White Paper

Arterial Traffic Control Integration

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Version 1

Prepared for:

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List of Acronyms

ATMS .... Advanced Traffic Management System
C2C .... Center-to-Center
DMS .... Dynamic Message Sign
FDOT .... Florida Department of Transportation
FHWA .... Federal Highway Administration
GBps .... Gigabyte per Second
GUI .... Graphical User Interface
HAR .... Highway Advisory Radio
ICD .... Interface Control Document
IM .... Incident Management
IP .... Internet Protocol
MBps .... Megabyte per Second
NTCIP .... National Transportation Communications for ITS Protocol
PTZ .... Pan-Tilt-Zoom
RTMC .... Regional Transportation Management Center
SNMP .... Simple Network Management Protocol
TCC .... Traffic Control Center
TCS .... Traffic Control System
TOD .... Time of Day

1. Scope

1.1 Document Identification

This *White Paper* discusses the potential areas of integration between arterial traffic control systems (TCSs) and freeway management systems (FMSs) using the SunGuide℠ software system,[1] and researches the options available to accomplish this integration.

1.2 Document Overview

The SunGuide software is a regional advanced traffic management system (ATMS) being developed for the State of Florida.[2] It is primarily designed for installation in regional transportation management centers (RTMCs) for managing freeway traffic. In Release 2 of the software, a center-to-center (C2C) interface will be added to allow the SunGuide software in each RTMC to exchange freeway data with other RTMCs and with external third-party participants.

In addition to exchanging data with other freeway systems, there has been interest expressed regarding the possible integration of the SunGuide software system with local arterial TCSs. Since the data exchanged between freeway systems and arterial systems is different from the data exchanged between two freeway systems, research needs to be performed regarding the possible benefits and costs of different levels of freeway/arterial integration.

The purpose of this paper is to encourage discussion of C2C integration issues, so opportunities to provide feedback on all topics will be provided.

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[1] SunGuide℠ is a service mark of the Florida Department of Transportation.

[2] More information regarding the SunGuide℠ Software System is available online at http://sunguide.datasys.swri.edu/.

1.3 Related Documents

The following documents can be used as references regarding the software integration issues discussed herein.

- *SunGuide*[SM] *Video Sharing Capability Analysis Using C2C*, *Version 2* – This document discusses the capabilities and limitations of the C2C software with regard to video frame transmission over communication links that support the Internet Protocol (IP).[3]

- *FHWA Freeway Management and Operations Handbook, Chapter 16, Regional Integration* – This section of the *Handbook* contains an overview of current practices, a discussion of institutional issues, and describes several examples of successful regional integration projects.[4]

[3] Dellenbeck, Steve (Southwest Research Institute), *SunGuide*[SM] *Software System – SunGuide*[SM] *Video Sharing Capability Analysis Using C2C*, *Version 2* (August 2004).

[4] Neudorff, Louis G., Jeffrey E. Randall, Robert Reiss, and Robert Gordon, *Freeway Management and Operations Handbook – Final Report* (September 2003). FHWA Report No. FHWA-OP-04-003. Available online at http://ops.fhwa.dot.gov/Travel/traffic/freeway_management_handbook/toc.htm.

2. Integration Options

There are several different levels of integration that are possible between FMSs and arterial TCSs. Each level has a different set of benefits and costs. The primary integration options are described in the following subsections.

2.1 Option Descriptions

There are four general options for the integration of arterial TCSs with the SunGuide software being utilized at the freeway management centers. These options are discussed below.

- **Option 1: Do not modify the SunGuide software.** Install a remote workstation for the TCS at the SunGuide operations center and a remote workstation for the SunGuide software at the traffic control center (TCC).

- **Option 2: Add a C2C interface and traffic control graphical user interface (GUI) module to the SunGuide software.** Add a C2C traffic signal management interface to the SunGuide software, modify the GUI for the SunGuide software to allow the display of traffic signal status, and enable the operator to control traffic signals through activation of local response plans. Local TCSs can be modified in a similar manner, if desired, to display freeway data and device status on the local system's GUI. Integration of the C2C module with various subsystems would allow implementation of all the capabilities listed in *Section 3* of this *White Paper*. This option will require the development of a C2C interface control document (ICD) for traffic signal status and response plan activation, as these capabilities are not present in the current C2C ICDs.

- **Option 3: Add a full traffic signal control module to the SunGuide software.** Modify the SunGuide software to fully support traffic signal management. Full-featured traffic signal management includes direct communication with traffic signals, a signal data editor, selection of a traffic-responsive timing plan, etc. This would enable local jurisdictions to choose the SunGuide software for arterial management and provide the Florida Department of Transportation (FDOT) with all the functionality needed to effectively coordinate with arterial traffic management systems. Integration with a C2C interface would not be necessary, since all arterial/freeway coordination would be done internally. Local agencies using the enhanced version of the SunGuide software would also be provided all the functionality needed to coordinate with FMSs.

- **Option 4: Interface a third-party TCS directly to the SunGuide software (no C2C).** Rather than writing a new arterial traffic control module for the SunGuide software from scratch, integrate an existing arterial TCS into the SunGuide software architecture. The TCS would interface directly with the SunGuide software's data bus rather than through a C2C connection. The GUI for the SunGuide software would be modified to display the status of the TCS, but the existing TCS GUI would still be used for most traffic control-specific functions.

Table 2.1 summarizes the above options, and shows what software would be running in the local TCCs and the RTMCs. Refer to the diagrams in Figures 2.2 for additional explanation.

Table 2.1 – Software Overview for Regional Transportation Management Centers and Traffic Control Centers

	Option 1	Option 2	Option 3	Option 4
TCC	TCS	TCS	SunGuide	SunGuide/TCS
RTMC	SunGuide	SunGuide	SunGuide	SunGuide
C2C Link	None	TCS-to-SunGuide	SunGuide-to-SunGuide	SunGuide-to-SunGuide

Figure 2.1 – SunGuide^SM Software Architecture Overview

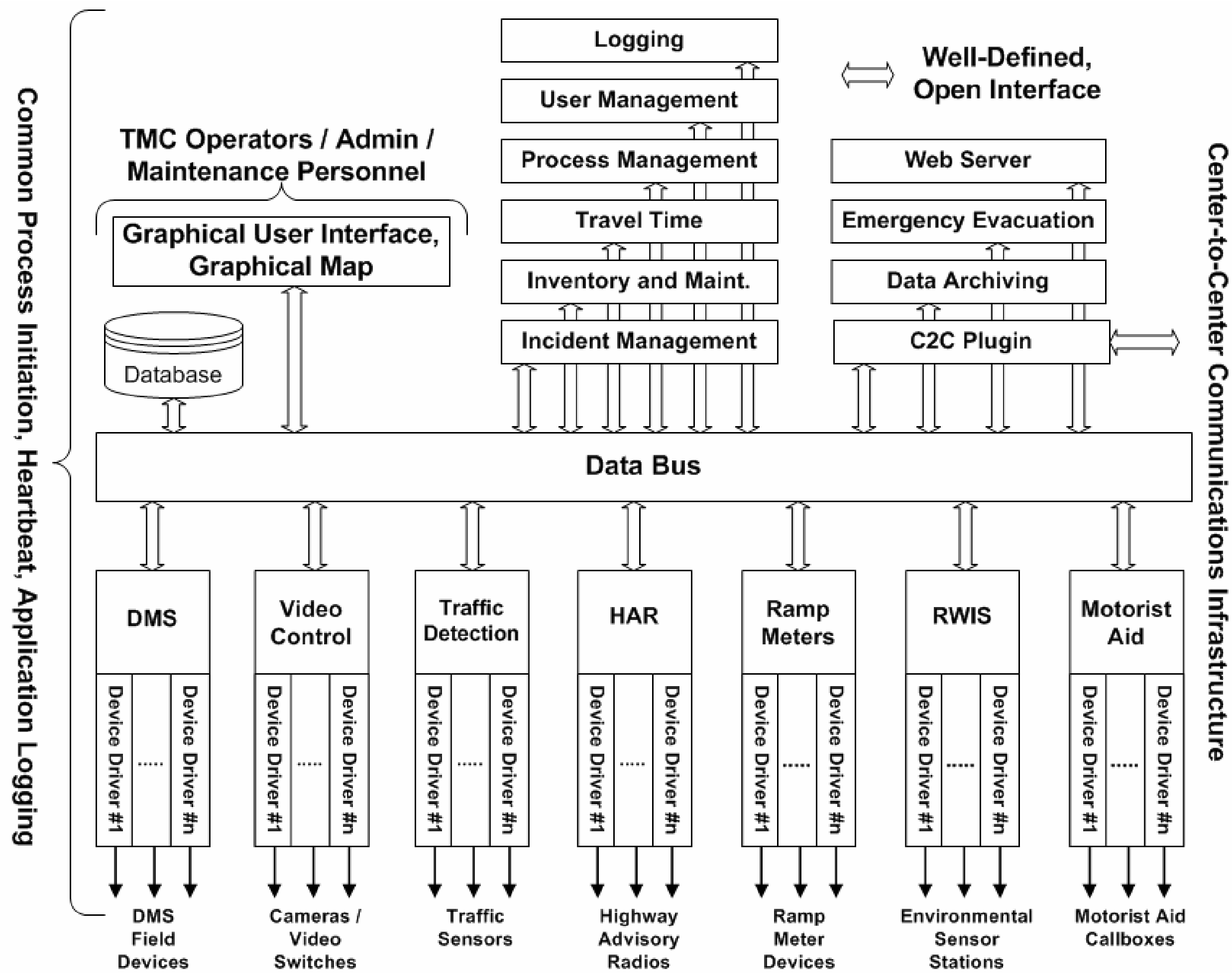
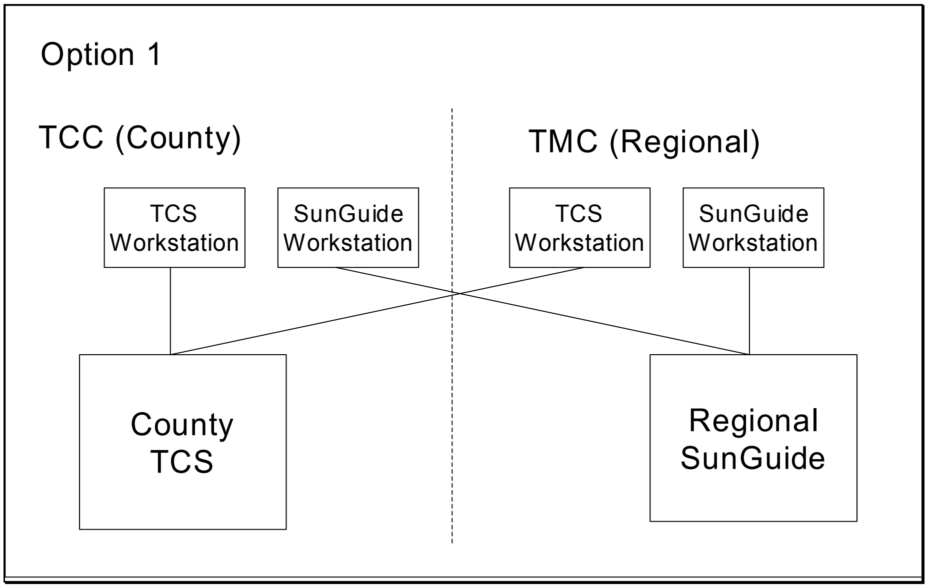


Figure 2.2 – Integration Option Diagrams



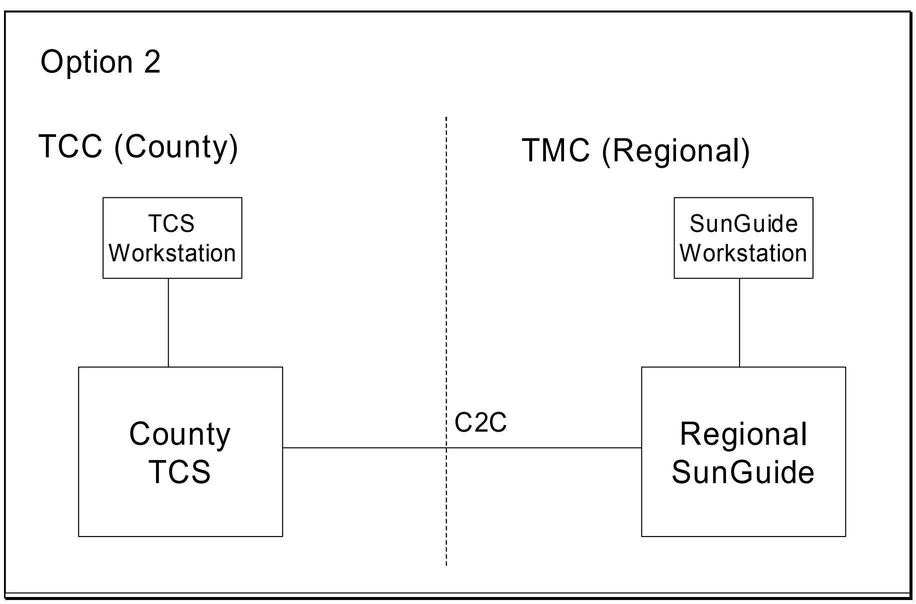


Figure 2.2

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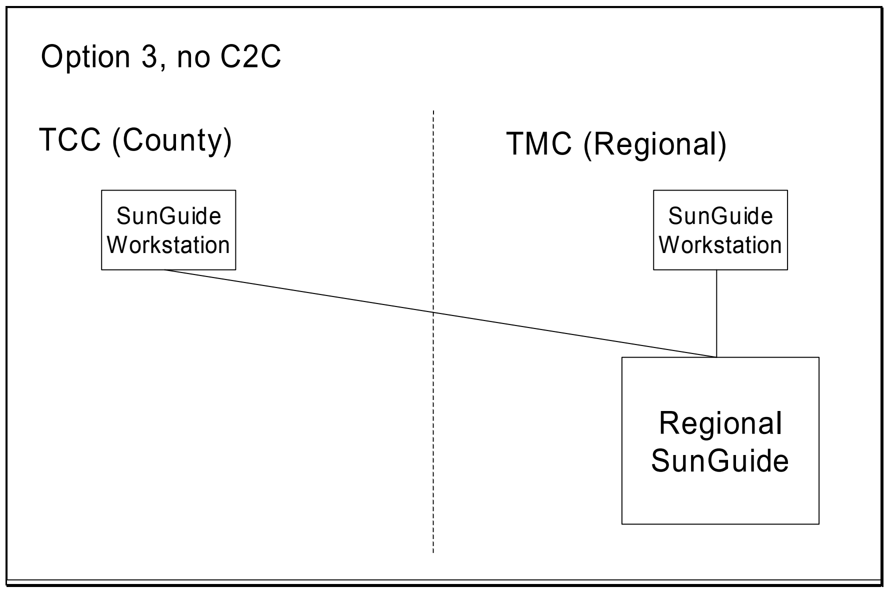

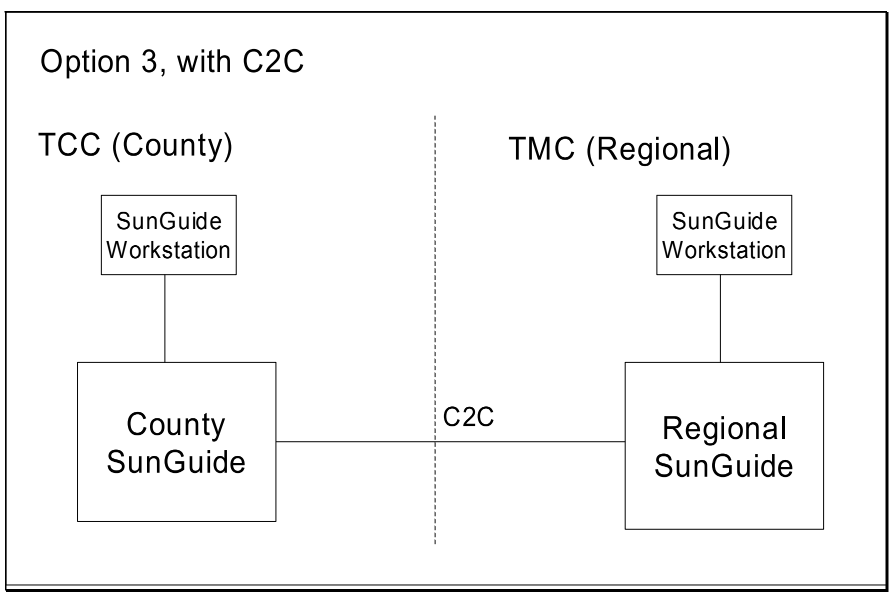

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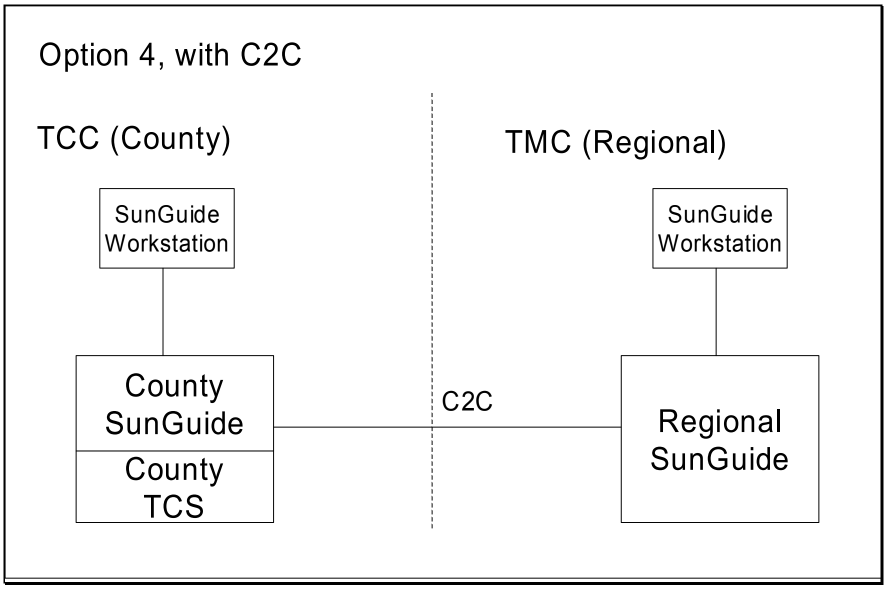

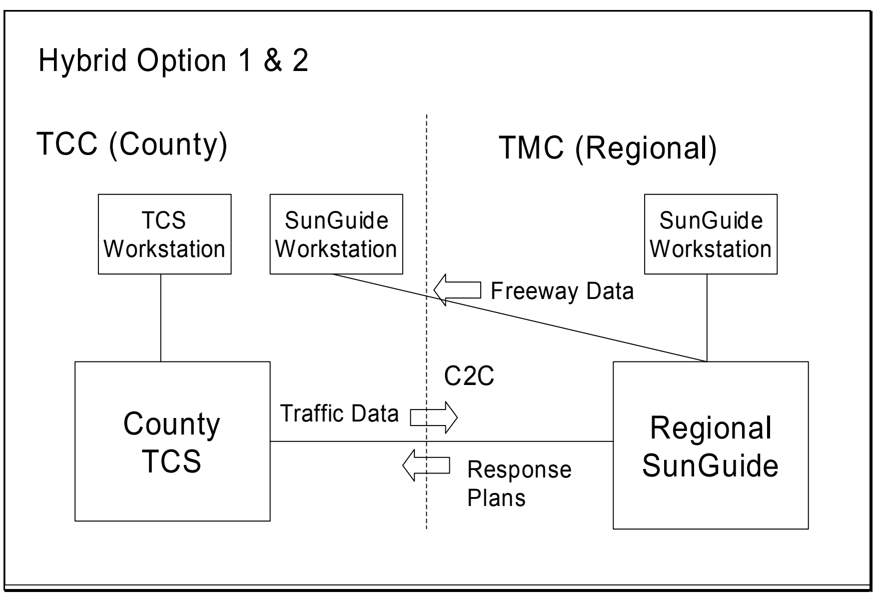

2.2 Pros and Cons

The pros and cons for each options are detailed below.

- **Option 1: Don't modify the SunGuide software.**

  Pros – The low cost associated with this option is a positive factor.

  Cons – This option would provide low functionality. While operators in each center can see data from another center via remote workstations, there is no way to implement any automatic functions. This option requires extra computers in the operator work area, which becomes a bigger problem if more than two centers are involved.

  Option 1 would also require duplicate data entry for such purposes as incident management, which means that data sharing is less likely when operators are busy.

- **Option 2: Add a C2C interface and traffic control GUI module to the SunGuide software.**

  Pros – This option allows implementation of all desired capabilities. The C2C interface can also be used to link adjacent SunGuide freeway systems that are operated by separate agencies. The use of a standardized C2C interface means local and regional systems can be integrated without the use of proprietary protocols or exposure of any internal system data to outside connections. (Note that there are video sharing issues that must be addressed outside the C2C interface. Refer to *Appendix A*.)

  Cons – This option requires modifications to local TCSs. This may be problematic for older legacy systems, although there are usually ways to accomplish at least a limited interface. Most modern TCS vendors will be able to implement a C2C interface without much difficulty.

- **Option 3: Add a full traffic signal control module to the SunGuide software.**

  Pros – This option provides efficient integration between arterial and freeway functions, since both are internal to the system. No C2C interface is required

  Cons – Implementing a full-function TCS is likely to be very expensive. Integrating traffic signal control into the freeway system itself means that there would no longer be separate freeway and local systems. The state would be hosting the TCSs for all the local agencies in a region. This may not be desirable for some local agencies.

If local agencies did want to run separate SunGuide software systems for arterial control, then it would be necessary to implement a full C2C interface to allow the local and freeway SunGuide software systems to be linked. This means that all the costs of Option 2 would be incurred, plus all the costs of Option 3.

No traffic signal control C2C interface means TCSs cannot share data with each other. Even two SunGuide software systems could not share traffic control data with each other.

- **Option 4: Interface a third-party TCS directly to the SunGuide software (no C2C).**

Pros – No C2C interface is required.

Cons – This option would require the development of a SunGuide software data bus interface for the TCS, which would take basically the same effort as developing a C2C interface for the TCS.

A GUI module for the SunGuide software would still need to be developed to display traffic control information (i.e., traffic data and device status) on the SunGuide software's map.

If there are problems with the TCS vendor's interface to the SunGuide software's data bus, it could potentially crash the entire SunGuide software system. The layer of protection provided by an external C2C interface would not present.

The TCS GUI would still have to be used for most traffic control management functions because modifying the GUI for the SunGuide software to replace this GUI would be expensive and would not provide any additional benefit.

Integrating traffic signal control into the freeway system itself means that there would no longer be separate freeway and local systems. The state would be hosting the TCSs for all the local agencies in a region. This may not be desirable for some local agencies.

If local agencies did want to run separate SunGuide software systems for arterial control, then it would be necessary to implement a full C2C interface to allow the local and freeway SunGuide software systems to be linked. This means that all the costs of Option 2 would be incurred, plus all the costs of Option 3. No traffic signal control C2C interface means TCSs cannot share data with each other. Even two SunGuide software systems could not share traffic control data with each other.

- **Hybrid Option: Combine the features of Options 1 and 2.**

  A common type of integration between freeway and local TCSs in other parts of the country is a hybrid between Options 1 and 2. There are many cases where an existing TCS can provide useful data to the freeway system, but cannot display freeway data or control freeway devices itself. In this case, a C2C interface is implemented for the TCS that can transmit the required data (i.e., device status and traffic data) to the C2C network, and accept limited commands (e.g., plan changes, response plan activations, etc.) from remote systems through the C2C network. Instead of trying to import freeway data and control features into the local system, a freeway management workstation is placed in the local TCC. This allows implementation of most of the capabilities listed above, including automated regional response plan implementation, without requiring major changes to the local system.

3. Center-to-Center Interface Features

The potential interactions between an arterial TCS and the SunGuide software include the following.

3.1 Exchange Traffic Flow Data

This interaction would display arterial traffic flow status information (e.g., midblock traffic volume) to SunGuide software operators, and perhaps allow the SunGuide software to use such data in automated alarm triggers and decision support features. Similarly, freeway traffic flow data would be sent to local arterial management systems where they would be displayed to the operator, and could be used to trigger alarms and automated responses.

3.2 Display Traffic Control Device Status

The SunGuide software could be modified to display icons for traffic signal controllers on the system map. The icons would indicate the status of the device, and would allow the SunGuide software operators to query for more detailed information about a traffic controller by clicking on its icon.

If the local TCS has the capability, it can also display data from the SunGuide software system on the local system map. This could include the SunGuide software's device status and freeway traffic data.

3.3 Integrated Response Plans

The SunGuide software's response plans could include the activation of local response plans on TCS that would change timing for diversion routes. This integration could occur in one of the following three ways:

- A SunGuide software system operator could view a list of response plans available on a local system and manually invoke one.
- The regional SunGuide software system's incident management (IM) subsystem could automatically include local response plan activation requests in addition to dynamic message sign (DMS) and highway advisory radio (HAR) messages. Invocation of local response plans would be subject to the approval of a local TCS operator.

- The local TCS could automatically trigger activation of its own response plans based on traffic data from a freeway system, or on changes in traffic or plan data from an adjacent TCS.

The response plan concept is key to the integration of arterial TCSs and regional FMSs such as the SunGuide software system. In the SunGuide software, a response plan is a list of DMS and HAR messages for specific signs, either suggested by the IM subsystem or created manually by an operator. In an arterial TCS, a response plan is a list of pattern selection commands for specific intersections, created manually by traffic engineers to handle specific traffic situations, such as diversion routes. Some systems refer to these plans as “action sets” or “quick response plans.”

When regional and arterial systems are integrated, it is useful to provide the regional operators with the capability of activating local response plans on the arterial systems. When a response plan is constructed on the regional system, it may include local response plan activation commands in addition to DMS and HAR messages. The local response plan activation request is sent using the C2C interface to the local system, which then performs the actions in the plan. This methodology enables the managers of the arterial system to maintain control of the actions in the response plan, but allows the regional operators to invoke the plan when required. The regional operators do not have to be aware of the details of the traffic control timing changes contained in the response plans; they can choose a plan by name from the list provided by the local system.

3.4 Video Sharing

The local agencies’ systems and the SunGuide software system can share the use of cameras. Center-to-center communications provide the means to obtain a list of the other system’s cameras and a way to select a camera for viewing without having to be aware of the other system’s video architecture. The C2C communications provide a way to use the pan-tilt-zoom (PTZ) control on the other system, if authorized. A C2C interface allows each system to select cameras on the other system for display.

Note that the C2C interface only handles camera control and video selection issues. It does not address the actual video transport and encoder/decoder interoperability issues. These must be addressed on a case-by-case basis. (Refer to *Appendix A* for more information.)

3.5 Shared Incident / Event Data

Incident notification, location, and details can be shared between local and regional agencies. Not all local TCSs support IM functions, so this information often ends up being shared by placing a regional workstation in the local TCC.

3.6 Shared Dynamic Message Sign Control

If the local agency has DMSs, it could share control of them with the SunGuide software and also request messages to be placed on SunGuide signs. If the local agency does not have any signs, it may still want to be able to see the messages activated on SunGuide signs, and possibly request message placement. Using a C2C interface eliminates compatibility issues between signs owned by various agencies. Each system implements the standard interface, which internally translates messages to whatever format is required.

3.7 Ramp Metering Coordination

In an area where ramp metering is in use on the freeways, it may be useful for the SunGuide software system to share ramp meter data with the local system. This can enable various types of traffic responsive signal coordination with ramp meters, such as changing the timing of nearby traffic signals when a ramp backs up onto an arterial or letting the local system request a change in the metering rate when this occurs.

3.8 Interjurisdictional Coordination

Although the SunGuide software would not be involved, the existence of a network link through the SunGuide operations center could facilitate adjacent agencies coordinating arterials across jurisdictional boundaries. Some of the ways that a C2C link can be used to improve interjurisdictional coordination are:

- Use external data for traffic responsive operations.
- Synchronize cycle lengths.
- Review other agencies' time-of-day (TOD) scheduled actions and timing plans.
- Review contents of response plans.
- Set signal groups on the local system to follow external system plan changes.

4. Example Scenarios

The following subsections provide possible activation scenarios and results obtained based on use of each option.

4.1 Local Agency Wants to Put a Message on a Freeway Sign

Option 1 (no C2C): The local system operator walks over to the SunGuide software's workstation in the local center and uses it to activate the desired message.

Option 2 (C2C): The local system operator uses the TCS GUI to request message activation on the SunGuide software system. The request is transmitted via the C2C link.

Options 3 and 4 (single system): The local system operator uses the GUI for the SunGuide software to activate the message.

4.2 Incident on the Freeway

Option 1 (no C2C): The regional operator detects an incident on the freeway and places an icon on the SunGuide software's map. The local operator walks over and look at the SunGuide software's workstation to view the new incident notification. The local operator activates the appropriate response plans on the local system, and enters incident response activities on the SunGuide software's workstation.

Option 2 (C2C): The regional operator places the incident icon on the SunGuide software's map. Incident information is transferred to the local system using the C2C interface and pops up on the local operator's map. The local operator enters incident response activities, which are transferred back to the SunGuide software using the C2C interface.

Options 3 and 4 (single system): The regional operator places the incident icon on the SunGuide software's map. The incident icon pops up on the local operator's SunGuide software map. The local operator enters incident response activities in the SunGuide software system.

4.3 Diversion Route that Affects Multiple Jurisdictions

Option 1 (no C2C): The regional operator walks to a table containing remote workstations for each of the three TCSs in the region and activates a set of timing plans on each system.

Option 2 (C2C): The regional operator activates a diversion route response plan within the SunGuide software. The response plan includes activation of local response plans in the three local TCSs, in addition to activation of DMS and HAR messages informing motorists of the alternate route. Notification of response plan activation is transmitted to each of the local systems, which then automatically implement their predefined timing changes for this diversion route according to their local policy.

Option 3 and 4 (single system): The regional operator activates a diversion route response plan, and the system implements the required timing plan changes.

4.4 After-Hours Delegation of Control

Option 1 (no C2C): A regional operator at a 24-hour-per-day, 7-day-per-week RTMC can operate a local TCS using a remote workstation at the RTMC.

Option 2 (C2C): The C2C interface and GUI module within the SunGuide software will probably not provide a sufficient level of control to support full TCS delegation. For example, editing of individual controller databases and modification of the contents of timing plans are not available through any of the C2C standards. If this capability is desired, it would be necessary to install a remote workstation at the RTMC.

Options 3 and 4 (single system): A regional operator at the RTMC can be given full traffic control management privileges during the hours that the local TCC is closed.

5. Effort Required

This section provides ballpark estimates of the work required to implement the options discussed. These are not precise estimates of the work involved, but are intended to allow a relative comparison of the work required for each option. The man-hours shown do not include integration, documentation, or testing.

Hardware and networking requirements are similar for all options and so are not discussed in detail. In general, all of the options require an IP network connection between participating centers. If no video is being shared, then a 1.5 megabytes per second (MBps) (i.e., a T1 line) connection is usually sufficient. If video is being shared, then a fiber connection at 100 Mbps or 1 gigabyte per second (GBps) would be indicated, depending on the number of video signals to be shared concurrently.

There are no software costs estimated for Option 1 because the software will not be modified if this option is implemented.

Table 5.1 – Estimated Work Effort Required for Option 2

Modifications Required for the SunGuide Software	Effort (in Man-Hours)
C2C Interface – Traffic Flow Data	Already in Release 2
C2C Interface – Signal Controller Status	300
C2C Interface – Request Local Response Plan Activation	300
C2C Interface – Video Sharing	Already in Release 2
C2C Interface – Incident/Event Data	Already in Release 2
C2C Interface – DMS Status/Control	Already in Release 2
C2C Interface – Ramp Meter Status	300
GUI Module – Display Signal Controller Status	500
GUI Module – Local Response Plan Activation and Monitoring	500
IM Subsystem – Local Response Plans in the SunGuide Software's Response Plans	500
Total	**2,400**

Table 5.1
(CONTINUED)

Modifications Required for the Local TCS	Effort (in Man-Hours)
C2C Interface – Traffic Flow Data	300
C2C Interface – Signal Controller Status	300
C2C Interface – Accept Local Response Plan Activation Requests	300
C2C Interface – Video Sharing	300
C2C Interface – Incident/Event Data	300
C2C Interface – DMS Status/Control	300
C2C Interface – Ramp Meter Status	300
GUI Module – Display Ramp Meter Status	300
Total	**2,400**

Note: An assumption is made that the above C2C interfaces will be implemented on a local system only if the system already supports display of that type of data; therefore, costs are not shown for implementation of display capabilities (except for ramp meter status, which is not typically part of a local TCS).

Table 5.2 – Estimated Work Effort Required for Option 3

Modifications Required for the SunGuide Software	Effort (in Man-Hours)
C2C Interface – Signal Controller Status	300*
C2C Interface – Request Local Response Plan Activation	300*
C2C Interface – Ramp Meter Status	300*
GUI Module – Signal Controller Status and Control	1,000
IM Subsystem – SunGuide Software Response Plans including Signal Controller Plan Changes	500
GUI Module – Arterial Traffic Analysis Features	1,000
GUI Module – Controller Database Editor (per controller type)	1,000
Traffic Control Subsystem (Hierarchical Scheduler, Command Manager)	1,000
Traffic Responsive Plan Selection	500
Controller Database Upload/Download Management	500
Real-time (once/second) Polling Support	500
Signal Controller Detector Data Upload, Processing, Reports	1,000
Signal Controller Device Admin Screens	500
Signal Controller Event Logging	500
Total	**8,900**

* The costs of a C2C interface is assumed to be necessary to meet the goals of integrating regional and local systems, even if both systems are running the SunGuide software.

Table 5.3 – Estimated Work Effort Required for Option 4

Modifications Required for the SunGuide Software	Effort (in Man-Hours)
C2C Interface – Signal Controller Status	300*
C2C Interface – Request Local Response Plan Activation	300*
C2C Interface – Ramp Meter Status	300*
GUI module – Display Signal Controller Status	500
GUI module – Local Response Plan Activation and Monitoring	500
IM subsystem – Local Response Plans in the SunGuide Software's Response Plans	500
Total	**2,400**

Modifications Required for Local TCS	Effort (in Man-Hours)
Data Bus Interface – Traffic Flow Data	300
Data Bus Interface – Signal Controller Status	300
Data Bus Interface – Accept Local Response Plan Activation Requests	300
Data Bus Interface – Video Sharing	300
Data Bus Interface – Incident/Event Data	300
Data Bus Interface – DMS Status/Control	300
Data Bus Interface – Ramp Meter Status	300
GUI Module – Display Ramp Meter Status	300
Total	**2,400**

* The costs of a C2C interface is assumed to be necessary to meet the goals of integrating regional and local systems, even if both systems are running the SunGuide software.

6. Institutional Issues

Successful integration of local and freeway systems depends on the resolution of institutional issues as much as it does on technical issues. Some of the issues that need to be addressed in an implementation plan include:

- Funding responsibilities;
- Maintenance responsibilities;
- Operational responsibilities;
- Level of shared control (e.g., response plans versus individual plan selection, sign message selection from libraries versus free text entry, etc.);
- Shared usage scenarios (e.g., when is an external agency allowed to issue commands, what format should be used for sign messages, etc.);
- Staff authorization for access to interagency control features (e.g., does the agency that owns the DMS want to know the name of the external operator who activated a message, or just the fact that the request came from an authorized system?);
- Training;
- Senior management involvement; and
- Problem resolution procedures.

It is important to have interagency agreements in place that cover these issues. It may be helpful for the FDOT to have a master agreement that serves as a template for agreements with local agencies.

Appendix A

Center-to-Center Video Overview

A.1 Overview

Sharing video between centers is a complex issue. In general, when a local TCC and an RTMC wish to share video, the centers are in the same region and the distances are not great, so a fiber connection is often available. (This may not be the case when sharing video between RTMCs, where the distances are greater.)

If a fiber connection is available, video-sharing issues can be greatly simplified by using a high-speed IP network connection between the centers. MPEG-2 Digital video encoders compliant with the Moving Pictures Experts Group (MPEG) enable high-quality video to be transmitted over the network, and the use of Ethernet®[5] switches that support IP multicast functions provide management of bandwidth issues. However, there are still a number of issues that need to be addressed in order to achieve interoperability.

Even if a fiber connection is used to allow sharing of video streams, it is still necessary to use a C2C interface to allow PTZ control of the cameras to be shared. The use of a C2C interface insulates systems from the details of other systems' implementations and hardware choices, and also provides a layer of security that allows system managers to control access to the cameras from external systems.

A.2 MPEG-2 Encoder Interoperability

A common problem in exchanging digital video between centers is that MPEG-2 video encoders and decoders from different manufacturers are often not interoperable. Even though MPEG-2 itself is a standardized means of video compression, the way the video stream is transported over the network is not fully standardized. The National Transportation Communications for ITS Protocol (NTCIP™)[6] C2C standards currently provide no help in this area, since they only address data sharing, not video sharing.

5 Ethernet is a registered trademark of the Xerox Corporation in the United States and/or other countries.

6 NTCIP is a trademark of the American Association of State and Highway Transportation Officials (AASHTO), the Institute of Transportation Engineers (ITE), and the National Electrical Manufacturers Association (NEMA). © 1997-2005 AASHTO, ITE, and NEMA.

A.3 Interoperability Testing

To quantify the interoperability issues with encoders and decoders from different manufacturers, FDOT consultants set up a test environment and tested all possible connection combinations between encoders and decoders from four manufacturers. The testing indicated that out of 16 possible encoder/decoder combinations, 9 combinations could be made to work.

However, achieving these connections required encoder settings to be changed in the following areas:

- Stream type (i.e., elementary, transport or program);
- Packet size; and
- Packet ordering.

Even though interoperability was achieved with a number of the combinations tested, the fact that settings had to be changed on the encoders to make this happen causes a problem: If an encoder is set up a certain way to work with the decoders in the center that owns it, the settings cannot be changed "on the fly" to work with the decoders at another center. This would "break" operation within the owning center. Settings on a decoder can be changed without causing problems, but in most cases the necessary settings are not available on the decoders. This means that agencies sharing video must agree on compatible settings in advance, since it is not possible to achieve interoperability by changing settings on the fly. (Refer to the *SunGuide^{SM} Video Sharing Capability Analysis Using C2C* for more details.)

Most of the interoperability problems are due to the use of different stream types. VBrick™[7] and Teleste use transport streams; *i*MPath uses elementary streams; and CoreTec uses program streams. While an *i*MPath decoder could display video from the VBrick encoder if the VBrick was set to produce an elementary stream, none of the other decoders could display video from the *i*MPath encoder. And while the CoreTec encoder could be set to produce any of the three stream types and therefore could be displayed by the other three decoders, the CoreTec decoder could not display video from any of the other encoders. Only VBrick and Teleste encoders and decoders were able to interoperate in both directions, since Teleste has made a specific effort to make this work.

To achieve direct IP video interoperability, participating agencies will need to agree on a particular stream type, and choose encoders and decoders that support that type.

[7] VBrick is a registered trademark of VBrick Systems, Inc.

A.4 Elementary Streams

The raw output from an MPEG encoder is called an elementary stream. The syntax of an elementary stream is rigidly defined in the MPEG standards to guarantee that all MPEG decoders are able to process it. (Decoders are not defined in the standard.) This data stream contains only information necessary for the decoder to approximate the original audio or video signal. The encoder itself is not defined; however, it must produce the proper syntax under the MPEG rules. This allows for proprietary encoding schemes by various vendors or manufacturers, and provides the potential for better quality video as the complexity or sophistication of the encoding scheme increases. For most applications, elementary streams will be broken into packets. Each elementary stream packet is identified by headers, which are used for time synchronization. These packetized elementary streams can be used to create either program streams or transport streams, which are the two data coding formats currently defined under the MPEG-2 standard

A.5 Transport Streams

A transport stream can carry multiple programs simultaneously and is optimized for use in applications where data loss (e.g., loss packets, dropped frames, etc.) are likely to occur. Using small, fixed packet sizes (i.e., 188 bytes), they are optimized for transmission over a network. A transport stream will typically provide a clocking routine to allow for the recreation of the clock for each multimedia program at the decoder.

A.6 Program Streams

Program streams, which are optimized for multimedia applications and MPEG-1 compatibility, use variable length packet sizes and are best used where a reliable media is available. Program streams are primarily intended for storage and retrieval rather than network distribution. For example, digital video discs (DVDs) use program streams.

A.7 Achieving Interoperability

Ideally, agencies wishing to share video would specify video encoders and decoders that use the same stream type as their sharing partners and that have been tested for interoperability. But this is not always possible, especially when incompatible hardware is already in place. If this is the case, there are still ways to achieve interoperability, including use of the following.

- Universal decoders may be used. The Barco Argus video wall controller can be equipped with universal digital video decoder cards that will accept streams from many vendors' encoders, including all of the vendors in the tests described above. If the only place that video will be displayed is on a video wall at the RTMC, then the use of these universal decoders eliminates most interoperability issues.

- Transcoding the video is an option. If no common video stream format can be chosen, then video must be transcoded (i.e., re-encoded) at the demarcation point between the sharing agencies. Transcoding can be accomplished by connecting the analog outputs from decoders from one vendor to the inputs of encoders from another vendor. The number of decoder/encoder pairs installed determines the number of video signals that can be shared concurrently. A C2C video switching protocol would be used to allow each agency to select the cameras from the other agency that would be connected to their decoder/encoder pairs.

  There are also software transcoding products available, but these require significant processing power (i.e., dedicated servers) and may introduce additional latency in the video stream.

A.8 Other Interoperability Issues

There are some additional issues that must be addressed in order to achieve interoperability.

- If two agencies are creating a direct connection between their IP networks, they must agree on an IP address assignment plan so that addresses in the two networks do not overlap.

- Video encoders can be configured to use Simple Network Management Protocol (SNMP) community names to control access to the devices. Agencies sharing access to video encoders must coordinate the use of these names.

- It is often necessary to use firewalls to provide connections between networks while maintaining each network's security. The participating agencies must agree on how the firewalls will be configured and what ports will be open between them.

Table A.1 – Video Encoder Compatibility Matrix

Encoder \ Decoder	VBrick 5200 Decoder	Teleste IPD301	*i*MPath i1000 Decoder	CoreTec VCX2400D
VBrick 4200 Encoder	Yes	Yes[a]	Yes[b]	No
Teleste IPE301	Yes[c]	Yes	No	No
*i*MPath i1000 Encoder	No	No	Yes	No
CoreTec VCX2400E	Yes[d]	No	Yes[e]	Yes[f]

[a] The VBrick 4200 encoder's primary destination packet payload size is set to 1316.

[b] The VBrick 4200 encoder's secondary destination stream type is set to *Elementary Stream* and the packet payload size is set to 1472.

[c] The VBrick 5200 decoder's network packet order is set to *Disabled*.

[d] The CoreTec VCX4200E encoder stream type set to *Transport*.

[e] The CoreTec VCX4200E encoder stream type set to *Elementary*.

[f] The CoreTec VCX4200E encoder stream type set to *Program* (the default).