DMS Upgrade and Expansion Program
Concept of Operations

Version 1.1
February 25, 2008

Prepared for

VDOT

Virginia Department of Transportation
Northern Region Operations

By

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Revision History

Version 0.3, October 31, 2007
Initial working draft without stakeholder input

Version 0.4, January 25, 2008
First completed draft, including stakeholder input, for VDOT review.

Version 1.0, February 19, 2008
Added sections on project architecture, revised name of TMC, and editorial revisions.

Version 1.1, February 25, 2008
Added this revision history.

Version 1.2, April 18, 2008
Referenced Appendix 3 in Table of Contents

1. Scope

1.1. Identification

This Concept of Operations describes user needs for the upgrade, relocation, and expansion of VDOT NRO dynamic message signs.

1.2. Concept of Operations Role within the Systems Engineering Process

Within the systems engineering process, the Concept of Operations describes what the users of the system will do. The ConOps is the first document in the systems engineering process, and is followed by requirements documents, design documents, and various verification and testing documents. Thus, the purpose of the ConOps is not to describe the system, but rather to describe the agency using the system. This description will support the development of requirements that are traced directly to those activities, to ensure that the system will support those activities.

This document will be used to describe user needs regarding dynamic messages signs, including their location and purpose. Maintenance needs and activities are also described. These needs will lead to requirements for sign location, size, general design, and maintenance to support VDOT's activities.

This document also includes a high-level requirements document in the Appendix. These requirements are traced directly to the needs described herein and that traceability is documented in a requirements traceability matrix. These high-level requirements are used to evaluate a master plan for DMS upgrade and expansion, which is also included as an appendix. The appendix also includes a Validation Plan, which will demonstrate that the replaced and new signs will support the documented activities of VDOT as described herein.

The purpose of the Validation Plan is to demonstrate that signs support the operations and maintenance activities of VDOT. As distinct from validation, test documents will be developed later in the design process that will demonstrate that specific sign implementation projects fulfill the requirements and conform to the design documents. This demonstration is called *verification* in the systems engineering process.

1.3. System Overview

Dynamic Message Signs are a direct information link between VDOT and the traveling public. DMS convey information about prevailing traffic conditions and can influence driver behavior, route choice decisions and overall transportation network efficiency.

DMS are arguably the most visible of all Intelligent Transportation Systems (ITS) field devices. Consequently, credibility with the public can easily be compromised if sign messages are untimely or inaccurate. Considering the current state of installed DMS, it is imperative that these assets be upgraded and/or relocated so that the critical mission of conveying information to the traveling public can be accomplished.

VDOT currently operates nearly two hundred dynamic message signs on area facilities, controlled by a variety of systems including the ASSIST software at the Traffic Management Center (TMC). These signs are used to provide motorist information in support of a variety of activities, including incident management, motorists information for routine and exception congestion, motorist information concerning work zones, and other specific motorist information events (e.g. Amber Alerts). The operation of DMS devices in the NOVA TMC face a variety of challenges, including:

1. Sign aging, leading to unmaintainability and unrepairable fault conditions
2. System integration, where control systems cannot operate all signs under all conditions
3. Expansion, where new DMS devices are being built as part of new major roadway projects
4. Expansion, where additional DMS devices will be installed as part of new major ITS projects

1.4. Goals and Objectives

The following goals have been identified in the Northern Region Operations Smart Travel Strategic Plan:

1) Goal 2: Enhance Mobility – Operate the Transportation System Effectively and Efficiently
    a) Maximize the use of the transportation system capacity to move traffic.
    b) Proactively monitor and assess the condition of the freeway, primary and secondary road system in real time.
2) Goal 2: Enhance Mobility – Expand ITS Infrastructure to Enable Corridor Management
    a) Expand the geographic coverage of ITS infrastructure on the arterial and freeway transportation system.
3) Goal 3: Make the Transportation System User Friendly – Support Traveler Information Services
    a) Improve network information dissemination.
    b) In cooperation with other agencies, increase the speed at which incidents are identified and communicated to travelers so that they can modify their travel plans as appropriate.

All of these goals imply four goals for implementation of dynamic message signs. They are:

1. Goal 1, Effective sign location. The sign must be located to fulfill the requirements of the various motorist information strategies.
2. Goal 2, Appropriate sign operation. Stakeholders must be able to operate the signs timely consistent with the various motorist information strategies.
3. Goal 3, Sign infrastructure versatility. As the communications network and central systems change, the communications and control environment for the signs will also change. Stakeholders must be able to operate the signs through these changes in the infrastructure environment.
4. Goal 4, Sign maintainability. If the signs cannot be maintained in an operational status, then no operational objectives can be fulfilled.

These four DMS goals lead to specific stakeholder needs, which in turn lead to specific requirements that can be used to drive the development of plans and specifications for signs implemented in new locations or to replace existing signs.

1.5. Vision for the System

The NOVA Smart Travel Program Plan envisions that:

> *"Intelligent Transportation Systems make travel "smart" through technology, as well as through automated, streamlined agency processes and procedures."*

NOVA Smart Travel is geared toward providing better services to NOVA customers by improving the quality of their travel and responding promptly to their issues. The focus is on attaining operating efficiencies from the existing roadway infrastructure as a compliment or alternative to building additional capacity. The NOVA Smart Travel Vision is as follows:

> *"Integrated deployment of Intelligent Transportation Systems will help NOVA optimize its services, supporting a secure multimodal transportation system that improves quality of life and customer satisfaction by ensuring a safer and less congested transportation network."*

The supporting vision for dynamic message sign operations must support the overall vision. In order to provide this support, the vision for DMS operations is suggested as:

> *Dynamic messages signs within the Northern Regional Operations of VDOT will provide timely and useful information to the motoring public by being located to fulfill operational objectives, achieving and maintaining full integration with existing and future control systems, and by achieving and maintaining high reliability.*

2. Referenced Documents

ATMS Concept of Operations for the statewide Advanced Traffic Management System, Version 0.7, January, 2007

DMS Work Plan, 2007 (draft)

NOVA Smart Travel Program Plan Update, March, 2006

VDOT Changeable Message Sign Usage Policy, Draft of 5/6/2003

NEMA TS-4, Dynamic Message Signs with NTCIP Objects

ATMS Existing and Proposed Description Part of the Concept of Operations, Draft of January 14, 2008

2003 Manual on Uniform Traffic Control Devices, as amended, Federal Highway Administration, sections 2A.07 and 2E.21.

3. User-Oriented Operational Description

3.1. Description of Existing Situation

Existing DMS are controlled by ASSIST and also as part of the Statewide Variable Message System. Some signs are not integrated with ASSIST and are controlled by local laptop computers. Some signs are under the control of newer systems that are not integrated with ASSIST, such as the Woodrow Wilson Bridge System. The input systems providing information to be displayed vary widely, with little integration. As a result, the ATMS Concept of Operations suggests a new system approach to integrated source information to prevent having to enter information repeatedly. Thus, it is expected that the control environment for dynamic messages signs is variable according to different control systems both architecturally and over time.

The ATMS Concept of Operations also suggests that “inaccurate, untimely, and/or inconsistent information” is being “disseminated to the traveling public”. Congestion-inducing events are not cleared timely, lane closure signs are not correctly activated, HOV operations and messages are not displayed timely, and no availability of travel time data for display on the DMS in the absence of more important messages, as is required by Federal policy. Ineffective sign placement as the roadway network and travel patterns change may also be contributing to this condition.

To respond to these issues, the ATMS ConOps suggests the integration of native support for all field devices, including dynamic message signs, into a single operator interface, in addition to a range of other additional integrated management features. Again, the environment for DMS control is expected to be in a state of change for the foreseeable future.

The ATMS report *does not* discuss the effect on these objectives of the field performance of the signs themselves, including maintainability, versatility of field deployment, interoperability between systems as they are upgraded, and so on.

Of the 199 Dynamic Message Signs installed throughout the Northern Region Operations footprint, 97 were manufactured by Lake Technologies, a company that is no longer in business. The remaining 102 signs were manufactured by three different companies - Daktronics, Skyline and Mark IV. The Lake Technology signs are obsolete (were installed more than 25 years ago) and it is quite difficult to obtain replacement parts for failing components.

The signs that were manufactured by the other companies are not as old but will reach the end of their service lives within the next decade. In addition, there are 19 signs that cannot be controlled using the central software at the Traffic Management Center (TMC); a site visit is required to display messages on these signs. Aside from the issues associated with the current infrastructure, there are major roadways within the Region that lack DMS coverage.

Signs that are non-functional because of maintenance or architectural obsolescence cannot fulfill any operational objectives. This condition is widespread among the current DMS installed base in Northern Virginia.

3.2. Identification of Stakeholders, Roles and Responsibilities

ATMS operators will control the messaging going to the dynamic message signs. Their roles and responsibilities (and their parent stakeholders) are defined in the ATMS Concept of Operations.

VDOT maintenance technicians will perform emergency and preventive maintenance of the dynamic message signs and communications infrastructure.

3.3. Operational Sequence

The ATMS Concept of Operations defines sequences for DMS operation. All information requiring display on dynamic message signs is generated by the ATMS.

Basic device configurations and other standardized sequences are defined in NTCIP 1203, Objects for Dynamic Message Signs, maintained by the National Transportation Communications for ITS Protocol Joint Committee.

4. Operational Needs

The ATMS Concept of Operations has defined a series of use cases for operation of dynamic message signs. These use cases pertain to the controlling system, but define the interaction between the operators and the signs. Thus, they lay out the user needs that the signs must support.

A high priority for providing native support of all key devices in the region has been established as a basic goal for the new ATMS. Consequently, existing and new dynamic message signs will be subjected to a migration of central control software, which establishes a basic need for sign configurability to different system and communications architectures.

The use cases from the ATMS Concept of Operations that relate to DMS operation including the following:

- 6.3.1 Manage Traffic
    - Manage VMS Operations
- 6.3.2 Manage Incidents
    - 6.3.2.2 Manage Incident Response
        - Publish Incident Information (group of use cases, shown on Figure 5-4 of ATMS Concept of Operations)
        - 6.3.2.2.3 Control Reversible Flow Lane
- 6.3.3 Manage Information Dissemination
    - 6.3.3.1 Define a Message
    - 6.3.3.8 Public Travel Times
- 6.3.4 Manage Infrastructure
    - 6.3.4.1 Manage Infrastructure Administration
        - 6.3.4.1.1 Diagnose Communication Problems
        - 6.3.4.1.3 Manage Field Device Database
    - 6.3.4.2 Operate Infrastructure
        - 6.3.4.2.1 Detect Cabinet Access
        - 6.3.4.2.2 Detect Malfunction
        - 6.3.4.2.3 Monitor Device and Incident Status

        - 6.3.4.2.4 Monitor Devices
- 6.3.5 Manage Parking
    - 6.3.5.3 Public Parking Space Availability

The use cases above define the user needs for use of dynamic message signs. These needs fall into or imply four categories specific to the specification of new sign hardware. These are:

- Message Display Needs
- Maintainability Needs
- Integration and Configurability Needs
- Physical Construction Needs

Additionally, the purposes for which dynamic message signs are used will suggest optimal sign locations. Thus, sign location is an important need category that is infused in the four categories above.

Finally, physical construction needs play a role in the upgrade of existing signs.

4.1. Message Display Needs

4.1.1. Real-Time Message Display

The ATMS operator will display messages on dynamic message signs in accordance with the following real-time applications. The operator will formulate a message, enter it into the ATMS, engage the message, and then receive confirmation that the message was displayed.

- Blank display
- HOV Restrictions
- Incidents
- Construction and Maintenance Activities
- Adverse Weather, Environmental, and Roadway Conditions
- Other Traveler Information
- Special Events
- Messages for other Agencies
- Emergency Messages
- Ozone Alerts
- Safety Campaigns
- Tests

The process by which a message is displayed includes the following steps:

1. Choose sign (a preference for flexibility in assigning signs to various collections of signs within the database was expressed, though this affects ATMS software and not sign capabilities directly).
2. Choose stored or new message.
3. Set priority to provide the ability to override messages being displayed for less critical purposes, without removing those messages from the priority queue.
4. Engage the message.

5. Verify that the DMS displayed the message properly. Existing methods for verification ranged from the basic status report, to a specific “confirmation status”, to the use of CCTV. CCTV aimed at the sign was acknowledged as the only reliable verification method.

All of the above message purposes are intended to provide an immediate display of relevant information formulated in accordance with VDOT policy.

Dynamic message signs are classed by VDOT operators into three categories:

- Regulatory. These signs are used to control lane use and HOV restrictions on restricted roadways and lanes.
- Gate Control, used at entrances to HOV facilities to explain the restrictions in effect.
- Advisory, to provide general motorist information in accordance with the above purposes.

Any sign may be used for any purpose, though each sign is intended for a specific purpose for the majority of the time.

Advisory messages include up to four basic informational elements, including:

- Facility
- Direction
- Condition
- Location

For example, the following message includes these four elements:

DELAYS I-95 SOUTH
SPRINGFIELD
TO NEWINGTON

Gate control messages include a description of the restriction and the time the restrictions are in effect. The following is an example:

HOV-3 AND
MOTORCYCLES
M-F 6-9AM

The operators may display some portions of a message in a way to increase target value. VDOT generally does not use flashing displays for whole sign messages because they require motorists to stare at the sign, but they do desire to increase target value for some messages in cases of special need. For example, a sign message responding to a major security event might include the following

ALERT!
EMERGENCY RESTRICTIONS
TUNE TO AMXXX FOR INFO

In this case, the word “ALERT” might be set to flash in order to command attention from motorists.

To provide sufficient display area for these messages and to minimize the need for scrolling or paging, it is assumed that the DMS will need to support the following message display features for the above applications:

- Message width of 20 characters (for standard font)
- Three lines of text
- At least four fonts, including a built-in 5x7 single-line font and a 7x7 double-line font
- Flashing displays (character-by-character, word-by-word, and line-by-line)
- Up to two pages of message information cycled automatically in user-configured timing intervals.

Displaying a message on a DMS follows a process determined by the ATMS control software and procedures developed for system operators and maintenance technicians. From the perspective of the sign, the implementation of a message follows a sequence dictated by the central software's application of NTCIP 1203 objects and dialogs.

4.1.2. Scheduled Message Display

VDOT policy allows for the display of messages in real time to inform motorists about future conditions, such as work zones and special events. Additionally, the operators may choose to program the signs to display messages about these conditions before they occur, so that they will automatically be displayed at the appropriate time. In these cases, the operator will enter a sign message and associated information, and a start and end time for the message, into the sign using the ATMS control software. The sign will display the message at the scheduled time in the absence of a command to display a message with higher priority.

For example, signs used to control access to the HOV facilities display a daily schedule of messages. An HOV clearance message is implemented over a user-defined set of signs 30 minutes before the HOV restriction goes into effect, at which time the restriction message is displayed. For some incidents, however, some HOV control signs may be retasked to display incident information. At the time the incident information is no longer needed, the operator will clear the incident-related message, and expect the sign to return to the normal HOV operational message for that time of day. Further, the operators expect the HOV messages to be displayed routinely without requiring functioning communications at the time the messages are implemented.

4.1.3. Travel Time

Federal policy requires that new dynamic message signs installed with Federal funds must provide an active display at all times. The policy is based on the perception that routinely blank signs do not appear to provide value to motorists, and signs with static displays (including a blank display) tend to undermine the target value of the sign when an important message is being displayed. Thus, the policy states that agencies should demonstrate the ability to display travel times on dynamic message signs as the background default message in the absence of higher priority messages.

The location of the sign plays a role in the travel time measurement and reporting system. When a travel time to a downstream destination is determined, the motorist assumes that the travel time starts at the location of the sign. Thus, the travel time sensing system must be able to measure or estimate travel times from the sign location to the named downstream location.

The system operator must be able to invoke a system that will display travel times measured by the system on the signs, including a generally understandable name for a downstream destination, and the distance to that destination, to which the travel time is reported. For example, typical message content might look like this:

I-495
7 MILES
12-14 MIN

This content may also be displayed on two lines, leaving a third line to provide a synopsis of the prevailing conditions. The choices of conditions would be limited to routine operation. It is assumed that incident information would override the display of travel times in any case. For example:

CONGESTION
I-495
7 MILES 22-27 MIN

In order to comply with the intent of the policy, the travel time must be dynamically updated as traffic conditions dictate. Thus, a manually controlled travel time message display will not satisfy this user need.

4.1.4. Future Applications

Some ITS applications around the world make use of color and full-matrix displays, though these technologies have not been commonly deployed in North America. For example, the Tokyo freeway management system uses a simplified map display of the Tokyo expressway system, displayed on all large dynamic message signs. The graphical representation of the network shows green for free-flow conditions, yellow for reduced speeds, and red for congestion. With few exceptions, no text is provided, though a smaller, text-only DMS a few hundred feet downstream provide estimated travel times to a range of destination landmarks. These displays have been implemented using a range of technologies from bulb-matrix signs with colored bulbs to full-color, full-matrix LED signs. The use of displays such as this implies the ability to convey relevant information more effectively by using graphics than text. In the case of Tokyo, the system was intended to be effective for the many tourists visiting the city who were not literate in the Kanji script used on text-only displays in Japan.

These approaches are not anticipated for present use in the VDOT NRO.

4.1.5. Message Legibility

Motorists need to be able to read and understand the sign message starting at the maximum distance normally expected for visual acuity, based on the free-flow speed of traffic on the facility. The MUTCD requires that sign messages be fully readable at least twice by motorists approaching at the posted or free-flow speed.

Motorists also need to be able to read the message in all potential ambient lighting conditions, without the need for supplemental sign or roadway illumination. These conditions may range from complete darkness in rural areas, where an overly bright sign makes visibility of the roadway surface difficult, to bright sun shining on the face of the sign.

Motorists need to be able to read complicated messages in one or a series of brief glances.

Motorists need to be able to read and comprehend the sign message right up to the time when they can no longer see the sign face.

The MUTCD states a desirable letter size of 18 inches for DMS messages on freeways and expressways.

4.1.6. Status Reporting

The ATMS operator needs to know the current status of the sign, including the following:

- Current message being displayed
- Stored messages, including their associated schedules and priority
- Message schedules
- Environmental status, including temperature and ambient light
- Faults, including:
    - Excessive temperature
    - Fan faults
    - Pixel faults
    - General faults

4.1.7. Sign Location for Messaging

For all of the above user needs, the signs must be located such that their underlying mission is accomplished. In general, signs need to be located so that the condition being reported by the sign is close enough to be relevant to a reasonable percentage of the motorists, yet far enough so that the motorist can explore options such as the use of an alternate route.

In rural areas where significant portions of the motorists may be on the facility for long distances, the first condition above is rarely a concern. Most any downstream condition is relevant. Rural areas impose greater minimum distance, however, because alternatives for the motorists are both more scarce and require more time for the motorist to explore.

Motorists in rural areas will need sufficient time to consult a map, or consult the 511 service, before reaching any relevant decision points.

In urban areas, the distances are shorter. Motorists need sufficient time to note the sign message, determine an alternative, and position themselves to use that alternative before reaching the alternative decision point.

Decision points are disbursed throughout the network upstream from potential conditions that may be reported on a sign. Conditions that affect major portions of the roadway network must be reported upstream from decision points that bypass the affected portion of the network.

Finally, motorists need to be able to read the sign over its full range of legibility, which affects the location of signs with respect to horizontal and vertical curves, etc.

4.2. Maintainability Needs

VDOT performs two classes of maintenance activities on dynamic message signs: Preventive maintenance (PM) and emergency maintenance to correct an unexpected fault. Some categories of maintenance needs apply to one type of activity, while others apply to both.

4.2.1. Preventive Maintenance

Preventive maintenance is performed annually. Technicians will approach the DMS device in a repair van (no bucket capability) and will perform the PM at the sign location without support from the TMC. PM is performed during normal sign operation with only brief periods of removing the sign from system control for specific PM procedures.

The activities performed during preventive maintenance are:

- Clean clear face panel.
- Replace or clean filters for both ground cabinet and sign.
- Text pixels and sign display features to identify failed pixels or display features.
- Correct any noted sign faults.

4.2.2. Emergency Maintenance

Emergency maintenance technicians are dispatched to repair signs on the basis of failures reported by the control software in the TMC, by the media, by the Virginia state police, or other source generally communicated from TMC personnel to the maintenance dispatcher. The failures that may cause an emergency repair include:

- Communications failure. These failures are diagnosed from the sign location, and are corrected by the technician if possible. If they cannot be corrected, the sign is placed in local control, and a suitable message (including a blank display) is displayed by local control. Communications failures include the following possible causes:
    - Fiber damage from construction, water infiltration, or rodent attack.
    - Modem failure
    - Power failure
    - TMC communications equipment failure
- Equipment failure, which may be caused by pixel failure, control board failure, ground control failure, or some other cause. They may be corrected by blanking the sign or programming a suitable message in the absence of central control until the sign can be repaired.

In all failure situations, the technician will usually first blank the sign using an available blanking control in the ground cabinet. The technician may also perform a processor reset from the ground control cabinet, without the use of a laptop computer. The technician may display a temporary message using a laptop computer.

The priority ranking for repair is highest for HOV gate control signs.

Technicians frequently repair ground-control cabinets that have been knocked down due to vulnerable placement.

4.2.3. Reliability

The standard for reliability set in the ATMS Concept of Operations is 99.9%. This standard corresponds to maximum total system downtime of 88 hours per year. The effectiveness of the system needs signs that will not limit system reliability.

The signs need to function properly in all ambient conditions of temperature and humidity. Proper function includes a fully readable display without fogging, and an effective ventilation and moisture management approach.

The objective for reliability is to avoid any emergency maintenance requirement, and provide only preventive maintenance on an annual basis for an expected 10-year life of the sign. This objective implies a mean time between repair for items not needing routine maintenance of 100,000 hours (to provide approximately 10 years of full-time operation).

Items receiving routine maintenance include pixels, the front sign face, and ventilation filters. This implies sufficient filter design and air movement to prevent the need for servicing more often than every 10,000 hours of use.

4.2.4. Reparability

Technicians will need to repair signs in field conditions by replacing modules without the use of tools and without manipulating the software, other than to load new software or download a sign parameter database.

Technicians need to be able to effect a repair as soon as possible to avoid the repair activity having an effect on traffic management.

VDOT technicians perform board-level repair of DMS hardware rather than electronic component-level repair. When an electronic component on a circuit board fails, VDOT technicians troubleshoot to determine which board failed, and then return the faulty board to the manufacturer for repair. VDOT’s mechanism for paying for these repairs is limited, and the use of extended warranties is preferred.

The expected field-serviceable lifespan of the signs is 10 years.

4.2.5. Maintenance Diagnostics

Technicians need to be able to diagnose sign faults as completely as possible from their shop location, or in consultation with ATMS operators.

4.2.6. Sign Location for Maintenance

Field technicians need to be able to effect maintenance and repair on the sign in all weather conditions without closing any lanes of the facility to traffic. Technicians need to be able to park maintenance vehicles safely with reasonable access to the sign, ground control cabinet, and all pull boxes for maintenance, without closing lanes and without deploying extensive work zone traffic management. Maintenance vehicles do not include buckets or lifts, and therefore need to access signs using secure access from the ground for technicians in accordance with state and federal worker safety requirements.

4.3. Integration and Configurability Needs

4.3.1. Operational Configuration

The ATMS Operator or the maintenance technician needs to be able to configure the sign for operation that supports all the purposes and activities defined in this document, which includes the needs identified in the ATMS Concept of Operations

4.3.2. Communications Versatility

Installers and technicians need to be able to configure the signs for operation on a wide range of communications infrastructure options, including:

- Dial-up telephone lines
- Local serial or Ethernet connection
- Leased telephone lines
- Multiplexed serial communications on existing fiber
- IP-based communications on existing fiber
- IP-based communications on new VDOT fiber ring

4.3.3. Interface Needs

The ATMS system needs to communicate with the dynamic message signs using standardized sequences as included in NTCIP 1203. The signs must conform to the standard such that they can be integrated into the ATMS software by using user-accessible configuration tools only.

4.3.4. Control System Versatility

Initially, existing signs will continue to be managed by ASSIST DMS Control Module and new signs will be controlled by TMC operators via device firmware. Ultimately all signs will be controlled by new ATMS Central Software DMS Control Module.

4.4. Physical Construction Needs

4.4.1. Existing Structure Compatibility

Some signs will be installed on existing structures to replace existing signs. The signs for these locations need to fall within the weight and size envelope allowed by existing structures, or if that is not possible, the structures need to be modified or replaced. The signs further need to provide mountings that can be mated to existing structures. However, some existing signs are too small to serve the purpose for which they are intended, and in these cases, the structure should be replaced as necessary to support a sign that fulfills all requirements.

4.4.2. Positioning

Motorists need to be able to see and understand the message being displayed within view of the face of the sign. VDOT needs to position the signs such that this visibility is achieved.

4.4.3. Roadway Appurtenance Clear Zone

The signs must be located outside the clear zone, or protected by guard rail, in accordance with current VDOT policy for maintaining a clear zone.

5. System Overview

5.1.1. DMS Subsystem

The DMS subsystem relates to the ATMS system directly. No subsystems related directly to the DMS subsystem. DMS devices are used in most ATMS systems applications that require motorist information.

5.1.1.1. Equipment Locations

Equipment locations within NRO will satisfy the messaging, maintenance and physical construction needs outlined above.

5.1.1.2. Communications

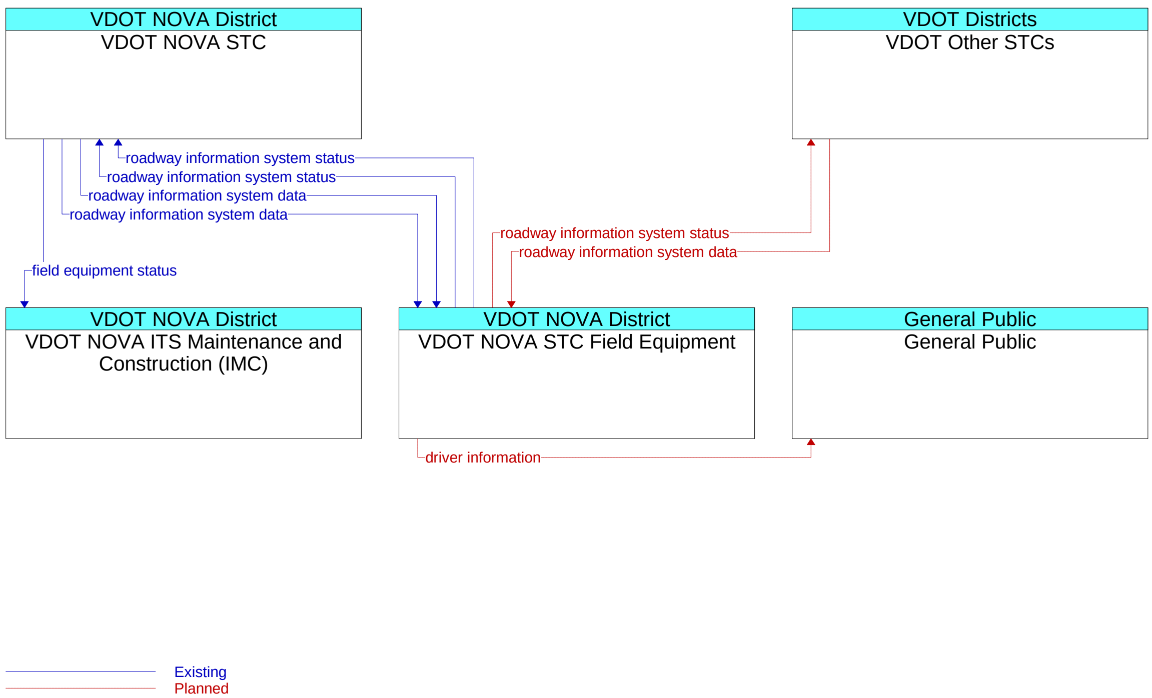
The DMS devices will communicate with the ATMS using existing leased or fiber communications, but must be able to migrate to the ultimate VDOT IP-based fiber ring.

5.1.1.3. Software

The DMS devices will communicate with the ATMS and with maintenance equipment on site, using standard protocols sufficient to support all the activities that relate to dynamic message signs.

5.1.1.4. System Architecture, High Level Requirements, and ITS Standards

The diagram below shows the architecture flows, elements, and stakeholders associated with the DMS Upgrade and Expansion program. These were derived from the current VDOT NOVA District Regional Architecture, Version 2.1, dated December 20, 2005. Flows are shown that affect the interface of the signs to the system, not that affect the information gathered that will be displayed on the signs.



Project Architecture, DMS Upgrade and Expansion (from Regional Architecture)

Various standards cover the information gathering process, including, for example, the "Field Device Status" flow shown above. For the acquisition and installation of field devices only, however, only the standards relevant to communicating with those field devices will be relevant to this project. These are part of the NTCIP Center-to-Field Standards Group in the Regional Architecture. These standards include:

Standard Designation	Title	Revision Date
1201	NTCIP Global Object Definitions (GO)	V02.31, March, 2005
1203	NTCIP Object Definitions for Dynamic Message Signs (DMS)	V02, March 2007 (Recommended Standard).
2201	NTCIP TP-Transportation Transport Profile	V01, March 2003
2101	NTCIP SP-PMPP/RS232	V01.17, May, 2001
2103	NTCIP SP-PPP/RS232	V02, 2103:2005, July 2006
2104	NTCIP SP-Ethernet	V01.11, 2104:2003, September 2005

The last four standards in the table above pertain to the interface to the communications infrastructure. Signs must be configured to support these standards to be implementable on the range of potential communications infrastructures in use during the course of the program.

5.1.1.5. Other Projects

Other projects that may affect installation and upgrade of dynamic message signs include:

- Capital Beltway HOT Lanes
- I-95/I-395 HOT Lanes
- Dulles Rail Extension
- US-50 Improvement Project
- I-66 Spot Improvements

NOTE: This is not an exhaustive list.

6. Operational and Support Environment

6.1. Personnel

NRO Planning Staff and SE staff will plan and design the project. NRO OIC will procure and install the project. NRO IMC will maintain the project. Some design of the sign may be delegated to the contractor with SE oversight. If decided to use a design-build contract, then SE & OIC will provide oversight.

6.1.1. Staffing Requirements

6.1.1.1. Operations

Operations staff currently include 28 people, generally divided into two shifts per day and two sets of shifts each week to provide operation 24 hours a day, seven days a week.

The impact of expanding the DMS operation will be expected to scale linearly, though some benefit from more efficient use new signs replacing unreliable signs will improve productivity. Many of the signs will be used in place of existing signs, and will not increase staffing requirements.

6.1.1.2. Maintenance

Replacing existing unreliable signs is expected to reduce maintenance requirements for the signs being replaced. New signs will increase maintenance staffing needs linearly for preventive maintenance, but are expected not to significantly increase staffing levels for emergency maintenance.

6.1.1.3. Integration

Improved integration features within the new signs are expected to reduce integration staffing requirements, though increasing the size of the sign fleet will increase the requirements. It is expected that only the initial implementation will impact integration staffing requirements.

6.2. Facilities

Devices will include existing sites and new high-priority sites to be identified.

6.3. Hardware and Software

Existing software conforms to NTCIP 1203 Version 1, and Version 2 is expected to be implemented in the industry during the period of this project. DMS devices will initially be operated under existing systems, and then under the new ATMS as it becomes available. Some signs may be directly implementable under the new ATMS.

Existing hardware that is not repairable will be replaced.

6.4. Operating Procedures

Standard Operating Procedures as currently followed for DMS Control by TMC operators will be followed.

6.5. Maintenance

Devices will be incorporated into NRO IMCs regular maintenance schedule. For new devices, the manufacturer will provide maintenance during the warranty period.

7. Operational Scenarios

7.1. ATMS Sign Control

Operation of the dynamic message signs will be initiated by the ATMS Operator according to the TMC operational policies. Messages will be displayed in support of use cases identified in the ATMS Concept of Operations, in support of the following activities:

7.1.1. Incidents

The ATMS Operator will direct the ATMS to display a message associated with an incident response plan. The directive will be communicated by the ATMS to the DMS via the communications infrastructure. The sign will display the message, and provide status reports back to the ATMS Operator. When the condition is relieved, the ATMS will direct the system to revert to the next lower priority message.

7.1.2. HOV Restrictions

The ATMS Operator will direct the ATMS to deploy an advance warning message 30 minutes prior to the effective time of the restriction. At the start time of the restriction, the ATMS Operator will direct the ATMS to deploy a restriction message. The messages will be implemented on all the gate control signs for the HOV facility being implemented, and will be communicated to the DMS via the communications infrastructure.

As an alternative, the ATMS Operator will schedule advance warning and restriction messages into the signs so that the messages will be displayed at the correct time even in the absence of communications from the ATMS. These scheduled messages will be communicated to the DMS via the communications infrastructure at the time they are programmed. Operators may display a higher-priority message on some gate-control signs as a result of specific incident scenarios, which will override the HOV messages. When the incident message is cleared, the sign will return to the HOV messages if they are still within their scheduled period.

7.1.3. DHS Alert

The ATMS Operator will direct the ATMS to display a message associated with an alert from the Department of Homeland Security. The directive will be communicated by the ATMS to the DMS via the communications infrastructure. The sign will display the message, and provide status reports back to the ATMS Operator. When the condition is relieved, the ATMS will direct the system to revert to the next lower priority message.

7.1.4. Amber Alert

The ATMS Operator will direct the ATMS to display a message associated with an Amber Alert. The directive will be communicated by the ATMS to the DMS via the communications infrastructure. The sign will display the message, and provide status reports back to the ATMS Operator. When the condition is relieved, the ATMS will direct the system to revert to the next lower priority message.

7.1.5. Special Event

The ATMS Operator will direct the ATMS to schedule the display of a message associated with an upcoming special event. The ATMS will either store the schedule and communicate a directive to the DMS via the communications infrastructure to display the message at the beginning of the schedule period and to revert to the next highest priority message at the end of the schedule period.. Alternatively, the ATMS will store the schedule information in the sign, allowing the sign to implement the message in accordance with the schedule and the message priority. The sign will display the message, and provide status reports back to the ATMS Operator, during the schedule period.

7.1.6. Work Zones

The ATMS Operator will direct the ATMS to schedule the display of a message associated with an upcoming road work activity. The ATMS will either store the schedule and communicate a directive to the DMS via the communications infrastructure to display the message at the beginning of the schedule period and to revert to the next highest priority message at the end of the schedule period.. Alternatively, the ATMS will store the schedule information in the sign, allowing the sign to implement the message in accordance with the schedule and the message priority. The sign will display the message, and provide status reports back to the ATMS Operator, during the schedule period.

7.1.7. Weather

The ATMS Operator will direct the ATMS to display a message associated with an weather condition. The directive will be communicated by the ATMS to the DMS via the communications infrastructure. The sign will display the message, and provide status reports back to the ATMS Operator. When the condition is relieved, the ATMS will direct the system to revert to the next lower priority message.

7.1.8. Congestion

The ATMS Operator will direct the ATMS to display a message associated with an incident response plan. The directive will be communicated by the ATMS to the DMS via the communications infrastructure. The sign will display the message, and provide status reports back to the ATMS Operator. When the condition is relieved, the ATMS will direct the system to revert to the next lower priority message.

7.1.9. Travel Time

The ATMS Operation will configure the ATMS to routinely measure and display travel times on the DMS. The ATMS will direct the DMS to display the current travel time information via the communications interface. The sign will display the current travel time message, and provide status reports back to the ATMS Operator. The Travel Time display will be the lowest priority display, and will thus be displayed at all times in the absence of any message with a higher priority.

7.2. DMS Design

In this scenario, the DMS designer will determine the location and size of the DMS. The designer will determine location appropriately based on being far enough from decision points to allow decision time and close enough to decision points to be relevant. The designer will select a location where maintenance vehicles have access without having to block traffic or construct an extensive work zone. The designer will consider roadway curvature to ensure that the motorists will be able to read the sign throughout its range of legibility.

The designer will determine the size of the sign. The designer will choose a size large enough to provide legibility and to support the largest potential message associated with the various activities that will use the DMS. The designer will choose a size small enough and lightweight enough to be mounted on the existing structure (if appropriate), In the case when an existing structure cannot accommodate a sign of the needed size and features, a new structure will be proposed and designed.

7.3. DMS Installation and Configuration

In this scenario, the DMS installer will determine the appropriate position of the sign on the structure to ensure that the sign will satisfy all user needs, including legibility and maintainability.

The installer will then provide power to the sign and configure the sign for the communications network. The ATMS operator will then configure the device database to include the sign and to reflect the sign's characteristics.

7.4. DMS Maintenance

The maintenance technician will work with the ATMS Operator to troubleshoot the sign and determine the most likely fault condition, either in the sign or in the supporting communications network.

The maintenance technician will then approach the sign and park the maintenance vehicle sufficiently out of the traveled way to avoid blocking traffic and the requirement for constructing an extensive work zone. The technician will then gain access to the sign using the vehicle's bucket. The technician will power the sign down, troubleshoot the problem, remove the defective modules, replace those modules with functional spares, and restore power and operation.

The technician will then communicate with the ATMS Operator to verify the operation and programming of the sign, performing any needed on-the-ground observation. Once correct operation has been verified, the maintenance technician will leave the site.

8. Next Steps

8.1. Detailed Requirements

The stakeholder needs identified in the Concept of Operations are reviewed, analyzed, and transformed into verifiable requirements that define what the system will do but not how the system will do it. Working closely with stakeholders, the requirements are elicited, analyzed, validated, documented, and baselined. (NRO Planning Team.)

8.2. System Design

A system design is created based on the system requirements including a high-level design that defines the overall framework for the system. Subsystems of the system are identified and decomposed further into components. Requirements are allocated to the system components, and interfaces are specified in detail. Detailed specifications are created for the hardware and software components to be developed, and final product selections are made for off-the-shelf components. (NRO SE.)

8.3. Software/Hardware Development Field Installation

Hardware and software solutions are created for the components identified in the system design. Part of the solution may require custom hardware and/or software development, and part may be implemented with off-the-shelf items, modified as needed to meet the design specifications. (NRO OIC)

8.4. Unit/Device Testing

The components are tested and delivered ready for integration and installation. (NRO Ops overseeing Vendor staff)

8.5. Subsystem and System Verification and Acceptance

The software and hardware components are individually verified and then integrated to produce higher-level assemblies or subsystems. These assemblies are also individually verified before being integrated with others to produce yet larger assemblies, until the complete system has been integrated and verified. (NRO Ops)

8.6. System Validation

After the ITS system has passed system verification and is installed in the operational environment, the system owner/operator, whether the state DOT, a regional agency, or another entity, runs its own set of tests to make sure that the deployed system meets the original needs identified in the Concept of Operations. (NRO Ops)

8.7. Operations & Maintenance

Once the customer has accepted the ITS system, the system operates in its typical steady state. System maintenance is routinely performed and performance measures are monitored. As issues, suggested improvements, and technology upgrades are identified, they are documented, considered for addition to the system baseline, and incorporated as funds become available. An abbreviated version of the systems engineering process is used to evaluate and implement each change. This occurs for each change or upgrade until the ITS system reaches the end of its operational life. (NRO Ops and NRO IMC)

Appendix 1, High-Level Requirements

Draft Version 0.4, February 25, 2008

Revision History

Version 0.2, October 31, 2007
Initial draft version corresponding to ConOps, Version 0.3

Version 0.3, February 20, 2008
Working draft incorporating most requirements tracing to ConOps, Version 1.0

Version 0.4, February 25, 2008
Added high-level requirements with separate traceability table to correspond to ConOps, Version 1.1

These requirements respond to the Concept of Operations at a high level, meaning that the requirements address broad capabilities required for the dynamic message signs. These requirements provide the basis for detailed functional requirements to be documented and fulfilled as part of the design of specific projects that carry out the DMS Upgrade and Expansion program.

Some of the requirements pertain to the ATMS, and are shown here to provide input to ATMS development efforts. ATMS requirements are beyond the scope of this document.

Traceability is explicitly shown in a separate document that serves as a companion to this Appendix, titled DMS Upgrade and Expansion Requirements Traceability.

1. DMS Message Display Requirements

1.1. DMS Message Display Requirements

1.1.1. Sign Size

The DMS shall provide a display of 20 characters (using the standard single-line font) on each of three lines.

1.1.2. Supported Fonts

The DMS shall support a minimum of four user-configurable fonts.

1.1.3. Built-In Fonts

The DMS shall include both a single-line (5x7-pixel) and a double-line (7x7-pixel) font built in as permanent fonts.

1.1.4. Display Effects

The DMS shall support text effects, including flashing display and font changes, on a character-by-character, word-by-word, and line-by-line basis.

1.1.5. Message Paging

The DMS shall be able to alternate between two pages of messages according to user-configured timing.

1.1.6. Blank Message

The DMS shall allow a blank display to be engaged with a single command.

1.1.7. Message Storage

The DMS shall be able to store messages downloaded from an ATMS within the sign memory for later display.

1.1.8. Message Scheduling

The DMS shall display a stored message at a stored time even in the absence of communications.

1.1.9. Message Priority

The DMS shall display the message either requested or scheduled for the current time that has been assigned the highest priority by the operator.

1.1.10. Timely Message Display

The DMS shall display the message within one minute of being engaged by the ATMS operator or maintenance technician.

1.1.11. Message Confirmation

The DMS shall provide status information describing the current message being displayed.

1.2. Travel Time Content Requirements

The Concept of Operations does not impose special requirements on the sign devices for the display of travel times. These requirements mostly affect the system, and those effects are beyond the scope of this document and are included for future reference.

1.2.1. Active Display

The system shall direct the DMS to display current travel times to specified downstream landmarks, updated actively. (Definition of “actively” to be determined, but for current discussion assumed to be once every five minutes.)

1.2.2. Default Display

The system shall display current travel times in the absence of being directed to display any other message. (This is a requirement on the ATMS, not on the DMS)

1.2.3. Sign Location for Travel Time

The sign shall be located such that travel time to a downstream destination can be meaningfully displayed.

2. Message Legibility Requirements

2.1. Character Size

2.1.1. Limited Access Facility Locations

Full-height DMS characters on each line of the message shall be 18 inches tall.

2.1.2. Arterial Roadway Locations

Full-height DMS characters on each line of the message shall be 12 inches tall.

2.2. DMS Brightness Requirements

2.2.1. Brightness Range

The DMS shall be able to display a range of pixel brightness such that motorists can clearly read the content of the sign in all ambient lighting conditions from full darkness to bright sun shining on the sign face.

2.2.2. Responsive to Ambient Lighting

The DMS shall automatically adjust the brightness of the sign to correspond to ambient lighting conditions, ranging from complete darkness to bright sun shining on the face of the sign.

2.2.3. Brightness Configurability

The DMS shall allow the operator to adjust the response of the sign to ambient lighting conditions.

2.2.4. Ambient Lighting Measurement

The DMS shall include sensing to determine ambient lighting conditions surrounding the face of the sign.

2.3. Message Angle of View

2.3.1. Minimum Viewable Distance

The DMS shall be clear and readable at the minimum distance at which a motorist can see the sign face. For this requirement, this distance is taken to be 60 feet.

2.3.2. Lateral Angle of View

The DMS shall be clear and readable over a lateral angle of +/- 20 degrees from a line perpendicular to and centered on the front face of the sign.

2.3.3. Sign Location for Angle of View

The DMS shall be positioned such that the angle of view is centered on the motorists in the viewing area. This requirement applies to both horizontal and vertical angular position.

2.4. Status Reporting Requirements

2.4.1. Current Displayed Message

The DMS shall be able to inform the ATMS or field technician the current message being displayed.

2.4.2. Stored Message Status

The DMS shall be able to inform the ATMS or field technician the stored messages, including their and priority.

2.4.3. Display Schedule Status

The DMS shall be able to inform the ATMS or field technician the display schedule for stored messages.

2.4.4. Environmental Status

The DMS shall be able to inform the ATMS or field technician the environmental status, including temperature and ambient light.

2.4.5. Fault Status

The DMS shall be able to inform the ATMS or field technician current faults, including:

- Excessive temperature
- Fan faults
- Pixel faults

2.5. Sign Location for Messaging Requirements

2.5.1. Sign Location for Readability

The DMS shall be located so that the motorist can see and read the sign over a minimum period of 12 seconds at the posted speed.

2.5.2. Decision Points

DMS Locations shall be based on decision point locations associated with established motorist alternatives in response to the conditions underlying the sign content.

2.5.3. Minimum Sign Distance

The DMS shall be located close enough to the alternative decision point that motorists are able to read and appropriately react to the content messages required herein. “React” in rural areas includes sufficient time to consult a map and seek and receive a relevant message from the 511 system and the time required to safely change lanes from any lane to the lane needed to exercise the alternative. “React” in urban areas includes sufficient time to change from any lane to the lane needed to react to the alternative. “React” always includes, in addition to the urban and rural components, perception-reaction time of 2.5 seconds.

2.5.4. Maximum Sign Distance

The DMS shall be located close enough to the alternative decision points that a reasonable percentage of the motorists are expected to find the message relevant.

3. Environmental Requirements

3.1. Proper Function

The DMS shall function properly in all ambient conditions of temperature and humidity, including condensing humidity.

3.2. Fog Prevention

The DMS shall prevent fogging of the front panel in all ambient conditions of temperature and humidity.

3.3. Temperature Range

The DMS shall operate normally over a temperature range of -20 to +70 degrees Centigrade.

3.4. Moisture

3.4.1. Moisture Intrusion

The DMS shall prevent moisture intrusion in a NEMA Rain Test, as specified for a NEMA 3R enclosure.

3.4.2. Moisture Management

The DMS shall operate indefinitely without the growth of mold, mildew, or any other damaging effects of moisture, no matter by what means the moisture entered the sign. This includes (but is not limited to) providing a means for the systematic draining and removal of any collected moisture in the sign enclosure.

3.4.3. Moisture Protection

All DMS components shall be protected against electrical damage from moisture, either through the use of circuit board coatings or some other method.

4. Maintainability Requirements

4.1. DMS Location for Field Accessibility

The DMS shall be located such that field technicians are able to effect a repair on the sign, ground cabinet, and pull boxes in all weather conditions without closing any part of the facility to traffic.

4.2. DMS Design for Field Accessibility

The DMS shall be physically designed to protect the field technician from inclement weather, so that the field technician can effect a board-level repair in all weather conditions without closing the facility to traffic and without exposing sign components to damage from inclement weather.

4.3. DMS Overhead Accessibility

The DMS shall be accessible by field technicians without requiring the use of bucket trucks or other personnel lifting devices.

4.4. DMS Access Safety

The DMS shall be designed such that technician access conforms to all state and federal worker safety requirements.

4.5. Reliability

The DMS system shall maintain a combined up-time of 99.9%. "Up time" is defined as a fully operational sign able to display messages as directed by the operator according to these requirements.

4.6. Durability

The DMS shall be designed for a field serviceable lifespan of 10 years (this means that all sign components not expected to be renewed as a part of normal maintenance shall have a mean time between failures of 100,000 hours).

4.7. Service Material Availability

The DMS Manufacturer shall make available replacement parts and other materials required for service for the field serviceable life of the sign plus five years.

4.8. Preventive Maintenance

The DMS shall be designed to avoid the need for preventive maintenance visits more frequently than at one-year intervals. This means that maintenance intervals for air filters and other identified and approved routine service items shall be a minimum of 10,000 hours of operation.

4.9. Reparability

The DMS shall be designed such that field technicians will be able to repair them in field conditions by replacing modules without the use of tools and without manipulating the software, other than to load new software or download a sign parameter database.

4.10. Timeliness of Repair

The DMS shall be designed such that technicians can effect any diagnosed repair in 20 minutes, assuming repair parts are on hand.

4.11. Maintenance Diagnostics

The DMS shall provide diagnostic information to the ATMS operator or maintenance technician.

4.12. Warranty

The DMS shall be covered under a service material warranty for ten years, covering all service materials, including circuit boards, and all mechanical and electrical components, for ten years from the date the signs are accepted. This does not include preventive maintenance materials such as air filters.

4.13. Emergency Maintenance Procedures

4.13.1. Operation during Communications Failure

The DMS shall display the currently scheduled messages during communications failure. If no messages are scheduled, the sign shall display a blank message. In no case shall leaving the last known message displayed until the repair is effected be considered a fulfillment of this requirement.

4.13.2. Blank Message from Control Cabinet

The DMS shall provide a means of displaying a blank message by a maintenance technician using a control available at ground level at the sign site.

4.13.3. Processor Reset

The DMS shall provide a means of resetting the sign processor by a maintenance technician using a control available at ground level at the sign site.

4.13.4. Field Message Engagement

The DMS shall allow a maintenance technician using a laptop computer to display a message on the sign by connecting the computer to the sign at ground level at the sign site.

5. Integration and Configurability Requirements

5.1. Operational Configuration

The DMS shall provide the capability to be configured through the communications interface to support all the requirements defined herein.

5.2. Communications Requirements

5.2.1. Communications Configuration

The DMS shall support communications from a remote system using one of the following methods and media:

- Dial-up telephone lines
- Local serial or Ethernet connection
- Leased telephone lines
- Multiplexed serial communications on existing fiber
- IP-based communications on existing fiber
- IP-based communications on new VDOT fiber ring

5.2.2. NTCIP User Integration

The DMS shall support NTCIP 1203 and 1201 simply and directly so that all NTCIP integration activities covering all required features can be performed by the implementing agency using commonly available tools.

5.2.3. NTCIP Profile Compliance

The DMS shall support standard profiles associated with the above communications methods.

5.2.4. NTCIP Object Compliance

The DMS shall support standard NTCIP 1203 and 1201 object definitions supporting all of the features required herein.

5.3. Control System Versatility

The DMS shall provide all access to features required herein when connected to a vendor-supplied system or a future ATMS system that supports NTCIP 1203 as required above and that supports the features required herein. This high-level requirement does not imply that the sign may not support required features just because they are not supported by the ATMS software.

6. Physical Construction Requirements

6.1. Existing Structure Strength

DMS devices to be installed on existing structures shall weigh less than the maximum weight that can be supported by the existing structure (to be determined on a sign-by-sign basis during design).

6.2. Existing Structure Mounting

The DMS shall be mountable on existing structures in a manner that does not require welding or other violation of the surface anti-rust treatment on the existing structure.

6.3. Existing Structure Size

The DMS shall be small enough to fit on the existing structure.

6.4. New Structures

If Requirements 6.1 through 6.3 cannot be fulfilled without fulfilling the other requirements in this document, a new structure shall be included in the project that fulfills all these requirements.

6.5. Clear Zone

The DMS structure and all components shall be located or protected to maintain the roadway appurtenance clear zone.

Appendix 2, Validation Plan

Draft Version 0.3, February 25, 2008

Revision History

Version 0.2, October 31, 2007
Initial working draft corresponding to Concept of Operations Version 0.2

Version 0.3, February 25, 2008
Draft incorporating revisions to Concept of Operations, Version 1.1

Introduction

Validation is the process by which an agency determines if the correct system was installed. “Correct” in this context means that the system fully and directly supports the intended activities of the agency. The validation test, therefore, comprises using the system as part of those activities to determine that the system supports rather than conflicts with those activities. Validation is a step that relates ultimate operation and maintenance of the system to the model of those activities as described in the Concept of Operations. Therefore, the validation steps are directly related to the needs expressed as activities in the ConOps.

Validation is different than verification. Verification is a process by which the system is tested to ensure that it complies with the design, and by which the design is tested to ensure that it fulfills the requirements.

Test plans and procedures are associated with verification, and this document is in no way intended as a test plan. The test plan should be linked tightly to the functional requirements and design, while this validation plan is linked to the user needs.

In the context of dynamic message signs, as distinct from the control system to which they are connected, validation ensures that the signs:

- Are able display messages effectively
- Can be maintained reasonably
- Can be integrated into existing and future systems and infrastructure
- Can be constructed.

Validation is also used to determine that a system meets its goals, which are defined at a higher level than the needs mentioned above. This validation, however, concerns the signs only and therefore does not attempt to evaluate the system as a whole against its goals.

1. Message Display

1.1. Real-Time Message Display

1.1.1. Message Engagement

Is the ATMS operator able to engage messages appropriate for the following applications in real time?

- Blank display
- Incidents
- Construction and Maintenance Activities
- Adverse Weather, Environmental, and Roadway Conditions
- Other Traveler Information
- Special Events
- Messages for other Agencies
- Emergency Messages
- Ozone Alerts
- Safety Campaigns
- Tests

1.1.2. Message Confirmation

Does the system provide confirmation of messages when engaged by the operator?

1.1.3. Message Appearance

Is the operator able to display messages with four informational elements representing the library of messages used in the TMC? Specifically, is the operator able to format messages of the size and using the text effects as listed below?

- Message width of 20 characters
- Three lines of text
- At least four user-defined fonts, plus a built-in 5x7 single-line font and a 7x7 double-line permanent font
- Flashing displays (character-by-character, word-by-word, and line-by-line)
- Up to two pages of message information cycled automatically in user-configured timing intervals.

1.2. Future Message Display

Can the operator store messages in the sign and schedule them for future display without communications from the system at the time?

1.3. Message Priority

Does the sign display the message with the highest priority?

1.4. Retasking

Can the operator retask a sign from a scheduled message or from an HOV control message to a real-time guidance message without losing the routine message schedule?

1.5. Travel Time

Is the sign capable of automatically displaying travel times in accordance with FHWA policy?

1.6. Travel Time Location

Is the sign located to provide a travel time message meaningfully?

1.7. Message Legibility

Are motorists able to easily read the messages at a glance under all lighting and environmental conditions and distances?

1.8. MUTCD Conformance

Are sign messages in conformance with MUTCD guidelines?

1.9. Status Reporting

Does the DMS allow the operator to learn the current message, schedule, operational status and fault condition at any time?

1.10. Sign Location for Messaging

Are signs located so that they can be read by motorists?

Are urban signs located such that motorists can reasonably act on their messages?

Are rural signs located such that motorists have time to consult 511 or a map to determine a reasonable response?

1.11. Decision Points

Are signs located upstream from meaningful decision points within the network?

2. Maintainability

2.1. Preventive Maintenance

Are signs designed to require no more frequent than annual routine preventive maintenance?

2.2. Emergency Maintenance

Do signs display either the scheduled message or a blank display during a malfunction? Can the sign be blanked and the processor reset at ground level by a maintenance technician? Can the technician display a message using a laptop connected to the sign at ground level?

2.3. Field Accessibility

Are signs located to allow field technician access in all weather conditions without closing lanes? Are signs located to minimize knockdowns? Can technicians safely perform all work on the sign without requiring a bucket truck?

2.4. Reliability

Do signs operate properly in all ambient conditions? Do the signs maintain at least 99.9% reliability? Is the sign designed for 100,000-hour MBTF (10,000 hours for routine maintenance items)?

2.5. Reparability

Are technicians able to effect repairs without special tools or manipulation of software? Can those repairs be made within 20 minutes of diagnosis?

2.6. Maintenance Diagnostics

Are technicians able to request and receive relevant diagnostic information from the sign?

2.7. Sign Location for Maintenance

Are the signs located to provide room for maintenance vehicles without deploying extensive work zones?

2.8. Warranty

Are the sign parts and circuit boards warranted for ten years?

3. Integration and Configurability

3.1. Operational Configuration

Is the ATMS operator able to configure the DMS for all the activities described in the Concept of Operations?

3.2. Communications Versatility

Will the DMS devices operate properly using any of the following communications options?

- Dial-up telephone lines
- Local serial or Ethernet connection
- Leased telephone lines
- Multiplexed serial communications on existing fiber
- IP-based communications on existing fiber
- IP-based communications on new VDOT fiber ring

3.3. Interface Needs

Is the DMS interoperable and interchangeable in NTCIP-compliant systems? Can the DMS be configured in an NTCIP system by the user, using common tools?

3.4. Control System Versatility

Will the sign operate properly both under the existing ASSIST software and also under new ATMS software?

4. Physical Construction Needs

4.1. Existing Structure Compatibility

Can the signs be mounted on existing structures? If not, have new structures been constructed?

4.2. Positioning

Are the signs positioned such that the motorists can read them over a 12-second period?

4.3. Roadway Appurtenance Clear Zone

Are the sign mountings and ground equipment outside the roadway appurtenance clear zone, or are they properly protected by guard rail?

Appendix 3, Upgrade and Expansion Master Deployment Plan (Summary)

Overview

Appendix A summarizes the scope of the NRO DMS Upgrade and Expansion Master Deployment Plan. This appendix consists of three main sections:

- Methodology Overview
- Scope Summary Tables
- Overview Maps

Its purpose is to provide an overview of the planned scope of activities that will comprise the DMS Upgrade and Expansion Program in the NRO. More detailed information, required to transition program or project phases from planning to detailed design, will be provided in the form of supplements to the DMS Master Concept of Operations. Each supplement is tailored to a specific project corridor which corresponds to the project coding used in this appendix (e.g., N-1, N-2, C-1, etc.).

Methodology

The methodology used to develop the overall scope of the expansion program was derived from a needs-based approach designed to address specific NRO operational goals. While relatively straightforward, there were a number of factors that indicate the need for additional analysis and scrutiny as each project corridor transitions from planning to detailed design. Problems with the inventory are such that the locations of many existing signs now identified for upgrade must be examined – while this was done to a large degree in the NOVA district, this process must be done for each corridor. The most current inventory available was developed in January 2008 to support development of the NRO ATMS. Significant discrepancies and inconsistencies exist within the DMS (labeled VMS in the inventory report) inventory. These issues complicated the development of the Master Plan. Examples of these issues included numerous DMS that were not located where indicated in the inventory, naming conventions that were followed haphazardly, inconsistent numbering – or renumbering that was not applied consistently.[1] Consequently, certain aspects of the planning work performed to date must be re-validated during design.

Based on NRO – Traffic Engineering and MUTCD guidance, DMS that heretofore were designed for regulatory purposes (i.e., HOV) should be replaced with static regulatory signs – DMS are no longer considered a reasonable tool for this use.

In addition, HOT Lane development will affect I-495, I-395, I-95, and, to a lesser degree, I-66. Consequently, DMS located within the HOV lanes which will pass from VDOT control in the near future, were not considered for upgrade. These include gate status and HOV status signs in these areas. HOT lane development will have an effect on opportunities for deployment of DMS on the GP lanes of the 495, 395, and 95. However, at the time this appendix was prepared, 30% plans were still under development for I-495 HOT. Plans in this appendix reflect discussions and planning meetings held with the HOT Lanes ITS Design Working Group, which arrived at agreement with NRO – Operations Planning and Programming (OPP) staff regarding locations and approach for DMS reconciliation. Nevertheless these

[1] For example, according to the inventory metadata, 'Route' is supposed to identify the roadway where a DMS is located. However, it was discovered that sometimes 'Route' refers to the facility that the sign is intended to provide information about. In other cases, signs were listed as having been removed from the inventory when in fact they had simply been moved to another location. In a number of cases the only way to resolve certain questions was to drive to locations and physically identify the sign by documenting cabinet, truss, and other identification.

plans must still be approved by VDOT leadership. In addition, HOT design plans for I-395 and I-95 were not sufficiently mature at the time this document was prepared to enable a more accurate estimate of numbers and locations of DMS for the these two facilities. It is recommended that DMS upgrade and expansion plans for I-395 and I-95 be revisited once respective HOT 30% design plans are finalized.

Due to breadth of the NRO DMS upgrade and expansion effort and associated deployment constraints, it is required that the upgrade and expansion of NRO DMS infrastructure be done in a phased manner. Deployment phases have been defined as part of the NRO ITS expansion and upgrade corridor priority development process.

Key planning activities are listed below.

- Initial DMS Placement: Leveraging the results of the NRO ITS expansion and upgrade corridor priority development process, key decision points and traveler information points for DMS placement were identified. This activity resulted in the "unconstrained" placement of DMS throughout NRO.
- Perform Gap Analysis: Compares "unconstrained" DMS placement with existing DMS inventory. As a result of this analysis, opportunities to leverage existing infrastructure are identified.
- Prepare Deployment Project Supplements (in progress): As part of the NRO ITS expansion and upgrade corridor priority development process, deployment projects were defined. Supplements to the NRO DMS Upgrade and Expansion Concept of Operations and Master Deployment Plan are to be developed for each deployment project. The supplements identify preliminary DMS locations.

As part of the project supplement development process, the following additional activities are to be performed:

- Operational Needs Refinement – Met with TMC operations staff to confirm preliminary DMS locations. As a result of these meeting, preliminary DMS locations are optimized to meet operational goals.
- Preliminary Field Review – NRO Operations Planning and Programming and Traffic Engineering staff conduct a preliminary field review for each project supplement.[2] This review, while outside the traditional concept of operation development scope, provides a valuable resource to support detailed design activities. A detailed field review is required during the design phase.

Upgrade and Expansion Scope Summary

The following tables summarize the scope of activities for the upgrade and expansion program. The activities are structured to facilitate policy-planning development by presenting activities from the perspective of net increase in signs, the total number of signs that will need to be addressed, and activities for which there may be a significant difference in effort and material cost. Three main areas are identified:

1. Upgrade at same location – Ideally this means that existing infrastructure could be re-used, resulting in significant cost savings compare to #3. In cases where the structures have past their useful life-cycle, a new structure will be needed. Whether or not a structure can be re-used will be determined during the design phase.

[2] The only field review conducted to date was for Phase 1, which transitioned from planning to design in March, 2008. TE field review for Phase 2 which was scheduled for transition at the end of April 2008 had been scheduled but not yet performed at the time this appendix was prepared.

2. Replace at new location – This case involves relocating a functioning DMS. In this case, the functioning DMS could either be relocated to another existing structure or a new structure with power and communications access.
3. Install new sign at a new location – This case involves the installation of a new DMS on a new structure with power and communications access.

The estimated scope of the program is provided in Table 1. A project corridor-level activity scope is provided in Table 2.

Table 1 DMS Master Summary

NRO DMS Project Phase	Upgrade at Same Locations	Replace at New Locations	New Signs at New Locations	Net Change	Total Signs
Phases 1 - 10	76	13	57	58	**147**
Phases 11 - 12	5	0	6	6	**11**
Phases 13 - 16	1	0	4	4	**5**
Totals	82	13	67[3]	68	**163**

[3] Plans in early corridor will result in net loss of one sign.

Table 2 DMS Master Plan Scope Summary

Project Corridor[4]	DMS Project/ Priority	Existing DMS	Upgrade at Same Location	Replace at New Location	New DMS at New Location	Remove	TMC Ops Staff Review	Net Gain/ Loss	Total DMS
I-66: DC to I-495 Rt.267: I-66 to I-495 Rt. 29: DC to I-495 Rt. 50: DC to I-495	N-1	14	7	5	5	2	YES	3	17[5]
I-66: I-495 to Rt. 50 Rt.29: I-495 to Rt. 50 Rt.50: I-495 to I-66 Rt.123: Rt. 7 to Rt.236 Rt.243: 123 to Rt. 29	N-1	8	5	3	4	-	YES	4	12
I-95: Prince William Co. (Nov 09 due to HOT Lanes)	N-2	5	5	-	-	-	YES	-	5
Rt 1: Prince William Co.	N-2	4	4	-	1	-	YES	1	5
I-95: I-495 to Rt.123 Rt.1: I-495 to Rt.123 Rt. 235 (I-95 Nov 09 due to HOT Lanes)	N-2	15	14	1	2	-	YES	2	17
I-395: DC to I-495 Rt. 110: Rt. 1 to I-66 GW Pkwy: DC to I-495 (non VDOT) (I-395 Nov 09 due to HOT Lanes)	N-2	12	10	2	10	-	YES	10	22
I-495 (Capital Beltway) (Oct 2010 due to HOT Lanes)	N-3	9	9	-	5	-	NO	5	14
Rt.50: I-66 to Rt.15	N-4	1	-	1	2	-	NO	2	3
Rt.3000: Rt.28/234 to I-95 Rt.28: DTR to I-66 Rt.28: I-66 to Rt.234/3000	N-4	4	4	-	3	-	NO	3	7
DTR: I-495 to Rt.28 (non VDOT) Rt.7: I-495 to Rt.28 Rt.7100 Rt.7 to DTR Rt.28: Rt. 7 to DTR	N-5	1	1	-	2	-	NO	2	3
Rt.7100: DTR to I-95 Rt. 123: Rt. 7100 to I-95	N-6	2	2	-	2	-	NO	2	4

[4] Includes arterials immediately adjacent unless listed specifically elsewhere in the table
[5] Does not include 3 new DMS to be added by I-66 Spot Improvement Project

Project Corridor	DMS Project / Priority	Existing DMS	Upgrade at Same Location	Replace at New Location	New DMS at New Location	Remove	TMC Ops Staff Review	Net	Total DMS
Rt.66: Rt.50 to Rt.15 Rt.29: Rt.50 to Rt.15 Rt.234: N of Rt. 29 to South of I-66	N-6	14	13	1	2	-	NO	2	16
DTR & Dulles Greenway: Rt.28 to Rt. 15 Leesburg (Non VDOT) Rt.7: Rt.28 to Rt.15 Rt.15: Leesburg & Rt.7 zone	N-5	-	-	-	3	-	NO	3	3
Rt.193: from Rt. 7 to Rt.90005 Rt.123: from Rt. 267 to 90005	N-5	-	-	-	1	-	NO	1	1
Rt.215: Rt.29 to Rt.28 Rt.234: I-66 to I-95 Rt.28: from Rt.234 to Prince William Co.	N-7	1	1	-	4	-	NO	4	5
Rt.244: Rt.27 to Rt.236 Rt.620: Rt.236 to Rt.7100	N-8	1	1	-	5	-	NO	5	6
Rt.236: Rt. 1 to Rt. 50/29 Rt.7: Rt.1 to I-395	N-10	-	-	-	1	1	NO	1	1
Rt. 7: Rt. 15 Leesburg to NRO boundary Rt. 9: Rt. 7 to NRO boundary Rt. 287: Rt. 9 to Rt. 7	N-9	-	-	-	1	-	NO	1	1
Rt.15: NRO boundary to Rt. 29 Rt.234: Rt.15 to Rt.29	N-9	-	-	-	1	-	NO	1	1
I-95 & Rt 1 in Stafford County	F-1	3	3	-	1	-	NO	1	4
I-95 & Rt 1 in Spotsylvania Co. Rt.208 in Spotsylvania Co.	F-1	2	2	-	2	-	NO	2	4

Project Corridor	DMS Project / Priority	Existing DMS	Upgrade at Same Location	Replace at New Location	New DMS at New Location	Remove	TMC Ops Staff Review	Net	Total DMS
Rt. 218 Rt. 3: Rt. 20 to I-95 Rt. 3: Rt.17 to King George boundary Rt. 301: Rt. 3 to King George boundary	F-2	-	-	-	3	-	NO	3	3
I-66 in Fauquier Co.	C-1	-	-	-	1	-	NO	1	1
Rt.15: Rt 29 to Rt 3 Rt 29: Rt 15 to Rt 215	C-2	1	1	-	-	-	NO	-	1
Rt 17 & Rt 28 in Fauquier Co.	C-2	-	-	-	1	-	NO	1	1
Rt 211: Rt 29 to Rappahannock Co.	C-3	-	-	-	1	-	NO	1	1
Rt. 3: Rt 20 to Rt 29 Rt 29: Rt 3 to Madison Co.	C-4	-	-	-	1	-	NO	1	1

As Table 2 indicates, a phased approach has been recommended. The phases directly correspond to the priority of the corridor. This approach reflects the time required for on-site reviews by TE and OPP staff and perhaps most importantly, likely manufacturing sequencing for DMS, many of which include critical components made by a small number of overseas vendors.

DMS Preliminary Location Overview Maps

The maps below provide an overall view of the scope of the program. Of most immediate interest is the breadth of the work geographically that is encompassed within NRO as well as the density of effort that must be performed in extremely challenging traffic and congestion environments. The first map provides an overview to illustrate relative density or the focus of likely work. Subsequent figures provide greater detail of various NRO sections and project areas.

Figure 1 shows all DMS in the NRO, without roadways, to illustrate relative density and activity focus.
Figure 2 shows a detailed view of DMS within the Beltway and the core NOVA District.
Figure 3 provides an overview of the I-95 and Route 1 Corridors between I-495 and Fredericksburg.
Figure 4 shows DMS in the south, southwestern areas of the NRO. NOTE: Figures 2 – 4 overlap.

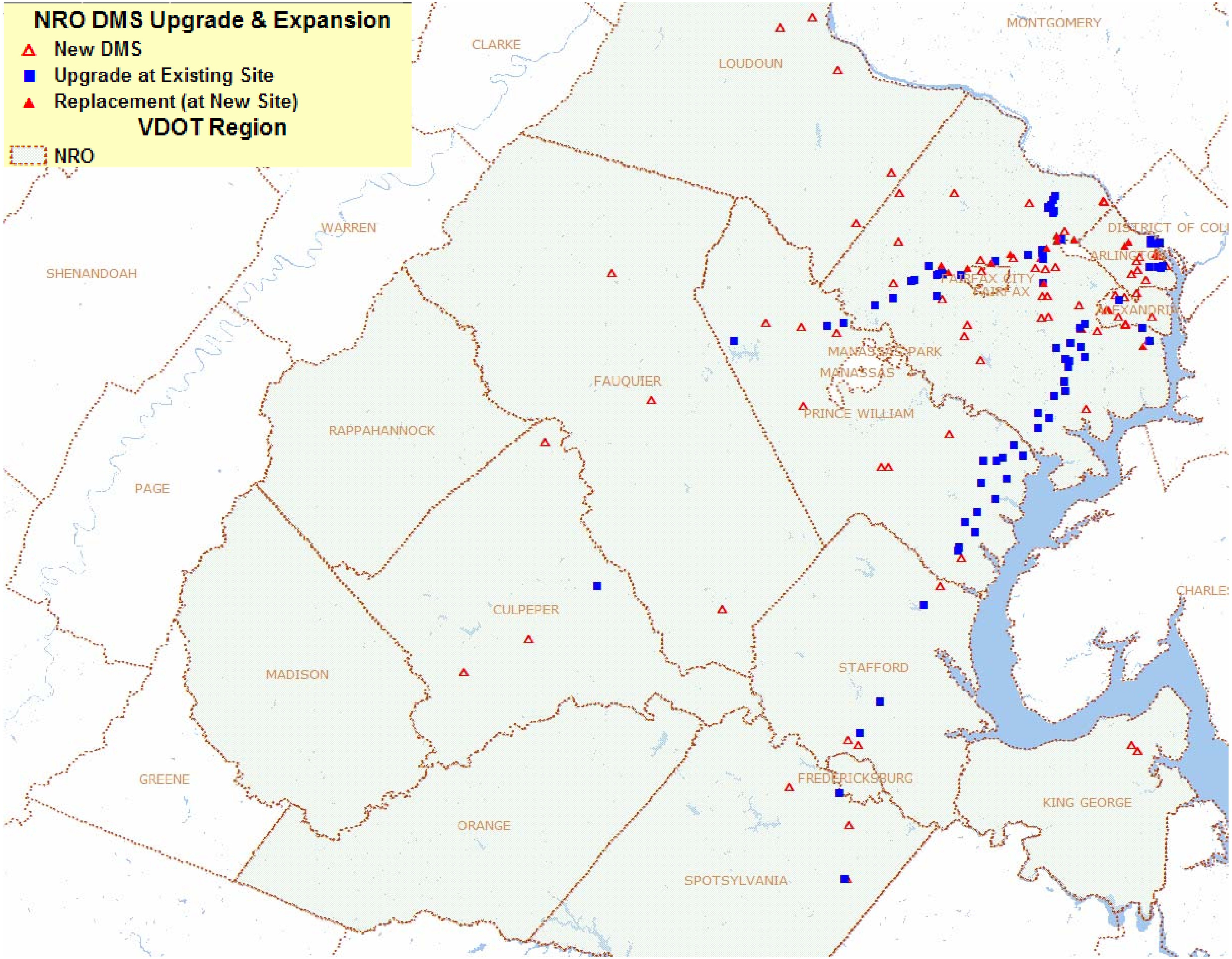


Figure 1 NRO DMS Master Plan Overview

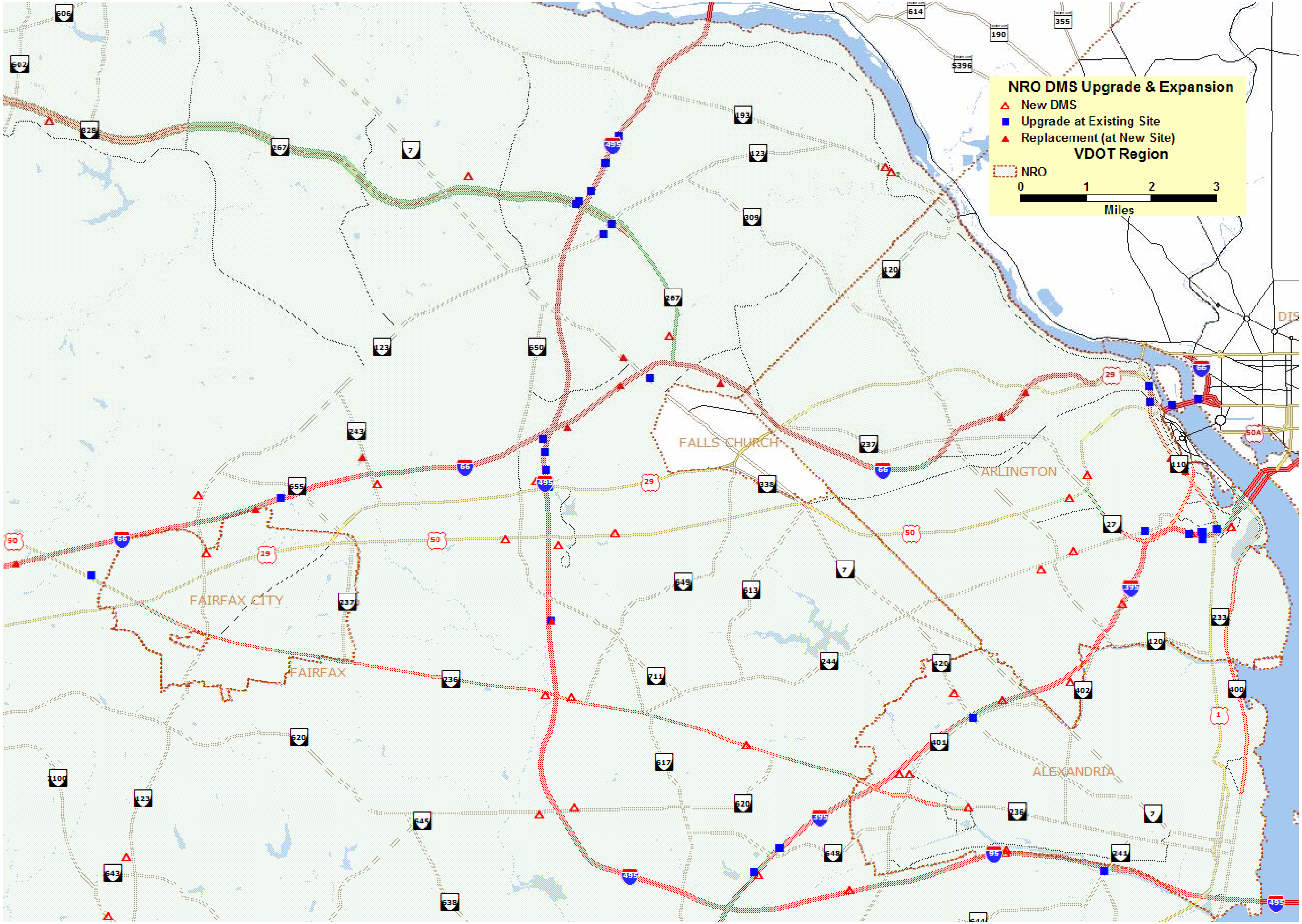


Figure 2 – Beltway and Core NOVA District Area

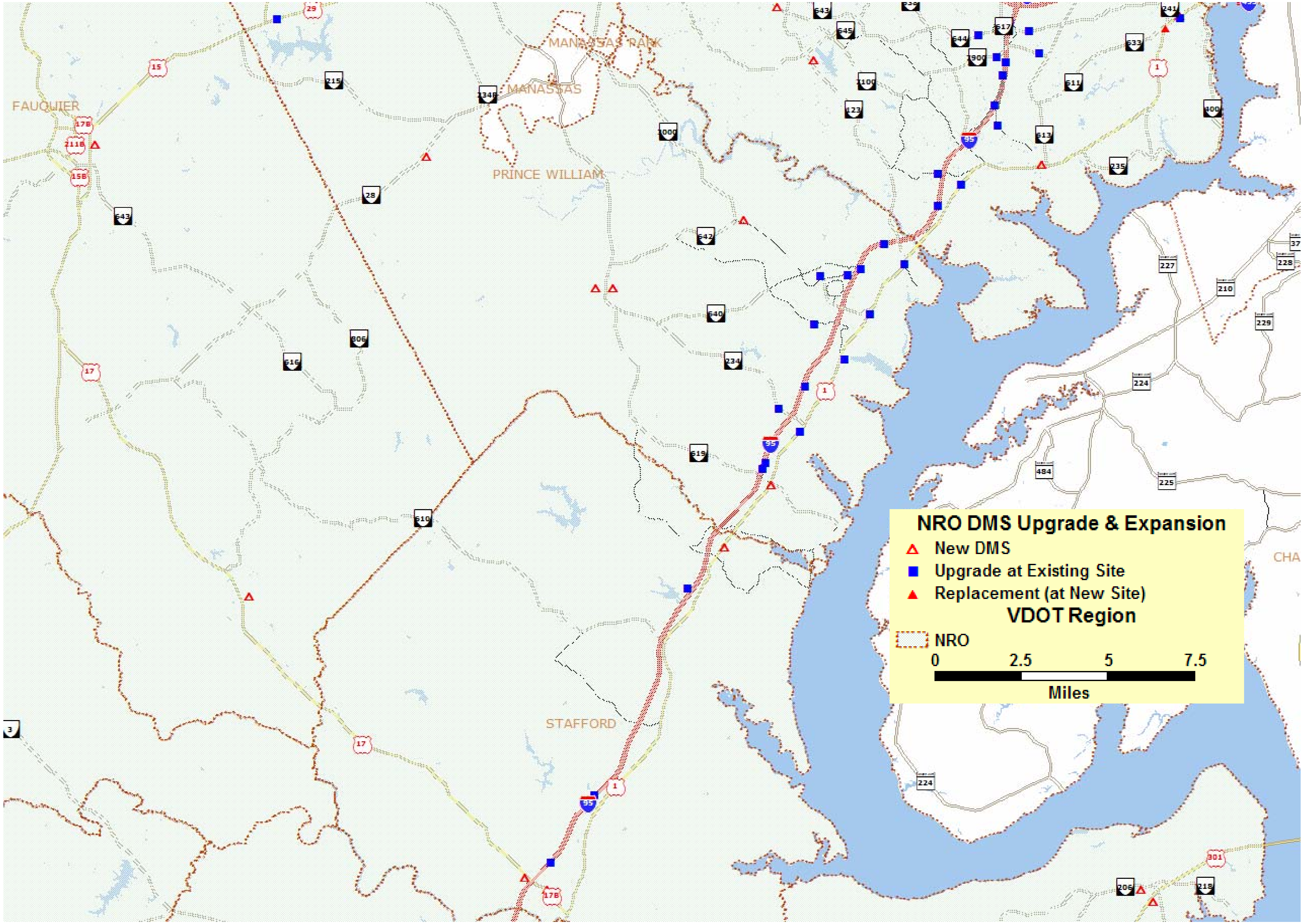


Figure 3 – I-95 and Route 1 Corridors

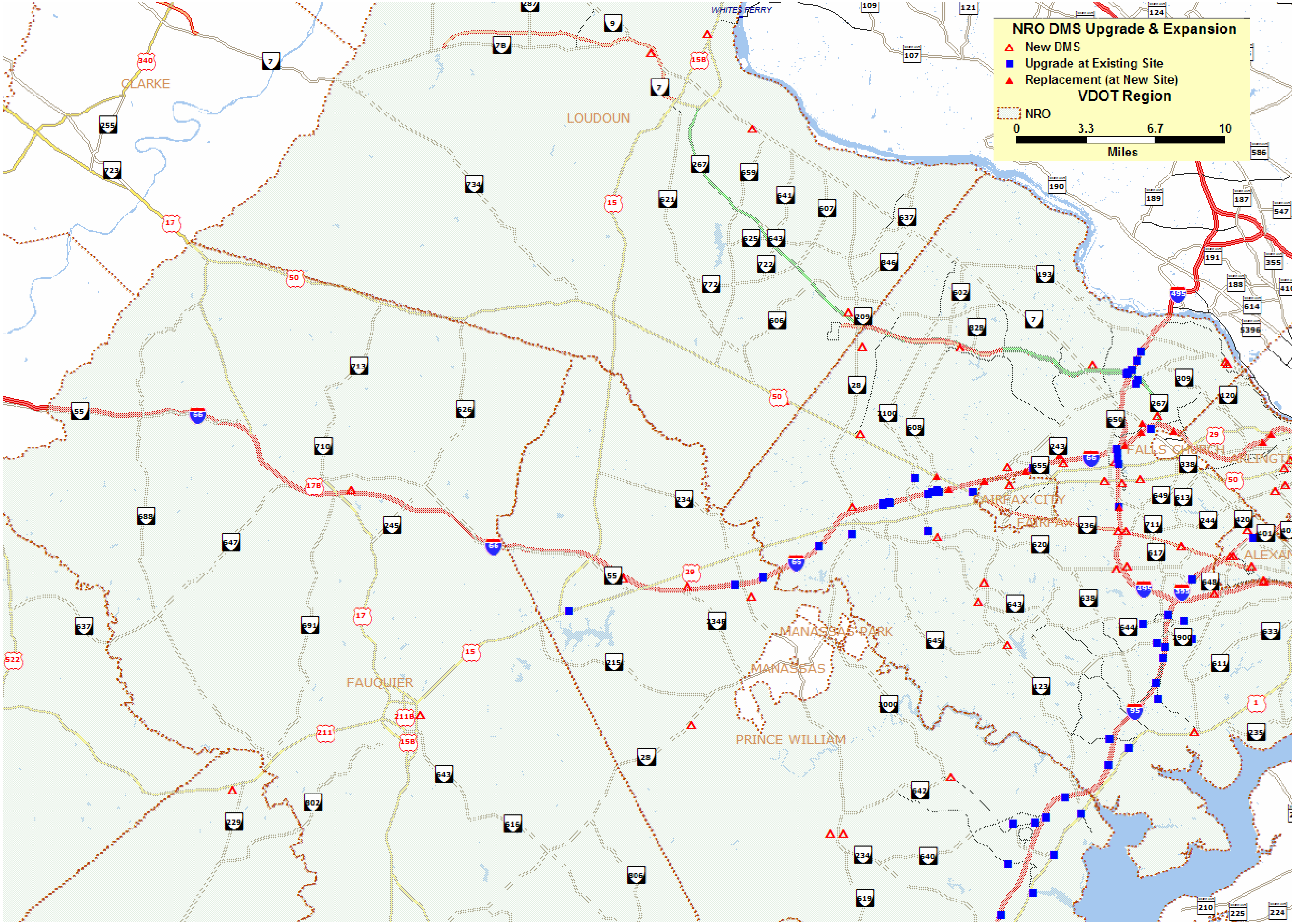


Figure 4 – DMS in Central and Western NRO