CCTV MASTER PLAN AND CONCEPT OF OPERATIONS

CCTV SYSTEM ENGINEERING DOCUMENTS

Prepared for:

VDOT Virginia Department of Transportation

VDOT Northern Region Operations

Prepared by:

Kimley-Horn and Associates, Inc.

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1.0 Scope

1.1 Identification

This Concept of Operations presents a plan for a new, expanded Closed-Circuit Television (CCTV) system for the Virginia Department of Transportation (VDOT) Northern Region Operations (NRO). In the development of this document several stakeholders were interviewed in one-on-one or small group settings in order to understand the breadth of current use and future needs for the CCTV system. In most cases the future needs are those that the Traffic Management Center (TMC) operators have for visual information obtained through a CCTV system, although there are also needs with respect to maintaining the field infrastructure and providing traveler information.

The "CCTV system", for the purposes of this document, is defined as the use of VDOT owned and operated video cameras located along VDOT and associated County assets in the NRO region for traffic surveillance, congestion monitoring, incident verification, and public/media information. The CCTV system includes the CCTV cameras, communication infrastructure, and the variety of output sources described throughout the document.

1.2 Role of the Concept of Operations within the Systems Engineering Process

A Concept of Operations is the critical first step in the systems engineering process that the Federal Highway Administration (FHWA) mandates in 23 CFR 940 per section 5307(c) of U.S. Public Law 109-59, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). The systems engineering process can be represented by the "Vee" Diagram in **Figure 1**. Besides being a federal requirement for project funding, the process is important to ensure the system or technology being designed and deployed meets the needs of its end users.

The Concept of Operations presents the users' perspectives on how the system will help them meet their business objectives. The term "system" can denote something as simple as a single CCTV camera or as complex as a multi-million dollar software application. The scope and detail of a Concept of Operations should be commensurate with the complexity of the system being deployed. In addition, it presents the case for the new system in the context of the current environment and defines any external dependencies that may affect or be affected by the system under consideration.

Written from the user's perspective, a Concept of Operations is designed to be reviewed and validated by the system users who may not necessarily have a detailed understanding of the underlying technologies or design considerations. The user needs lead to system requirements, which are used to design the system. Once the system is designed and implemented, the process proceeds up the right side of the "Vee," where the system is validated against the requirements and the Concept of Operations to confirm that it has been designed and implemented appropriately to meet the objectives for which it was intended. This linkage of integration steps with definition steps enables the system to be tested and verified early and often to reduce the risk that the final product does not meet user needs.

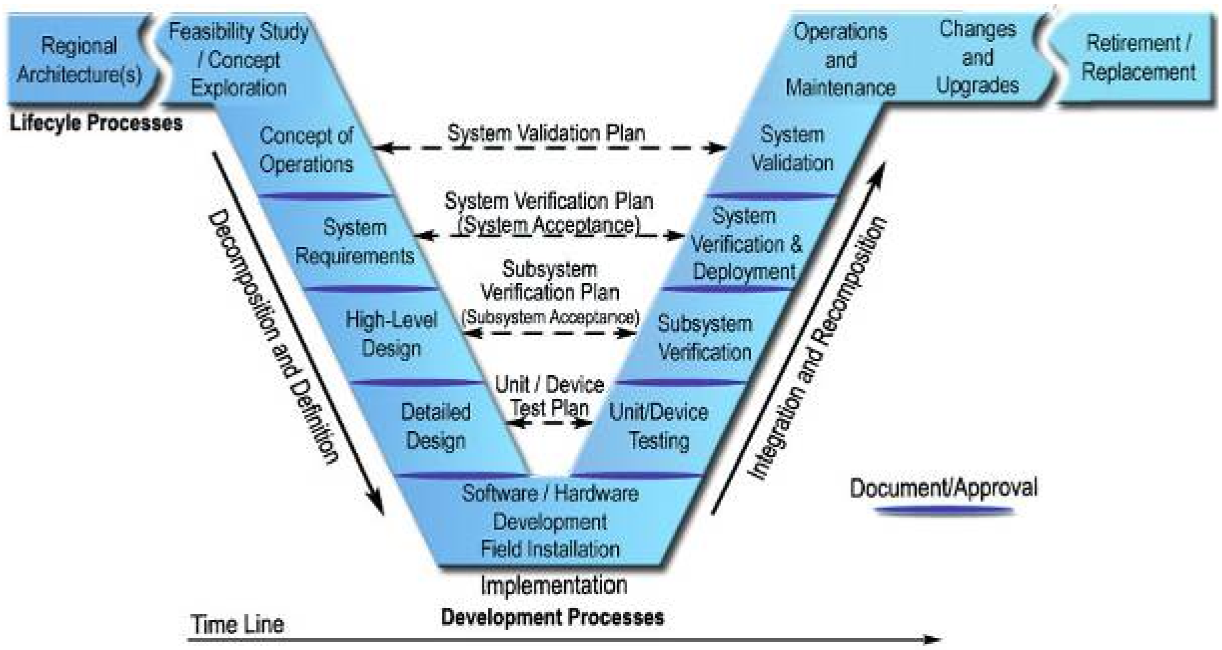

Figure 1 The Systems Engineering Process "Vee"

1.3 System Overview

The CCTV system provides versatile real-time visual information to the NRO TMC operators. Acting as eyes in the field, the system aids TMC operators in quickly and effectively identifying and responding to incidents, events, and maintenance needs. A CCTV camera is typically equipped with pan-tilt-zoom capabilities to allow the operator to adjust the view and observe specific areas. The information obtained from the video provides confirmation of traffic incidents, event, weather conditions, and emergency issues. The CCTV camera system also provides video distribution for public and media use.

1.4 Goals, and Objectives

The CCTV Concept of Operations supports the following goals and objectives identified in the Northern Region Operations Strategic Plan. It should be noted, however, that the Strategic Plan is currently being updated.

1) **Goal #1 - Enhance Public Safety**
   - Objective 1.B: Respond Efficiently to Incidents
   - Objective 1.C: Improve Transportation security
2) **Goal #2 - Enhance Mobility**
   - Objective 2.A: Operate the Transportation System Effectively and Efficiently
   - Objective 2.C: Expand ITS Infrastructure to Enable Corridor Management
3) **Goal #3 - Make the Transportation System User Friendly**
   - Objective 3.B: Support Traveler Information Services

1.5 Vision for the System

VDOT NRO's vision for CCTV camera operations is provided below:

> *The VDOT Northern Region Operations Closed Circuit Television (CCTV) Camera System will provide Traffic Management Center (TMC) operators with the ability to detect incidents, verify incident information, and monitor traffic conditions on VDOT roadways. CCTV images will be shared with regional and statewide stakeholders to improve interagency coordination. Additionally video images depicting real-time roadway conditions will be available to the motoring public.*

The system envisioned in this Concept of Operations combines upgrades to the existing system's camera and communications equipment, camera infill within the existing system's covered corridors, and installation of new field equipment to expand coverage to new areas within the region. The system also includes new system control, both in terms of new control software and a new TMC.

The new CCTV system should enhance the benefits that the existing CCTV infrastructure provides its users while providing adequate coverage to new key areas through expansion. The system should use CCTV technology's full potential for gathering and distributing real-time visual information about remote locations to empower operators to practice corridor management of freeways and alternate routes. The CCTV system will be an integral part of the regional ITS network operated through a combination of automated control by Advanced Traffic Management System (ATMS) software and human operators at the Public Safety Transportation Operations Center (PSTOC) TMC.

2.0 Referenced Documents

The CCTV system is one component of VDOT NRO's Intelligent Transportation System (ITS) and likewise, this Concept of Operations must be consistent with other related work. Those concurrent efforts and their relationship to this Concept of Operations are described in this section. In addition, this document builds on past work on the state and future direction of the CCTV system in the Northern Region.

- <u>NoVA Smart Travel Program Plan Update (2006, under update)</u>. This document identifies VDOT NRO's overall vision, goals and objectives, ITS-related needs identified by stakeholders, and the regional operating concept.
- <u>Go-Forward Plan (2005)</u>. This document identifies the need to evaluate and recommend system upgrades to existing traffic management TMC, Safety Service Patrols (SSP), and the Traffic Signal System (TSS).
- <u>VDOT NRO ATMS Concept of Operations (concurrent)</u>. At the same time as this document is being written, VDOT NRO is in the process of replacing its ATMS software. ATMS functionality is to include an expert system for incident detection through CCTV and other device input.
- <u>VDOT NRO Dynamic Message Sign (DMS) Concept of Operations (concurrent)</u>. In a parallel effort, VDOT NRO is developing a concept of operations for DMS. One of the primary operational needs for DMS, as identified in this document, is to ensure proper display and operation of the DMS via CCTV cameras.
- <u>VDOT NRO Vehicle Detector Concept of Operations (concurrent)</u>. In a parallel effort, VDOT NRO is developing a concept of operations for vehicle detectors. This work is being

performed under the same contract as this CCTV concept of operations and the stakeholder information gathering meetings were held jointly in most cases.

- VDOT NRO I-66 Spot Improvements Project Concept of Operations (2008). This document discusses spot improvements along westbound I-66 in Arlington and Fairfax Counties to improve mobility and safety. This document references several upgrade aspects for the CCTV system in this area.
- VDOT NRO TMC/Camp 30-to-PSTOC Transition Plan (2007). This document discusses the transition from the existing NRO TMC to the PSTOC. It describes the communications between the PSTOC and field equipment including CCTV cameras.
- VDOT Northern Region Operations Standard Operating Procedures (2007). This document defines VDOT NRO Traffic Management Center (TMC) standard operating procedures.
- Interviews with Stakeholders (2008). In developing the CCTV Concept of Operations, several one-on-one and group meeting were held to identify stakeholder needs. Input was received from the following stakeholders:
  - VDOT NRO Freeway Operations;
  - VDOT NRO Signal System Operations;
  - VDOT NRO Maintenance;
  - VDOT NRO Systems Engineering;
  - VDOT NRO Traffic Engineering;
  - VDOT NRO Planning & Programming; and
  - VDOT NoVA Transportation Planning.

3.0 User-Oriented Operation Description

3.1 Existing CCTV System

The Northern Virginia TMC currently operates and monitors a total of 126 CCTV cameras. The current CCTV camera system serves several purposes including incident detection, incident verification, traffic management, event monitoring, providing video feeds for general public, media, and public safety responder use. Main video coverage resides along I-66, I-95, I-395, I-495, and Route 267 (Dulles Toll Rd). Smaller groups of CCTV cameras are located at key locations along Route 27, Route 123, Spring Hill Road, and Route 7. Existing CCTV cameras are currently connected to the TMC though a variety of methods that include leased lines, twisted pair, coaxial cable, and fiber optic connections.

3.2 Stakeholders and their Roles & Responsibilities

3.2.1 VDOT NRO Freeway Operations

Freeway Operations includes the real-time operations staff at the NRO TMC which is responsible for monitoring freeway traffic conditions and controlling the freeway ITS elements and SSP. The TMC – located in Arlington, VA – is the centerpiece of operations, monitoring the freeway 24 hours, 7 days a week. ITS field equipment is primarily controlled by the TMC including CCTV cameras, DMS, and Highway Advisory Radio (HAR). Woodrow Wilson Bridge (WWB) operates their own ITS infrastructure apart from the TMC. Additionally, Safety Service Patrols are dispatched by the TMC. Fredericksburg currently has 7 freeway cameras that are connected/monitored by the Thornburg TMC via T-1 lines. Typical freeway operations responsibilities include:

- Coordinate road closure activities
- Collect and process automated traffic data from traffic speed monitoring sites
- Monitor traffic on freeway mainlines and on-off ramps using field equipment including cameras, inductive loops, and non-intrusive equipment
- Initiate traffic management strategies on incident impacted facilities
- Initiate emergency medical assistance until help arrives
- Provide traffic control on freeways (i.e., ramp metering)
- Assist motorists with disabled vehicles
- Provide traveler information utilizing DMS, 511, and HAR traveler information services
- Determine and implement incident clearance and roadway repair needs
- Establish and operate alternate routes
- Coordinate clearance and repair resources
- Repair transportation infrastructure

3.2.2 VDOT NRO Signal Systems Operations

VDOT NRO Signal System Operations staff is responsible for the development and maintenance of traffic signal timing plans for more than 1,400 traffic signals throughout the region. Although special plans are not typically programmed as part of the standard time-of-day clock, special plans can be fine-tuned in the field as needed. Special plans can be called up from the TMC based on phone calls from the public, known event schedules, or incidents observed on the monitors. As traffic incidents are monitored from the TMC, VDOT staff can make changes by downloading adjusted splits or cycle lengths for a temporary period of time when there are no defined incident management plans. Signal operations staffing is not currently structured around a 24x7x365 environment.

3.2.3 Transportation Planning and Engineering

VDOT Northern Virginia District Transportation Planning and NRO Traffic Engineering staff are collectively responsible for studying existing and new corridors, as well as making determinations about transportation infrastructure, needs, regulations, and operations in the NRO.

3.2.4 Maintenance

The Maintenance staff is responsible for the upkeep of VDOT NRO field assets and for repairing and replacing nonfunctioning equipment. This includes the maintenance of static signs, pavement markings, lighting, traffic signals, ITS assets, and telecommunications infrastructure.

3.2.5 VDOT's Statewide Video Distribution System (SVDS) Clearinghouse

VDOT shares its CCTV camera images with the regional stakeholders and the general public through its statewide video clearinghouse. TrafficLand is the current SVDS contractor acting as an agent for VDOT for video distribution. VDOT policy allows up to three (3) private contractors to serve as clearinghouses. Video images are currently made available to the general public on the SVDS contractor's website (currently TrafficLand www.trafficland.com).

3.2.6 Regional Integrated Transportation Information System

The University of Maryland's Center for Advanced Transportation Technology (CATT) Laboratory has taken the lead in developing a system to help improve the transportation efficiency, safety, and security through the integration of existing transportation management systems. This system, the Regional Integrated Transportation Information System (RITIS), will enable the Metropolitan Washington D.C. region to share transportation related information including video images.

3.2.7 Media/Information Service Providers (ISPs)

The typical roles and responsibilities of the media and ISPs as they relate to incident management activities include:

- Report traffic incidents
- Broadcast information on delays
- Provide alternate route information
- Update incident status frequently
- Provide video or photography services

VDOT NRO is covered by the regional media encompassing the entire Metropolitan Washington, D.C. area. These media outlets provide news, traffic, and weather information on a regular basis. VDOT NRO and several emergency management agencies in the area have a close working relationship with personnel at these media outlets. When VDOT migrates to the PSTOC, media entities will obtain video images solely through the SVDS contractor (currently TrafficLand). However, there are several media entities that have a direct connection to the analog video switching equipment at the Arlington TMC.

3.3 Existing Operational Sequence

The existing operational sequence for CCTV cameras is best described using the incident management process. Incident management includes a series of activities, which are carried out by personnel from a variety of response agencies and organizations. It includes the following activities: (1) detection, (2) verification, (3) response, (4) site management, (5) traffic management, and (6) clearance. The use of CCTV cameras throughout this process is discussed below; in addition, the use of CCTV cameras in gate control operations is discussed.

3.3.1 Detection

Detection is the process by which an incident is brought to the attention of the agency or agencies responsible for maintaining traffic flow and safe operations in the project area. Incident detection is performed using several different techniques including:

- Calls from motorist cell phones
- VDOT Safety Service Patrols (phone, two-way radio)
- Virginia State Police (phone, scanner, CAD)
- Fire and Rescue (scanner)
- Police Department (scanner)
- Local jurisdiction emergency alert and notification systems (i.e., Fairfax County CEAN, Arlington Alert)
- Media (phone)

In addition to these detection techniques, the NoVA TMC has three (3) workstations assigned to monitor designated geographic areas. These geographic areas include I-66, I-95/I-395, and the Capital Beltway (I-495). TMC operators observe traffic conditions within their assigned areas by touring CCTV cameras along their designated corridors. The existing camera-to-operator ratio averages 42:1.

VDOT NRO is currently investigating video incident detection (VIDs) which is a technology for automatic real-time detection of traffic incidents on roadways based on image processing techniques. VIDs use images from CCTV cameras which are processed by a video detection unit that extracts pertinent information enabling the system to spot stopped vehicles. This information is then transmitted to a TMC Operator via the ATMS software. Incidents and events are logged into VOIS (Virginia Operational Information System) which is the current source of information for VDOT's 511 traveler information system. In the near future, VOIS will be replaced by a new system called VA Traffic.

3.3.2 Verification

Verification includes confirming that an incident has occurred, determining its exact location, and obtaining as many relevant details about the incident as possible. Verification includes gathering enough information to dispatch the proper initial response. Verification is usually performed by TMC operators viewing CCTV cameras or by dispatched field units (e.g., police and freeway service patrol vehicles) at the incident site.

According to VDOT NRO's Standard Operating Procedures (SOP), verification of incidents requires TMC operators to obtain the following information:

<u>Location:</u>

- Location of incident (e.g., I-66)
- Direction of travel (e.g., westbound, eastbound)
- Nearest reference point (e.g., mile marker, exit number)
- Number of lanes blocked

<u>Nature of the Problem:</u>

- Are there any injuries?
- How many vehicles are involved?
- Is the vehicle overturned?
- Are any commercial vehicles involved?

3.3.3 Response

Response includes dispatching the appropriate personnel and equipment and activating the appropriate communication links and motorist information media as soon as there is reasonable certainty that an incident is present. This coordination is usually led by operators at the TMC. TMC operators determine through response units the estimated duration and severity of the incident. First responders with access to video images through TrafficLand or RITIS may use the video images to assist with the response.

3.3.4 Site Management

Site management is the process of effectively coordinating and managing on-scene resources. The foremost objective is ensuring the safety of response personnel, incident victims, and other motorists. CCTV cameras are used during the site management stage to monitor incident response activities from the TMC. The TMC Operator may occasionally need to block video access to external agencies, media, and the public depending on the severity of the on-scene conditions and/or security concerns.

3.3.5 Traffic Management

Traffic management is the application of traffic control measures in areas affected by the incident. Traffic management occurs both at the incident site and at the TMC. Responders are responsible for the incident scene while the TMC looks at the regional view. The TMC is responsible for determining the impact that the incident has on the region and reacting accordingly. VDOT NRO utilizes several strategies to manage traffic during an incident including:

- Posting messages on dynamic message signs (DMS) or portable changeable message signs (PCMS) to advise motorists of incident details and potential actions to take (i.e., alternate routes, expected delays, travel times, etc). CCTV cameras are used by TMC operators to verify message content posted on the message signs.
- Operating Ramp Meter System (RMS) on I-66 and I-395. TMC operators utilize CCTV cameras to fine tune and monitor operation of individual metered ramps, precluding the necessity for on-site field observation. Additionally, TMC operators use cameras to monitor operations throughout the peak periods.
- Operating Lane Control Signals (LCS) on I-66 where the signals are currently for shoulder usage and are used to enable extra capacity during morning and evening rush periods. TMC operators use CCTV cameras to ensure that the roadway is clear of obstructions before opening the shoulder; monitor the shoulder for incidents; and verify LCS displays (red X or green arrow.
- Adjusting traffic signal timing plans to account for excess demand during an incident. VDOT staff can make changes by downloading adjusted splits or cycle lengths, and use CCTV cameras to monitor roadways when changing timing plans.

3.3.6 Clearance

Clearance is the process of removing wreckage, debris, or any other element that disrupts the normal flow of traffic and restoring the roadway capacity to its pre-incident condition. Private towing companies are responsible for clearing incidents. TMC operators confirm that an incident has been cleared using CCTV cameras and / or information received from on-site representatives.

3.3.7 Gate Control Operations

TMC operators coordinate with a technician located in the field and use CCTV cameras to verify that HOV gates and the Monument Drive gates are opened / closed at the time specified.

4.0 Operational Needs

This section details specific needs that will drive the requirements for the future CCTV Camera System. These operational needs were identified thru a series of one-on-one and group interviews with VDOT and Virginia Transportation Research Council staff as well as extensive research on the use of CCTV cameras. The needs ensure that the goals identified in Section 1.4 are integrated into the development of the specific requirements. Needs are grouped below into the following categories: freeway operations; signal operations; maintenance; and transportation engineering / planning needs.

4.1 Freeway Operations

Freeway Operations staff uses the CCTV system to detect and verify freeway incidents such as accidents, breakdowns, and debris on the roadway as well as to monitor planned and unplanned events such as lane closures for road work. Freeway Operations staff needs to be able to verify the performance of other ITS systems using the CCTV system. The Freeway Operations staff need the system to help increase operator efficiency through a Video Incident Detection (VID) expert system to notify operators of road condition changes in a camera's feed while another feed is being viewed.

System objectives based on Freeway Operations user needs are presented in the following traceability matrices.

4.1.1 Traffic Management

Objective	User Need
4.1.1.1 Corridor Management	a. Monitor freeways and arterials with limited gaps b. Ability to monitor and compare parallel arterials that can support diversion during an incident and report on congestion c. Monitor regular lanes as well as express and reversible lanes
4.1.1.2 Condition Monitoring	a. Provide camera coverage of full mainline laneage in both directions b. Ability to monitor interchanges: merge areas, diverge areas, and weave areas c. Avoid visual obstructions such as vegetation, ramps, overpasses, buildings, and signs d. Ability to view images in low light conditions e. Ability to view images in fog, rain, snow conditions f. Ability to view steady, clear image g. Cameras programmed to return to preset angle, zoom, and focus when not under active operator control.
4.1.1.3 Inform Public and Media	a. Create low bandwidth copy of TMC video feed and make available to general public via internet sites such as VDOT 511 webpage b. Create low bandwidth copy of TMC video and provide to media and ISPs through a media feed c. Disable public feeds during emergencies, security events, or other events of a sensitive nature (i.e., fatalities)
4.1.1.4 Regional Coordination	a. Share video images with regional stakeholders (state and local DOTs, Police, Fire & Rescue) b. Share video images via Video Clearinghouse c. Share video images via RITIS

4.1.2 Incident and Event Monitoring

Objective	User Need
4.1.2.1 Freeway Incidents	a. Provide full camera coverage on interstates and limit coverage gaps where incidents can occur without detection

	b. Ability to monitor interchanges: merge areas, diverge areas, and weave areas c. Ability to monitor bridges d. Visually verify incident reports from other detection means such as Virginia State Police Computer Aided Dispatch (VSP CAD), Traveler Calls, and the SSP e. Ability to focus cameras on suspected incidents f. Ability to select displayed camera feed g. Potential for automatic notification of incidents: VID
4.1.2.2 Planned Events	a. Ability to monitor planned events entailing lane or interchange closures or route diversion, such as long-term construction, parades and festivals, and the Marine Corps Marathon
4.1.2.3 Unplanned Events	a. Operator ability to detect and monitor traffic conditions due to unplanned events such as early school closures

4.1.3 Validating Other Infrastructure

Objective	User Need
4.1.3.1 DMS	a. Operator ability to verify DMS status and message display
4.1.3.2 High-Occupancy Vehicle (HOV) Lanes	a. Ability to detect wrong-way vehicles and notify SSP operator b. Ability to tour HOV lane cameras and determine lane clearance c. Monitor for stalled vehicles in HOV lanes d. Monitor HOV lane gates to
4.1.3.3 High-Occupancy/Toll (HOT) Lanes	a. Monitor the impacts of HOT lanes on general purpose lanes b. Monitor HOT lane entry points / exits
4.1.3.4 Ramp Metering System	a. Ability to monitor the ramp metering system
4.1.3.5 Lane Control System (LCS)	a. Ability to monitor Lane Control System (LCS) displays on I-66 b. Ability to use VID on LCS shoulders

4.1.4 Active Speed Limit Management

Objective	User Need
4.1.4.1 Adjust Speed Limit to Traffic Conditions	a. Obtain qualitative visual descriptive information about traffic conditions

4.1.5 Performance Measurement for Freeway Operations

Performance measurements will be used to evaluate the CCTV system’s effectiveness in freeway operations. Criteria will be needed to evaluate the CCTV system’s performance in traffic and incident/event management. The system’s incident/event management contribution can be judged by its mean time-to-verification between when an event is detected or reported and when TMC operators using the CCTV system finish verifying the detected event. This can be contrasted with the time needed to verify events in areas with little or no CCTV coverage.

Sensitivity settings for the proposed VIDs expert system would need to be evaluated and adjusted based on false alerts and/or slow response times. The numbers of reported non-events and missed events by the expert system as a percent of total events during the reporting period is a quantitative performance measurement for the expert system. These types of systems traditionally require a lot of care and feeding (i.e., configuration, adjustment, and maintenance), and thus should play a secondary role given the maintenance burden.

4.2 Signal Operations

The CCTV system will include cameras on signalized arterial highways. These cameras will provide information that can help Signal Operations monitor the arterials and manage traffic and incidents.

System objectives based on Signal Operations user needs are presented in the following traceability matrices.

4.2.1 Arterial Congestion Management

Objective	User Need
4.2.1.1 Responsive Timing Plan Selection	a. Observe and note overall traffic conditions on the arterial network. b. Observe the effectiveness of selected timing plan in the form of throughput volume. c. Provide real-time traveler information on 511-designated arterials.

4.2.2 High-Accident Location Monitoring

Objective	User Need
4.2.2.1 Key Location Monitoring	a. Observe and monitor key "high accident" locations. b. Provide real-time incident information to the public/media for major arterials.

4.2.3 Performance Measurement for Signal Operations

The CCTV system will provide a method to measure traffic signal performance. VDOT NRO's Signal and Freeway Systems Operations group has calculated signal optimization benefits using modeled, rather than empirical, data about stops and delays at signalized intersections. With appropriate software, the CCTV system can record the actual number of stops and the lengths of the delays at a signal. This field data will provide a direct performance measurement for observed signals and validate the model used to judge the performance of other signals. Also, when NRO staff receives citizen concerns regarding arterial signal timing, the CCTV system expedites investigation of concerns within its coverage area by allowing personnel to observe traffic conditions in real time from afar.

4.3 Maintenance

The CCTV system will be unable to meet freeway and signal operator needs if its elements are not working. New and replacement CCTV devices will need to be comprised of reliable components with a high Mean-Time Between Failures (MTBF) rating in order to reduce the likelihood of failure during an average 5-7 year life span. When elements do fail, VDOT NRO Maintenance needs to be able to restore system functionality as quickly and easily as possible in order to provide for other users' needs to be met. A system that has minimal cost and downtime when serviced will also help the maintenance department to effectively steward its budgetary and labor resources.

System objectives based on Maintenance user needs are presented in the following traceability matrices.

4.3.1 Reliability

Objective	User Need
4.3.1.1 Device Reliability	a. CCTV device power and communications should not be affected by other devices. b. Key CCTV locations and associated communication repeater locations with backup power. c. Long lasting equipment: components rated for continuous operation without failure for 5+ years d. Robust, weatherproofed equipment.
4.3.1.2 System Reliability	a. Ability to control and monitor cameras from main PSTOC facility or backup TMC b. Overlapping coverage to prevent coverage gap due to single device failure.

4.3.2 Preventative Maintenance, Repair & Replacement

Objective	User Need
4.3.2.1 Minimizing Maintenance Cost and Down Time	a. Field equipment that is simple to replace, remove, and service, resulting in a short Mean Time To Repair (MTTR) b. Readily available device replacements. c. Appropriate maintenance funds allocated prior to increase in field devices. d. Ability to remotely reset equipment power. e. Ability to remotely test devices via IP protocol.
4.3.2.1 Managing Replacement Stocks	a. Device components traceable within Inventory & Maintenance Management System (IMMS) b. Device's unique IP numbers logged in IMMS c. Devices identified according to logical system d. Devices bar coded in accordance with Appendix 2, Inventory Barcode Requirements

4.3.3 Camera Location for Maintenance

Objective	User Need
4.3.3.1 Minimize physical damage	a. Protect equipment from vehicle impact damage through appropriate placement or guardrail. b. Power and communication cables protected against line breaks. c. Provide lightning and surge protection for devices and electrical/communication lead-in conductors. d. Install on stable foundations. e. Vandalism prevention and mitigation.
4.3.3.2 Accessible to	a. Safe access to CCTV locations for maintenance

Maintenance crews	crews. b. Accessible with existing 35' maintenance bucket trucks. c. Ample flat, level, and stable surfaces for bucket trucks with outriggers to operate safely off of the travel surface without lane closure. d. Locations to avoid heavy vegetation. e. Avoid mounting on bridges, overpasses, flyovers, or other structures.

4.3.4 Maintenance Performance Measures

CCTV availability can be measured by the equipment's MTBF. When equipment does fail, the mean outage duration, measured as the MTTR, will also be an indicator of maintenance performance and CCTV availability.

The number of maintenance personnel trips to service cameras along with travel time and time-on-site can all be tracked as performance measures of system maintenance needs. These measurements will show the system's demand on the maintenance staff and budget.

4.4 NoVA District Transportation Planning and NRO Traffic Engineering Needs

Northern Virginia District Transportation Planning and NRO Traffic Engineering staff has a need for aggregated road user and network-wide traffic data. Although fulfillment of these data needs does not incorporate the real-time capabilities of the CCTV system, the system's cameras can be used as data collectors within its coverage area for short durations at different times of the year.

System objectives based on Planning and Engineering user needs are presented in the following traceability matrices.

4.4.1 Planning and Engineering Data Collection

Objective	User Need
4.4.1.1 Origin and Destination Studies	a. Ability to augment outsourced data collection with CCTV system.
4.4.1.2 Spot Analyses	a. While current VDOT policy is not to record CCTVs, Planning & Engineering may consider monitoring or recording an area for verifying safety, geometric, or other traffic-related issues.

5.0 System Overview

5.1 Software Subsystem

The new ATMS software that is being developed for the new PSTOC facility will need to be able to operate and monitor CCTV cameras. Additionally, the new ATMS software should eventually support a field-based or central-based detection algorithm that will detect anomaly conditions from CCTV imaging. The new ATMS software should be compatible with high speed Ethernet communications and networking. In the future, the new ATMS software can recommend specific CCTV cameras for verifying DMS message displays, gates, and ramp meters at adjacent locations.

5.2 Cameras

As per the VDOT NRO's Go Forward Plan, CCTV camera images should allow for operators to detect and verify events, verify status of other ITS devices, and provide information on traffic conditions to the public and the media. CCTV cameras should be added on arterials adjacent to key highways to monitor their traffic conditions and make informed diversion decisions. The cameras should be placed so that there are no major coverage gaps for either direction's traffic. In addition, views of all dynamic message signs and HOV lane gates should be incorporated within the CCTV coverage in accordance with the VDOT NRO DMS Concept of Operations and FHWA funding guidelines for DMS. All CCTV cameras will be equipped with standards-based (i.e. MPEG-4, H.264, or equivalent) IP-formatted digital encoding with images able to be distributed via high speed communications and compatible with the new ATMS. Existing cameras will be upgraded and replaced as funding or device failures warrant. The camera images should continue to be shared with regional stakeholders and the general public through VDOT's existing Video Clearinghouse for traffic incident and condition information dissemination, TrafficLand, or its successor(s). In an effort to automate the incident detection process, VID expert systems may be incorporated at strategic locations to support incident management, as well as to further maximize the ratio of cameras to TMC Operators.

5.3 Communications

As part of VDOT NRO's IP Video Migration deployment, the Department is planning to return video from its existing video cameras back to the TMC over an Ethernet network. Digital video relies on network bandwidth (rated in terms of 1000s of bits per second (kbps)) and communication media (copper, fiber, wireless). The amount of available bandwidth is dependent on the chosen media, and indirectly determines the image quality/resolution that can be achieved.

There are different perspectives on video quality based on the type of user, and the application. For instance, low-resolution video at a rate of 5-10 frames per second (fps) may be acceptable to some operators who are merely monitoring for stopped vehicles or incidents. However, congestion monitoring, and post-processing traffic analysis require a higher resolution at nearly 30 fps.

Most agencies have determined that the lowest level of acceptable quality for traffic condition monitoring is 1.0 to 1.5Mbps, which is just below the threshold for a leased T-1 telephone service line. However, when fiber resources are available, many elect to use 2.5 to 3.0Mbps for near-DVD quality video using MPEG-4 compression standards.

VDOT NRO is upgrading to an IP-based 10 Gigabit Ethernet (10GigE) backbone for ITS field communications along I-95/395 and I-66 with a physical ring connection along Route 234. This upgrade is expected to be completed by the end of 2008. Cameras along these routes will have access to VDOT's fiber optic resources. A CCTV master plan is being developed concurrently to evaluate and prioritize the deployment of additional cameras along existing routes with fiber, as well as those that will require alternate communication methods including leased lines or wireless.

For CCTV cameras that will be connected to the fiber optic backbone, the CCTV system is to be connected to the PSTOC on an Ethernet ring architecture as shown in **Figure 2**.

Each camera will have a digital encoder that converts the camera's output into a digital network signal. The encoder will feed the digital signal into an Ethernet field switch. Chains of these field switches will be consolidated at hubs with much higher-bandwidth network switches. These hubs will connect to the PSTOC, where switches will distribute the digital signals to the ATMS software and servers as well as to the digital decoders that convert the digital signal to analog output for the PSTOC displays. The ATMS software will also transmit signals back through the network to control the cameras and displays.

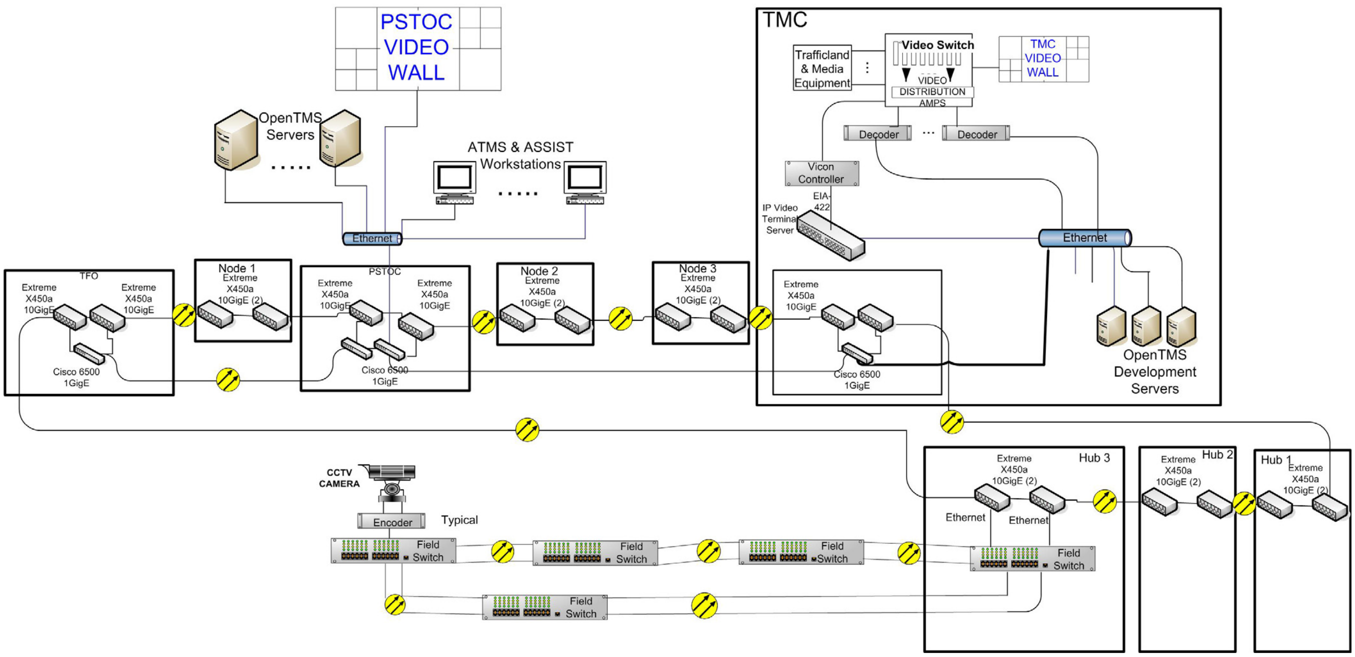

Figure 2: High-Level CCTV Communications Architecture

6.0 Operations and Support

6.1 Personnel

The current CCTV system has an overall camera-to-operator ratio of 42:1 and is monitored with continuous touring through each operator's assigned camera set, the size of which varies with the assigned area. This method's effectiveness will be challenged as the system expands with the installation of additional cameras, which will increase the time between tour visits to each camera. Having a VIDs expert system to notify operators of cameras needing their attention because of conditions out of the ordinary would allow each operator to monitor a greater number of cameras and improve efficiency from the touring method. Without this type of system additional operators would be needed to maintain a similar ratio. Existing geographic areas would be reassigned to adequately tour cameras and perform responses in a timely manner. Even at full system deployment and maximum final staffing levels, the number of operators in the TMC will be constrained to seven per shift. Using current ratios this implies that an expert system will be needed when the system expands beyond approximately 290 cameras.

6.2 Facilities

By 2009, the PSTOC will house the operators and their control terminals. The existing TMC will act as a redundant operations facility until adequate equipment and communication networks are in place in the Traffic Field Operations (TFO) Building in Gainesville. The TMC will continue to house the remaining SONET communication subsystem that supports the remaining ASSIST software functionality. The existing CCTV field devices will have digital video encoders and Ethernet switches in roadside cabinets.

VDOT NRO plans to use the existing Arlington TMC as a backup operations center until the Traffic Field Operations (TFO) is capable of serving in this role sometime in 2009. Regardless of which location is used, this Concept of Operations is based on the need to monitor and control cameras from two locations without significant software or hardware configuration changes. The IP Video migration upgrades in the field, along with the parallel ATMS software replacement will ultimately achieve this operating concept.

6.3 Operating Procedures

Most new and / or replacement CCTV devices should retain the existing operating procedures such as panning, tilting, zooming, and focusing. After construction, additional procedures should be developed for automating, through software development or scripts, as many processes as feasible. Potential changes that may be incorporated into the existing operating procedures are listed below.

- Specific CCTV locations should be considered as locations to perform Video Incident Detection (VIDs). This will automate part of the incident detection within the corridor and should be incorporated into the operating procedure as part of incident detection methods. The incident will still need to be verified and handled as done currently.
- Loss of video signal to a camera for greater than one minute should trigger an email notification to a System Administrator or Maintenance staff member.

6.4 Maintenance and Budget

There will be a greater maintenance demand and cost due to the increase in CCTV devices. This demand and cost should be minimized whenever possible through proper design, installation, and device selection. Reliability as discussed above is a key factor in keeping a sustainable system. A predetermined number of spare units (typically 5-10% of total installed) should be available for installation in case devices fail in order to reduce the amount of down time or MTTR. Typically 10% of the capital infrastructure cost is allocated per year for routine maintenance and replacement of electronics and support equipment.

For planning purposes, *$6,000 per camera* should be allocated per year *for maintenance* to accommodate camera failures/replacement, as well as repairing/replacing surge arrestors, cables, UPS'/batteries, cabinets, and other support equipment. Additionally, fiber cabling infrastructure is at the heart of the majority of the NRO communication system. *$15-$20,000 per mile of cabling infrastructure* should be allotted for both labor and material expenses to support emergency splice *maintenance* and replacing small cable sections damaged by construction or other incidental activities.

It is anticipated that all maintenance activities for permanent devices will be performed by VDOT NRO's Maintenance staff and its contractors utilizing their current maintenance contract. To support maintenance activities, all ITS field equipment should be deployed in a manner that allows maintenance staff to safely perform maintenance activities. Field equipment should be positioned in a manner that allows staff to perform maintenance with minimum impact on the traveling lanes.

Information identifying and describing each piece of equipment will be collected and logged in the IMMS at the time of installation. This IMMS data will streamline the process of monitoring, locating, and tracking parts and equipment for maintenance purposes. Personnel should update the IMMS information whenever performing maintenance work.

Two additional devices are recommended for maintenance purposes. First, the addition of a telemetry device that is interlocked with the communications fiber would continuously report the status (voltage and current) of each circuit in a service panel, including the main supply. The main benefits would be faster detection of trouble and a more cost-effective response. Second, the addition of a remotely managed (IP-based) power distribution strip would minimize maintenance trips to a site for a simple device power restart.

7.0 Operational Scenarios

Operational scenarios present narratives of the system in typical use. Each scenario provides an example of a situation that implicates a user need and explains how the system would be used to address that need. These scenarios describe the system being used in concert with other ITS systems to satisfy objectives in everyday operations.

7.1 Scenario 1 - Integrated Corridor Management

At 1:40 PM on Wednesday afternoon, an accident occurs on I-95 northbound at the Prince William Parkway overpass in the left lane of the three-lane section. Traffic begins to queue and the ATMS expert system notifies the TMC operator, who is touring through the I-95 cameras at Springfield, of unusual conditions south of Prince William Parkway. The operator responds to the alert by selecting the affected segments and quickly sees the growing congestion south of the accident. Using cameras' pan-tilt-zoom features, the operator detects the accident beneath the overpass and identifies it as a two-vehicle collision. One car is flipped over on its side and a former occupant appears to be lying on the shoulder.

The TMC operator notifies the VSP of the incident then shuts off the public and media feeds from the camera viewing the scene. The operator next logs the incident into VOIS and dispatches the nearest SSP unit. (In the future when VA Traffic replaces VOIS, the operator will be able to log incidents into the ATMS software once, and it will be distributed to VA Traffic and 511.) Continuing to monitor the incident and its developments with that camera, the operator quickly tours through the cameras on the parallel integrated corridor route, U.S. Route 1. Seeing regular traffic conditions on Route 1, the TMC requests approval from traffic signal engineers before notifying motorists about Route 1 as an alternate to I-95. Northbound DMS on I-95 are programmed to announce an incident at Prince William Parkway. A secondary message alerts motorists about the travel times to Gordon Boulevard via Route 1 and I-95. With the CCTV system, the TMC operator confirms that the DMS are displaying the messages properly. An I-95 Detour signal timing plan is activated for Route 1.

Northbound Motorist Alpha sees the DMS notice and decides to bypass the accident area. Alpha exits I-95 at Dale Boulevard and gets on U.S. 1 to bypass the incident and its congestion. The I-95 Northbound Detour plan on Route 1 helps Alpha and other northbound motorists circumvent the incident.

Northbound Motorist Bravo sees the DMS notice and decides to stay on I-95 northbound. Forewarned by the DMS, however, Bravo changes lanes out of the left lane shortly after Opitz Boulevard and is prepared to slow down before Prince William Parkway. Bravo and other northbound motorists are able to avoid secondary collisions on I-95, where traffic slows but does not stop.

The TMC operator continues to use CCTV to monitor congestion levels along both I-95 and Route 1. As backups increase, the operator activates additional DMS alerts further south of the incident in the same fashion.

7.2 Scenario 2 - HOV Clearance Procedures

At 11:30 AM on a Friday morning, the I-395 HOV lane transition from northbound to southbound flow is scheduled to begin. The process begins with the TMC operator remotely commanding the northbound entry gates to close. The TMC operator checks the northbound gates with the CCTV cameras and confirms that all northbound entry gates are closed as the SSP begins a ride-through to verify that the lanes are clear before the southbound gates open.

The SSP finds a stalled vehicle in the HOV lane. The TMC operator monitors the situation via CCTV as the SSP renders assistance and/or requests towing service. Once the stall is cleared the SSP continues the ride-through, finding no more obstructions, as the TMC operator uses the CCTV system to monitor the motorist's progress out of the HOV lane. Once the motorist has returned to the I-395 northbound local lanes, the TMC operator gives the instructions for the northbound exit gates to close and the southbound gates to open.

The TMC operator uses the CCTV system to check the southbound gates and sees that the entry gate north of Edsall Road has malfunctioned and remains closed. The TMC operator dispatches the SSP to that gate and observes while the SSP manually opens the gate. By 12:30 PM, all gates are open and the SSP returns to patrolling the freeway while the TMC operator resumes touring the CCTV system.

It should be noted that plans are in process to deploy High-Occupancy Toll (HOT) lanes along I-395 and I-495, which would then be operated by private firms.

7.3 Scenario 3 – I-66 Shoulder Lane Control

At 5:19 PM on a rainy Tuesday evening the I-66 Westbound shoulder has been serving as an additional lane for westbound traffic since 4:00 PM. The TMC operator's attention has been focused on the CCTV feed from the camera on I-66 Westbound at Route 234, where the wet roadway and poor visibility contributed to an accident that is being cleared from the inside lane. Suddenly, the operator receives a notification from the VID that the Route 655, Waples Mill Road, camera has detected an anomaly in the shoulder being used as a supplemental lane. The operator passes control of the Route 234 camera to another operator and brings up the feed from the Waples Mill Road camera. The camera shows a disabled vehicle in the shoulder 1,000 feet east of Waples Mill Road.

In response, the operator notifies the SSP of the disabled vehicle. The operator then initiates a progressive closure of the shoulder lane from the disabled vehicle upstream to Route 123. Each LCS display in turn, starting with the display immediately upstream from the disabled vehicle, changes from the green arrow indicating permitted travel on the shoulder to the red X indicating normal prohibition of travel on the shoulder. The operator also programs a message for the DMS at Blake Lane to notify westbound drivers of the disabled vehicle at Waples Mill Road and the shoulder closure west of Route 123.

Using CCTV to verify that this message is showing properly on the two DMS, the operator sees that a westbound LCS display between Blake Lane and Route 123 has malfunctioned and is displaying neither the green arrow nor the red X. The operator logs the malfunction and notifies maintenance personnel of the display needing attention.

8.0 Next Steps

The Concept of Operations for the CCTV system presents new devices and operating procedures requiring integration into the new ATMS and daily operations of the system stakeholders. This section reviews areas of next steps within the systems engineering process to carry these operations concepts forward to the implementation stage.

8.1 Detailed Requirements

The VDOT NRO Systems Engineering group will develop functional and performance requirements for system components along with the physical location of these components, including CCTV cameras and supporting equipment, which may need to have backup power and communication facilities at key locations for their extended uses. Design requirements will cover a robust, dependable installation of field devices and requirements for operations and maintenance staff. More detailed requirements for incorporation into specification and procurement documents will be provided as part of system design.

8.2 System Design

Detailed design of integrated communications to the ITS elements and integration with existing VDOT TMC systems will be performed as part of detailed design activities. This will include new CCTV cameras and related communications and power supply equipment. If creative approaches or unfamiliar equipment are incorporated into the design, prototype testing should be performed to minimize risk. The VDOT NRO Systems Engineering group or consultants will develop the system design. System procurement(s) may occur as part of a design-bid build or as part of a design-build procurement; the approach will be determined by VDOT. System design will include identifying the new corridors and specific camera locations, as well as existing locations that are to be upgraded/included in each deployment package.

If the field equipment, communication system, or intended operations require changes to the ATMS, the designers will prepare detailed specifications for the software work, so that VDOT can arrange for that work to be performed.

8.3 Software/Hardware Development Field Installation

All hardware field installation for CCTV will be conducted by VDOT NRO Operations Installation & Construction (OIC) according to the specifications (detailed design or design-build, as approved by VDOT), and will be inspected by VDOT NRO OIC. OIC, however, may choose to use a contractor for either activity. During installation, OIC or the contractor should collect information on all devices for logging in the IMMS. Meanwhile, VDOT’s central software contractor will complete the necessary modifications of the ATMS. VDOT NRO ITS Information Technology Section (ITS-IT) will oversee coordination between the CCTV contractor and the central software contractor. This may include providing samples of field equipment to the software contractor for use in testing the software during development. VDOT NRO ITS-IS (or representative) will also oversee software field installation.

8.4 Unit/Device Testing

This project will require testing geared toward CCTV cameras, encoders/decoders, CCTV related communications equipment, and CCTV related power supply equipment. Factory acceptance testing will be required for each unit of certain materials, such as CCTV cameras. Some equipment may be tested after delivery but prior to installation, if that makes testing easier. For example, the water tightness of camera assemblies may be tested prior to installation. All items will be inspected or tested after installation.

Prior to testing, the contractor will be required to provide proposed test procedures for VDOT NRO OIC and ITS-IT approval. For some items, the project specifications will describe some of the tests that must be performed. In addition, there will be a general requirement that all tests and diagnostic activities recommended by the equipment manufacturer must be performed. There will also be a general requirement that unit testing of items that are intended to communicate with the TMC must be tested while communicating with the TMC.

The project specifications will stipulate the relationship between the unit testing and payment. For most items, the contractor will receive a progress payment when the materials are delivered, and the remaining portion of the bid price (other than retainage) when the item passes its unit test. For items whose suitability cannot be completely determined by inspection upon delivery, no progress payment will be allowed. For items whose suitability cannot be completely determined based on unit testing, a portion of the bid price may be paid when the item passes its unit acceptance test, but the remainder will not be paid until the related subsystem and system tests have been passed. For example, cameras can be tested locally at the field cabinets to demonstrate working units, but they require subsystem testing with the digital encoders, Ethernet equipment, and central software prior to complete acceptance.

8.5 Subsystem & System Verification and Acceptance

Once all devices and components are individually tested and accepted by VDOT NRO OIS & ITS-IT Sections, the contractor is responsible for testing of specific subsystems functionality (e.g., Traffic Operations Requirement, Signal Operations Requirements, etc.) to verify that they meet all pertinent operational and performance requirements as documented in the specifications. In most cases, the system or subsystem under test will include the central software, so testing may reveal problems that are the responsibility of the central software contractor, not the CCTV contractor. The project specifications must deal with this possibility, indicating how this eventuality will affect payment. VDOT NRO OIC and ITS-IT are to witness the testing and will either (a) develop a punch list of items or issues to be resolved, or (b), if there are no remaining items or issues to be resolved, authorize the start of the system acceptance test.

The system acceptance test, sometimes called a “burn-in” period, entails 30-days of normal operation with all systems in place. Completion of the acceptance test will assure that all systems are fundamentally operational. Any major failures which occur within the system operation during the 30-day period will cause the 30-day clock to start again, until such time that 30 days go by with the system in full operation. Any item that fails in large numbers will be replaced in its entirety.

8.6 System Validation

As part of the systems engineering process, a validation plan is typically completed to complement the Concept of Operations. This plan defines expectations so that when completed, all stakeholders can agree on whether the system designed or deployed met its objectives.

During the first year of operation, VDOT will determine the extent to which this project meets its intended objectives based on the validation plan and the data collected in accordance with that plan. Data likely to be deemed indicative of the success of this project include:

- Number and location of accidents detected through VIDs
- Time to detect and verify incidents

- Reliability of the CCTV system and equipment
- Stakeholders' perceptions of the project impacts

The validation may reveal opportunities to improve the procedures used to develop and implement similar projects in the future. The validation plan should be developed prior to project implementation, so that relevant data can be collected before the project for use in before/after comparisons.

8.7 Operations & Maintenance

Camera system expansion will continue to serve as a cornerstone of TMC's traffic management processes. Disruptions or failures in the performance of these functions can impact traffic safety, reduce system capacity, and ultimately lead the traveling public to lose faith in the information generated by the transportation network. The problem is further complicated by the fact that today's systems, subsystems, and components often are highly interdependent, meaning that a single malfunction can critically impact the ability of the overall systems to perform their intended functions.

The existing operational sequence and standard operating procedures will need to be modified and updated both to meet all user needs and to fit the new system architecture.

Operators are currently assigned for given segments (one for I-95/395, one for I-66, and one for I-495) of freeway. Arterials outside of Tysons Corner have not been traditionally been monitored by the TMC operators. A dedicated TMC operator will be assigned to the Dulles Metrorail project during the core hours of 6am to 10pm for approximately two years of construction. However, this is neither a long-term solution for these, nor the remaining arterials. VDOT NRO currently has two dedicated call-takers in the TMC that hand off calls to the appropriate segment operator. In the PSTOC, this model will change to one where all operators will share in fielding incoming calls. However, it is still planned to have area or "segment" experts primarily assigned to the area(s) where they have the most experience. VDOT will have a maximum total of seven freeway management operator positions in the PSTOC. While not the only factor influencing a need for additional TMC freeway operators, current staffing levels would suggest an additional operator for every increase of 40-50 cameras throughout the freeway system.

VDOT NRO Maintenance will continue to own and maintain the system within the expansion areas. However operations and maintenance for the cameras, as with other similar systems in the region, could be included in contracted maintenance, since most if not all the components are expected to be compatible with similar devices elsewhere in the Northern Region Operations area. Additionally, funding routine device maintenance and/or replacement should be included in annual budget reviews. The use of 10% of the initial capital investment cost is widely accepted industry practice. Outsourcing warranty and repair of these items will come at a higher premium, which will be dependent on the quantity and type of equipment to be maintained, and more importantly the response times.

Appendix 1

User Need	ConOps Section	High-Level Requirement Number and Title	High-Level Requirement
		1.0 - Functional Requirements	
Ability to monitor and compare parallel arterials that can support diversion during an incident and report on congestion	4.1.1.1.b	1.1 – Video Wall & Monitors	Operators should have the ability to select and view single or multiple CCTV locations on either their computer monitor or the PSTOC video wall.
		1.2 – Corridor Bundle Camera Groups	ATMS should support device groupings for parallel routes in support of incident management diversion corridors.
Create low bandwidth copy of TMC video feed and make available to general public via internet sites such as VDOT 511 webpage	4.1.1.3.a	1.3 – Low Quality Video	CCTV encoders and/or software shall be capable of producing a lower quality/lower bandwidth copy of each camera feed.
		4.1 – Equipment Compatibility With Other Agencies	Defined in High Level Requirement 4.1 - Equipment Compatibility With Other Agencies.
Disable public feeds during emergencies, security events, or other events of a sensitive nature (i.e., fatalities)	4.1.1.3.c	1.4 – Cutting Video Feeds	Operators should have the ability to disable selected low bandwidth video feeds to designated agencies, public, or media during justified events. The feed(s) should remain disabled until the operator reactivates the feed(s). Primary video feeds for ATMS operators should remain active at all times.
Visually verify incident reports from other detection means such as Virginia State Police Computer Aided Dispatch (VSP CAD), Traveler Calls, and the SSP	4.1.2.1.d	1.5 – Pan/Tilt/Zoom Controls	Cameras shall be able to pan/tilt/zoom. Operators will be able to control the cameras from the PSTOC, or the backup TMC.
		2.1 – Freeway Spacing	Defined in High Level Requirements 2.1 – Freeway Spacing.
		2.2 – Arterial Spacing	Defined in High Level Requirements 2.2 – Arterial Spacing.
		4.3 – ATMS Software Compatibility	Defined in High Level Requirements 4.3 – ATMS Software Compatibility.
Ability to select displayed camera feed	4.1.2.1.f	1.1 – Video Wall & Monitors	Previously defined.
Potential for automatic notification of incidents: VID	4.1.2.1.g	1.6 – Video Incident Detection	ATMS shall have the ability (where specified by design plans), through predefined algorithms, to detect a possible event from CCTV video feeds and notify the appropriate operator. These events include, but are not limited to accidents, stalled vehicles, unusual congestion and wrong-way vehicles.
Ability to monitor planned events entailing lane or interchange closures or route diversion, such as long-term construction, parades and festivals, and the Marine Corps Marathon	4.1.2.2.a	1.2 – Corridor Bundle Camera Groups	Previously defined.
		2.1 – Freeway Spacing	Defined in High Level Requirements 2.1 – Freeway Spacing.
		2.2 – Arterial Spacing	Defined in High Level Requirements 2.2 – Arterial Spacing.
Operator ability to detect and monitor traffic conditions due to unplanned events such as early school closures	4.1.2.3.a	1.7 – User Defined Camera Set	Operator shall have the ability to define a set of cameras as a group to monitor during an unplanned event. This group can easily be recalled through the ATMS for a user defined timeframe.

		1.6 – Video Incident Detection	Previously defined.
		2.1 – Freeway Spacing	Defined in High Level Requirements 2.1 – Freeway Spacing.
		2.2 – Arterial Spacing	Defined in High Level Requirements 2.2 – Arterial Spacing.
Ability to detect wrong-way vehicles and notify SSP operator	4.1.3.2.a	1.6 – Video Incident Detection	Previously defined.
Ability to tour HOV lane cameras and determine lane clearance	4.1.3.2.b	1.2 – Corridor Bundle Camera Groups	Previously defined.
Monitor for stalled vehicles in HOV lanes	4.1.3.2.c	1.6 – Video Incident Detection	Previously defined.
Monitor the impacts of HOT lanes on general purpose lanes	4.1.3.3.a	1.8 – Comparison of Roadway Sections	The CCTV system shall provide the ability to visually compare side-by-side videos of selected roadway segments for an operator to assess the traffic conditions.
Obtain qualitative visual descriptive information about traffic conditions	4.1.4.1.a	1.9 – Obtain Visual Information	The CCTV system shall be capable of providing operators clear, concise visual indication and verification of real-time traffic conditions on arterials and freeway roadway networks.
Observe and note overall traffic conditions on the arterial network.	4.2.1.1.a	1.9 – Obtain Visual Information	Previously defined.
Observe the effectiveness of selected timing plan in the form of throughput volume.	4.2.1.1.b	1.9 – Obtain Visual Information	Previously defined.
		1.10 – Predefined Congestion Indicators	The ATMS shall be capable of processing CCTV images to compare them to historical or predefined congestion limits. These limits can then be identified through the ATMS to the operator and used to verify a signal timing plan or to indicate an incident.
Provide real-time traveler information on 511-designated arterials.	4.2.1.1.c	1.11 – Relaying Information	The CCTV system shall be capable of relaying real-time information (visual and/or data) to the media, VDOT 511 system, RITIS, and other approved agencies.
Observe and monitor key "high accident" locations.	4.2.2.1.a	2.3 – Key Locations	Previously defined.
Provide real-time incident information to the public/media for major arterials.	4.2.2.1.b	1.11 – Relaying Information	Previously defined.
Ability to augment outsourced data collection with CCTV system.	4.4.1.1.a	1.12 – Outsourced Data Input	The CCTV system shall be capable of accepting outsourced video feeds from other agencies.
Optional monitoring or recording an area for off-line verification of safety, geometric, or other traffic-related issues.	4.4.1.2.a	1.13 – Monitor and Recording of CCTV	The ability to monitor and record CCTV cameras for the possibility of conducting studies or verifying planning and engineering data shall be supported by hardware or software means.
Automatic return to default camera setting.	4.1.1.2.b	1.14 – Automatic Return Home	After period of operator inactivity/no direct control, cameras will automatically pan, tilt, and zoom to a programmed "home" view regardless of where left by operator.

		2.0 - Physical Construction Requirements	
Monitor freeways and arterials with limited gaps	4.1.1.1.a	2.1 – Freeway Spacing	CCTV locations along freeways should be spaced in close proximity to each other, approximately every 1 mile to ensure full coverage. Where video analytics are intended and elsewhere as budgets permit, cameras should be spaced approximately every ½ mile. Twice as many cameras will be needed where heavily vegetated medians exist. NOTE: CCTV spacing may vary depending on pole height. One mile spacing is recommended for pole heights in the range of 65'.
		2.2 – Arterial Spacing	CCTV locations along arterials should be spaced depending on the AADT. Cameras should be placed at intersections of VDOT NRO Expansion Corridors and spaced approximately every 2-5 miles between intersections.
		2.3 – Key Locations	CCTV locations should be at key intersections, bridges, interchanges, and high accident areas.
Monitor regular lanes as well as express and reversible lanes	4.1.1.1.c	2.4 – Monitoring Multiple Objectives	CCTV locations should be located to view multiple desired objectives such as regular lanes, DMS, HOV gates, metering ramps, HOV lanes, reversible lanes, express lanes, merge areas, diverge areas, and weave areas.
Provide camera coverage of full mainline laneage in both directions	4.1.1.2.a	2.1 – Freeway Spacing	Previously defined.
		2.2 – Arterial Spacing	Previously defined.
Ability to monitor interchanges: merge areas, diverge areas, and weave areas	4.1.1.2.b	2.3 – Key Locations	Previously defined.
		2.4 – Monitoring Multiple Objectives	Previously defined.
Avoid visual obstructions such as vegetation, ramps, overpasses, buildings, and signs	4.1.1.2.c	2.5 – Avoiding Visual Obstructions	Camera locations shall be selected to avoid obstructions whenever possible. Locations with heavily vegetated medians, by bridges, overpasses and other visual obstructions may require multiple camera locations to achieve the desired full visual coverage of the area.
Ability to view images in low light conditions	4.1.1.2.d	2.6 – Light Levels	CCTV equipment shall have the ability to adjust sensitivity to low light level conditions during nighttime hours and high light levels during daytime hours.
Ability to view images in fog, rain, snow conditions	4.1.1.2.e	2.7 – Weather Conditions	Camera shall have an internal heater to avoid fog, ice or snow formation on the lens. CCTV equipment shall be capable of operating at a temperature range of -10 to 50 degrees Celsius and humidity range of 20 to 100 percent, at a minimum. CCTV cameras should be housed in a weatherproof enclosure intended for pole mounted outdoor locations. Other CCTV equipment should be mounted inside a weatherproof enclosure or cabinet.

Ability to view steady, clear image	4.1.1.2.f	2.8 – Avoiding Vibration and Glare	Avoid installing CCTV cameras where subject to vibration and glare. Locations on structures that may have vibration such as bridges, overpasses, flyovers, or areas of high winds should be avoided whenever possible. CCTV cameras should be capable of withstanding a wind load of 90 mph without permanent damage to the mechanical or electrical equipment. CCTV cameras should be aimed so that it is not subject to direct sun glare during daylight and transition times. Glare from other facilities and sources should be avoided as well.
		2.9 – Image Quality	Camera systems shall be color, and have a minimum resolution of 450 horizontal and 350 vertical TV lines per frame and support a frequency of up to 30 frames per second.
Ability to monitor interchanges: merge areas, diverge areas, and weave areas	4.1.2.1.b	2.3 – Key Locations	Previously defined.
		2.4 – Monitoring Multiple Objectives	Previously defined.
Ability to monitor bridges	4.1.2.1.c	2.3 – Key Locations	Previously defined.
Ability to focus cameras on suspected incidents	4.1.2.1.e	2.10 – Pan/Tilt/Zoom Ability	CCTV cameras shall be capable of pan/tilt/zoom operation. Pan and tilt operations shall be able to run concurrently. Cameras shall be able to zoom in to accurately and reasonably observe conditions up to a half-mile away. Cameras shall be able to pan 360 degrees and tilt 180 degrees.
		1.5 – Pan/Tilt/Zoom Controls	Defined in High Level Requirements 1.5 – Pan/Tilt/Zoom Controls
Operator ability to verify DMS status and message display	4.1.3.1.a	2.4 – Monitoring Multiple Objectives	Previously defined.
		2.10 – Pan/Tilt/Zoom Ability	Previously defined
Monitor HOV lane gates	4.1.3.2.d	2.4 – Monitoring Multiple Objectives	Previously defined.
Monitor HOT lane entry points / exits	4.1.3.3.b	2.4 – Monitoring Multiple Objectives	Previously defined.
Ability to monitor the ramp metering system	4.1.3.4.a	2.4 – Monitoring Multiple Objectives	Previously defined.
Ability to monitor Lane Control System (LCS) on I-66	4.1.3.5.a	2.4 – Monitoring Multiple Objectives	Previously defined.
CCTV device power and communications should not be affected by other devices.	4.3.1.1.a	2.12 – Electrical Service	Provide a separate electrical service to CCTV cabinets. If an electrical service drop must be shared with other equipment, provide CCTV equipment on separate surge protection devices.
Key CCTV locations and associated communication locations with backup power	4.3.1.1.b	2.13 – Backup Electrical Service	Provide identified key CCTV locations and associated communication repeater locations with backup uninterruptable power supply unit and generator receptacle.
Robust, weatherproofed equipment	4.3.1.1.d	2.7 – Weather Conditions	Previously defined.

Overlapping coverage to prevent coverage gap due to device failure	4.3.1.2.b	2.14 – Overlapping CCTV Conditions	Key locations and areas should fall within the in-focus field of view for a minimum of two cameras.
Accessible for maintenance bucket trucks	4.3.3.2.b	2.15 – Mounting Height Accessibility	CCTV cameras should avoid a mounting height higher than approximately 65'. Existing VDOT NRO maintenance bucket trucks can only extend to reach this height. If cameras are mounted at a height higher than 65', lowering devices must be included.
		3.14 – Accessible Maintenance Locations	Defined in High Level Requirements 3.14 – Accessible Maintenance Locations.
		3.0 - Maintenance Requirements	
Long lasting equipment	4.3.1.1.c	3.1 – Equipment Life Expectancy	Components should be rated for 5+ years of continuous operation before major repair and/or replacement is needed.
Field equipment that is simple to replace, remove, and service, resulting in a short Mean Time To Repair (MTTR)	4.3.2.1.a	3.2 – Replacement, Repair, and Service	Equipment shall be installed so that a replacement can be easily replaced or repaired during a failure. Cameras shall have lowering systems for easy access.
Readily available device replacements	4.3.2.1.b	3.3 – Replacement Equipment	Additional CCTV system components should be purchased in addition to those for installation. These components shall be handed over to maintenance staff for quick device replacement during failures. CCTV components shall be readily available from the manufacturer. CCTV equipment shall not be installed if it has a known end of life cycle within 3 years of the design procurement.
Appropriate maintenance funds allocated prior to increase in field devices	4.3.2.1.c	3.4– Maintenance Budget	An annual maintenance budget of 10% of the capital cost for each device should be allocated before device acquisition and installation. An annual maintenance budget of 10% of the capital cost for each communication and power cable should be allocated before cable acquisition and installation.
Ability to remotely reset equipment power	4.3.2.1.d	3.5 – Remote Power Resetting	Provide a contactor for remote reset of power to CCTV field equipment from the PSTOC or backup TMC.
Ability to remotely test devices via IP protocol	4.3.2.1.e	3.6 – Unique IP numbers to Devices	Each device shall have a unique IP number which can be accessed from the PSTOC to trouble-shoot field device problems.
Device components traceable within Inventory & Maintenance Management System (IMMS)	4.3.2.2.a	3.7 – IMMS System	All CCTV component devices shall be logged into the IMMS system. The inventory shall include each communication device's unique IP number, corridor information, and location information for traceability.
Devices' unique IP numbers logged in IMMS	4.3.2.2.b	3.7 – IMMS System	Previously defined.
Devices identified according to logical system	4.3.2.2.c	3.7 – IMMS System	Previously defined.
Devices coded in accordance with	4.3.2.2.d	3.8 – NRO ITS Barcodes	All devices shall be coded to conform with the NRO ITS Barcode

NRO ITS Barcode Requirements			requirements.
Protect equipment from vehicle impact damage through appropriate placement or guardrail	4.3.3.1.a	3.9 – Safe Access to CCTV Locations	Mount CCTV poles and cabinets in a safe area protected by guardrail or within a clear zone to protect workers' safety and equipment damage.
Power and communication cables protected against line breaks	4.3.3.1.b	3.10 – Power and Communications Cable Protection	Install power and communications cable in separate conduits and junction boxes. Conduits and junction boxes shall be sealed to prevent damage from water, ice, snow, dirt, traffic, vegetation, and rodents.
Provide lightning and surge protection for devices and electrical/communication lead-in conductors	4.3.3.1.c	3.11 – Lighting and Surge Suppression	Provide and install lightning rods with all pole assemblies. Provide transient voltage surge suppression on all incoming electrical and non-optical communication services to cabinets.
Install on stable foundations	4.3.3.1.d	3.12 – Cabinet Installation	Cabinets shall be installed on a flat (less than 5% grade) surface to prevent erosion damage. Cabinets shall be installed on a flat stable concrete foundation.
Vandalism prevention and mitigation	4.3.3.1.e	3.13 – Vandalism Prevention	Mount equipment away from public foot-traffic to prevent vandalism. CCTV equipment shall be vandal resistant. All cabinets shall be locked and keyed according to VDOT NRO standards.
Safe access to CCTV locations for maintenance crews	4.3.3.2.a	3.9 – Safe Access to CCTV Locations	Previously defined.
Accessible with existing 35' maintenance bucket trucks	4.3.3.2.b	2.16 – Mounting Height Accessibility	Defined in High Level Requirements 2.16 – Mounting height Accessibility.
Ample flat, level, and stable surfaces for bucket trucks with outriggers to operate safely off of the travel surface without lane closure	4.3.3.2.c	3.14 – Accessible Maintenance Locations	Ensure there is adequate space for maintenance crews to safely park and deploy bucket trucks. Bucket trucks require flat, level and stable surface for deployment of outriggers. Avoid mounting on structures or other roadways which require a lane closure for maintenance or require maintenance personnel to work in an unsafe area.
		3.9 – Safe Access to CCTV Locations	Previously defined.
Locations to avoid heavy vegetation	4.3.3.2.d	3.15 – Cabinet Locations	Mount cabinets in an area free of heavy vegetation which can damage equipment and prohibit easy access by maintenance personnel.
Avoid mounting on bridges, overpasses, flyovers, or other structures	4.3.3.2.e	3.14 – Accessible Maintenance Locations	Previously defined.
		2.8 – Avoiding Vibration and Glare	Defined in High Level Requirements 2.8 – Avoiding Vibration and Glare.
		4.0 - Integration and Configurability Requirements	
Create low bandwidth copy of TMC video and provide to media and ISPs through a media feed	4.1.1.3.b	4.1 – Equipment Compatibility With Other Agencies	CCTV equipment in the PSTOC will be compatible with media, VDOT 511 system, RITIS, and other approved agencies for adequately providing high or low quality video feeds as needed.

		1.3 – Low Quality Video	Defined in High Level Requirement 1.3 – Low Quality Video.
Share video images with regional stakeholders (state and local DOTs, Police, Fire & Rescue)	4.1.1.4.a	4.1 – Equipment Compatibility With Other Agencies	Previously defined.
Share video images via Video Clearinghouse	4.1.1.4.b	4.1 – Equipment Compatibility With Other Agencies	Previously defined.
Share video images via RITIS	4.1.1.4.c	4.1 – Equipment Compatibility With Other Agencies	Previously defined.
Ability to control and monitor cameras from main PSTOC facility or backup TMC	4.3.1.2.a	4.2 – Backup TMC Abilities	PSTOC CCTV controls and monitoring capabilities should be easily transferred to the backup TMC when needed. The backup TMC should be identically configured to accept and control all CCTV locations. All camera feeds should have the ability to be redirected to the backup TMC.
		4.3 – ATMS Software Compatibility	CCTV cameras should support NTCIP or existing camera control protocols that are compatible with the ATMS software
Support a field-based or central-based detection algorithm	5.1.1	4.4 – VID Alert Manager	ATMS software should support the ability to manage alerts generated by automated detection devices such as VIDs
Ability to recommend CCTV to verify adjacent devices (i.e. DMS, gates, ramp meters)	5.1.2	4.5 – ATMS Device Groups	ATMS software should support the ability to group and/or recommend CCTV locations to operators in order to verify message displays on DMS, and/or proper operation of ramp meters and reversible lane gates.
		1.2 – Corridor Bundle Camera Groups	Previously Defined.

Appendix 2

NRO ITS Inventory – Devices / components requiring a barcode:

Gates	LCS	VMS
Gate unit boxes		
Control boxes	Control boxes	Control boxes
	Controllers	Controllers
Modems	Modems	Modems
Encoders / decoders	Encoders / decoders	Encoders / decoders
Gate arms		Dimmer units
		Row boards
		Column boards
		Modules
		Upper control units
		Power supply units
		Wireless comm.

CCTV	COMMUNICATIONS
	Hub / Node
Control boxes	
Local control units	
Cameras	
Modems	Modems
Encoders / decoders	Encoders / decoders
Cortech	
Wireless heads	
Transmitters	
	UPS / inverters
	Impath cards
	Cards (other)

Incident Detect. Sys.	Ramp Meters	HAR	Tunnel	Detection / Classification	Truck Rollover
			Computer		
	Control boxes	Control boxes		Control boxes	Control boxes
Controllers	Controllers			Controllers	Controllers
Modems	Modems	Modems	Modems	Modems	
Encoders / Decoders	Encoders / Decoders	Encoders / Decoders	Encoders / Decoders	Encoders / Decoders	
				Detector Heads	
Detector cards				Detector Cards	

Virginia Department of Transportation
Contract# 27090 (Task NRO-27090-007)

NRO CCTV Master Plan

Virginia Department of Transportation Northern Region Operations

Prepared for:

VDOT Virginia Department of Transportation

Prepared by:

Kimley-Horn and Associates, Inc.

May 2008

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1 INTRODUCTION / BACKGROUND / PROJECT OVERVIEW

This CCTV Master plan presents a logical progression for the Virginia Department of Transportation (VDOT) Northern Region Operations (NRO) to expand the Closed-Circuit Television (CCTV) system based upon the needs of the various stakeholders which include groups within NRO and across the Commonwealth. In the development of this document several groups were interviewed in one-on-one or small group settings in order to understand the breadth of current use and future needs for the CCTV system. In most cases the future needs are those that the Traffic Management Center (TMC) operators have for visual information obtained through a CCTV system, although there are also needs with respect to maintaining the field infrastructure.

The “CCTV system”, for the purposes of this document, is defined as the use of VDOT owned and operated video cameras located along VDOT and associated VDOT-managed County assets in the NRO region for traffic surveillance, congestion monitoring, incident verification, and public/media information. The CCTV system includes the CCTV cameras, communication infrastructure, and the variety of output sources described throughout the document. This document summarizes the prioritization criteria, basis for device spacing, and identifies communication alternatives when fiber deployment is cost-prohibitive in the near-term. This document is intended to supplement the GIS mapping for the proposed CCTV locations to better understand the reasons for the various locations that have been identified.

2 EXISTING CONDITIONS & PLANNED NEAR-TERM PROJECTS

The following section describes the existing operational, existing nonoperational and planned CCTV camera locations for the NRO Region. Corridor segments have been combined to form corridor bundles. These bundles group key segments of roadways that are parallel routes and interstates as well as the key routes that connect them together. Roadways which may not be included in these bundles should be evaluated again in the future.

Figure 1 displays corridor bundle locations. **Table 1** below describes each corridor bundle in detail. These bundles were developed by the NRO prior to the May 2008 realignment of operating region boundaries.

Table 1: Corridor Bundle Segment Breakdown

DISTRICT	BUNDLE	BUNDLE DESCRIPTION
NOVA	**A**	I-395: DC Line to I-495 Rt. 110: Rt. 1 to I-66 GW Pkwy: DC Line to I-495 (non VDOT)
NOVA	**B**	I-95: I-495 to Rt.123 Rt.1: I-495 to Rt.123 Rt. 235
NOVA	**C**	I-95 & Rt 1 in Prince William County
FRED	**D**	I-95 & Rt 1 in Stafford County
FRED	**E**	I-95 & Rt 1 in Spotsylvania County Rt.208 in Spotsylvania County
NOVA	**F**	I-66: DC Line to I-495 Rt.267: I-66 to I-495 Rt. 29: DC Line to I-495 Rt. 50: DC Line to I-495
NOVA	**G**	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
NOVA	**H**	I-66: Rt.50 to Rt.15 Rt.29: Rt.50 to Rt.15 Rt.234: N of Rt. 29 to S of I-66
NOVA	**I**	Rt.215: Rt.29 to Rt.28 Rt.234: I-66 to I-95 Rt.28: from Rt.234 to Prince William Co.
CULP	**J**	I-66 in Fauquier County
NOVA	**K**	DTR: I-495 to Rt.28 (non VDOT) Rt.7: I-495 to Rt.28 Fairfax County Parkway (Rt.7100): Rt.7 to DTR Rt.28: Rt. 7 to DTR

NOVA	**L**	DTR & Dulles Greenway: Rt.28 to Rt. 15 Leesburg (Non VDOT) Rt.7: Rt.28 to Rt.15 Rt.15: Leesburg & Rt.7 zone
NOVA	**M**	Rt. 7: Rt. 15 Leesburg to NRO boundary Rt. 9: Rt. 7 to NRO boundary Rt. 287: Rt. 9 to Rt. 7
NOVA	**N**	I-495 (Capital Beltway)
NOVA	**O**	Rt.7100: DTR to I-95 Rt. 123: Rt. 7100 to I-95
NOVA	**P**	Rt.3000: Rt.28/234 to I-95 Rt.28: DTR to I-66 Rt.28: I-66 to Rt.234/3000
NOVA	**Q**	Rt.15: NRO boundary to Rt. 29 Rt.234: Rt.15 to Rt.29
FRED	**R**	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
CULP	**S**	Rt.3: Rt.20 to Rt.29 Rt.29: Rt.3 to Madison County
CULP	**T**	Rt.15: Rt.29 to Rt.3 Rt.29: Rt.15 to Rt.215
CULP	**U**	Rt.17 & Rt.28 in Fauquier County
CULP	**V**	Rt.211: Rt.29 to Rappahannock County
NOVA	**W**	Rt.50: I-66 to Rt.15
NOVA	**X**	Rt.236: Rt. 1 to Rt. 50/29 Rt.7: Rt.1 to I-395
NOVA	**Y**	Rt.244: Rt.27 to Rt.236 Rt.620: Rt.236 to Rt.7100
NOVA	**Z**	Rt.193: from Rt. 7 to Rt.90005 Rt.123: from Rt. 267 to 90005

Due to the May 2008 operating region realignment, previously defined corridor bundles have been removed from the CCTV system and two new bundles added. These changes will be described in **Section 3.3**.

2.1 Location of CCTVs

The VDOT Northern Region TMC operates and monitors a total of 120+ CCTV cameras. Main video coverage resides along I-66, I-95, I-395, I-495, and Route 267 (Dulles Toll Rd). Smaller groups of CCTV cameras are located at key locations along Route 27, Route 123, Spring Hill Road, and Leesburg Pike. Existing CCTV cameras are currently connected to the TMC though a variety of methods that include leased lines, wireless, and fiber optic connections. Existing CCTV Cameras and those cameras planned as part of currently programmed projects are shown in Figure 2.

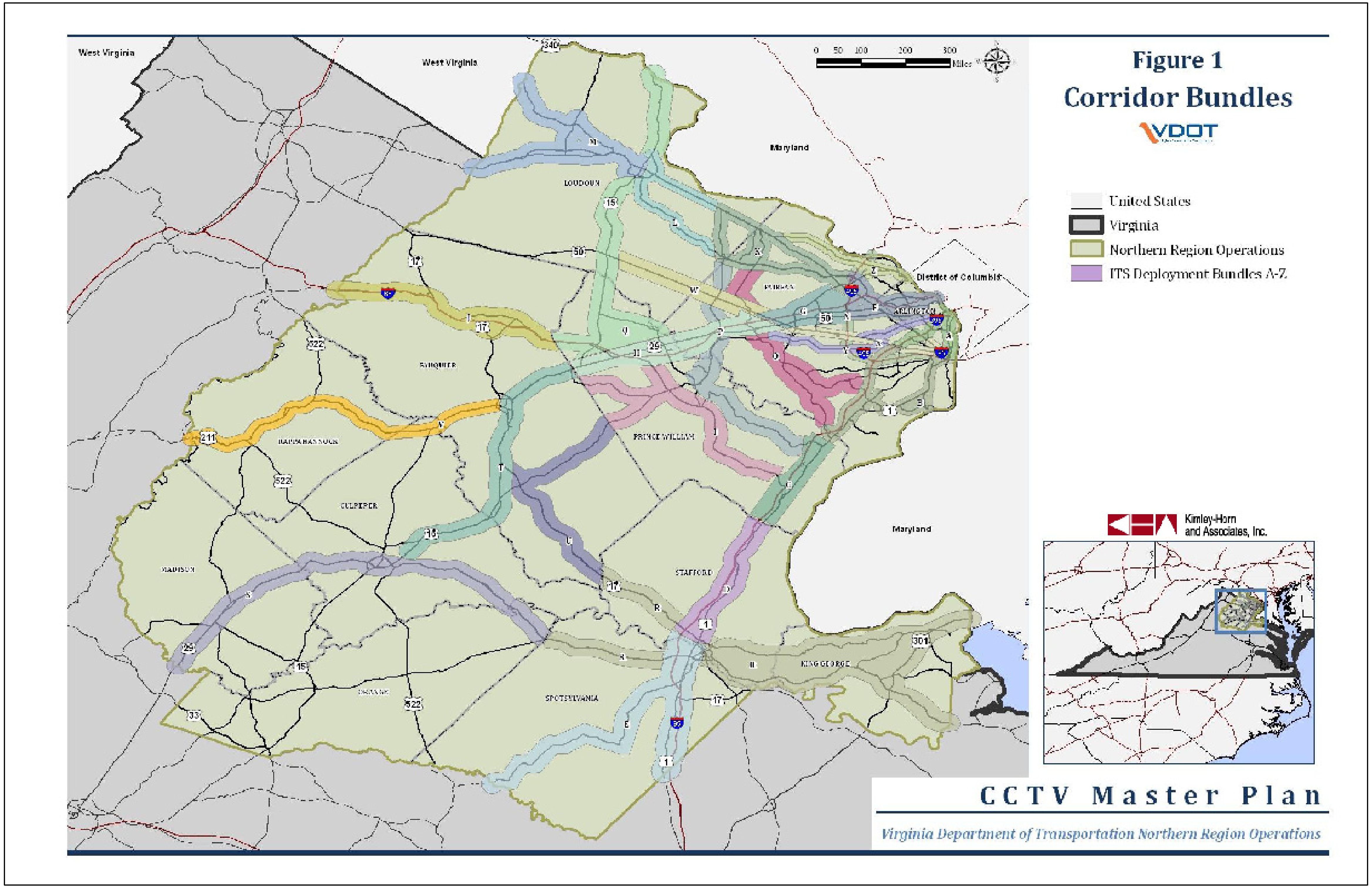

Figure 1: Historic NRO Boundary and Corridor Bundles

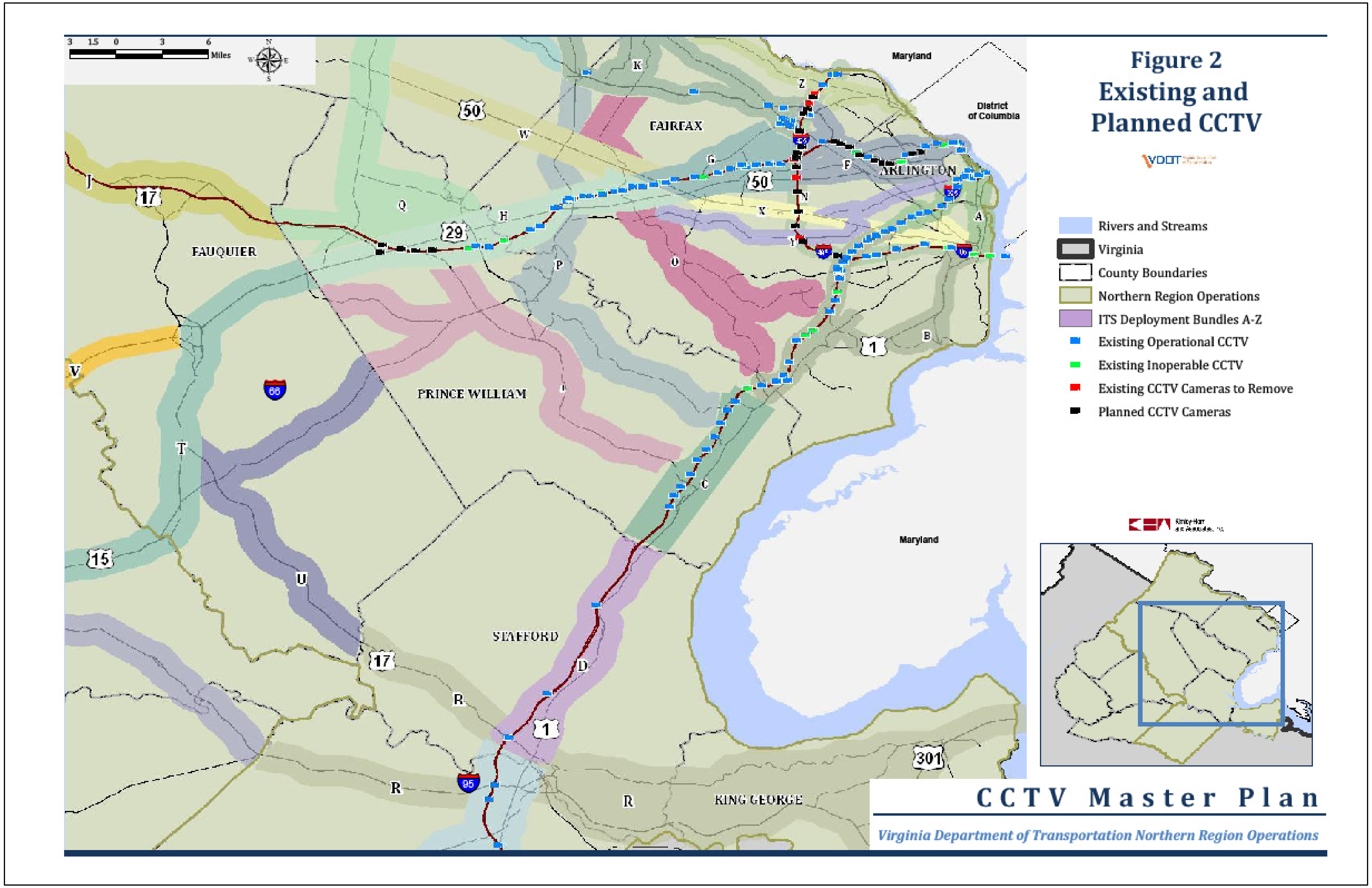

Figure 2: Existing and Planned CCTV Cameras

2.1.1 Existing CCTV Cameras

The existing cameras identified in the GIS database are subdivided into two categories: functional, and non-functional. **Table 2** summarizes the quantities of cameras by category to assign them to the prioritized coverage corridors.

Table 2: Existing Cameras

BUNDLE	NUMBER OF FUNCTIONAL EXISTING CAMERAS	NUMBER OF NONFUNCTIONAL EXISTING CAMERAS
A	23	0
B	14	3
C	11	1
D	7	0
E	0	0
F	9	3
G	11	2
H	16	4
I	0	0
J	0	0
K	11	0
L	0	0
M	0	0
N	17	4
O	0	0
P	1	0
Q	0	0
R	0	0
S	0	0
T	0	0
U	0	0
V	0	0
W	0	0
X	0	0
Y	0	0
Z	0	0
TOTAL	120	17

2.1.2 Planned/Programmed CCTV Cameras

This Master Plan references several specific projects in the NRO area that include plans for CCTV cameras. These four referenced projects are discussed below.

2.1.2.1 I-66 Spot Improvements Project

The VDOT NRO I-66 Spot Improvements Project Concept of Operations (2008) discusses spot improvements along westbound I-66 in Arlington and Fairfax Counties to improve mobility and safety. The twelve planned CCTV deployments in this area are listed in **Table 3**, all in Bundle F.

Table 3: I-66 Spot Improvement Cameras

I-66 & Lincoln / Monroe St
I-66 @ the Parking Deck at Quincy (West)
I-66 @ the Parking Deck at Quincy (East)
I-66 @ Pedestrian Bridge Between Harrison and Patrick Henry Dr. (West)
I-66 @ Pedestrian Bridge Between Harrison and Patrick Henry Dr. (East)
I-66 @ Patrick Henry (West)
I-66 @ Patrick Henry (East)
I-66 @ Ohio St.
I-66 @ Lee Highway
I-66 @ Williamsburg Blvd. / 29th St. (West)
I-66 @ Williamsburg Blvd. / 29th St. (East)
I-66 @ Great Falls St.
I-66 @ Haycock Rd.

2.1.2.2 I-66/Linton Hall Project

During review of the VDOT NRO I-66/Linton Hall DRAFT Master Plan, five CCTV locations in Gainesville (Prince William County), Virginia, were identified for deployment. These sites are listed in **Table 4**.

Table 4: I-66/Linton Hall Cameras

LOCATION	BUNDLE
US 29 (Lee Highway) @ Linton Hall Road	T
I-66 West of Eastbound Exit 43A	H
I-66 Between Westbound Exits 43A and 43 B	H
I-66 West of Eastbound Exit 44	H
I-66 East of Westbound Exit 44	H

2.1.2.3 I-495/Capital Beltway High Occupancy Toll (HOT) Lanes

Modifications to the existing CCTV system on I-495 have been planned as part of the Interstate 495/Capital Beltway High Occupancy Toll (HOT) Lanes project. These five modifications consist primarily of removing existing single cameras and installing new four-camera clusters on single poles. Each camera cluster will consist of a camera pair for VDOT and a camera pair for Fluor-Transurban, the HOT lane private operator. In each pair, one camera will be equipped with full pan/tilt/zoom capabilities for traffic observation while the other is a fixed camera for use with a Video Incident Detection system.

The NRO Office of Planning and Programming has received and offered comments on CCTV placement in the 30% Drawings for the I-495 / Capital Beltway HOT Lanes. There are currently nine (9) existing CCTV Cameras in the Project Area. Actions to be taken regarding these nine existing cameras are listed below.

Table 5: Existing I-495 VDOT CCTV Cameras

CAMERA ID#	LOCATION	ACTION
CCTV-0564	I-495 @ Backlick Road	Maintain
CCTV-1030	I-495 @ Braddock Road	Maintain
CCTV-1035	I-495 @ Little River Turnpike	Maintain
CCTV-1037	I-495 @ Little River Turnpike	Maintain
CCTV-1040	I-495 @ US 50	Maintain
CCTV-0230	I-495 @ I-66	Maintain & Remove after Construction
CCTV-1045	I-495 @ Lewinsville Road	Maintain & Remove after Construction
CCTV-1050	I-495 @ Old Dominion Boulevard	Maintain & Remove after Construction
CCTV 1055	I-495 @ Georgetown Pike	Maintain

Capital Beltway HOT Lanes 30% drawings call for new cameras at 12 locations along the length of the I-495 HOT Lanes. The locations for these cameras, which will all be part of Bundle N, are listed below.

Table 6: I-495 HOT Lanes Cameras

I-495 between Backlick and Braddock Road
I-495 between Braddock Road and Route 236
I-495 @ Route 236
I-495 @ Gallows Road
I-495 @ Lee Highway
I-495 @ I-66 (South)
I-495 @ I-66 (North)
I-495 between Idylwood Road and Oak Road

I-495 @ Route 7
I-495 between Route 123 and Jones Branch Road
I-495 at the Dulles Toll Road
I-495 between Lewinsville Road and Old Dominion

In order to provide full camera coverage, VDOT NRO Planning & Programming recommended new CCTV cameras to be installed at the following locations.

Table 7: VDOT NRO Recommendations for I-495 Camera Coverage

I-495 near Backlick Road
I-495 between Route 50 and Route 236

2.1.2.4 I-95/395 HOV/Bus/HOT Lanes

Modifications to the CCTV system on I-95/I-395 are expected as part of the Interstate 95/395 HOV/Bus/HOT Lanes project. Like the I-495/Capital Beltway HOT Lanes project, this is a public-private partnership between VDOT and Fluor-Transurban. Accordingly, duplication of the four-camera cluster field architecture from the I-495/Capital Beltway HOT Lanes can be reasonably expected. However, this project has not progressed far enough into its design and engineering stages, so locations for camera addition or removal have not yet been identified.

2.2 Location of Existing Cables/Infrastructure

Information regarding existing fiber cables and communications infrastructure comes from the September 29, 2005 *ITS Inventory for Communication Bandwidth Demand Assessment Memorandum* within the VDOT NRO Go-Forward Plan.

2.2.1 I-66

Trunk and distribution fiber runs along I-66 from Route 234 Business/Sudley Road to the Roosevelt Bridge. An existing 48 fiber trunk cable interconnects three nodes that are located near Route 2548/Bull Run Drive (Node 1), Route 608/West Ox Road (Node 2), and Route 650/Gallows Road (Node 3). Distribution fibers consist of a 36 fiber cable running west from Node 2 and 24 fiber cables elsewhere.

2.2.2 I-95

Trunk and distribution fiber runs along I-95 from Russell Road to the I-95/I-395/I-495 interchange. Fiber has been rerouted around the Springfield Interchange via Backlick Road (Fullerton Road to Industrial Road) as a result of construction. An existing 48 fiber trunk cable interconnects three hubs that are located near Route 234/Dumfries Road (Hub 3), Route 123/Gordon Boulevard (Hub 2), and Route 7100/Fairfax County Parkway (Hub

1). Distribution fibers consist of a 36 fiber cable running north from Hub 1 and 24 fiber cables elsewhere.

2.2.3 I-395

Trunk fiber runs along Interstate 395 from the I-95/I-395/I-495 interchange to the 14th Street Bridge.

2.2.4 I-495/Capital Beltway

Fiber runs along the Capital Beltway from the I-95/I-395/I-495 interchange to the Woodrow Wilson Bridge. A 12 fiber trunk cable ties into a single node located near Van Dorn Street.

2.2.5 SR-267/Dulles Toll Road

Approximately 144 fibers run along the length of the Dulles Toll Road from I-495 to Washington Dulles International Airport. The system is interconnected to the TMC via a 48 fiber cable from I-66 along the Dulles Toll Road to Spring Hill Road. Operational responsibility for this road is in the process of being transferred to the Metropolitan Washington Airports Authority (MWAA).

2.2.6 SR-234

A resource-sharing arrangement has provided 24 fibers running along Route 234 between I-66 and I-95. This fiber is currently connected to the TMC, and soon to the PSTOC, to provide a physical communication route redundancy for ITS equipment on I-95 as well as I-66. ITS devices have not been connected to this fiber cable as of yet.

3 PRIORITIZATION CRITERIA AND ANALYSIS

A base prioritization scheme was developed by the NRO Office of Planning & Programming, which ranked the corridor bundles listed in Table 1. This prioritization scheme and its results are presented in Section 3.1 and further modified in the following sections. The prioritization scheme establishes the corridor rankings for use in planning camera deployments in order of need throughout the region.

3.1 Base NRO Prioritization

The 26 corridor bundles were analyzed by NRO and given overall ITS priorities within their districts according to the formula

$$\frac{AADT}{10,000} * (.1D + .2E + .3F) + EX + \frac{CRASHES}{100} = SCORE$$

Where:

AADT = Average Annual Daily Traffic, veh/d

D = % of length with LOS D

E = % of length with LOS E

F = % of length with LOS F

EX = Dummy variable for existing ITS infrastructure: 8 if yes, 2 if no

CRASHES = Crash rate along bundled corridors

This formula was, with one exception, the basis for the overall ITS deployment priority assigned to the 26 bundles. The one exception to prioritization by this formula was in the Culpepper District, where Bundle J was raised to the top of the priority list because of its being on an Interstate Highway, I-66, and the Office of Systems Design’s desire to make that interstate corridor a model ITS corridor. The VDOT NRO prioritization is shown below in Table 8.

Table 8: NRO Office of Systems Design Bundle Prioritization

DISTRICT	PRIORITY	BUNDLE	AADT	LEVEL OF SERVICE (%)				EXISTING ITS INFRASTRUCTURE (Yes =8, No =2)	CRASHES	SCORE
				D	E	F	Weighted Average			
NOVA	1	**B**	200,000	10	10	80	2.70	8	409	66.1
NOVA	2	**A**	175,000	10	20	70	2.60	8	497	58.5
NOVA	3	**F**	160,000	40	10	50	2.10	8	430	45.9
NOVA	4	**G**	120,000	0	15	85	2.85	8	254	44.7
NOVA	5	**C**	100,000	10	0	90	2.80	8	383	39.8
NOVA	6	**N**	160,000	50	20	30	1.80	8	125	38.1
NOVA	7	**H**	135,000	40	30	30	1.90	8	345	37.1
NOVA	8	**W**	120,000	30	40	30	2.00	8	203	34.0
NOVA	9	**P**	100,000	50	0	50	2.00	8	227	30.3
NOVA	10	**K**	100,000	30	0	70	2.40	2	301	29.0
NOVA	11	**O**	140,000	80	20	0	1.20	8	273	27.5
NOVA	12	**Z**	80,000	10	80	10	2.00	2	278	20.8
NOVA	13	**I**	40,000	10	80	10	2.00	8	219	18.2
NOVA	14	**Y**	80,000	80	10	10	1.30	2	497	17.4
NOVA	15	**X**	80,000	20	80	0	1.80	2	353	16.4
NOVA	16	**M**	60,000	30	65	5	1.75	2	314	15.6
NOVA	17	**Q**	40,000	35	60	5	1.70	2	345	12.3
NOVA	18	**L**	60,000	80	20	0	1.20	2	211	11.3
FRED	1	**D**	80,000	10	20	70	2.60	2	239	25.2
FRED	2	**E**	100,000	40	50	10	1.70	2	424	23.2
FRED	3	**R**	60,000	40	50	10	1.70	2	269	14.9
CULP	1	**J**	40,000	60	40	0	1.40	2	N/A	7.6
CULP	2	**T**	60,000	80	20	0	1.20	8	273	17.9
CULP	3	**U**	40,000	50	50	0	1.50	2	215	10.2
CULP	4	**V**	40,000	80	20	0	1.20	2	320	10.0
CULP	5	**S**	40,000	90	10	0	1.10	2	N/A	6.4

3.2 Criteria for use in Prioritization of CCTV Expansion Projects

Various characteristics of a corridor are considered for refining prioritization of CCTV system expansion projects. Criteria that are generally applicable to CCTV deployment prioritization are discussed below.

- **Existing Nonfunctional CCTV Cameras** – Existing CCTV locations that are inoperable on a corridor present opportunities for an economical expansion of the CCTV system. These locations require only repair or replacement of devices or communications in order to establish CCTV coverage and enhance CCTV coverage on a corridor. Additionally, the existence of the camera indicates that the site was previously identified as a key location for CCTV coverage, and if not for the malfunctioning or damaged equipment that coverage would exist already.
- **Volume –** The importance of having CCTV coverage on a corridor increases with the volume on that corridor. Higher volumes mean more people to be negatively impacted by congestion delays and more people exposed to secondary crashes due

to highway incidents. Accordingly, a higher priority is assigned to higher volume corridors along with a higher density of cameras.

- **Existing ITS Infrastructure** – Corridors with existing but incomplete CCTV coverage should be given greater priority than corridors with no existing ITS infrastructure. These corridors can be expanded by "infill" of existing coverage gaps by connecting new ITS devices to existing communications infrastructure. Existing infrastructure enables less expensive deployment of complete coverage on a corridor.

- **Evacuation Routes** – Congestion management and incident detection and clearance are more pressing on corridors that serve as evacuation routes than on corridors that do not. However, the Northern Virginia area does not face a strongly directional evacuation hazard, as do coastal areas subject to hurricanes, and all corridors under consideration for CCTV deployment are major routes that may be called upon to serve as an evacuation route in the event of an emergency. Accordingly, evacuation routes are not a major criterion for prioritizing CCTV deployment in the NRO area.

- **TMC Operator "Wish List"** – TMC operators can be asked to identify, based on their experience operating and monitoring the CCTV system, locations that are high-accident locations in a CCTV coverage gap or otherwise have a strong need for CCTV coverage. Although not every location identified in this manner will necessarily be appropriate or feasible for CCTV, corridors with several such locations can be given a higher priority than corridors with few or no such locations.

Several other criteria, more specific to the NRO area or the user needs defined in the NRO CCTV Concept of Operations, are discussed below.

- **DMS** – One of the user needs for the CCTV system is to verify that Dynamic Message Signs (DMS) are working and displaying messages to motorists properly. The presence of DMS on a corridor increases the need for CCTV on that corridor and by extension the priority of providing CCTV coverage to that corridor. This is particularly the case for the NRO area as the NRO DMS Concept of Operations and the NRO CCTV Concept of Operations both envision CCTV coverage of every permanent DMS installation.

- **HOV Gates** – One of the user needs for the CCTV system is to verify that High Occupancy Vehicle (HOV) lane gates other than those for the I-395 and I-495 HOT Lanes are working properly and in the correct open or closed position. The presence of HOV gates on a corridor increases the need for CCTV on that corridor and by extension the priority of providing CCTV coverage to that corridor.

- **Priority Arterial List** – NRO Signal Systems Operations has identified 77 "Priority 1" locations and 121 "Priority 2" locations on the signalized arterial network for CCTV deployment. Although deploying CCTV to all 198 of these signalized arterial intersections in addition to Interstate and freeway locations is not feasible within the next twenty years, the list provides a pool of candidate locations for consideration as key arterial locations for CCTV deployment. The number of these locations on or alongside each corridor should have a slight impact on bundle prioritization.

- **LCS Displays** – One of the user needs identified for the NRO CCTV system is to verify that Lane Control System (LCS) displays on I-66 are functional and displaying properly. Although it is not anticipated that each LCS display will be given its own CCTV camera as with the DMS system, this is an additional benefit to consider when selecting CCTV locations within the I-66 corridors.

3.3 Revised Bundle Prioritization Scoring

Based on the above prioritization concerns, the following adjustments factors were developed to modify the base NRO prioritization in Section 3.1. These scoring adjustments are listed below.

FACTOR	SCORE ADJUSTMENT
Existing Nonfunctional Cameras	+1 per camera
DMS in Bundle	+.5 per sign
HOV Gates in Bundle	+.5 per gate
AADT < 80,000 vehicles/day	-2 for bundle
AADT > 110,000 vehicles/day	+1 for bundle
Cameras on “Arterial Priority One” List	+.1 per camera
Cameras on “Arterial Priority Two” List	+.1 per 3 cameras, rounded down
Locations on TMC Operator Wishlist	+.5 for bundle if more than 1 location
LCS Present	+.3 for bundle

Applying these score adjustments to the original 26 NRO bundles results in the ranked prioritization in **Table 9**.

Table 9: Adjusted NRO Corridor Bundle Rankings for CCTV

BUNDLE	OLD RANK	# NOT WORKING	VOLUME ADJUST	DMS		HOV		LCS	# "PRIORITY"			WISHLIST		NEW SCORE	NEW RANK	RANK CHANGE
				#	POINTS	#	POINTS		1	2	Weighted Points	#	POINTS			
B	1	3	1	20	10	6	3	0	12	13	1.6	0	0	84.7	1	0
A	2	0	1	12	6	7	3.5	0	4	0	0.4	0	0	69.4	2	0
F	3	3	1	16	8	1	0.5	0	4	4	0.5	2	0.5	59.4	3	0
G	4	2	1	12	6	2	1	0.3	4	9	0.7	0	0	55.4	4	0
C	5	1	0	7	3.5	7	3.5	0	11	4	1.2	2	0.5	49.5	5	0
N	6	4	1	10	5	1	0.5	0	4	0	0.4	6	0.5	49.5	6	0
H	7	4	1	4	2	0	0	0	10	4	1.1	2	0.5	45.7	7	0
W	8	0	1	6	3	0	0	0	0	2	0	0	0	38.0	8	0
P	9	0	0	5	2.5	0	0	0	0	14	0.4	0	0	33.2	9	0
K	10	0	0	2	1	0	0	0	2	22	0.9	0	0	30.9	10	0
D	12	0	0	7	3.5	0	0	0	13	0	1.3	6	0.5	30.5	11	1
E	14	0	1	10	5	0	0	0	5	1	0.5	8	0.5	30.2	12	2
O	11	0	1	2	1	0	0	0	1	10	0.4	0	0	29.9	13	-2
Z	14	0	0	0	0	0	0	0	1	0	0.1	0	0	20.9	14	0
X	15	0	0	0	0	0	0	0	2	4	0.3	0	0	20.2	15	0
T	17	0	0	1	0.5	0	0	0	0	0	0	4	0.5	18.9	16	1
Y	18	0	0	1	0.5	0	0	0	3	7	0.5	0	0	18.4	17	1
I	16	0	-2	1	0.5	0	0	0	0	4	0.1	0	0	16.8	18	-2
R	20	0	-2	4	2	0	0	0	0	8	0.2	0	0	15.1	19	1
M	19	0	-2	2	1	0	0	0	0	1	0	0	0	14.6	20	-1
Q	21	0	-2	3	1.5	0	0	0	0	0	0	0	0	11.8	21	0
V	24	0	-2	3	1.5	0	0	0	0	0	0	0	0	11.5	22	2
U	23	0	-2	1	0.5	0	0	0	0	0	0	2	0.5	11.2	23	0
J	25	0	-2	7	3.5	0	0	0	0	0	0	1	0	11.1	24	1
L	22	0	-2	0	0	0	0	0	3	3	0.4	0	0	9.7	25	-3
S	26	0	-1	6	3	0	0	0	0	0	0	1	0	9.4	26	0

The May 2008 reorganization of the VDOT operational regions changed the boundary of the NRO. Culpepper, Fauquier, Orange, Madison, and Rappahannock Counties were moved from Northern Region Operations to Northwestern Region Operations. However, the NRO retained responsibility for I-66 in Fauquier County and gained responsibility for I-66 in Warren County. Also, I-95 and Route 1 within Caroline County were moved from Central Region Operations to Northern Region Operations. As a result, bundles S and V were removed from further consideration in this master plan and two new bundles, Bundles AA and AB, were created for I-95/US 1 in Caroline County and I-66 in Warren County respectively. Bundles T and U were kept in this Master Plan to preserve logical route/corridor continuity between Bundles I and R. Keeping Bundles T and U in this Master Plan serves the user needs expressed in the NRO CCTV Concept of Operations. These two bundles, however, were reduced in priority below all ITS bundles that are within the new NRO boundaries.

Bundle AA was placed in the priority listing based on having an AADT of 85,000 vehicles per day, five TMC operator wish list locations, no other ITS, and assumed crash rates and weighted levels of service 90% of the adjacent Bundle E. Bundle AB was placed in the priority listing based on having an AADT of 37,000 along its busiest segment, no other ITS, and assumed crash rates and weighted levels of service 90% those of the adjacent Bundle J. This yields the final priority ranking below in **Table 10**.

BUNDLE	PRIORITY	DISTRICT	BUNDLE DESCRIPTION
B	2	NOVA	I-95: I-495 to Rt.123 Rt.1: I-495 to Rt.123 Rt. 235
A	6	NOVA	I-395: DC Line to I-495 Rt. 110: Rt. 1 to I-66 GW Pkwy: DC Line to I-495 (non VDOT)
F	1	NOVA	I-66: DC Line to I-495 Rt.267: I-66 to I-495 Rt. 29: DC Line to I-495 Rt. 50: DC Line to I-495
G	3	NOVA	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
C	4	NOVA	I-95 & Rt 1 in Prince William County
N	5	NOVA	I-495 (Capital Beltway)
H	8	NOVA	I-66: Rt.50 to Rt.15 Rt.29: Rt.50 to Rt.15 Rt.234: N of Rt. 29 to S of I-66
W	7	NOVA	Rt.50: I-66 to Rt.15
P	9	NOVA	Rt.3000: Rt.28/234 to I-95 Rt.28: DTR to I-66 Rt.28: I-66 to Rt.234/3000
K	10	NOVA	DTR: I-495 to Rt.28 (non VDOT) Rt.7: I-495 to Rt.28 FfxCo. Pkwy (Rt.7100) Rt.7 to DTR Rt.28: Rt. 7 to DTR
D	11	FRED	I-95 & Rt 1 in Stafford County
E	12	FRED	I-95 & Rt 1 in Spotsylvania County Rt.208 in Spotsylvania County
O	13	NOVA	Rt.7100: DTR to I-95 Rt. 123: Rt. 7100 to I-95
Z	15	NOVA	Rt.193: from Rt. 7 to Rt.90005 Rt.123: from Rt. 267 to 90005
X	16	NOVA	Rt.236: Rt. 1 to Rt. 50/29 Rt.7: Rt.1 to I-395
AA	17	FRED	I-95 & Rt 1 in Caroline County
Y	18	NOVA	Rt.244: Rt.27 to Rt.236 Rt.620: Rt.236 to Rt.7100
I	19	NOVA	Rt.215: Rt.29 to Rt.28 Rt.234: I-66 to I-95 Rt.28: from Rt.234 to Prince William Co.
R	20	FRED	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
M	21	NOVA	Rt. 7: Rt. 15 Leesburg to NRO boundary Rt. 9: Rt. 7 to NRO boundary Rt. 287: Rt. 9 to Rt. 7
Q	22	NOVA	Rt.15: NRO boundary to Rt. 29 Rt.234: Rt.15 to Rt.29
J	23	CULP	I-66 in Fauquier County
AB	24	CULP	I-66 in Warren County
L	14	NOVA	DTR & Dulles Greenway: Rt.28 to Rt. 15 Leesburg (Non VDOT) Rt.7: Rt.28 to Rt.15 Rt.15: Leesburg & Rt.7 zone
T	25	CULP	Rt.15: Rt.29 to Rt.3 Rt.29: Rt.15 to Rt.215
U	26	CULP	Rt.17 & Rt.28 in Fauquier County

Table 10: Final Bundle Prioritization

3.4 Device Placement Considerations that Affect Quantities

- Where video detection analytics are planned, CCTV cameras should be placed at ½-mile intervals. Elsewhere, key CCTV cameras should be placed at one-mile intervals on freeways until funding permits fill to ½-mile intervals.
- CCTV locations along arterials should be located at key intersections but no less than every 2 miles on main routes, as identified by AADT volumes greater than 110,000. Along routes with AADT volumes between 80,000 and 110,000 cameras should be located at key intersections but no less than every 3.5 miles, and along routes with AADT volumes less than 80,000 cameras should be located at key intersections and no less than every 5 miles.
- Large median vegetation will prohibit CCTV locations from monitoring both the northbound and southbound or westbound and eastbound roadway facilities. If both directions are desired and median vegetation prevents clear vision, two cameras will be required for installation instead of one. The maps in Figures 3 through 3C do not reflect this consideration.
- CCTV locations that serve multiple purposes will help to alleviate redundant cameras. Placement where a camera can monitor both the display of a DMS sign or a HOV gate while monitoring traffic in that area should be considered key locations.
- Visual obstructions such as flyovers and overpasses will require multiple CCTV locations rather than one. The maps in Figures 3 through 3C do not reflect this consideration.

Figures 3 through 3C show the proposed CCTV layout.

3.5 Additional Prioritization Considerations

Recognizing that covering the region's corridor bundles will be challenging within a 20-year horizon, the GIS data for the CCTV locations is broken into two groups: key and backfill locations. Examples of key locations include DMS sites, freeway interchanges, one mile spacing on freeways, and major arterial intersections. Backfill locations are those locations provided to give complete freeway coverage and regularly-spaced arterial coverage. This distinction allows for prioritization of locations within a corridor bundle and lends itself to a two-phase deployment in bundles needing many cameras.

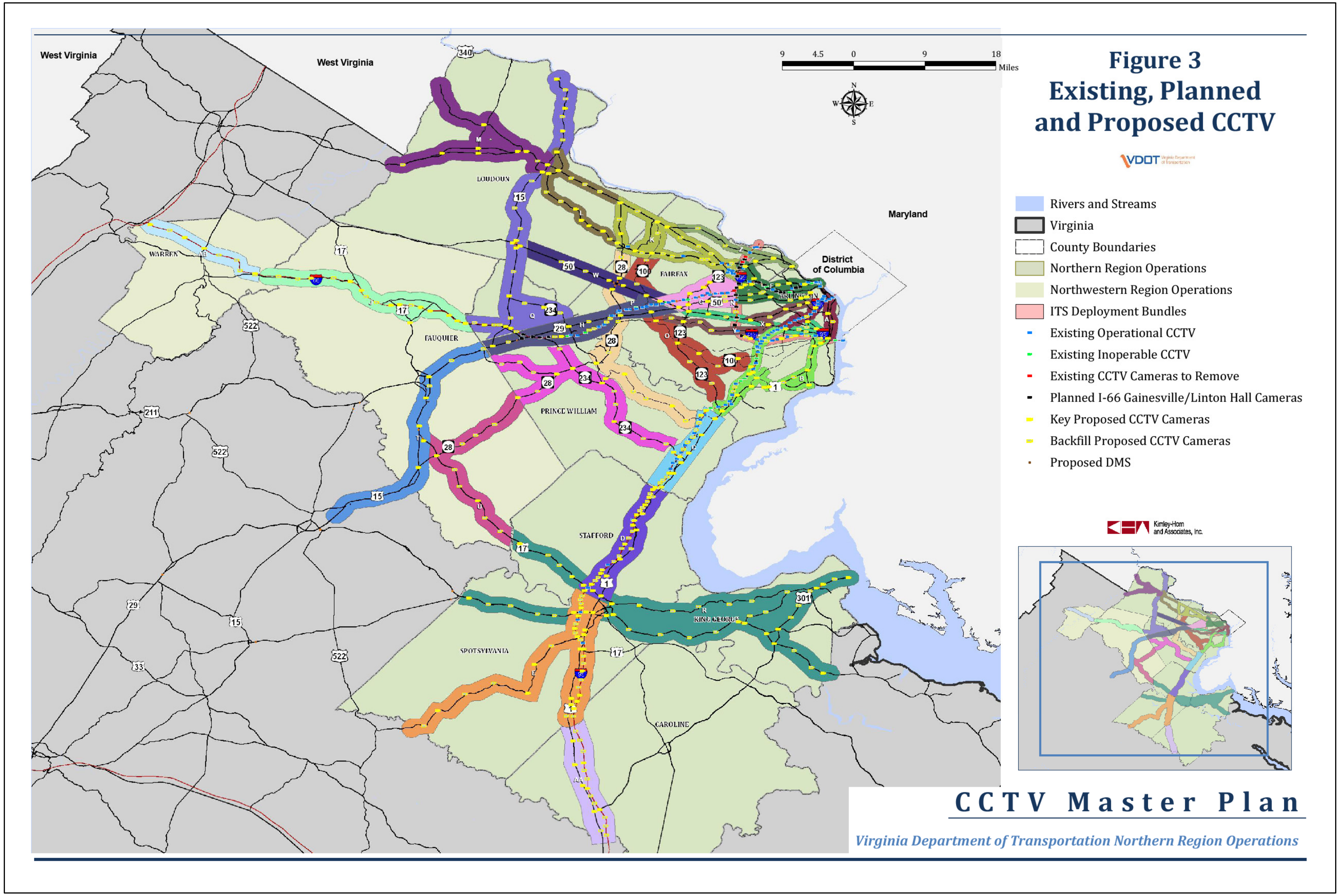

Figure 3: Existing, Planned, and Proposed CCTV Cameras

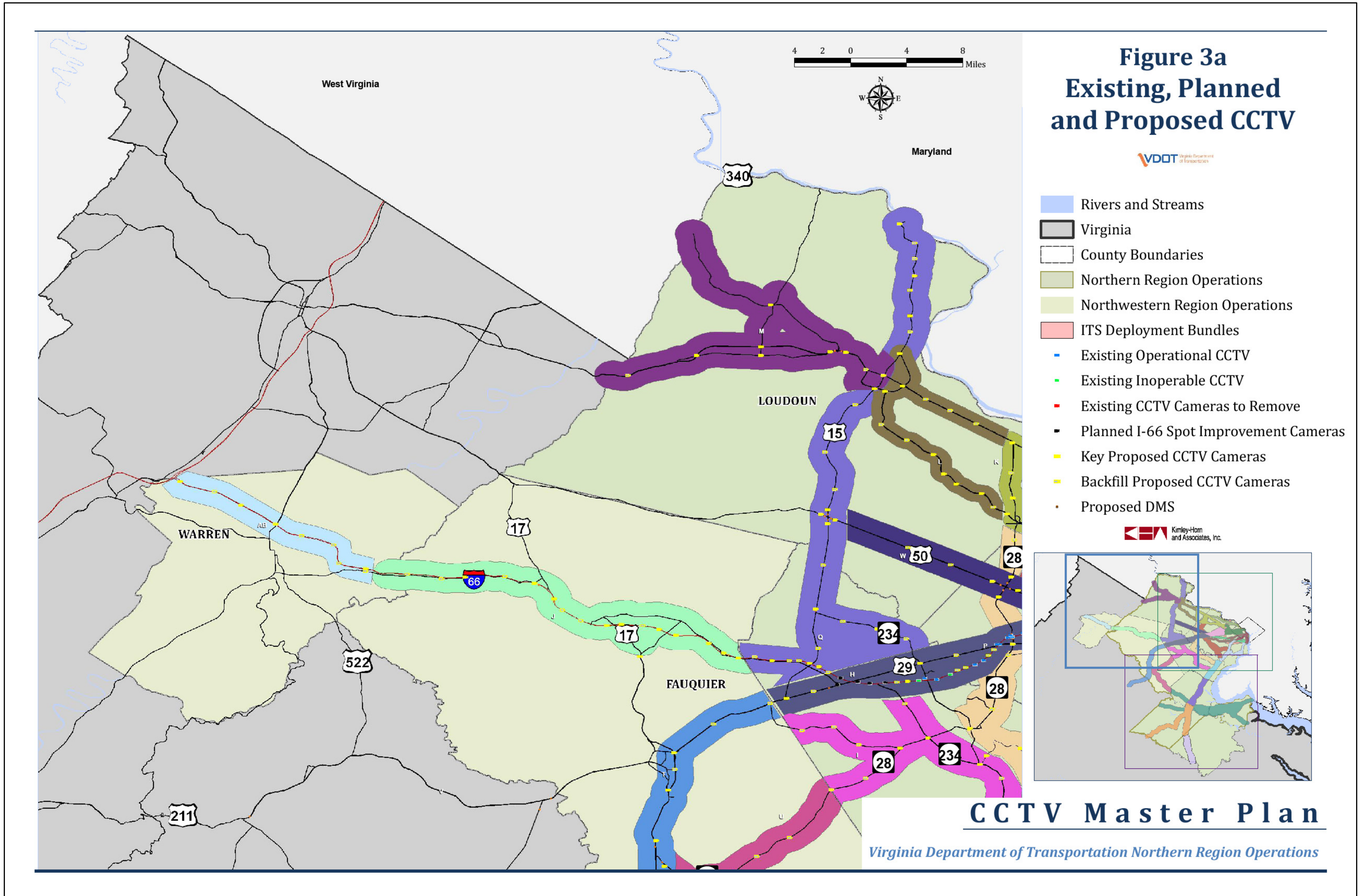

Figure 3a: Existing, Planned, and Proposed CCTV Cameras - NW Inset

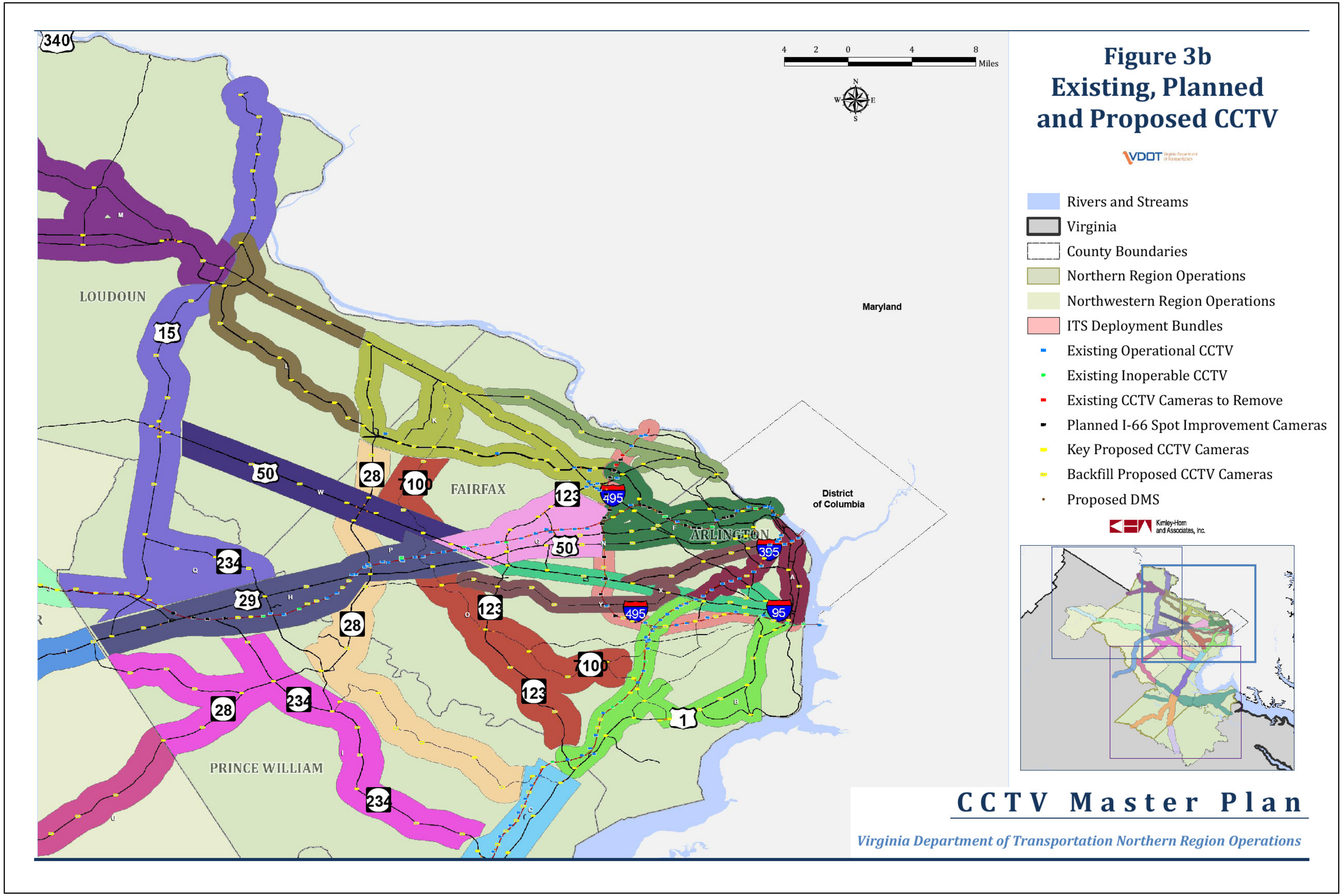

Figure 3b: Existing, Planned, and Proposed CCTV Cameras - NE Inset

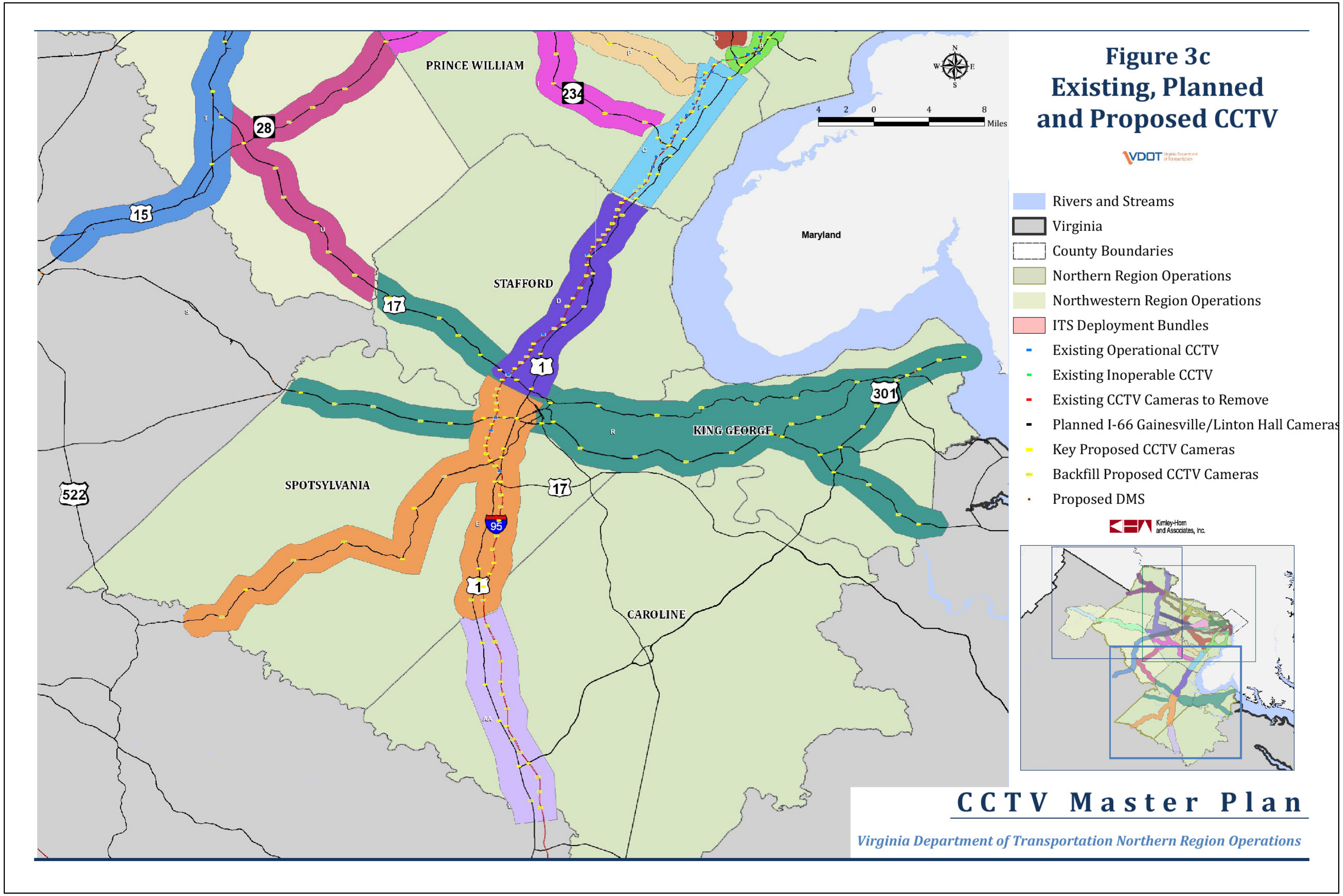

Figure 3c: Existing, Planned, and Proposed CCTV Cameras - South Inset

3.6 Summary

This Master Plan combines existing cameras in need of repair or replacement, cameras whose installation has been planned as part of current VDOT projects, and newly proposed cameras to provide 435 new cameras to the CCTV system. The 391** proposed new cameras consist of 202 Key cameras and 189 Backfill cameras. Backfill cameras will provide full coverage by filling in the area between key cameras. The number of cameras to be installed in each corridor bundle is shown below in **Table 11**.

Table 11: New Cameras

BUNDLE	# OF CAMERAS TO REPAIR/REPLACE	# OF PLANNED CAMERAS	# PROPOSED KEY CAMERAS	# PROPOSED BACKFILL CAMERAS	COMBINED NEW CAMERAS
F	3	13	11	6	**33**
B	3	0	13	5	**21**
G	2	-1	6	2	**9**
C	1	0	10	8	**19**
N	4	11*	4	6	**25**
A	0	0	2	2	**4**
W	0	0	6	2	**8**
H	4	4	3	7	**16**
P	0	0	7	6	**13**
K	0	0	6	13	**20**
D	0	0	15	13	**28**
E	0	0	17	15	**32**
O	0	0	5	5	**10**
L	0	0	7	6	**13**
Z	0	0	3	2	**5**
X	0	0	7	4	**11**
AA	0	0	7	12	**19**
Y	0	0	3	5	**8**
I	0	0	6	9	**15**
R	0	0	22	23	**45**
M	0	0	7	2	**9**
Q	0	0	12	15	**27**
J	0	0	11	7	**19**
AB	0	0	4	4	**8**
T**	0	0	4	3	**7**
U**	0	0	4	7	**11**
TOTAL	17	27	202	189	**435**

*Overall change due to planned removal of 3 cameras and installation of 14 cameras for I-495 HOT Lanes.

** NOTE: 18 proposed cameras within corridors T and U are included in the 391 proposed cameras for the regional CCTV camera expansion. While they are included for continuity of operations, they should not be considered in the final project budget allocations for NRO, since they have now been allocated to the Northwestern Region Operations (NWRO).

4 COMMUNICATION ALTERNATIVES FOR HIGH-PRIORITY LONG-TERM SEGMENTS

4.1 Network Bandwidth Requirements

Network bandwidth, measured in megabits per second (Mbps) is determined by the communications media used. Bandwidth requirements are driven by the number of cameras connected through a network segment, by video quality both in terms of frames per second (fps) and image resolution, and by the digital file format used for video feeds. There are different perspectives on video quality based on the type of user and the application. For instance, low-resolution video at a rate of 5-10 frames per second (fps) may be acceptable to some operators who are merely monitoring for stopped vehicles or incidents. However, congestion monitoring and post-processing traffic analysis require a higher resolution at nearly 30 fps.

Most agencies have determined that the lowest level of acceptable quality for traffic condition monitoring is VHS-quality at 1.0 to 1.5Mbps, which is just below the maximum bandwidth of a leased T-1 telephone service line. However, when fiber resources are available, many elect to use 2.5 to 3.0Mbps for near-DVD quality video using MPEG-4 compression standards.

4.2 Criteria for Considering Alternative Communications

A number of communication approaches are available for the CCTV system. Different infrastructures are discussed below. Each alternative's approximate cost, as well as its strengths and weaknesses, is briefly reviewed. Throughout, "download" refers to transmitting data from the TMC to a camera, while "upload" refers to transmitting data from a camera to the TMC.

Fiber: An agency-owned fiber network has nearly unlimited bandwidth and will enable multiple cameras to be controlled on a network line. VDOT would own any new fiber and would be responsible for installing the fiber and maintaining the fiber and related equipment (including line break repairs), but would have guaranteed exclusive use of the fiber network. Once fiber was provided along a corridor, VDOT could splice future cameras into the network on the existing fiber line. Because of right-of-way acquisition and installation that involves trenching or directional drilling, fiber has a high up-front capital cost. However, this alternative provides the greatest possible bandwidth and thus maximizes possible video quality as well as the number of cameras and other ITS devices that can be installed on a network segment.

Telephone Line: Regular twisted-pair copper wire DS-0 telephone lines can be used for ITS data transmission. However, it is not suited for CCTV cameras since its maximum bandwidth is 64 kilobits per second (kbps).

Leased T-1 Lines: A T-1 line is created through the digital multiplexing of 24 DS-0 telephone lines on a single twisted-pair copper wire. T-1s can provide 1.544 Mbps of upload and download bandwidth for a single CCTV camera. These lines are leased from a commercial telecom provider such as Verizon with typical monthly costs of approximately $300 per line. They do not require VDOT to obtain right-of-way or install and maintain communication lines and equipment. They are ideal for isolated cameras in rural areas and those outside the planned fiber network expansion/coverage.

Digital Subscriber Lines (DSL): DSL services, regardless of the particular DSL variation, generally allow download bandwidth to 3 Mbps and upload bandwidth to 384 kbps. DSL circuits are generally less expensive than T-1s but are limited to a three-mile range from the nearest telecommunications provider Central Office (CO) or fiber optic digital loop carrier (DLC) cabinet. DSL's available bandwidth also diminishes farther away from the CO/access point. These characteristics make DSL best suited for isolated arterial cameras that will be used only for incident detection, and do not require the high video quality that necessitates a T-1 line. DSL generally entails an internet connection. This will ease connections to backup TMCs, but will create the possibilities of internet-based tampering with the cameras and loss of data due to internet "clogging" unless statewide measures are employed for maintaining access to critical locations during an emergency. Like other leased lines, DSL is a commercial service provided by telecom companies for $80 to $100 monthly per connection.

Leased T-3 Lines: Using coaxial copper cable, these leased lines provide the same 672 channel capacity of OC-1 fiber, though with a somewhat lower 44.032 Mbps maximum bandwidth due to being multiplexed from 28 T-1 lines. They typically cost approximately $2,000 to $2,500 a month, thereby costing only as much as 8 T-1 lines which provides a clear cost basis for picking between T-1 and T-3 leased lines. T-3 lines are ideal for isolated clusters of cameras, which would have prohibitive costs for fiber deployment, or for receiving multiple field cameras at the TMC head-end.

Wireless Broadband: A number of broadband wireless technologies exist with off-the-shelf commercial service provided by telephone companies. Currently, these services are based on third-generation cellular technology with bandwidth averaging 700 kbps download and 144 kbps upload. Pricing for these services has tended to range from $60 to $80 per month for unlimited use with each device, but Verizon has begun charging monthly fees for overall use in excess of 5 GB and other providers may follow suit. Even accounting for the low upload bandwidth, connecting a camera through this network for round-the-clock daily use would exceed the 5 GB monthly cap by tens to hundreds of GB per month, resulting in extreme fees. Also, currently available technology's low bandwidth sharply limits the video quality that can be obtained with wireless broadband connections. However, for temporary installations using portable cameras wireless broadband is the most convenient connection method since it does not require a fixed, immovable connection. Video quality limitations due to bandwidth availability for wireless broadband should loosen in the near future with the deployment of fourth-generation wireless technologies such as Worldwide Interoperability for Microwave Access (WiMAX) and Long Term Evolution of the Universal Mobile Telecommunications System (LTE). The first of these technologies expected to be available in the NRO's area is WiMAX, which Sprint has indicated will be available in late 2008. Competing wireless carriers have selected the LTE cellular technology, with Verizon's LTE network expected to deploy in 2010.

5 SUMMARY

This plan calls for the VDOT NRO CCTV System to contain 557 cameras after a 20-year build-out: 120 functional existing cameras, 17 existing nonfunctional cameras to be repaired, 27 planned cameras to be installed, and 391 new cameras to be installed. These cameras will be distributed among 26 corridor bundles throughout the NRO. Also, although they are no longer part of the NRO, this plan calls for 18 cameras to be installed along US Routes 15, 17, 28, and 29 in Fauquier County to maintain continuity and logical route management for NRO corridors in Stafford and Prince William Counties. After adjusting for the 18 NWRO cameras along corridors T and U, the remaining proposed NRO cameras have been subdivided into 194 key locations and 179 backfill locations to provide coverage along the prioritized corridors.

A rough order of magnitude probable cost estimate for the cameras in the CCTV system can be made assuming costs of $65,000 per new camera, $10,000 per repair/replacement of inoperable/existing cameras, and $6,000 per upgrade of existing cameras to new communications. This yields a probable construction cost of:

- $720,000 for upgrades to existing cameras,
- $170,000 for repair and replacement of existing cameras,
- $1,755,000 for installation of planned/programmed cameras, and
- $24,245,000 for installation of proposed new cameras ($12,610,000 for key cameras and $11,635,000 for backfill cameras).

Fiber optic cable expansion of the CCTV communications infrastructure is estimated to cost $200,000 per mile, and is not included in the CCTV system expansion probable costs above. Multiple options for leased communication services exist in the interim.

On-going maintenance costs of 10% of each capital construction project (i.e. $6,500 per camera location per year) should be allocated for repairs and device replacement services over the life of each device. Allocating funds for this purpose will accommodate cameras deployed in the near-term, which may be replaced two to three times during the course of a 20 year deployment plan.

Virginia Department of Transportation
Contract# 27090 (Task NRO-27090-007)

CCTV Validation Plan

Virginia Department of Transportation Northern Region Operations

Prepared for:

VDOT Virginia Department of Transportation

Prepared by:

Kimley-Horn and Associates, Inc.

May 2008

1. Introduction

A Validation Plan provides a guide for evaluating a deployed ITS system to determine if it has met its goals. The Validation Plan lists criteria for judging whether or not the ITS system meets the user needs and objectives defined in the Concept of Operations. This Validation Plan addresses the needs and objectives defined in the CCTV Concept of Operations for the Virginia Department of Transportation (VDOT) Northern Region Operations (NRO). It is intended to be used in validating the future Closed-Circuit Television (CCTV) System in Northern Virginia against the VDOT NRO CCTV Concept of Operations and the High Level Requirements for VDOT NRO CCTV.

The validation plan is divided into “need categories” corresponding to Section 4: Operational Needs of the VDOT NRO CCTV Concept of Operations. These categories are Freeway Operations, Signal Operations, Maintenance, and Transportation Planning/Engineering Needs. For each operational need, the Validation Plan asks if the deployed system meets that need.

2. Freeway Operations

2.1. Traffic Management

The following checks validate the CCTV system against the user needs defined in Section 4.1.1 of the CCTV Concept of Operations.

2.1.1. Corridor Management

2.1.1.1. Monitoring Freeways and Arterials with Limited Gaps

Are there critical gaps in the CCTV system’s coverage of freeways and arterials for each deployed roadway bundle?

2.1.1.2. Monitor and Compare Parallel Routes

Is the CCTV system able to effectively compare conditions on bundled parallel routes and guide diversion management decisions?

2.1.1.3. Monitor Regular & Express Lanes

Does the CCTV system coverage sufficiently monitor conditions on express lanes, such as High Occupancy Vehicle (HOV) or High Occupancy/Toll (HOT) Lanes?

2.1.2. Condition Monitoring

2.1.2.1. Full Mainline Coverage

Can the CCTV system be used to monitor conditions on mainline laneage in both directions of covered freeways?

2.1.2.2. Interchange and Intersection Coverage

Can the CCTV system be used to monitor conditions at weave areas, merge areas, and diversion areas for freeways and arterials?

2.1.2.3. Unobstructed Views

Do objects such as vegetation, buildings, signs, or overpasses and flyovers block lines of sight to any camera locations?

2.1.2.4. Day/Night Use

Can imagery from the CCTV system be used at night or in other low-light conditions?

2.1.2.5. All-Weather Use

Can imagery from the CCTV system be used during rain, fog, snow, or other inclement weather conditions?

2.1.2.6. Constant Image

Do all cameras provide a steady in-focus image?

2.1.2.7. Automated Return to Preset Image

Do cameras automatically return to a preset angle, zoom, and focus after a set period of operator inactivity?

Do VIDs automatically re-establish detection/monitoring/alerting upon the camera's return to its preset?

2.1.3. Informing the Media and Public

2.1.3.1. Internet Video Feeds

Can members of the general public obtain CCTV feeds via a website using typically available bandwidth?

2.1.3.2. Media Video Feeds

Can Information Service Providers or mass media services access CCTV imagery via a designated media feed?

2.1.3.3. Disabling Feeds

Can TMC operators disable individual camera feeds to the public and media during sensitive events such as fatalities, emergencies, and security events?

2.1.4. Regional Coordination

2.1.4.1. Video Sharing Methods

Can video be shared with stakeholders via the Statewide Video Distribution System (SVDS) contractor and the Regional Integrated Transportation Information System?

2.1.4.2. Video Sharing Users

Are stakeholders including local DOTs, Virginia State and Local Police, and Fire & Rescue able to access shared video?

2.2. Incident and Event Monitoring

The following checks validate the CCTV system against the user needs defined in Section 4.1.2 of the CCTV Concept of Operations.

2.2.1. Freeway Incidents

2.2.1.1. Full Coverage

Are there gaps in camera coverage allowing incidents to occur in a location where the CCTV system is unable to detect or verify them?

- Is there full mainline coverage?
- Is there full coverage of interchanges, including merge, diverge, and weave areas?
- Is there coverage on and under bridges, overpasses, and flyovers?
- Is camera spacing sufficient (e.g. ½ mile)?
- Is camera coverage sufficient for Video Incident Detection (VID) systems?

2.2.1.2. View Control

Are TMC operators able to control the camera and image?

- Can TMC operators select the camera to control and view?
- Can TMC operators direct cameras at suspected incidents using pan/tilt/zoom features?

2.2.1.3. Incident Verification

Are TMC operators using the CCTV system to verify incident reports received from motorists, the Safety Service Patrol (SSP), and the Virginia State Police (VSP)?

2.2.1.4. Automated Condition Alerting

- Is a Video Incident Detection (VID) expert system alerting TMC operators of suspected incidents and/or unusual traffic conditions in a timely manner?
- Is a VID expert system effectively alerting TMC operators of shoulder lane incidents, debris, and/or stalled vehicles in a timely manner?
- Do VIDs relying on pan, tilt, zoom cameras work as effectively as fixed cameras?
- Do PTZ-based VIDs stop alerting when operators switch from the “alerting” preset camera view, and re-start upon return to the preset?
- Do the VIDs require too much operational adjustment and maintenance time in order to minimize false alerts?

2.2.2. Planned Events

Can the CCTV system be used to monitor planned events affecting traffic patterns or the roadway?

- Can the CCTV system be used to monitor long-term construction?
- Can the CCTV system be used to monitor diversions due to road closures for planned events such as parades, festivals, and road races?
- Can the CCTV system be used to monitor traffic due to planned trip generating events such as Washington Nationals games, concerts at the Nissan Pavilion, etc.?

2.2.3. Unscheduled Events

Can the CCTV system be used to monitor and manage traffic due to unscheduled events such as evacuations or early school closures?

2.3. Validating Other Infrastructure

The following checks validate the CCTV system against the user needs defined in Section 4.1.3 of the CCTV Concept of Operations.

2.3.1. Dynamic Message Signs (DMS)

Can TMC operators view all DMS with the CCTV system to verify correct message display?

2.3.2. High-Occupancy Vehicle (HOV) Lanes

2.3.2.1. Wrong-Way Vehicles

Can TMC operators view HOV lanes with the CCTV system and detect vehicles traveling the wrong way?

2.3.2.2. Lane Clearance

Can TMC operators tour CCTV cameras to determine that HOV lanes are cleared when switching HOV lane direction?

- Can TMC operators verify with CCTV that HOV lanes are clear of moving vehicles?
- Can TMC operators verify with CCTV that HOV lanes are clear of stalled or otherwise nonmoving vehicles and/or debris?

2.3.2.3. Gate Status

Can TMC operators view all HOV lane entry/exit gates to confirm that gates are correctly open or closed?

2.3.3. High-Occupancy/Toll (HOT) Lanes

2.3.3.1. Entry/Exit

Can TMC operators view entry and exit points for HOT lanes to verify clear ingress and egress?

2.3.3.2. Impacts

Can TMC operators use the CCTV system to monitor HOT lane impacts on main travel lanes?

2.3.4. Ramp Meters

Can TMC operators use the CCTV system to monitor ramp meters and gauge their queues and their real-time effects on the mainline?

2.3.5. Lane Control System

- Can TMC operators use the CCTV system to verify lane control displays for shoulders used as auxiliary laneage?
- Is a VID expert system alerting TMC operators of shoulder lane incidents, debris, and/or stalled vehicles in a timely manner?
- Do VIDs relying on pan, tilt, zoom cameras work as effectively as fixed cameras?
- Do PTZ-based VIDs stop alerting when operators switch from the “alerting” preset camera view, and re-start upon return to the preset?

- Do the VIDs require too much operational adjustment and maintenance time in order to minimize false alerts?

2.4. Active Speed Limit Management

Does the CCTV system meet the user need defined in Section 4.1.4 of the Concept of Operations by enabling CCTV operators to obtain qualitative descriptions of traffic conditions for use in active speed limit management?

3. Signal Operations

3.1. Arterial Congestion Management

The following checks validate the CCTV system against the user needs defined in Section 4.2.2 of the CCTV Concept of Operations.

3.1.1. Observe Arterial Network

Can the CCTV system be used to note overall conditions on the arterial network?

3.1.2. Timing Plan Selection

Can the CCTV system be used to evaluate the effectiveness of a selected timing plan in a Responsive Timing Plan Selection scheme?

Does the CCTV system provide improved performance measures in comparison to those prior to installation of cameras?

3.1.3. Traveler Information

Can the CCTV system be used to gather real-time traveler information for the 511 system?

3.2. High-Accident Location Monitoring

- Does the CCTV system meet the user need defined in CCTV Concept of Operations Section 4.2.3 by being useful for monitoring key high-accident locations?
- Does the CCTV system decrease the amount of time needed to verify computer-aided dispatch (CAD) information from the police?
- Does the CCTV system decrease the response and clearing time in contrast to prior to installation of cameras?

4. Maintenance

4.1. Reliability

The following checks validate the CCTV system against the user needs defined in Section 4.3.1 of the CCTV Concept of Operations.

4.1.1. Device Reliability

4.1.1.1. Independent/isolated Power

Does CCTV equipment have an independent power supply such that other ITS equipment cannot adversely affect the CCTV system?

4.1.1.2. Backup Power
Do CCTV camera and communication locations have Uninterruptable Power Supply (UPS) backup power supplies?

4.1.1.3. High Mean Time Between Failures (MTBF)
- Are components rated for at least five years of continuous operation?
- Are components robust and weatherproofed?
- Are components reaching their expected life expectancy?

4.1.2. System Reliability

4.1.2.1. Backup Control
Can the CCTV system be controlled and monitored from a backup TMC in addition to the main PSTOC facility?

4.1.2.2. Overlapping Coverage
Are cameras placed so that there is overlapping coverage to prevent excessive coverage gaps if a device fails?

4.2. Preventative Maintenance, Repair, and Replacement
The following checks validate the CCTV system against the user needs defined in Section 4.3.2 of the CCTV Concept of Operations.

4.2.1. Minimized Maintenance Cost and Time

4.2.1.1. Remote Testing and Reset
- Can maintenance personnel test CCTV devices remotely using Internet Protocol (IP)?
- Can maintenance personnel reset CCTV equipment remotely?

4.2.1.2. Easy Servicing
- Do maintenance personnel find it simple to remove, replace, and service CCTV equipment?
- Does the camera equipment Mean-Time-to-Repair (MTTR) adequately support TMC operations?

4.2.1.3. Maintenance Preparation
- Has additional yearly funding for maintenance been set aside at the time of new camera deployments?
- Are device and part replacements readily available for existing installations?

4.2.2. Replacement Stock Management

4.2.2.1. Bar Coding
Are all devices and components bar coded in accordance with the NRO Inventory Barcode Requirements?

4.2.2.2. Inventory and Maintenance Management System (IMMS)

Does the IMMS track all CCTV system devices and components through logged descriptors and identifiers, including IP number?

- Is all field equipment logged in the IMMS at the time of deployment?
- Are replacement devices and equipment stocks logged in the IMMS?
- Do maintenance personnel update the IMMS after performing maintenance?
- Do maintenance personnel update the IMMS after replacing bar-coded equipment?

4.2.2.3. Logical Identifier System

Does the method of identifying CCTV cameras help to systematically describe and locate them?

4.3. Maintenance Placement Needs

The following checks validate the CCTV system against the user needs defined in Section 4.3.3 of the CCTV Concept of Operations.

4.3.1. Minimization of Damage

4.3.1.1. Vehicle Impact

Is all CCTV equipment protected from vehicle impact by guardrail or placement away from edge of pavement?

4.3.1.2. Line Breaks

Are all CCTV power and communication cables protected against line breaks with sealed conduits and junction boxes?

4.3.1.3. Lightning and Surge Protection

Do all devices and electrical/communication lead-in cables have protection against lightning and transient electrical surges?

4.3.1.4. Foundations

Are all CCTV field devices installed on stable foundations on level ground to prevent erosion and undermining?

4.3.1.5. Vandalism

Are all CCTV field devices placed out of reach or in locked cabinets to prevent vandalism?

4.3.2. Maintenance Access

4.3.2.1. Safe Access

Can maintenance personnel access CCTV cameras and equipment in a safe manner?

4.3.2.2. No Traffic Impact

Can maintenance personnel access CCTV cameras without requiring lane closures or encroaching on a travel lane?

- Are cameras mounted off of the roadway and road-spanning structures such as bridges, overpasses, and flyovers?

- Are cameras and equipment placed with adequate space off of roadway for maintenance personnel, equipment, and vehicles?

4.3.2.3. Accessible Height

Are CCTV cameras accessible with VDOT's standard bucket trucks?

5. NoVA District Transportation Planning and NRO Traffic Engineering

The following checks validate the CCTV system against the user needs defined in Section 4.4.1 of the CCTV Concept of Operations.

5.1. Origin/Destination Studies

Can the CCTV system be temporarily equipped with external hardware and software (i.e. license-plate readers) to track vehicles through a corridor and report pairings of entry and exit points?

Is the data accuracy provided by this approach comparable to conventionally-outsourced data collection methods?

5.2. Spot Analyses

Can the CCTV system be used to record imagery of a location for use in later analysis of safety, geometric, or traffic-related issues?