Evaluation – Northern Virginia Smart Traffic Center (NVSTC) Integration Program

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Introduction

The Northern Virginia Smart Traffic Center (NVSTC) Integration Program was an ambitious undertaking to enhance the effectiveness of intelligent transportation systems (ITS) in the Washington metropolitan area by interconnecting regional systems. The complexity of this undertaking, both from a technical and institutional perspective, required significant innovation from all parties involved. The purpose of this report is to present the results of an evaluation of the NVSTC Program.

The evaluation report is organized as follows. First, the report begins by reviewing other national ITS integration programs. Many of the lessons learned were common among the various programs studied, providing a foundation for evaluation of the NVSTC Program. Following the lessons from the national experience, there is an introduction to the scope of the NVSTC Program, including each of the 4 major components of the integration. Next, there is a review of program activities and key contractor deliverables. Following this, there is a detailed explanation of the lessons learned specifically during this Integration Program. In addition, these lessons are compared to those learned on the national level. Finally, the report concludes with general conclusions about the overall success of the program and guidance for future similar efforts.

It should be noted that the evaluation effort was not intended to serve as a critique of the parties involved in the effort. Rather, it was intended to identify key lessons learned on "big picture" issues critical to large-scale ITS integration. It is expected that the results presented in this report will be of use in future regional and national integration initiatives.

1. The National ITS Integration Experience:

To provide context for the lessons learned in the NVSTC Integration Program, this section summarizes common national experiences in large-scale ITS integration efforts. There have been a number of integration initiatives similar to that of the NVSTC Integration Program. Some of the most studied and documented efforts took place in: Southern California, Houston, Phoenix, Seattle, San Antonio, the New Jersey-New York-Connecticut region and the Gary-Chicago-Milwaukee region. They share several common lessons learned that project participants considered crucial.

1.1 Lessons of the Past:

One of the first lessons that emerges upon examination of national efforts is that participants benefit greatly from previous integration programs. Initially studying other projects eliminates time spent on preliminary planning and consultation among contributors. The savings in resources justifies the study of similar ITS integration programs. Actual technological specifications and detailed information, however, will be of minimal use because projects vary by region and application. On the other hand, general study of previous ITS deployments will help raise awareness of ITS applications among project participants {7}.

In the case of the New Jersey-New York-Connecticut region integration effort, the previous success of the E-ZPass electronic toll collection system helped illustrate to stakeholders the potential of a structured ITS framework {5}. Actions such as these are of particular importance when consulting with decision-makers such as government officials or upper-level management. Evidence of success in previous efforts will only make the approval process for the next integration program less difficult.

1.2 Involvement/Participation of Stakeholders

Participation of all stakeholders and decision-makers throughout the entire process is important to integrating the systems in the desired fashions, and is cited as a major factor in the cases studied.   Involvement of these groups from beginning to end will ensure that all participants share the same vision of the eventual system. One of the lessons of the Houston effort to integrate its traffic signals within an ITS framework was to promote interaction among the stakeholders in order to ensure eventual system ownership. The system is more likely to fit the users' requirements if they are involved throughout the process and there is more likely to be a common understanding among all participants rather than simply those involved in the integration itself {4}.

In the report regarding Arizona's attempt to develop a rural statewide architecture, the authors list three important stakeholders with whom to maintain close relationships during the project; early champions *(those who may introduce the concept to a stakeholder organization)*, local advocates *(government officials or agency managers who encourage the program)*, and proactive stakeholders *(agency managers or government officials directly responsible for financial and executive decisions such as these)* {7}. This will help ensure that each eventual stakeholder's needs will be met.

Finally, the stakeholders can significantly aid the consultants (or those working on the integration) by developing a *Concept of Operations* to guide the integration. In the case of the integration of several Southern California counties, the consultant benefited from a clear understanding of how the systems were intended to work together, described in a *Concept of Operations* {6}.

1.3 Demonstration of Benefits to Stakeholders:

It is important to demonstrate the benefits of the integration to all stakeholders. Whether the project is a public or private sector venture, cooperation from outside groups will be beneficial for all involved. Private sector firms will benefit from the integration and the project itself will have a reduced cost because of increased private support. Before beginning an integration project, educating the eventual users and beneficiaries is crucial to its success. In the case of the Southern California multi-jurisdictional integration, project managers conducted workshops and guided "scanning tours" to allow decision-makers to see ITS implementation in other cities {6}. Activities such as these will allow non-technical stakeholders to grasp the concept of an ITS integration and to become more comfortable with it.

Understanding the differences in technical knowledge of the stakeholders is crucial to "selling" the integration project at its initial stages. One lesson that emerged from the New Jersey-New York-Connecticut integration project was the need to acknowledge the distinction between planning personnel and operations personnel. Typically, planning personnel are the stakeholders most interested in cooperation and regional involvement but the operations personnel are the ones that will be utilizing the new system {5}. For this reason, operations personnel must be made to understand the direct benefits to their work before there is widespread support.

Many of the planning personnel will not have the backgrounds necessary to fully understand the technical aspects of a complex integration architecture. Because of this, those trying to promote the project should use simple graphical representations to demonstrate the concepts behind an ITS architecture {7}. Doing this will allow planning personnel to understand who is involved with what parts of the project without forcing them to delve deeply into the technical aspects of the integration program. In the case of the Gary-Chicago-Milwaukee integration program, the managers found it useful to present only the benefits relevant to a user rather than all of the benefits of the project. The state police cooperated in this effort because the benefits of the metropolitan-based traffic incident management system were shown to them without overwhelming them with other information {3}. Demonstrating the simplicity of the portion of the system that will be relevant to them will likely increase support and acceptance among potential users.

1.4 Interagency/Multi-Jurisdictional Cooperation:

Once the project is approved and underway, interagency and multi-jurisdictional cooperation are essential to the integration proceeding effectively. It may seem as though each agency or body has its own interests, but finding common ground is beneficial as the basis for cooperation. Realizing aspects that are common, such as weather, geography and tourism, can provide a familiar set of issues to unite an otherwise diverse coalition {7}. To facilitate the establishment of an ITS integration coalition, use of existing relationships and organizational umbrellas is critical {6}. Existing relationships may be based on previous projects or an ongoing affiliation. In the absence of previous relationships, the establishment of cross-cutting organizations, with representation from all stakeholders, may greatly facilitate the process {1}. Once these groups have been brought together, they must define and understand their roles clearly before proceeding on the project. Especially on government projects, issues such as funding, staffing, and oversight will need to be discussed and negotiated among the agencies involved {4}. Each group involved in the integration will hold ITS at its own priority levels. Only once these priority levels are understood can a productive collaboration take place {5}.

After the inter-agency, multi-jurisdictional relationships have been established, maintaining these relationships will help on future projects and in daily operations. This cooperation will open up lines of communication and personal relationships that were not present before. It is senseless to allow these associations to terminate at the conclusion of the project. As stated in the report on the Gary-Chicago-Milwaukee integration project, "Just as important as the regional ITS architecture is the interagency coordination and cooperation fostered by the architecture development process" {3}. These new relationships can facilitate any project on which the agencies are working, including those not within the scope of ITS. Regarding this concept, the New Jersey-New York-Connecticut report states that several agencies reported "an attitudinal shift towards the compounded benefits of coordination in all spheres" {5}. It is likely that communication among participating groups will be easier and more standardized after the project is complete.

1.5 Experienced Information Technology Professionals:

In virtually all of the previous integration efforts, a key lesson learned is the significant value realized by involving experienced Information Technology (IT) professionals. One of the most significant benefits of including such expertise is the ability to shorten project length. The authors of the Gary-Chicago-Milwaukee report state: “Capable consultants can be crucial when working through detailed architecture design and development stages of the process. While integration consultants represent an additional cost, their support may yield valuable dividends in time-savings and other efficiencies” {3}. In the discussion of Arizona’s Rural Statewide Architecture, the authors emphasize the value of IT professionals, writing, “The complex yet short-term nature of developing a statewide architecture makes it a suitable task to contract out to a consultant” {7}. The Southern California integration report discusses both positive and negative consequences that can result from hiring a consultant. The report states: “The systems integrator also provides technical guidance to project level designers and assists in establishing regional ITS standards.” {6}

However, experience has also shown that it is necessart to guard against over-reliance on “outside” IT professionals. For example, The Southern California integration report states that “it is important, however, to avoid over-reliance on the integrator so that the stakeholders remain sufficiently engaged to comfortably provide meaningful technical direction.” {6} The Houston integration report even argues against the use of consultants altoghether, writing that it is crucial that agency staff be involved in every stage of the project. In Houston, stakeholder staff worked to develop the architecture with no assistance from consultants.

1.6 Education of Users/Stakeholders:

As integration projects proceed, the importance of educating users and stakeholders becomes an important issue. They must become comfortable with the system architecture and have a significant knowledge of their roles in the new system for it to be of value upon completion. Also, it is important that they understand the ITS architecture in greater detail as they proceed with the project. At the initial stages of the New Jersey-New York-Connecticut integration, many agencies reported the need for further education and guidance {5}. Without continuing education about the architecture and performance of the integrated system, the process will be slowed and will certainly become more costly. One lesson learned during the Gary-Chicago-Milwaukee project was that employees, uneducated about basic ITS concepts, could “significantly hamper development and implementation schedules” {3}. The Houston authors state the need to have stakeholders using the system as it evolves, saying: “Participants in the development of the project architectures learn by doing. Although the Houston stakeholders had some familiarity with the National ITS Architecture, the individuals reached a comfort level with the National ITS Architecture only after having used it” {4}.

1.7 Highlight Accomplishments:

The final major lesson common to most of these projects is the need for the stakeholders to highlight the accomplishments of the integration. The majority of the public and even many involved within stakeholder organizations will have little knowledge of the capabilities of the newly integrated ITS. Use of good public relations and communications tools will help build public awareness and support. Stakeholders should make the benefits known to the public through sources such as the Internet, television reports and other media outlets {1}. If the value of the integration effort is demonstrated properly, public support, and therefore the support of influential officials, will increase. When the assets of an integrated ITS are demonstrated to the public, the likelihood of approval for similar projects in the future significantly increases. Currently, ITS is not likely to be the first consideration in solving many transportation problems. Documentation and highlighting of successes along the integration are crucial to promoting the use ITS in the future.

2. NVSTC Integration Program Scope:

As stated earlier, the focus of the NVSTC Integration Program was to integrate key regional ITS systems with the NVSTC. To accomplish this, the NVSTC Integration Program was comprised of 4 key components;

- Integration with the Smart Travel Lab (STL)
- Integration with *Partners in Motion (PiM)*
- Integration of the Beltway Detection System (BDS)
- Ongoing System Maintenance and Administration

The Integration Program resulted in significant benefits to the NVSTC and its partner systems.

- Partnership with *PiM* and the integration of the BDS greatly expanded the scope of NVSTC's traffic monitoring capabilities, providing significant improvements in terms of information gathering.
- Integration with the STL provided benefits for both the NVSTC and the STL, enabling a strong applied research and development program centered on NVSTC needs.
- System maintenance and administration not only made the integration program possible, but it also laid the foundation for future enhancements.

This integration will serve as a resource for future regional integration efforts, therefore, one of the primary objectives of this report is to evaluate the program and document lessons learned.

The key participants and stakeholders involved in this Integration Program were:

- **The Northern Virginia Smart Traffic Center (NVSTC) –** *The Virginia Department of Transportation (VDOT) Freeway Management System for Northern Virginia, serving as a base for Intelligent Transportation Systems (ITS) operations*
- **The Smart Travel Laboratory (University of Virginia/Virginia Transportation Research Council) –** *ITS Research laboratory supporting VDOT's Smart Travel Program*
- ***Partners in Motion (PiM) –*** *Consortium of 25 public agencies and 12 private organizations that developed and operate SmarTraveler, a Washington D.C. traveler information system*
- **Battelle Memorial Institute –** *Project manager and systems integrator for Partners in Motion*
- **Lockheed Martin Canada, Inc. (LMC) –***Contractor responsible for executing the Integration Program*

The following sections describe each of the four components of the integration program in greater detail.

2.1 Smart Travel Laboratory Integration Scope:

The STL was developed by the University of Virginia (UVA) and the Virginia Transportation Research Council (VTRC) to provide an ITS research and development facility for VDOT. In this effort, the NVSTC was integrated with the STL, establishing a satellite NVSTC workstation at the STL in Charlottesville, Virginia. The availability of NVSTC data and video, plus access to NVSTC application software, will enable the STL to conduct applied research that will improve NVSTC operations. Given the STL's existing link to the Northern Virginia signal system, this element of the integration program will also allow the STL to support further integration of regional ITS elements.

To aid in the data transfer and acquisition processes, a replicated database server (CDBr) was developed to replicate with the primary Compute Database (CDB) at the NVSTC. The CDBr allows the STL to utilize NVSTC data without impacting core NVSTC processes. Initially, the integration included three Closed Circuit Television (CCTV) video signals transmitted to the STL, but that system will accommodate an increase to six. Lockheed Martin Canada, Inc. (LMC) developed the satellite workstation at the STL based on the specifications of the workstations at the NVSTC. This workstation provides basic data and video functions, such as camera selection, but provides no control over any operational elements such as Variable Message Signs (VMS) or High-Occupancy Vehicle (HOV) lane signals. VDOT purchased the workstation and LMC integrated it and its software to operate remotely with the NVSTC.

2.2 Integration with Partners in Motion Scope:

The integration effort with *PiM* involved the integration of the NVSTC with the Washington area's public/private traveler information venture. SmarTraveler, the system that was developed and is operated by *PiM*, allows users to access traffic data, via the Internet or telephone schedules.

The data used in the SmarTraveler system is collected from both public and private travel information sources, and includes weather, travel times, incident reports and bus and rail information. The data is collected using resources such as highway cameras, aircraft surveillance, two-way radios, police scanners and private individuals. *PiM* is a partnership of 25 state and federal agencies and 12 private organizations that developed the SmarTraveler system at a cost of $12.2 million. It is intended that the SmarTraveler system will eventually be self-supporting as more private corporations become involved. Some of the organizations involved have operational responsibility while others are involved in planning. *PiM* seeks to promote better cooperation among these different types of participants, which is very important considering the multi-jurisdictional nature of the project.

Battelle Memorial Institute served as project manager and systems integrator for the project and was the primary source for information on the *PiM* component. Integration in this task included 2-way sharing of data and involved challenges such as linking to a private entity. *PiM* will use the CDBr, just as the STL, in order to minimize disruptions to core NVSTC processes.

2.3 Integration of Beltway Detection System Scope:

This component was intended to provide the NVSTC monitoring capability on the Capital Beltway, I-495. Passive acoustic detectors were installed at 84 locations, and 2.4 GHz spread spectrum radio is used to transfer the data to a hub. Data consolidated at the hub is then transmitted to the STC via the existing communications plant. Designers replicated firmware in the 170 controllers of the current NVSTC in the new 2070 controllers used for the BDS. This was intended to provide an identical data stream coming out of the new detectors.

This element of the NVSTC Integration Program was needed to directly integrate data from the Beltway system to the STC software. This included incorporating the data into all applicable databases, modifying the system map to reflect the new detectors, and including the data in all applicable processes (such as incident detection).

2.4 Ongoing System Maintenance and Administration Scope:

A software system of the complexity of the NVSTC's requires constant administration and maintenance support. Basic administration services such as the establishment of user accounts, system back-ups, and database administration are essential. In addition, minor system bugs are discovered over time that need to be remedied.

LMC maintained all hardware and software components within the NVSTC facility (note: this excludes field hardware). LMC provided system software and hardware support to include technical assistance in evaluating and resolving problems. For this purpose, LMC provided one full-time, on-site administrator at the NVSTC during normal work hours. Outside of normal work hours, LMC responded to any maintenance call within four hours of notification by VDOT. LMC was expected to work with VDOT personnel to respond to system maintenance and administration needs.

Maintenance included the integration of field devices into the NVSTC system GUI, databases, and analytical processes, as applicable. VDOT provided full protocol information to facilitate integration efforts. As part of the ongoing software and hardware maintenance support, LMC performed all system administration activities, including addition of users to the system, changes in user privileges, and system backups.

3. Program Review

The following section, organized by components of the Integration Program, is a review of the activities of the integration program and the status of deliverables at the time of publication of this report.

3.1. STL Integration

1. Setup, development, and integration of the STL workstation and its software to operate remotely with the NVSTC

The contractor, LMC, has developed, integrated and tested the STL workstation and its software. They remotely operate with the NVSTC as designed. STL conducted an independent acceptance test of the workstation. This test verified correct integration was completed.

2. Onsite presence for core STC and STL integration services as needed to accomplish the above task

The contractor provided a full-time system administrator on site at the NVSTC. He oversaw all system maintenance and administration activities and had physical access to control spaces, enabling him to provide effective support to the integration progress.

3. Preliminary and Critical Design Reviews

Various versions of the STL design document were created and reviewed by the stakeholders. The first version was submitted on June 22, 2000. The next version incorporated the preliminary design review comments and contained detailed design phase changes, along with peer review comments. The second revision, dated November

29, 2000 incorporated design review comments, detailed design phase changes and peer review comments. The final draft, issued on August 22, 2001 incorporated more design review comments and changes to video and network solutions. The design documents included sections such as: system overviews, detailed designs and customer furnished equipment (CFE). The design documents effectively guided contractor and stakeholder personnel in the effort to integrate the NVSTC with the STL.

3.2 *Partners in Motion* Integration

1. An interface to NVSTC link level data made available to *Partners in Motion*

The contractor has successfully provided an interface with NVSTC link level data to *PiM*.

2. Enhanced NVSTC software which integrates *Partners in Motion* data

The contractor has adequately enhanced the NVSTC software that integrates the *PiM* data. NVSTC and *PiM* use a system in which each extract data from the other, in what is called a "pull" relationship. NVSTC is now receiving incident data from *PiM*, which is being integrated into the normal interface.

3. Onsite presence for core STC integration services as needed to accomplish the above tasks

The contractor provided a full-time system administrator on site at the NVSTC. He oversaw all system activities and had physical access to control spaces, enabling him to have a total knowledge of integration progress. The systems administrator was responsible for maintenance and access to the system during the integration

4. Preliminary and Critical Design Reviews

The PDR was conducted and comments reflected in the *PiM* Design Document. Subsequent discussions were addressed by various teleconferences and e-mail exchanges. The final documentation for all software and database modifications was included in the *PiM* design document.

3.3 Integration of Beltway Detection System

1. Updated central software to incorporate data from additional acoustic detectors into all relevant processes

The contractor has updated the central software to incorporate data from additional acoustic detectors into all relevant processes and is working on the validation process.

2. Updated databases, map and user interfaces to integrate new detectors

The contractor has successfully updated the databases and the map and user interfaces to integrate the new detectors.

3. Onsite presence for core STC integration services as needed to accomplish the above task

The contractor provided a full-time system administrator on site at the NVSTC. He oversaw all system activities and had physical access to control spaces, enabling him to have a total knowledge of integration progress.

4. Preliminary and Critical Design Reviews

Because the new system is using the existing map and has simply added fields to the database, project participants decided that detailed designs and reviews would not be necessary. This portion of the program was simpler and lacked some of the system complexities that were evident with the other portions, reducing the need for such documentation.

3.4 Ongoing System Maintenance and Administration:

The contractor provided an on-site system administrator at the NVSTC to oversee hardware and software modifications. The system administrator regulated physical access to all control spaces, meaning that all modifications to the system would have to be approved by him. His role was to understand the functionality of the system at the time and to have knowledge of how the system would eventually work as a whole. With regards to the integrations of STL, *PiM*, and BDS, the system administrator worked only on the NVSTC side of these projects. System maintenance and administration at these stakeholder organizations was either handled by stakeholder personnel or other contractors.

3.5 Benefits Realized From Integration

The NVSTC Integration Program will provide tangible benefits to all involved stakeholders and users of the newly integrated system. The primary beneficiaries will be: the NVSTC, the STL, *PiM*, and the public. The completion of this integration will allow these groups access to more data and information than was previously available.

3.5.1 NVSTC

The NVSTC has a significantly increased capability in terms of data collection and processing as a result of the NVSTC Integration Program. The integration of the BDS allowed the NVSTC to more carefully monitor and analyze traffic on the Capital Beltway. With the many detectors and sensors installed on the Beltway, the quantity of data has increased significantly, which is of great benefit to other stakeholders that are involved in the integration. The integration of the BDS offers benefits to the NVSTC in that it will be a proof of new technology. The passive acoustic detectors are significantly easier to install and maintain, which provides obvious benefits to NVSTC. The new incoming data was incorporated into all relevant systems, such as incident response, providing each applicable system within the larger NVSTC system a significantly increased capability.

The NVSTC greatly increased its capability to collect quality data as a result of the integration with the STL. Because data is shared virtually in real-time, the NVSTC will have another set of operational personnel examining the data, verifying its quality. The NVSTC also benefited in this relationship because of the ongoing projects and research at the STL that may be applicable to NVSTC operations and will be tested directly using NVSTC data.

3.5.2 Smart Travel Laboratory

The Smart Travel Laboratory at the University of Virginia realized many benefits through this integration. Both the laboratory's research and educational efforts were greatly enhanced by the integration with NVSTC. The significantly increased data stream allowed for more analysis and project research, including applications that may soon help NVSTC in its daily operations. The link between the two centers will allow users at the STL to gain a greater knowledge of complex systems, such as that of the NVSTC. Educational efforts were greatly enhanced at the STL because of the analytical capabilities that data and video provide.

3.5.3 *Partners in Motion*

PiM benefited greatly from their integration with the NVSTC. They now have more data and video for use in their public applications. This proves useful to both *PiM* and to those who use *PiM* for their travel information. The incoming data from the NVSTC can be compared to their own data for data quality assurance and also to fill gaps in detection capabilities. *PiM* now receives incident data and other information that increase their functionality. The video feeds will allow users of *PiM/*SmarTraveler to reach a greater understanding of ongoing traffic situations.

3.5.4 Benefits Summary

All of the groups involved benefited from being involved in this integration in that their personnel now have significant knowledge concerning ITS integrations. This will serve all of these groups (NVSTC, STL, *PiM*) well should they choose to integrate further in the future. Given current trends, it is likely that each of the stakeholder organizations involved in this integration will integrate further in the future. This project demonstrated to these organizations the logistical concepts involved with an integration and demonstrated how to overcome problems that are likely to be seen again. This experience could save time and money on future integration projects.

4. Lessons Learned During the NVSTC Integration Program

By participating in all Integration Program activities, the UVA research team witnessed first-hand both strengths and weaknesses of the program. In addition, interviews were conducted throughout the program with key participants to gain their insight. This section summarizes key lessons learned from the NVSTC Integration Program.

4.1 Importance of System Administration and Information Technology Support

One of the major lessons learned on the NVSTC Integration Program confirmed the national experience that qualified information technology professionals provide invaluable services. They can greatly shorten the length of the project and reduce costs.

Having a system administrator on site, with knowledge of the whole system greatly facilitated the location of, and repair of, system defects. The consultants had knowledge of how the system functioned as a whole, as well as a vision of the system's capabilities upon completion. The system administrator for NVSTC oversaw the entire system and, in terms of this integration, the division line for his responsibility was the NVSTC firewall. For aspects of the integration beyond this sphere, other personnel achieved the requirements.

With an integration such as this, having many personnel from many different organizations performing many tasks, the system administrator oversaw all hardware and software modifications. No one could access the system components without the knowledge of the system administrator, who was aware of what was being worked on and for what purpose, providing, at least, a minimal level of configuration management.

The system administrator was responsible for addressing security and survivability issues with regards to the integration. Disaster recovery was a major consideration considering the size of and complexity of the system. Planning was made for scenarios such as the loss of a component of the system such as a data processing facility or of the entire NVSTC building. The system administrator sought to anticipate contingencies and plan for data archiving and data recovery.

Because of the scope and complexity of the systems involved in this integration project, it was vital to have personnel responsible for ongoing system maintenance and administration. Some of the important tasks that the system administrator oversaw throughout the integration effort include; the purging of temporary files to allow adequate space for operation, space management in general, and management of physical access to control spaces. This allowed the system administrator to have a full knowledge of the status of the system's progress and to regulate all modifications to the system. With many personnel from different organizations involved in the integration, it was key to have one common link to oversee the source. To this end, the system administrator also handled requests for system information that would come in from stakeholder organizations for their portion of the integration effort.

4.2 Proper Project Definition

Another lesson learned in the NVSTC Integration Program was the necessity of properly defining the project goals. With several components involved in the program and many stakeholders, a scope that promoted the interests of all of the parties of the integration was essential. In this program, each stakeholder had a set of goals that they sought to achieve. These goals were not always compatible with what other stakeholders sought. For this reason, the scope needed to provide some benefit to all parties that would be affected. In this case, there were benefits to STL, NVSTC, and *PiM*. Without these benefits, cooperation during the project's duration would have been much more difficult to achieve. Another reason that it is important to properly define the projects goals is that many involved personnel were less than fully aware of what the entire integrated system was intended to do.

Also important when defining project goals is to define project responsibilities and schedules. In some cases, there was confusion over which party was responsible for tasks. This invariably led to program delay. Significant delay was experienced during the integration because of telecommunications issues in which contractor responsibilities were not clearly defined and because policies about scheduling were not detailed.

4.3 Interagency/Multi-Jurisdictional Cooperation

Participants noted that good interagency cooperation significantly benefited this initiative, and in the future will reduce the duration of new efforts. In order to keep the systems as compatible as possible, it was found that regular meetings should be held on a monthly basis among all the relevant organizations. There is a need for there to be system administrator level personnel at each integrated agency to communicate frequently. Any specific changes that have been made to a specific system should be announced to the group. Information that should be covered would include: new controls, new devices, and upcoming plans for system modification. Operating this way, on a continuous basis, will eliminate the need for major system overhauls for compatibility reasons in the future.

As discussed with the national experiences, this sort of cooperation is essential on projects of this size. As was done on many of these integration efforts, personnel at the various stakeholder organizations familiarized themselves with the operations at the other organizations or agencies to understand at what priority level they held ITS and the necessity for integration.

4.4 Proper Documentation

A very important lesson that was learned during this integration effort was the need for proper documentation of system architecture and software code. The process was slowed, at times, because of lack of, or poor organization of, system documentation. It was important to properly document this integration program for use on future integration efforts that will involve the NVSTC system. A document management plan and system, developed at the outset of the project would have greatly facilitated all relevant stakeholders having the most up-to-date information. With designs being reviewed and modified frequently, document management is essential.

Some highlighted the importance of proper documentation when addressing connectivity. The systems that were being connected were often quite different and required conversions to achieve compatibility. Properly documenting how these conversions are achieved will save time and money in the future when the system is involved in further integration. This problem was especially evident when considering the issue of highway segment, or link, definition. Each system defined links slightly differently. This resulted in significant effort being placed on developing link conversions from system to system. At times, the development of such conversions was made more difficult due to poor documentation of link definition.

4.5 Integration Impacts on Scalability

The NVSTC Integration Program required careful consideration of scalability, both in terms of system(s) size and spatial scope. All of the systems involved in the integration are scalable in terms of software and database capabilities. However, the NVSTC, STL and *PiM* systems all needed improved hardware capabilities to handle the larger amounts of data to be transferred. With software modifications and hardware procurement, these systems were all easily scalable. As the transfer of data progresses and stakeholder organizations begin to archive some of this data, physical space will become an issue, as more hardware will be needed to house the data. Stakeholders should pay particular attention to their physical capabilities and possibilities for expansion in order to ensure total system integrity.

4.6 Security Issues

One of the most significant issues that arose during the integration was the need for additional security and the benefits that this additional security would offer. As part of the program's enhancement, a firewall was installed at the NVSTC facility. The overriding rule for the firewall is to deny access to everything except to those who are authorized. In conjunction with the firewall, there was significant effort put into the design of the network architecture. Some of the major issues related to security were:

- *Policy* – It was essential to determine who should have access and to what materials through the firewall.
- *Network architecture* – For future work on the system, designing an organized network architecture will save time and money.
- *Firewall* – The firewall was an essential part of the physical system, greatly improving network security at the NVSTC.
- *Physical Connection* – Because of some security precautions, connections will be disturbed or altered, a fact that must be taken into account at the outset of the project.

Therefore, the lesson learned in this case was that security is a complex issue when one integrates systems, and must be considered a top priority in an integration program.

5. Conclusion

In conclusion, the Northern Virginia Smart Traffic Center Integration Program successfully provides connectivity between multiple ITS systems. The newly integrated system will offer benefits to all of the participating organizations in terms of increased capabilities. Based on the lessons learned described in the previous section, the following recommendations are provided to VDOT and the transportation community as a whole:

- **Clearly Define Project Requirements and Responsibilities –** It is important that the requirements of an integration program be clear and understandable to the personnel that will be undertaking the integration. Only if each component's role in the system is properly defined will the project proceed effectively.
- **Proper Documentation is Essential –** One of the primary lessons learned is that there is a need to take steps to ensure proper document management. To keep track of the design changes and volumes of correspondences among participants, a document management system is ideal.
- **Sound System Administration and Maintenance is Essential to Support Integration –** Having a system administrator to oversee the modifications to the system who has a knowledge of all the changes that are to take place will reduce confusion, overlapping work, and alteration of the work of others.
- **Integration is an Ongoing Program and not a Project –** It is important to understand that an integration is a continuing process that evolves as obstacles

are encountered, and not a project with rigid requirements that will be met at a certain date. Because of the complexities of integrating several entities, the goals and requirements will be constantly evolving.

- **Security Issues Must Be Carefully Considered –** Because an Integration Program such as this provides more access to more users, it is important to carefully consider the security issues at the outset of the program. Considerations such as firewalls and user policy modifications will prove essential.

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7. Appendix – List of Acronyms

Acronym:	**Meaning:**
BDS	Beltway Detection System
CCTV	Closed Circuit Television
CDB	Compute Database
CDBr	Replicated Compute Database
CFE	Customer Furnished Equipment
GUI	Graphical User Interface
HOV	High-Occupancy Vehicle
IT	Information Technology
ITS	Intelligent Transportation System(s)
LMC	Lockheed Martin Canada, Inc.

NVSTC	Northern Virginia Smart Traffic Center
PiM	*Partners in Motion*
STL	Smart Travel Lab
UVA	University of Virginia
VDOT	Virginia Department of Transportation
VMS	Variable Message Signs
VTRC	Virginia Transportation Research Council