical user interface (GIS map-based GUI). Another source for incident information will be through the current traveler information system (TIMS) that will need to be modified to provide geographic location information for each event being reported. The Incident Management subsystem will be responsible for generating a plan for messages to be placed on pre-selected DMS in response to an event, according to the severity of the event. The ability to generate a response plan will greatly reduce the operator workload and improve efficiency in managing traffic. Response plans will always need to be approved by an operator and will be able to be edited before being activated. In later phases of Smartlink, data from traffic sensors will be used to provide automatic event detection that will still need to be confirmed by the operator.

All NCDOT Divisions will be able to view the Smartlink GUI but not all will be able to control ITS devices through Smartlink. By the third phase of the project, the NCDOT maintenance personnel will access a subsystem to manage the NCDOT assets through the Smartlink GUI subsystem. This Maintenance Management subsystem will track NCDOT assets such as DMS signs, CCTV cameras, vehicles and other assets used by the NCDOT regarding their current location, their assigned location (who the asset is assigned to), the status of the asset (in repair, in service, failed waiting for repair, etc.).

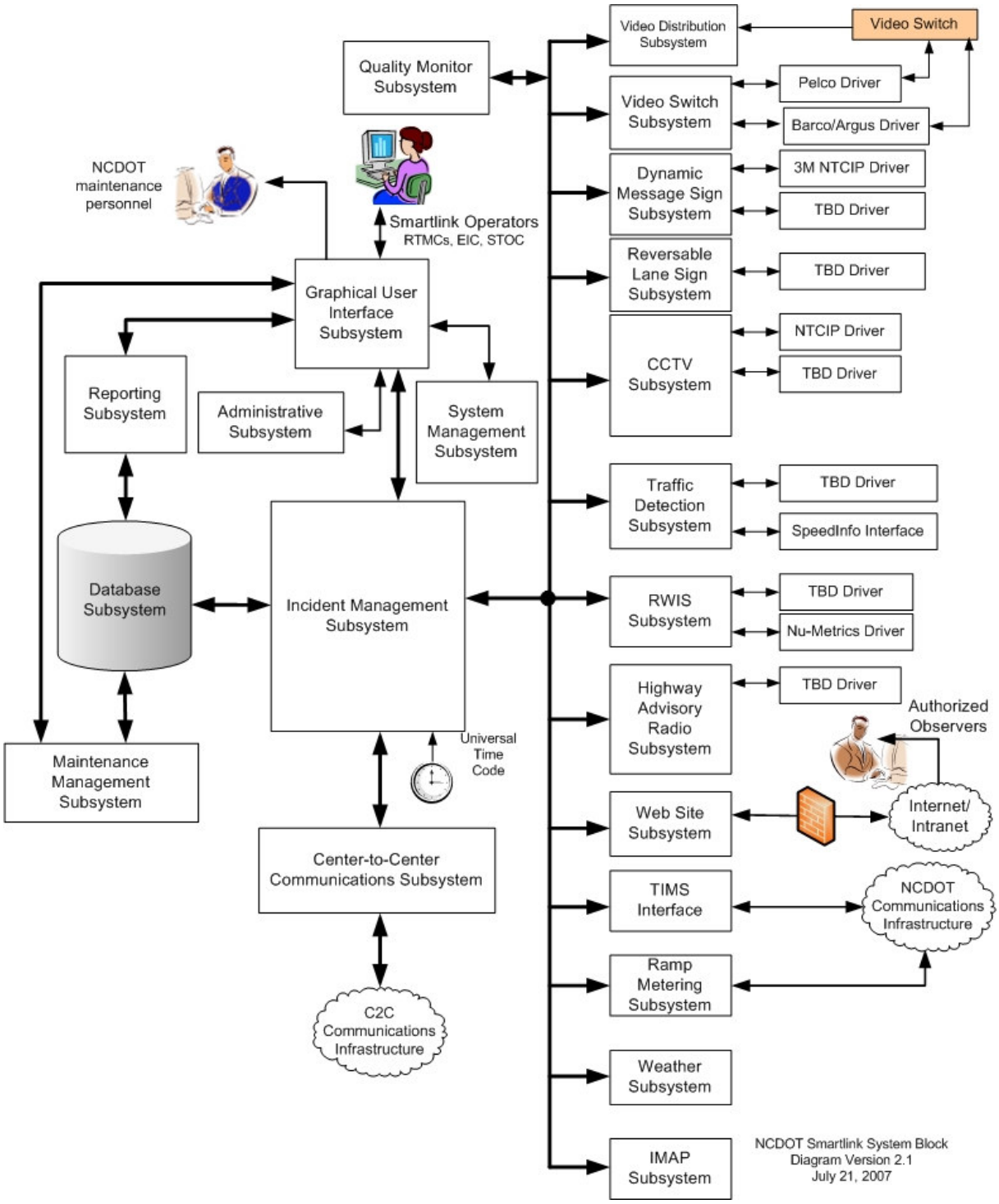

Figure 5-1 Overview of the Smartlink Functions

Smartlink servers will be synchronized to a Universal Time Code (UTC) so that all data that is time stamped in the system will be accurate. A UTC signal can be obtained through the Internet or through a circuit card added to the server that receives radio signals containing the UTC signal or connects to the Global Positioning System (GPS) to obtain an accurate time signal. How the UTC is obtained is left to the designer.

The Smartlink architecture is modular and it is expected that Smartlink will be configured for each installation to load only the necessary subsystems needed at that site. Smartlink will be highly configurable in an operational sense so local practices such as DMS message format and HAR message format will be configurable at the site level. Smartlink will also incorporate the concept of layer permissions for user access and control so the NCDOT managers at each site can decide who can control which NCDOT ITS devices and which ones can administer the system configuration.

Smartlink architecturally can be implemented in a single central site if that site has access to all the ITS devices in the state. It also can be locally deployed and the various Smartlink systems can exchange information through the Center-to-Center link that is currently based on the TMDD 2.1 Standard. That standard is expected to migrate to the TMDD 3.0 standard by 2009. The C2C link supports complete access and control of another site's ITS devices so in case of a local emergency such as a hurricane forced evacuation along coastal regions, an inland Smartlink site can continue to manage the evacuation routes. Command and control of another site through C2C is based on permissions established by the site being controlled and this can be based on time of day, based on passwords or other criteria to be determined by NCDOT. Certain time critical messages such as an AMBER Alert can be disseminated from a single Smartlink site throughout the state to place the AMBER Alert messages on DMS signs throughout the State or in specific regions of the State without needing local permission. Also since C2C is a national standard, Smartlink will be able to exchange data with other ATMS/ATIS systems in adjacent states to coordinate incidents that straddle state lines.

Eventually Smartlink will be able to dispatch Incident Management Assist Patrol (IMAP) vehicles to the scene of an incident to assist in clearing it. AVL and real time wireless communications can be used to link a vehicle based computer tablet to Smartlink so that the IMAP driver can fill in a report of the incident in real time. AVL tracking through Smartlink will assist in dispatching the nearest vehicle and to track the drivers work day. Future interfaces may be with the SHP Computer Aided Dispatch (CAD) system through the TIMS to exchange incident information. Sometimes the Smartlink operator will be the first to detect an incident through the CCTV or automated traffic sensors and at other times the State Highway Patrol will be the first to report an incident. By exchanging the most current information, both SHP CAD and Smartlink will be more up to date and provide consistent and accurate information.

Smartlink will incorporate a Quality Monitor function to watch over the system's performance and alert NCDOT and others by e-mail if a problem occurs, such as a failed process or a failed server or the data between two subsystems or an external system has too great a latency. The Quality Monitor will support the ability to display a summary of the current status of key performance parameters on NCDOT supervisor computer screens. This functionality is referred to as a dashboard.

5.2 Description of the Proposed Smartlink ATMS

Smartlink is specified to be a software system operating on two or more servers and many operator workstations all connected through a Ethernet Local Area Network (LAN). The software will be modular meaning that when the software is started from a workstation by an operator, the user profile or even the operator may designate what software modules need to be loaded which allows for easy site customization. A site with no traffic sensors can choose not to load the traffic sensor module but when they are deployed in that region in the future, the Smartlink will need only to configure the system for the traffic sensors and load the traffic sensor module on startup. Every Smartlink installation will consist of a dual redundant database server using RAID[4] technology and one or more servers depending on how many ITS field devices are managed at that site and how many operator workstations are connected to the servers.

5.2.1 Conceptual Smartlink Network

Figure 5-2 depicts a conceptual Smartlink network needed to support the Smartlink system specified by the functional requirements specification. The actual network topology will need to conform to NCDOT network security requirements and meet the VENDOR's design requirements.

Conceptually the Smartlink servers all operate on a 100 Mbps Ethernet LAN (also referred to as a 100BASET network), using several routers or hubs that can subdivide the network. The database server and at least one application server is the minimum configuration because of the performance penalty incurred running a large database application like Oracle on the same server as the applications. More than one application server is probably required to allow the technicians to load balance the Smartlink servers for optimum system performance. If dual processors servers are purchased, care should be taken to use software that can take advantage of dual processors.

Workstations connect to the servers through the LAN and it is expected that each Smartlink site can support a dozen or more operator workstations with no noticeable degradation in response time.

The applications access the ITS field devices in one of three ways through modem banks to talk to devices using serial analog protocol, terminal servers to talk to devices also using serial analog protocol or through a router/switch to communicate to each device using TCP/IP and NTCIP message protocol. Using a digital to analog converter box or circuit board, the servers can send commands through a bank of modems to dial up a particular field device and send it data or retrieve serial data. Using terminal servers Smartlink can communicate with field devices connected to the Smartlink site through copper wire or fiber optic cable using serial data. The field devices that use digital communications are assigned an IP address and digital commands and data are sent and received using NTCIP Center-to Field protocol. Note that CCTV video is routed back to one or more switches and video converters at the Smartlink site

[4] RAID-Redundant Array of Independent Disks

through discrete cables if analog NTSC video is the camera output. Smartlink routes the video to different displays by controlling video switches and video encoders.

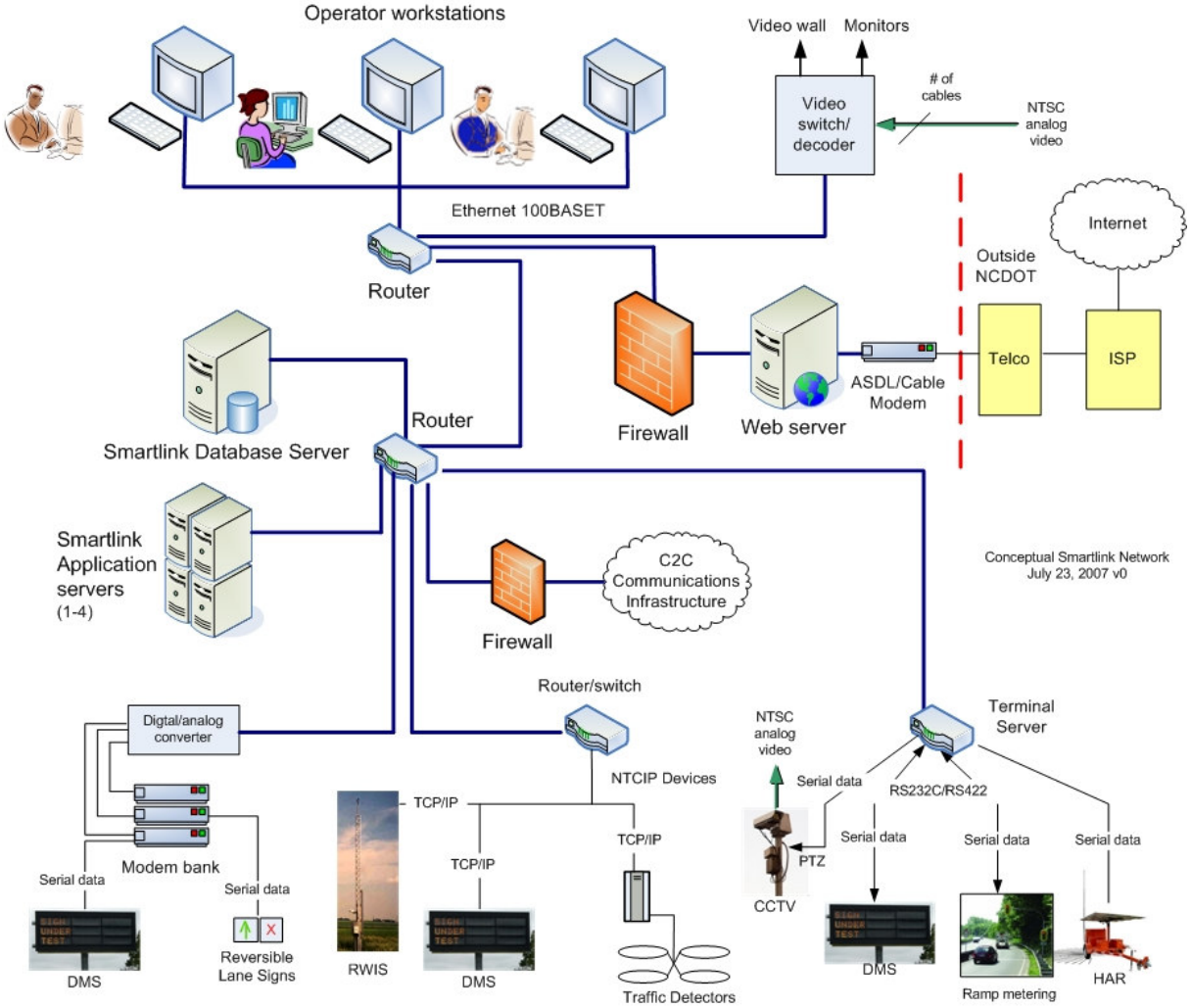

Figure 5-2 Typical Smartlink Network Topography

Cameras that send video back already digitized in the MPEG2 or MPEG4 format do not require the video converter so the video is routed by IP addresses by Smartlink.

5.2.2 Server Sizing Estimate

An example of the server size and performance needed by the Smartlink system is shown in Table 5-1. The actual equipment specification is expected to be provided by the VENDOR providing the software. It is assumed that a Windows operating environment is preferred rather than a UNIX or LINUX environment because of the availability of off the shelf applications available on the market. The information in the table below is only indicative of what hardware will be needed.

Server Function	Specifications
Smartlink Database Server	▪ Microsoft Standard Server 2003 ▪ Database Management Software (e.g. Oracle, Sybase , Windows SQL) ▪ 2.4 GHz processor or faster ▪ 12 GB RAM ▪ 120 GB of disk using RAID architecture
Application Servers	▪ Microsoft Standard Server 2003 ▪ DBMS Client ▪ Smartlink Executive Handler Service ▪ 2.4 GHz processor or faster ▪ 8 GB RAM ▪ 80 GB of disk
Smartlink Workstations	▪ Microsoft Windows XP or Vista ▪ Microsoft Internet Explorer 7 or greater ▪ SVG Viewer 3.0 or greater ▪ 2.8 GHz processor or faster ▪ 4 GB RAM ▪ 40 GB disk ▪ Dual display monitors

5.2.3 Estimated Cost

The cost of the Smartlink system can vary greatly depending on how much off-the-shelf software is available that meets the Smartlink functional requirements and how much new software has to be either developed or modified from existing software. The software cost estimate is based on an existing system that has approximately 60% new software developed specifically for the project and about 30% code that was modified and 10% of the code reused. It is assumed that Smartlink can take advantage of ATMS software already deployed and require only a part of the software be either modified or developed as new software especially if NCDOT is flexible in its requirements. A best case is assumed to be 60% reuse and 40% new software or modified software. For the purpose of this cost estimate the cost to modify software is assumed equal to the cost to develop new software. The third phase of Smartlink adds a number of ITS field devices and IMAP dispatch and tracking capability so it is thought to only be able to reuse 25% of the existing code base. Table 5-1 depicts the costs estimate for the average case that was just described. These percentages are just an estimate based on engineering experience.

Table 5-1 Average Case Software Cost Analysis

Item	Equivalent cost	Reuse factor	Smartlink Estimate
Smartlink Phase 1	$5.6M	50%	$2.8M
Smartlink Phase 2	$2.0M	50%	$1.0M
Smartlink Phase 3	$2.7M	25%	$2.03M

Total: $5.83M

The Smartlink functional requirements are based on existing systems so there will be software proposed by vendors that can be reused. Assuming that the percentages in Table 5-1 are wrong by 40% on the low side, Table 5-2 was created to estimate the higher cost estimate for the software.

Table 5-2 Worst Case Software Cost Analysis

Item	Equivalent cost	Reuse factor	Smartlink Estimate
Smartlink Phase 1	$5.6M	30%	$3.9M
Smartlink Phase 2	$2.0M	30%	$1.4M
Smartlink Phase 3	$2.7M	15%	$2.3M

Total: $7.6M

Hardware costs are estimated based on the server configuration described above using typical pricing available in 2007. NCDOT may be able to purchase the hardware at a lower price using a government discount or have equipment in inventory that can be used. Table 5-3 provides a cost estimate for the hardware based on previous projects for each full scale Smartlink installation assuming a Microsoft SQL Server database program. An Oracle database costs more and is harder to install and operate, but it is also a full scale enterprise database software package that can grow as Smartlink grows.

Table 5-3 Smartlink Hardware Cost Estimate

Item	Unit cost	Quantity	Estimated Cost
Database server (RAID)	$15,000	1	$15,000
Application server	$12,000	3	$36,000
Workstation	$4,000	5	$20,000
Web server	$4,907	1	$4,907
Routers/switches	$1,000	3	$3,000
A/D converters	$1,200	2	$2,400
Cables, racks, misc.	$5,000	lot	$5,300
Support software licenses	$2,500	lot	$2,500
MS SQL Server license/yr	$1,300	lot	$1,300

Total: $90,407

Add $40,000 if an Oracle DBMS is used in lieu of the Microsoft SQL Server.

5.2.4 Schedule

The time it takes to develop each phase of Smartlink is highly dependent on how much software the vendor can reuse and how much software needs to be customized or developed new. The following schedule for Phase 1 shown in Figure 5-3 is a rough approximation at what could be expected based on the Smartlink requirements having been developed from existing systems already deployed.

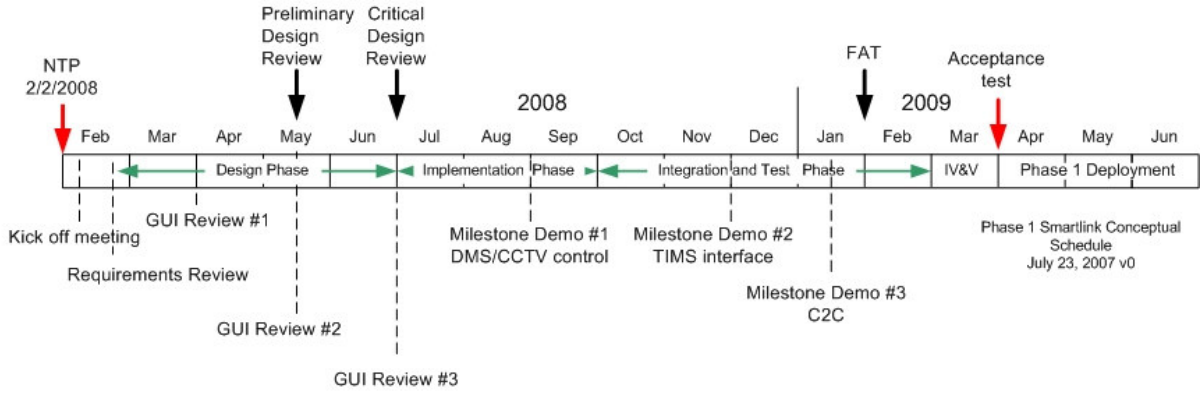

Figure 5-3 Conceptual Schedule for Smartlink Phase 1

The second phase of Smartlink can be expected to start about the time the first phase has completed integration and factory testing. Figure 5-4 depicts the conceptual schedule to add traffic sensors and a secure web site to the Phase 1 capabilities of Smartlink.

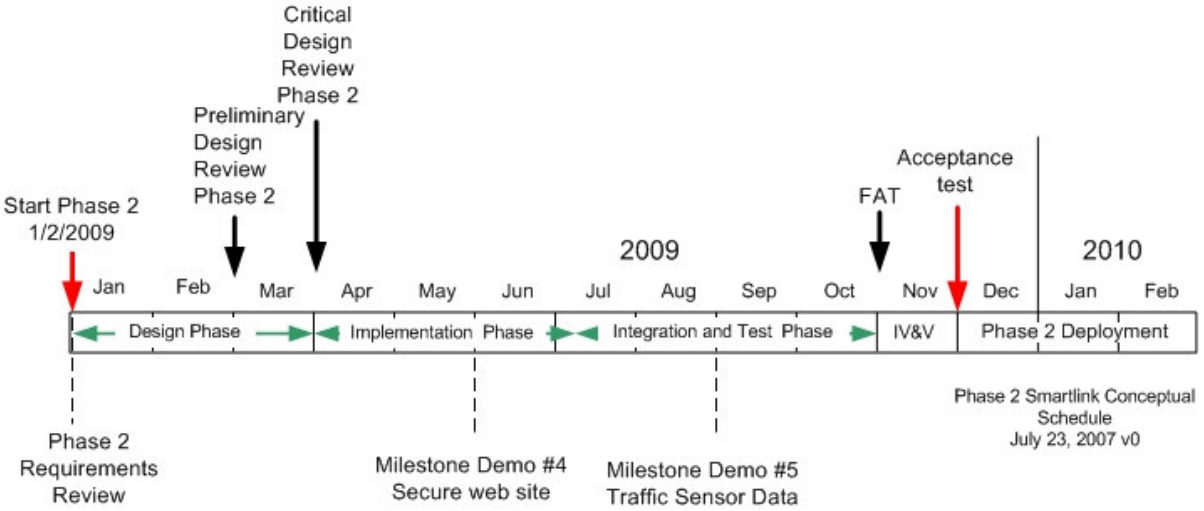

Figure 5-4 Conceptual Schedule for Smartlink Phase 2

The third phase is harder to predict since many of the functions may be bid as an option to be implemented as funding becomes available. The Schedule shown in Figure 5-5 assumes that all the functions specified for the third phase will be implemented.

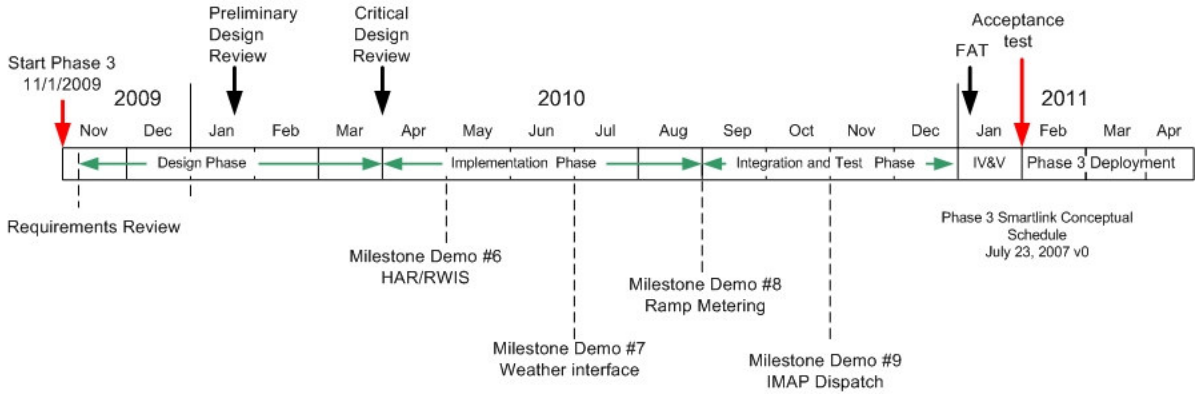

Figure 5-5 Conceptual Schedule for Smartlink Phase 3

Each phase will start with a review of the functional requirements and then a design phase for the vendor where the vendor will develop the physical requirements to build the system with. The first review of the design requirements take place at the Preliminary Design Review and based on feedback from NCDOT, the vendor will complete the design and present it at the Critical Design Review. The design reviews are the opportunity for the NCDOT to see how the vendor is going to provide a solution to the functional requirements. As the system is being designed and integrated, various milestone demonstrations of significant functions will be required. In phase in addition to the milestone demonstrations, the vendor will be required to develop the operator interface (GUI) using a spiral design methodology where a quick prototype is developed and shown to NCDOT operations personnel for feedback. Three iterations of the design of the GUI are planned. After the vendor completes the factory acceptance test, the Smartlink software will be installed at a NCDOT facility where an independent test of the system against the functional requirements will be conducted. This Independent Verification & Validation (IV&V) testing will be the final acceptance test for the software and after that it will be deployed and considered operational.

5.3 Modes of Operation

Smartlink will have 5 modes of operation as follows:

- Startup
- Configuration
- Operational
- Remote Operation
- Failed

5.3.1 Startup Mode

This mode is defined as a cold start of the system. The database server is started first followed by the application servers and finally the workstations. It is assumed that the Smartlink network is already operating and connectivity to field devices exist. The servers are expected to be left on all the time and restarted every week to reinitialize the Microsoft operating system to deleted temporary files, recover unused memory and perform other housekeeping.

An operator can log into Smartlink from any workstation by clicking on a shortcut to the Smartlink GUI. Each user will be required to enter their user ID and password that will be

recognized by Smartlink to configure the GUI according to the user's preferences and their privileges. It is expected that the GUI software will allow the user to specify what screens are to be displayed as a default and even what color schemes to use for icons, roads, and other map features.

5.3.2 Configuration Mode

A Smartlink administrator authorized to configure the system will be able to enter ITS field device information such as the name of the device where it is located both in a text description and in geographic coordinates. The system administrator will be able to tell Smartlink which applications to run on which of the servers so that the processing load at a particular Smartlink site can be optimized. The system administrator will be able to define what privileges each operator has; for example, a senior operator may have the privilege to create DMS messages, approve words not in the approved library and be able to override a CCTV locked by another user. More junior operators may be restricted to approving automatically created response plans but not changing them.

5.3.3 Operational Mode

In normal operation each Smartlink site will control the ITS field devices associated with that site. Smartlink will make sure that only one operator ID is active on only one workstation at a time. Incidents created or automatically detected will require an operator acknowledge the incident and take ownership of it. The Smartlink software will log everything the operator does so later a supervisor or manager authorized to review the logs can see what incidents were managed by which operators and the time stamps for all activities associated with the incident such as when an incident was first entered into the system and the time the operator took ownership of it, the time a response plan was created and the time it was approved.

When an operator logs off at the end of the shift all active incidents owned by that operator become "orphans" and the other workstations are alerted until someone else takes ownership.

Authorized observers are NCDOT personnel who are given read-only access to Smartlink through a secure web site. The authorized observers will see the same GUI that an operator sees and be able to access different views, see what messages are currently displayed on DMS, and view CCTV video of any camera at the site. Some observers will be able to access the database to generate performance reports.

The TIMS data will automatically be shared with Smartlink so that a TIMS incident will appear on the Smartlink GUI and be identified as having originated from TIMS or from the SHP CAD since it interfaces with TIMS. It is possible that both Smartlink and TIMS operators will enter the same incident and initially there will be a duplication of the incident. The Smartlink software will be able to recognize the characteristics of a duplicate and alert the operator to that fact. The operator can choose to view the information on both and decide which one is more accurate and current and delete the duplicate or combine the information into one incident.

5.3.4 Remote Operation

Through C2C one Smartlink site will be able to control another site. C2C defines two interfaces based on TMDD 2.1. One is a command and control interface supporting control of

ITS field devices and the other is a data interface for transferring data between centers. C2C contains information about the sites ITS field devices so that one Smartlink site connects to another site through C2C, a complete inventory of the ITS field devices are published so that the map displays the other sites ITS devices.

Typically each site controls access to its field devices through permissions so the system administrator can create a local account consisting of user ID, password and privileges for a remote site to use. If all the Smartlink sites open their C2C connections, any site can see what any other site is doing. C2C can be very helpful if one site is operated part time during the week so during hours of non-operation, a nearby site that is operating 24/7 can take over.

Performance measures can be aggregated through C2C so that a site such as the STOC can generate performance measure reports for all the regions.

5.3.5 Failed Operation

Smartlink is specified to have a very high availability and to degrade gracefully as parts of it fail. Because software processes can be stopped and started on different servers, a failed server's processes can be quickly taken over by the remaining servers. Smartlink software will be able to alert key personnel of any failures that occur by using e-mail, pagers and even a call to a cell phone or Personal Digital Assistant (PDA). If enough servers fail the Smartlink may operate noticeably slower but still function until the remaining server fails. It is expected that long before that happens, maintenance personnel will have replaced the failed servers and restore them to operation.

The database server is required to use RAID technology which provide redundant disk drive that are typically hot swappable. For added insurance, NCDOT may elect to install a fully redundant server and run the system in a fully redundant configuration with mirrored databases. Fail over from a failed unit to the hot standby will be automatic but since maintenance will be required, restoration will most likely be manual.

5.4 User Involvement and Interaction

Smartlink will have five levels of user that are defined as:

- Operator - An operator will use Smartlink and all its capability every day to manage the traffic on the roads assigned to the operator.
- Senior Operator/Supervisor – A senior operator or supervisor will have a higher set of operating privileges that allow them to preempt an operator if needed.
- System Administrator – A supervisor or manager that is authorized to configure the Smartlink system, set up user accounts, configure road segments and in general create the operational environment for Smartlink operators.
- Maintenance Personnel – IT personnel or senor staff who are trained in trouble shooting computer systems and fixing them.
- Authorized Observer – Designated NCDOT personnel who have the need to observe Smartlink operations but not control the ITS field devices.

5.5 Support Environment

Each Smartlink site is expected to be unique depending on the region it operates in, the number and type of ITS field devices and the operational objective of each region. The local area network will be installed and configured by NCDOT according to its own security requirements and the needs for each site. Since Smartlink is a networked computer system it is required to be house in a sheltered environmentally controlled facility. It is also expected that each facility have secure access where the operators are working and a separate secure facility where the servers and network equipment is installed. On-site spares should be readily accessible so any failed part can quickly be replaced and the failed part sent back to the factory for repair. The number of spares of each type depends on the published mean time between failure (MTBF) of each hardware unit and how quickly a spare can be ordered and received at that facility.

6. Operational Scenarios

The following are brief descriptions of a day in the life of people who are involved with a fully deployed Smartlink system including all capabilities through Phase 3. The descriptions are in story format and follow the same story from the perspective of each player in the story. The intent of an operational scenario is to provide a clear example of what it will be like to experience Smartlink. The names of the centers and field devices are fiction although the area the scenario takes place in is not. Figure 6-1 is a map of the scenario showing an over turned truck one quarter of a mile before I-440 Exit 3.

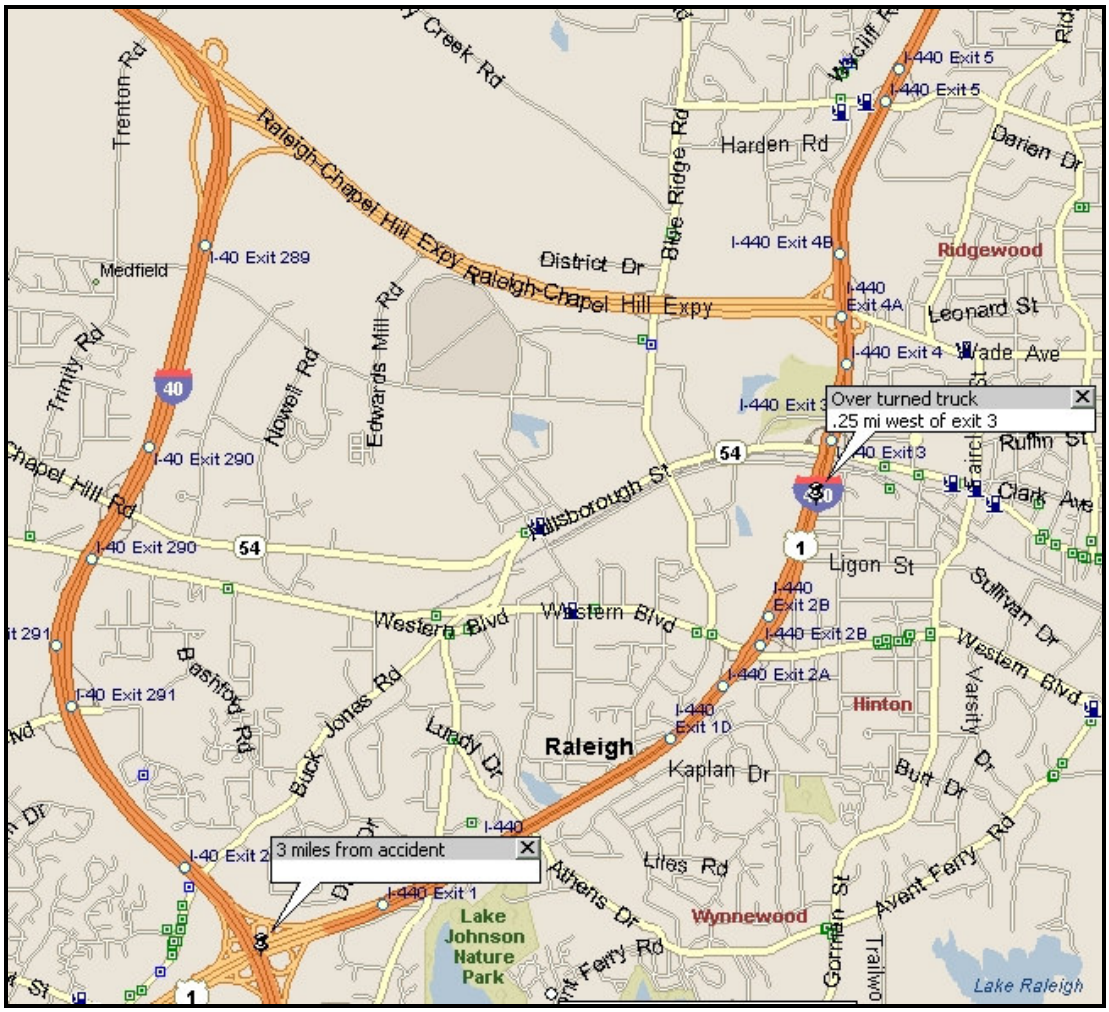

Figure 6-1 Location of Truck Crash

6.1 Smartlink Operator's Experience

Time: 0600 Monday September 7th 2009.
Place: Smartlink Regional Transportation Management Center-Raleigh.

The TMC operator reports for his shift and settles in behind the two 25-inch computer screens with his cup of coffee and clicks on the Smartlink icon on the display to his left. A Smartlink

log-in screen appears for the operator to log-in. Within seconds a map of the Raleigh area appears on the screen and the operator is given the choice to change what Smartlink subsystems load at startup. The operator chooses not to change anything and Smartlink subsystems begin to load. The computer screen on the operator's right displays the status of each subsystem as it is being loaded. Within seconds DMS, CCTV, IMAP Dispatch, RWIS and other subsystems are loaded and ready for use. The last subsystem to load is the traffic sensors and, as they complete their loading, the Smartlink map displays color bars indicating traffic speeds on the segments of I-440, I-40 and I-540. All the segments appear green indicating traffic speeds at or faster than the posted speed limit.

The operator looks at the video wall in the RTMC and can see that not all displays cubes have an image so he selects Video Wall Control from the Smartlink drop-down menu, a small graphic showing the video wall divided into display squares that correspond to the physical wall display in front of the operator. He selects a camera icon on the GUI map and drags it over to the Video Wall screen and drops it into a square that has no image on it. Almost instantly the video from the camera appears on the video wall at the same location. Next the operator selects the menu option to create a schedule of CCTV camera positions so a set of cameras that follow a prescribed pan-tilt-zoom sequence can be displayed on the video wall. The operator selects camera I440EB001, I440EB023, I440WB010 and RCHWB010 to be a part of the scheduled video tour and moves those CCTV icons to places on the video wall. He sets the initial position for each camera and, in 30 second intervals, designates more positions for each camera. After five minutes worth of entries he activates the CCTV schedule. On the video wall, each camera image appears and after 30 seconds changes position to show a new scene. He remembers to update the sunset schedule for some of the cameras so they avoid pointing at the setting sun in the late afternoon during peak drive time.

At 0630 the operator is getting up to get another cup of coffee when he hears a beeping tone from his console. He turns to see an incident alert icon displayed on the GUI map that is a flashing question mark located about a quarter mile to the left of Exit 3 where Hillsborough Street intersects I-440. He also notices that a nearby CCTV icon has a flashing circle around it. He right clicks on the icon and selects to view the image from that camera on his operator workstation. A still picture appears on the workstation showing a tractor-trailer truck on its side blocking all of the middle lane and parts of the lanes on either side. It looks like traffic is starting to back up at the scene. Checking the video wall, he notices that none of the displays have the camera he is looking at so he again opens the video wall menu from the top of the Smartlink display and drags the CCTV icon to the largest display square on the video wall. He now sees full motion video displayed on the video wall of the over turned truck.

The I-440 inner loop lanes are showing red on the Smartlink map expanding to the southwest as yellow and then green about 2 miles from the incident. The operator clicks on the question mark icon thereby taking ownership of the incident and an incident management screen appears on the right hand display of the workstation. The operator notices that a lot of information is already filled in such as the location, the operator's name, the main road name (I-440 IL) the nearest intersection (1/4 mile before Exit 3 on I-440), the time of day and date. The operator quickly clicks the "confirm" box and enters information about the type of accident (over-turned truck), the severity (high) and how many lanes are blocked (3). Next he clicks the box asking for a response plan and within 20 seconds a list of DMS signs are

displayed with a preformatted message on each that reads "Overturned Truck Middle Lane Traffic Stopped Ahead." The signs further away from the incident have messages indicating how miles ahead the incident occurred. The operator looks at the plan and decides to add to the list a sign located on the eastbound Raleigh Chapel Hill Expressway two miles north of the I-440 interchange. Because the severity of the incident is indicated to be high, DMS signs are selected many miles away to give motorist plenty of advanced warning. The operator approves the plan by clicking on "Activate" and the messages appear on the selected signs within 30 seconds. The operator verifies that the messages are being displayed by choosing a CCTV camera near one of the signs, places the camera image on the video wall and, using the virtual joystick control in Smartlink, he positions the camera to look at the DMS so he can verify that the sign is showing the response plan message.

So by 0635, the operator has implemented a response plan to warn drivers of the incident but now he has to get to work getting the lanes cleared. The Smartlink incident record screen has an option to list the names of responders and their resources based on the location of the incident. The operator opens up the list and sees he has a list of five people and/or companies in the immediate area and sends them an e-mail and fax alert of the incident by just selecting their names, associating the current incident with the name and clicking the box that says "notify".

He then notices an IMAP vehicle on duty about a mile away on Western Boulevard near I-440. He clicks on the vehicle icon and sees that the vehicle has not been dispatched and is showing its status as "gas stop" and that it is available. Using the IMAP Dispatch screen selected from a drop down list in Smartlink, the operator composes a brief text message to send the driver of the truck to the scene of the accident on I-440. He clicks send and the text message and some incident location details from Smartlink appear on the driver's in-vehicle mobile data terminal. The driver presses acknowledge and a confirmation message appears on the Smartlink display. At the same time the IMAP vehicle is associated with the incident record by Smartlink in the Incident Management screen. The IMAP vehicle is indicated to have been dispatched to the scene at 0636.

At 0640 another incident icon appears at about the same place as the over turned truck incident icon. The operator clicks on the new icon and can see it originated from TIMS by way of the SHP. Most of the information is repetitive except it also states that there are only minor injuries and an ambulance has been dispatched to the scene. The operator transfers this information to his Incident Management screen and deletes the TIMS originated icon.

At 0644 the operator watches the video wall show the arrival of the SHP on scene and updates the incident record to indicate the arrival time. A few minutes later the IMAP truck makes it way through the traffic jam and a message is received from the truck indicating it arrived on scene. This message causes the IMAP arrival time to be recorded in the Smartlink incident record.

By now it is 0700 and Smartlink is showing all the lanes on I-440 inner loop southwest of Exit 3 as red up to the I-40 interchange at Exit 1. At that time a message is received from the IMAP vehicle on scene indicating that all lanes of I-440 inner loop are closed by the SHP from Exit 1 to Exit 3. The operator calls up the response plan and modifies it to indicate that all lanes are closed and that a detour is in place to route traffic off the inner loop of I-440 at I-

40 north to the Raleigh-Chapel Hill Expressway back to I-440. The operator activates the new plan but almost immediately a warning comes back stating the message contains words that are not on the approved list in the DMS message library. He quickly looks over at his supervisor who has been following the events and gets a nod of the head from her. By the time he looks again at his Smartlink display he sees the messages have been approved for release. He then sends them and within seconds the new messages appear on the signs, the operator also includes HAR units in the plan so drivers can tune their radio to the highway advisory radio frequency and hear about the detour. At the same time TIMS is getting the updated incident information from Smartlink so the same information is made available on the 511 traveler information system and public web sites.

At 0715 the operator notices that the icon for DMS I440WB010 has turned red and there is an alert message indicating a problem with the sign. He right clicks on the red icon and a small window appears showing the current message, the status of the sign as failed and has few buttons to select more detailed information. He selects "detailed status" and in a few moments a list of diagnostics is returned indicating that the internal temperature of the DMS has exceeded 130 degrees and that a fan has failed. He changes the status of the DMS from failed to off line and then clicks on the button "notify" and the status of the DMS is sent to the Division 5 maintenance personnel in Durham by e-mail. He then selects a sign further east that is not a part of the current response plan and drags it over to the current response plan and selects the option to create a new response plan. Within 20 seconds a new plan is generated that includes DMS I440WB011 and has dropped DMS I440WB010 since it is now off line.

By 0800 two tow trucks have arrived and clear the truck from the traffic lanes. The IMAP crew assists in cleaning the debris from the roadway and by 0815 all lanes are clear. The operator cancels the incident response plan and the signs revert to the default messages they are programmed to display when no urgent messages are needed. The DMS around the I-440 loop display travel time message and initially they are showing significant delays since their last known data was from the traffic jam due to the accident. The operator blanks the signs that are showing significant delays since the lanes are clear now and when the travel times are accurately reflecting the traffic flow the operator turns the signs back on.

Taking one last look at the Smartlink map and seeing no further problems, the operator gets up to get a fresh cup of coffee.

6.2 A Smartlink Supervisor's Experience

Time: 0630 Monday September 7th 2009.
Place: Smartlink Regional Transportation Management Center Raleigh.

The shift supervisor arrives and conducts a turnover with the outgoing shift supervisor. She then settles into her supervisor's console that is nearly identical in setup as the operators but is behind the operator's workstations and slightly higher. Almost immediately she notices the incident icon alert pop up and sees that it is quickly owned by the operator to her right front. She checks the video wall and sees that a camera is already pointing at the crash site and that traffic is backing up. She calls up the incident record and can follow along as the operator working the crash generates and approves a response plan. She can see that all the procedures are being followed and there is no need for her to get involved. Out of curiosity she decides to

look upstream of the incident on the outer loop side of I-440 to see what impact there is to traffic westbound. According to her Smartlink map the camera she would like to use is a part of a CCTV schedule that is positioning cameras according to an operator defined schedule. She clicks on the camera anyway since she has supervisor privileges and takes control of the camera locking it to her station. She then turns the camera to point east bound and surveys the traffic which appears to be traveling well above the posted speed limit. This concerns her since as soon as the drivers get around the next bend they will see the crash on the inner loop and start to slow down, perhaps too fast for the drivers following behind them. Not wanting any secondary crashes she selects DMS I440WB015 and I440WB020 and selects a message from the DMS message library that reads:

She then changes the "X" to 5 miles on DMS I440WB020 and to 2 miles on DMS I440WB015 and sends the messages to the signs. That should warn the drivers to slow down and avoid any rear end crashes caused by drivers looking at the crash in the opposite lanes.

A few minutes later she saw an alert that a message was created that contained a word not in the approved list of words in the DMS library. She could see that it was related to the over turned truck on the inner loop of I-440. About the time she noticed the alert she saw the operator to her right turn and look at her to approve the wording. The operator was abbreviating some words to fit in one phase of the sign and one of them wasn't in the library. She saw that he was using "CLSD" for "CLOSED" and felt that it was appropriate and would not cause any misunderstanding so she approved it and nodded to him that she had taken care of it. He turned back and sent the approved response plan.

She next sent an e-mail message to the Smartlink system administrator to add the abbreviation "CLSD" to the approved list in the DMS library.

6.3 A Raleigh Driver's Experience

Time: 0655 Monday September 7th 2009.
Place: East bound US 1/US 64, quarter mile east of I-40/I-440.

The driver of the Ford Escape noticed a message on a sign over the freeway that read:

Traffic was slowing down and appeared to be getting congested ahead so the driver picked up his cell phone and dialed 511 for traveler information. When prompted by the 511 audio menu, he said "Highways" and then said "Interstate 440 Inner Loop". In a few moments he heard that "Over-turned truck, on Interstate 440 inner loop, a quarter mile before Exit 3 Hillsborough Street. All lanes closed 2 miles west of Exit 3 Hillsborough Street. Expect stopped traffic."

After about 15 seconds he noticed a second message appear on the sign that read:

RCMD EXIT 1 N
TAKE I-40NB TO
RCH EB TO I-440

So the driver knew to take the upcoming exit to the north and take the Raleigh-Chapel Expressway around the accident. After another 15 seconds the message changed again to read:

I-40NB TO
RCH EB TO I-440
6 MILES 6-8 MIN

So he knew that it would only take about 8 minutes to circumnavigate the accident ahead. He smiled and was grateful that the NCDOT has been a big help in getting him to work on time by avoiding trouble spots on his commute this day. As he merged into the right lane to exit he noticed the message sequence repeating on the sign for other drivers.

6.4 IMAP Driver's Experience

Time: 0615 Monday September 7th 2009.
Place: Shell gas station Western Boulevard.

The driver of the IMAP vehicle just finished filling up the truck and was settling in behind the wheel when he noticed a message appear on his mobile data terminal (MDT) in the cab. The three line message was a dispatch message telling him of an over-turned truck a quarter mile before Exit 3 on the inner loop of I-440. He pressed the accept button on the MDT and turned his yellow flashers on and headed for the entrance to the inner loop of I-440. As he drove he picked up his radio and called the SHP dispatch to see what they knew and was informed that an ambulance and two trucks were heading to the scene and that an SHP had just arrived on scene. All the lanes were blocked with stalled cars as he came upon the entrance ramp but he saw he could get to the left shoulder so he proceeded slowly towards the accident site. About 100 yards out he noticed the SHP officer setting up flares and trying to direct traffic around the over turned truck on the south side of the road. The driver stopped near the scene and pressed the arrival button on the MDT which logged his arrival time back in Smartlink at the Raleigh TMC. He checked in with the SHP officer and was told to set cones up to direct traffic off the road around the accident. A second SHP officer radioed in and was told by the first officer to close the inner loop at Exit 2 and direct traffic off at that exit. The IMAP driver returned to his vehicle and typed a brief text message informing the TMC that the road was being closed at Exit 2 by the SHP. As he got back out and started retrieving traffic cones from the back of the truck he noticed the DMS over head had changed its message telling everyone that the road was now closed and to take a detour. He marveled at how quickly the system was responding thinking it must be that new Smartlink software they installed last year.

By 0720 all lanes were cleared of traffic back to Exit 2, the two trucks were righting the tractor trailer truck and the ambulance had driven the driver of the truck who appeared to have minor injuries to the hospital. NCDOT maintenance crews had arrived on scene to clean up the debris so the driver returned to his truck to see another dispatch message appear on his MDT. A driver was stalled about a half mile before Exit 2 and needed assistance. The driver hopped back in the truck and pressed the "Depart" button signaling he was leaving the truck incident and then pressed the "Accept" button to take on the next assignment.

6.5 Maintenance Personnel Experience

Time: 0800 Monday September 7th 2009.
Place: Division 5 Offices in Durham

The duty technician walked over to the computer terminal and brought up Smartlink to see if anything new was posted on the Maintenance Management software. When Smartlink opened it displayed the Maintenance Management Module (M^3) main screen according to the preferences established by the local IT offices. He saw an alert that DMS I440WB010 had failed at 0715 today and he clicked on it to get the details. He saw that a fan had failed in the unit and the sign had shut itself off to prevent damage to the electronics as the internal temperature rose. He checked the inventory of spares using the Smartlink M^3 software and saw that a spare fan was available in Durham so he changed the status of the sign to "In-Repair" from "Failed" and assigned the repair to one of the technicians on duty that morning. By 10 o'clock that morning the technician had replaced the fan in the field and sent a message back to Smartlink using the MDT in the maintenance truck to indicate the sign was repaired. Smartlink M^3 automatically changed the status from "In-Repair" to "Repaired" and noted the time.

Back at the RTMC the supervisor noticed the DMS icon change from red to green indicating it was available. She then clicked on it and brought it on-line by clicking the status box and selecting "on-line". The sign was now available for any operator to post messages on.

6.6 Manager's Experience

Time: 1630 Monday September 7th 2009.
Place: Smartlink Regional Transportation Management Center-Raleigh.

It was nearing the end of the day for the operations manager of the Raleigh TMC and she wanted to review what happened that day at the center. She opened up the secure Smartlink web site using the browser on the computer in her office and selected reports from the drop down menu. She selected "Incidents" and selected a time span for the day to be from 0001 to 1630 which was from midnight to the current time. In a few seconds a report was displayed listing the events of the day by timeline starting with the over turned truck at 6:30 that morning. She clicked on that incident and saw a detailed time line indicating when the incident was first entered into Smartlink and who entered it. She was pleased that her operator confirmed the incident within one minute of it being posted and that a response plan was generated and activated within two minutes of the crash occurring. Also noted was that an IMAP was dispatched to assist at the scene three minutes after the incident was initially

detected. She smiled to herself pleased that the team worked so well with the new Smartlink software to respond quickly to a major incident like the over turned tractor trailer truck.

She next selected the M^3 menu to review the status of the field devices in her Division and saw where a sign had failed at 7:30 that morning and was back in operation by 10:15 AM. She thought that Division 5 had done a good job that day and shut down the computer and prepared to leave for home knowing that Smartlink would send her an alert on her PDA if anything critical happened during the off hours. Besides she could also use her home computer to access the secure web site at anytime to see what was happening.

She turned off the lights and closed the door to her office at 5:30 that evening and left satisfied that everything was running smoothly in large part due to the integrated Smartlink software system and her well trained staff.

7. Summary of Impacts

This section describes and summarizes the operational impacts of the proposed Smartlink system from NCDOT's perspective.

The biggest operational impact will be in transitioning from the legacy systems to the integrated Smartlink system and then deploying it statewide. An integrated ATMS software package tends to drive operational procedures so the deployment of Smartlink statewide will result in standardization of operational procedures and the collection of uniform performance measures.

To ease the transition between Smartlink and older systems, a single site will be selected to serve as the prototype installation. Because milestone demonstrations of Smartlink functionality had been conducted during development, the ability for Smartlink to operate at the site will have already been demonstrated before final acceptance. Cut over from the old systems to the Smartlink can take place by operational areas in a region to further mitigate the stress of transition. For example, Smartlink could take over control of the ITS field devices in a section of Raleigh while the legacy systems continued to manage the field devices in other parts of the City. It is expected the legacy systems will be maintained for a few months after Smartlink is operational in case of any major problems.

Since Smartlink is specified to use standard interfaces such as NTCIP Center-to-Field and TMDD Center to Center communication protocols, new ITS field equipment can be installed that will work immediately with Smartlink and over time the non-compliant devices can be replaced.

All the ITS field devices are integrated through Smartlink so the system's diagnostic software will identify failures and alert maintenance personnel automatically when there is a failure. In Phase 3, Smartlink will provide a software module for tracking ITS device inventory and facilitating repair of failed field devices. The automated diagnostic capabilities of Smartlink will help streamline maintenance processes and reduce the workload needed to track ITS device status and reduce paperwork.

After the initial installation, subsequent deployments of Smartlink are expected to be at one site every two to three weeks. Training of operators and managers should take place before installation so it would help if NCDOT designated a Smartlink site to serve as a training center and had a spare set of equipment that could be devoted to training. This can be accomplished by requiring the vendor to develop a Smartlink test bed at a central NCDOT facility that can be used to verify new software meets the system requirements, to test ITS field devices before installation in the field and to conduct training. The test bed would need a sample set of ITS field devices and data simulators so an operational environment can be created for training or testing purposes.

During system development NCDOT personnel will be asked to review and comment on a number of technical documents. Key personnel will be asked to participate in a technical advisory board and, later, representatives from each Smartlink site will be asked to participate in a Change Management Board that will review any proposed changes to Smartlink and approve them

CONOPS APPENDIX A
Definitions, Acronyms, and Abbreviations

ATIS ..... Advanced Traveler Information System
ATMS ..... Advanced Transportation Management System
AVL ..... Automatic Vehicle Location
CAD ..... Computer Aided Dispatch
CCTV ..... Closed Circuit TeleVision
C2C ..... Center-to-Center
DMS ..... Dynamic Message Sign
EIC ..... Emergency Information Center
GIS ..... Geographic Information System
GUI ..... Graphical User Interface
HAR ..... Highway Advisory Radio
ID ..... Identification
IDI ..... Intelligent Devices Incorporated
IMAP ..... Incident Management Assistance Patrols
IP ..... Internet Protocol
IVR ..... Interactive Voice Response
IV&V ..... Independent Verification and Validation
LAN ..... Local Area Network
MDT ..... Mobile Data Terminal
NCDOT ..... North Carolina Department of Transportation
PC ..... Personal Computer
PDA ..... Personal Digital Assistant
PTZ ..... Pan-Tilt-Zoom
RAID ..... Redundant Array of Independent Disks
RAM ..... Random Access Memory
RWIS ..... Road Weather Information System
SHP ..... State (North Carolina) Highway Patrol
TCP/IP ..... Transmission Control Protocol/Internet Protocol
TIMS ..... Traveler Information Management System
TMDD ..... Transportation Management Data Dictionary
UTC ..... Universal Time Code

VPN.....Virtual Private Network
WAN.....Wide Area Network
XML.....Extensible Markup Language