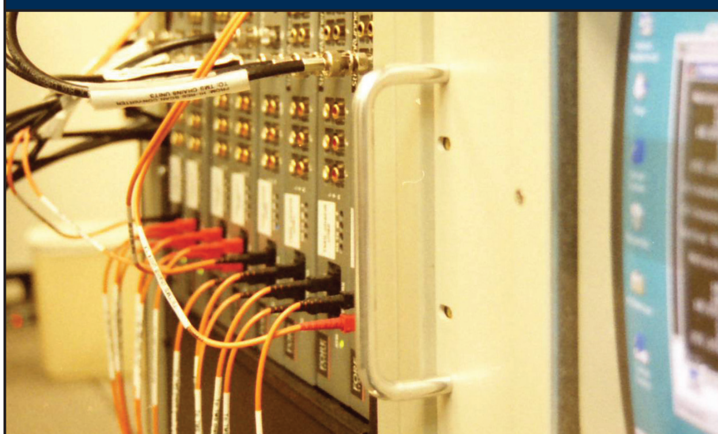
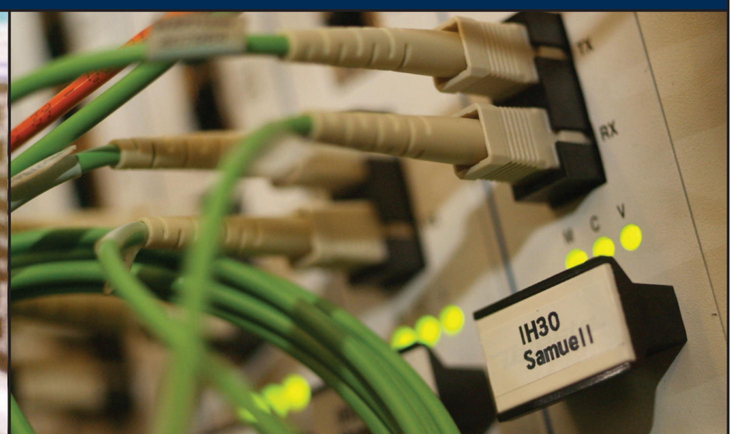
Project: 0-5942

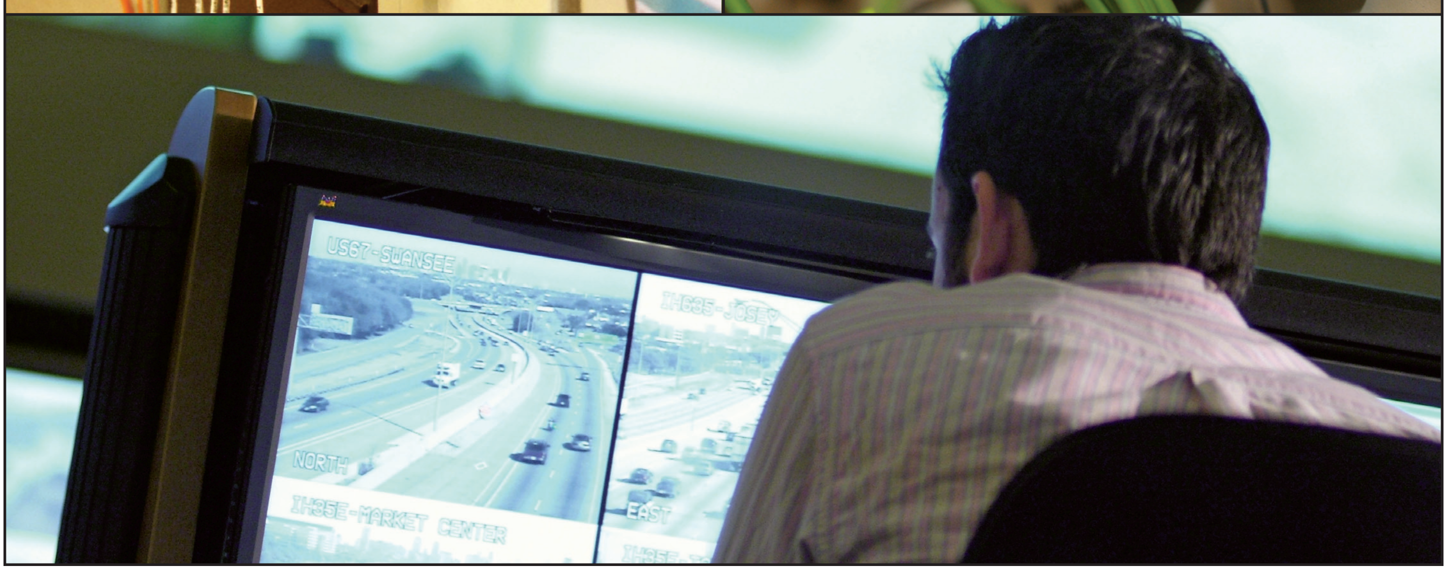
Product: 0-5942-P1

December 2009

VIDEO OVER IP DESIGN GUIDEBOOK







http://tti.tamu.edu/documents/0-5942-P1.pdf

Texas Department of Transportation

Texas Transportation Institute

Technical Report Documentation Page

1. Report No. FHWA/TX-10/0-5942-P1	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle VIDEO OVER IP DESIGN GUIDEBOOK		5. Report Date February 2009 Published: December 2009
		6. Performing Organization Code
7. Author(s) Robert E. Brydia, Byron E. Brackin, Robert F. De Roche, Jeremy D. Johnson, and Gary B. Thomas.		8. Performing Organization Report No. Product 0-5942-P1
9. Performing Organization Name and Address Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. Project 0-5942
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office P. O. Box 5080 Austin, Texas 78763-5080		13. Type of Report and Period Covered Product September 2007–August 2008
		14. Sponsoring Agency Code

15. Supplementary Notes
Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.
Project Title: Comprehensive Guide to the Use of IP-Based Video for Traffic Operations
URL: http://tti.tamu.edu/documents/0-5492-P1.pdf

16. Abstract
Texas Department of Transportation (TxDOT) engineers are responsible for the design, evaluation, and implementation of video solutions across the entire state. These installations occur with vast differences in requirements, expectations, and constraints. Because the systems require extensive interoperability to other systems, agencies, and deployments, a systems engineering process (SEP) is employed to develop a consistent and structured approach to the development of concepts, needs, requirements, design, testing, and ongoing operations. The guidebook contains an accompanying CD which illustrates many aspects of video, which are more easily understood from a visual perspective.

The goal of this guidebook is two-fold:

(1) to establish a fundamental level of knowledge in video concepts, and
(2) to frame the discussion within the concept of systems engineering to provide a logical, consistent, and structured approach to video system development and deployment.

17. Key Words Video, Systems Engineering, Communications	18. Distribution Statement No restrictions. This document is available to the public through NTIS: National Technical Information Service Springfield, Virginia 22161 http://www.ntis.gov

19. Security Classif.(of this report) Unclassified	20. Security Classif.(of this page) Unclassified	21. No. of Pages 166	22. Price

VIDEO OVER IP DESIGN GUIDEBOOK

Product Number 0-5942-P1

**Performed in cooperation with the
Texas Department of Transportation
and the
Federal Highway Administration**

**Research conducted by
Texas Transportation Institute
The Texas A&M University System
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**February 2009
Published: December 2009**

DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of FHWA or TxDOT. This report does not constitute a standard, specification, or regulation. The researcher in charge of the project was Robert E. Brydia.

ACKNOWLEDGMENTS

This project was conducted in cooperation with TxDOT and FHWA.

The authors gratefully acknowledge the contributions of numerous persons who made the successful completion of this project possible.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1. Scope

This guidebook introduces the reader to the concepts associated with digital video. Digital video is most often transmitted using Transmission Control Protocol/Internet Protocol (TCP/IP). This is commonly shortened or referred to as Video over IP.

This guidebook presents information on the design and implementation of digital video deployments within the context of systems engineering.

While the guidebook contains significant detail on the technical aspects of digital video, an equally important concept is also presented in the use of systems engineering. Systems engineering is a formalized process of examining the user needs and requirements to determine project needs and any particular solution. Throughout this guidebook, the discussion of designing and deploying video over IP systems is discussed within the context of systems engineering.

With this broad base of knowledge, the guidebook explores how to use the above information to either evaluate or design digital video solutions. Where helpful, the use of graphics, flowcharts, and tables present information to the reader in an easy to use and understandable format. Finally, because there are several aspects of digital video, which are much easier to communicate visually instead of via text, the guidebook includes an accompanying CD. Where applicable, the guidebook will reference the CD to prompt the reader to view concepts on the CD for a deeper or more intuitive understanding.

1.2. Organization of this Guidebook

The chapters in this guidebook are organized to walk the reader through video over IP using the systems engineering process. Chapters following this introduction include:

- Chapter 2 – A Brief Introduction to Systems Engineering
- Chapter 3 – Early Phases of the Systems Engineering Process
- Chapter 4 – The Functional Requirements Phase
- Chapter 5 – The System Design Phase
- Chapter 6 – The Testing and System Acceptance Phases
- Chapter 7 – The Concluding Phases of the Systems Engineering Process
- Chapter 8 – Procurement to Support Systems Engineering
- Chapter 9 – Glossary

Note that while these chapter titles are generic to the systems engineering process, the topic for this guidebook is video over IP and the vast majority of the discussion will focus on that topic.

1.3. Audience for This Guidebook

The typical audience for this guidebook is a TxDOT engineer with some level of responsibility for the design and/or deployment of video systems.

The typical audience of this guidebook is an employee of the Texas Department of Transportation (TxDOT) who has some level of overview or responsibility for the design and deployment of video solutions. While the guidebook only covers the aspect of digital video, the system engineering concepts are applicable to other video projects as well.

While the emphasis is on digital video, some level of background in communications may prove helpful. The reader is referenced to Product P1 of Project 5-4969-01, "*Wireline Communications: A Design Guidebook for Intelligent Transportation Systems*" for more detail and background information on communications.

This guidebook is not intended to provide comprehensive training in all aspects of video over IP design and deployment. Many aspects of deployed solutions are project and/or location specific, hence the use of systems engineering principles to provide an overall consistent approach to the topic. The level of information contained in the guidebook should be applicable to employees across the state.

1.4. Brief Review of TCP/IP

TCP/IP is a low-level networking protocol used by computers and other hardware to communicate across networks. In reality, TCP and IP are two separate protocols that are part of a large number of Internet protocols. TCP/IP has, however, become known to the industry to stand for the family of common Internet protocols. The protocols stem from a Defense Advanced Research Projects Agency (DARPA) project dealing with the interconnection of networks in the late 1970s. By 1983 it was mandated for all U.S. defense long-haul networks. Over time, TCP/IP became accepted throughout the world and is now an internationally known and supported protocol. As such, its use is commonplace for the transmission of all types of data, including video.

The information below is a very brief overview of TCP/IP. If this information is not familiar to the reader, some further study of communication concepts and/or TCP/IP overview may be warranted prior to proceeding.

1.4.1. How It Works

The IP portion of TCP/IP works as the "messenger" part of the protocol – its functions are to address and send data packets. The IP protocol contains three pieces of information: the IP address, subnet mask, and default gateway. The IP address, which is the identity of each node on the network, is 4 bytes long, each separated by a dot. It contains two pieces of information, the node's network ID, and the system's host ID. The subnet mask, also 4 bytes separated by dots, is used to extract the network and host ID from the IP address. The default gateway is the entrance point to the nodes network.

The TCP in TCP/IP is a reliable connection-oriented protocol. Connection oriented means that the protocol establishes a communications pathway or connection between two devices before sending data. Once the connection is established, TCP begins sending data, broken into chunks of information (called packets) across the network to the intended recipient. TCP numbers each packet as it is sent so that the receiving end knows the correct order in which to reassemble them as they are received. TCP also verifies that the data are correctly received. This is done using a "checksum" calculation on both the sending and receiving ends. If the calculation is the same on both ends then an acknowledge response is sent to the sender, verifying that the data were properly received by the intended target. If the results do not match, a request to resend is sent by the recipient, and the sender resends the necessary data.

In contrast, the IP portion of TCP/IP is a best-effort protocol and can be characterized as unreliable. Where TCP is connection-oriented, IP is connectionless-oriented. The inherent lack of reliability in IP transmission means multiple events can occur, such as:

- data corruption
- lost data packets
- duplicate packet arrival
- out-of-order packet delivery.

Within TCP/IP networks, the success of any transmission is dependent on the availability of the various links and nodes that comprise the infrastructure. The most well-known TCP/IP network is the Internet. Common equipment in use on the Internet and any TCP/IP network includes switches and routers.

1.4.2. Performance

TCP/IP is the most complete networking protocol available. Because of this it has also become almost universally accepted and can be utilized in virtually any networking environment.

In addition to protocol support, the source code is available on many operating systems. This has made it much easier over time to extend the suite of protocols. In addition to the software source code, virtually every piece of network software produced has TCP/IP support. TCP/IP packets are actually "encapsulated" or surrounded by the network protocol in use, such as Ethernet, Frame Relay, ATM, etc. Because TCP/IP is universal, it can be used to provide functionality and communications across disparate networks.

2. A BRIEF INTRODUCTION TO SYSTEMS ENGINEERING

2.1. Introduction

More so than ever, the types of projects undertaken by today's transportation engineers are highly complex and involve many different aspects. Often, a project involves not only the physical aspects of building a facility, but also monitoring it, and using the data from the monitoring systems to analyze the situations, react to incidents, predict future conditions, send information and alerts to both drivers and agencies, and overall, manage the facility to obtain the best utilization of the capacity.

The need to accomplish so much, means that today, the planning for any facility encompasses far more than the physical design. As an example, consider a new roadway in an urban area. In addition to the physical design and construction, planning for the new facility could also include:

- the type, amount, and location of infrastructure for roadway monitoring systems;
- the type, amount, and location of infrastructure for disseminating information to travelers;
- the provision of the communications capability to carry the data;
- the expansion of analysis capability for roadway data;
- the integration into display systems inside control center;
- the expansion of operational software inside control center;
- the updating of response plans for incidents and roadway events;
- the expansion of web-based information (if present) for new facility; and
- the integration of new facility into toll systems (if present).

As might be obvious after reading the above list, the requirements of how the facility will be used dictate that the actual planning must start long before the steps of earth-moving and placing pavement take place. Even after the facility is built, the process continues with the integration with other regional systems and the daily operations.

To address a similar need to take the 'big picture' view in other fields of study, practitioners have turned to the Systems Engineering Process (SEP). The SEP focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, and then proceeding with the design process and system validation to ensure that the functional requirements identified early in the process are met.

The systems engineering process was created by the Department of Defense (DOD) to quantify and verify that complex systems perform the required tasks and are implemented correctly. Later, other agencies, including the Federal Highway Administration (FHWA), adopted the use of SEP as a method to deploy solutions that better meet the stated needs. For Intelligent Transportation System (ITS) projects, FHWA has a rule that specifies that any project moving to design is required to follow a systems engineering process appropriate to the scope of the project.

2.2. What Is Systems Engineering?

Systems engineering is an interdisciplinary approach and means to enable the realization of successful systems.

In simple terms, systems engineering is a process for designing and managing complex projects. If a system is defined as "*a combination of interacting elements organized to achieve one or more stated purposes (1)*", then systems engineering can be defined as "*an interdisciplinary approach and means to enable the realization of successful systems (2)*."

Overall, the objective of the systems engineering process is to focus participants on identifying the needs and functionality early in the development cycle, creating designs that meet those requirements, supporting the design process with strong testing and validation procedures, and maintaining the system throughout its life cycle. The International Council on Systems Engineering (INCOSE) states that when properly implemented, systems engineering will:

- Create a structured process for integrating and linking requirements, schedules, decision milestones, and verification.
- Allow a project team to work to a single set of integrated requirements.
- Move the integration aspect of the project to the requirements and design stage.
- Reduce unplanned and expensive fixes necessary to resolve omissions and oversights *(3)*.

2.3. Why Use Systems Engineering?

The use of systems engineering allows two major factors to not only be present, but work in concert, during the lifetime of the project. The first aspect is often referred to as a disciplined focus on the end product, which allows all technical aspects of the project to be designed to support the end product. The potential end products, or alternatives, are envisioned up front, by analyzing stakeholder needs and converting their expectations into technical requirements. These technical requirements are then balanced with feasibility and economic considerations to develop the alternatives.

The second aspect is often referred to as a disciplined focus on the stakeholder's expectations, outside of the daily focus of the project needs. It has certainly been evident over time and past experiences, that technical or project needs have overshadowed the stakeholder expectations, resulting in project solutions that 'lost their way' and in the end, did not meet the initial requirements. By designing to the end product and verifying that the solution meets stakeholder requirements, this focus can be maintained throughout the design process.

In general, systems engineering allows for:

- improved stakeholder participation,
- more adaptable systems,
- more resilient systems,
- reduction in the risk of schedule and cost overruns,
- more functionality in designs,
- fewer defects, and
- better documentation *(3)*.

2.4. The Systems Engineering Process

Systems engineering is guided by several principles, including:

- *Start with your eye on the finish line* – reach consensus at the beginning of the process of what will constitute success.
- *Stakeholder involvement is key* – while stakeholders may vary throughout the process, they hold key information to define the problem and the range of potential solutions as well as the criteria to determine the best solution.
- *Define the problem before implementing the solution* – Because there are often multiple ways to solve a problem, focusing on the problem first allows a more open process for defining all potential solutions.
- *Delay technology choices* – specifying technology too early will lead to outdated results,
- *Divide and conquer* – break down a big problem into several small ones, and
- *Relate the items in one step of the process to another* (traceability) – Traceability connects the process together and allows designers to ensure that requirements are being met in implementation *(3)*.

As listed below, the systems engineering process contains several aspects or phases.

- *Plan or organize technical aspects* – Understand the general problem that needs to be solved, as well as the influencing factors and constrains. Understand the organization and schedule as well as the methodology to be employed in implementing the process.

- *Analyze the problem posed by the stakeholders* – Define the problem from the aspect of the system looking out toward its environment. How is the product affected by the environment and constraints? How will politics and policies affect any technical solutions?
- *Assess, develop, and select alternatives* – Development of alternatives allows the project team to respond to stakeholder direction without preconceived notions, to challenge requirements, to explore viable alternatives, and to identify unbiased selection criteria.
- *Design the end product* – The concept of 'design follows requirements' applies here. Develop models and prototypes as necessary to reduce risks. Perform sensitivity analyses to establish design margins and evaluate each design alternative.
- *Verify solution meets stakeholder's needs* – Verification that the end product meets the design requirements and integrates with other end products. Resolve any implementation irregularities *(3)*.

While guided by the principles and phases listed above, the SEP is perhaps most commonly viewed in the "Vee" diagram. Figure 2-1 shows the generic systems engineering process. Examination of the diagram shows that the process starts on the left-hand side with the formulation of a management plan and the proceeds to a concept of operations, followed by the establishment of requirements. The process then moves into the design phases followed by implementation, which can cover coding and testing if there are hardware and software aspects to the project. Along the right-hand side of the diagram are the verification and validation aspects of the project, followed by long-term operations and maintenance.

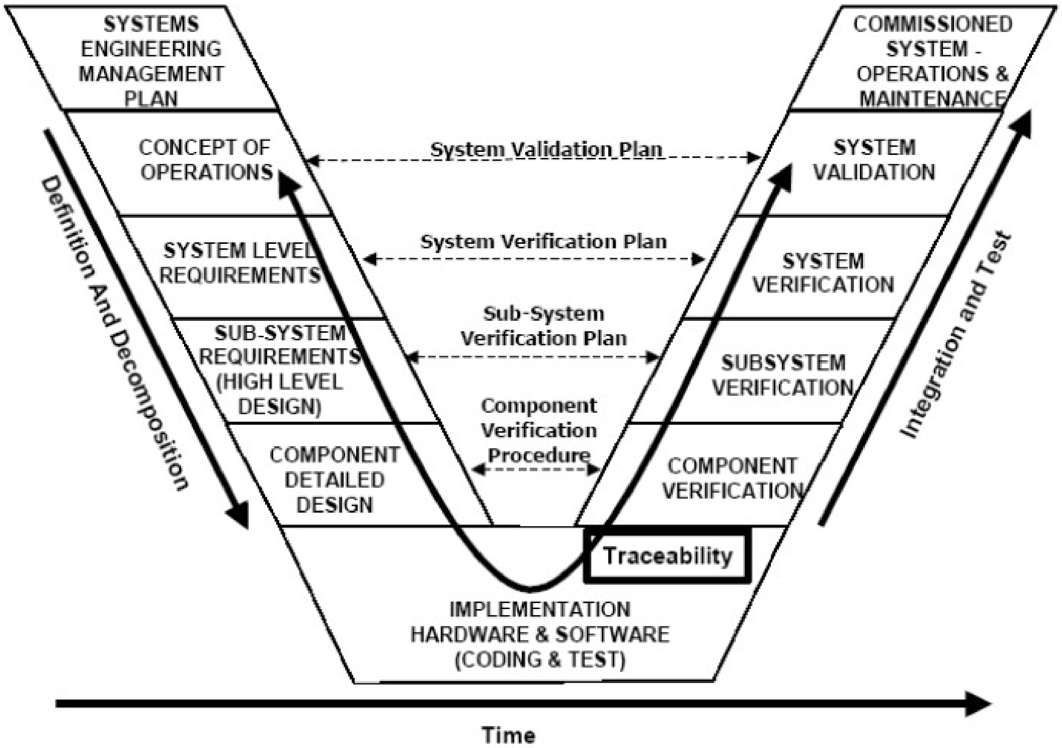

Figure 2-1. Systems Engineering Process [Souce: 4].

Figure 2-2 shows the "Vee" diagram applied to a traditional ITS project. While the basic application is the same, note that "wings" have been added to each side of the diagram. Aside from looking a little more stylized, the starting point is now the regional architecture, which should govern the introduction and integration of any individual project into the overall systems deployed in a region, typically incorporating multiple partners.

On the right side of the diagram, the ending point is now changes and upgrades and retirement and replacement. This speaks to the fact that no system lasts forever, and consideration of the life-cycle aspect of projects in the design phase may make subsequent maintenance and replacement an easier process.

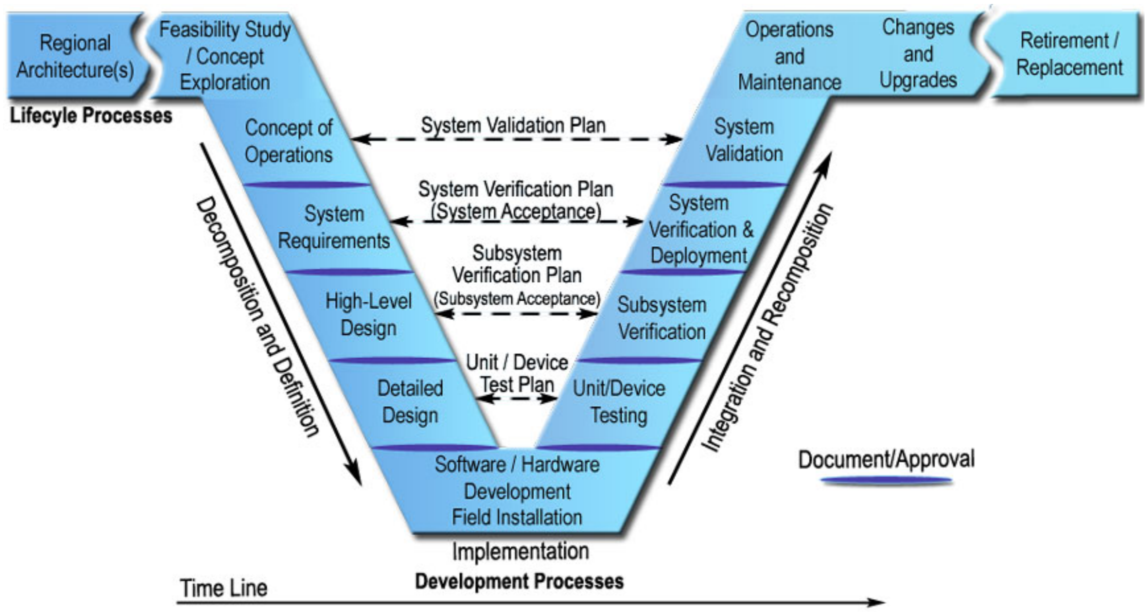

Figure 2-2. Systems Engineering Process for an ITS project.

2.5. Systems Engineering for Video Over IP

Perhaps the most striking aspect of the diagrams presented in Figure 2-1 and Figure 2-2 is that while they address similar topics and show the same generic process, they are in fact different. This is actually one of the least understood aspects of systems engineering. SEP is as much a way of thinking and doing business as it is a process. In fact, it is not only "ok", but encouraged to adapt the traditional "Vee" diagram to the particular project at hand. This streamlines the approach while keeping the important aspects in place. It should be noted that project level modifications to the SEP are recognized as being necessary by organizations that promote its use, such as FHWA.

Project level modifications to the SEP are recognized as being necessary by organizations that promote its use, such as the Federal Highway Administration (FHWA).

Figure 2-3 shows the systems engineering process developed for this guidebook to illustrate the approach to digital video projects. As an overview, the diagram is the same as the traditional ITS "Vee" diagram although some similar sections have been combined. On the right-hand side of the diagram, the testing and verification sections have been combined, as this guidebook presents one chapter on the overall testing methodology for video systems. Another chapter will focus on system acceptance, which is closely related to testing. On the left-hand side of the diagram, the process reflects the development of a concept of operations, which gets translated to functional requirements. A system design follows from the requirements.

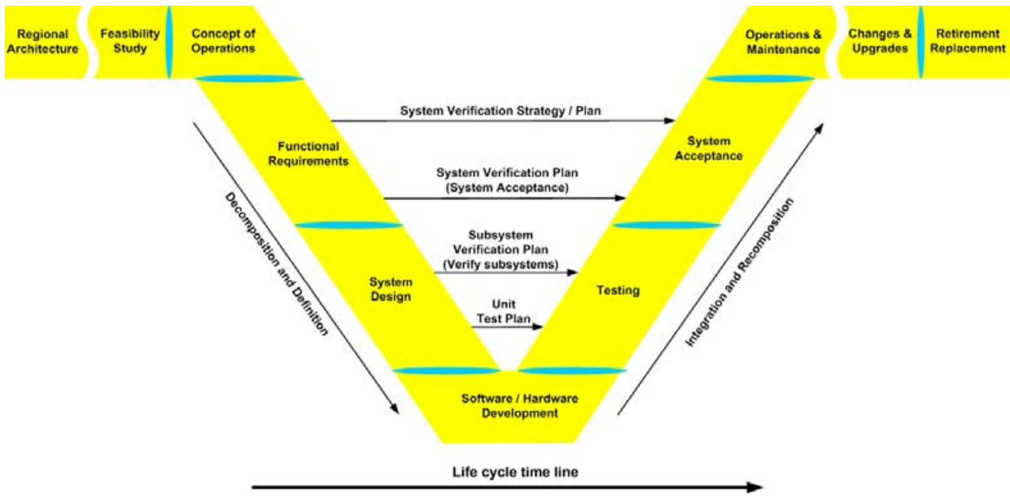

Figure 2-3. Systems Engineering Process for Video Projects.

Readers should note that this guidebook will not focus or discuss the software/hardware development phase identified in Figure 2-3 at the bottom of the "Vee" diagram. While included in the "Vee" for completeness, this type of information is typically very project specific and would be substantially more detailed than any other chapter. Additionally, it would also present the least value to the reader since much of the information would not be transferrable across projects.

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3. EARLY PHASES OF THE SYSTEMS ENGINEERING PROCESS

3.1. Introduction

As described in Chapter 2, the adaptation of the “Vee” diagram for ITS projects incorporated a number of important steps to promote high-level awareness and compatibility across projects within a region. These projects include the recognition and use of the ITS regional architectures as well as feasibility studies and the concept of operations (COO). Each of these steps is described briefly below. The level of detail provided is meant to promote awareness and an understanding of the overall relation of each step in the SEP process. The level of detail is not intended to be sufficient for the reader to create, as an example, a regional architecture.

3.2. Regional Architecture

Texas regional architectures are online at: http://www.consystec.com/texas/default.htm

Numerous areas within the state of Texas have completed a regional architecture. (See archive at: http://www.consystec.com/texas/default.htm). The architectures in part, cataloged current ITS resources and identified future needs of the region. The purpose of this portion of the SEP is to define the current project’s scope while considering any regional vision or opportunities for integration.

Resources can be systems such as a small closed circuit television camera, or CCTV, installation on a freeway or a closed loop traffic signal system along a main arterial. A future need may be to expand CCTV coverage along the freeway or add another arterial to the closed loop traffic signal system. The resources and needs are organized into groups called market packages. Market packages represent a general service in transportation management such as surface street control, incident management, or network surveillance. During project definition, planners should be aware of the region’s market packages and needs and strive to incorporate as many as feasible into projects under consideration.

As an example, Figure 3-1 shows the network surveillance market package from the Austin area regional architecture. Originally developed in 2003 and updated in 2006, the regional architecture provides a 20-year planning horizon for integrating transportation systems in the Austin area. The figure shows two agencies with existing video capabilities (typically CCTV). The figure also shows where those images go to in terms of agencies and what other systems interact with the video systems. In short, the figure is a high-level overview of not only the deployed systems, but also the systems anticipated to be developed within the planning horizon. This type of information and diagrams can be a valuable input into any agency seeking to deploy additional video capabilities.

Note that Figure 3-1 makes no distinction between the types of video systems. For example, it does not classify whether a CCTV system is analog or digital. That is detail beyond the level of the regional architecture. Additionally, the architecture does not identify how video is shared or transmitted, merely that it is.

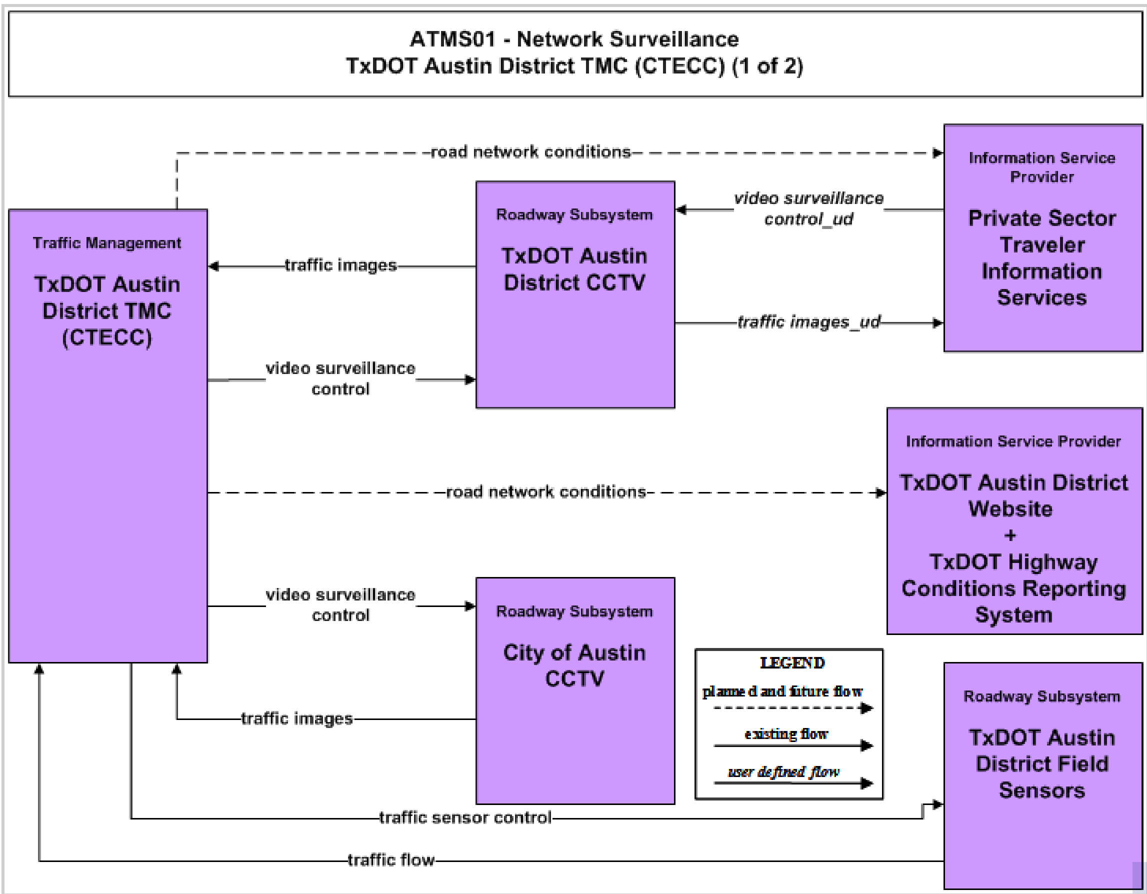

Figure 3-1. Network Surveillance Market Package from Austin Regional Architecture [Source: 1].

In addition to cataloging resources and needs into market packages, the architecture process typically produces a ranking of market packages. Many regions have labeled items such as the network surveillance market packages as high priority items. This in turn provides another valuable input into the project level planning process because priorities of the stakeholders have now been identified.

Starting the process with the regional architecture will accomplish the following steps:

- Definition of objectives – Define the project scope and opportunities for integration as well as improving consistency between ITS projects.
- Identification of supporting sources of information – Identify the relevant ITS regional architectures as well as any other regional or national resources that would support the development of this project.
- Identification of specific areas of integration – Identify the relevant portions of the ITS regional architecture that apply to or will interface with this project.
- Definition of project starting points – Helps to define the project stakeholders, affected systems, and/or elements and provides a starting point for the requirements process as well as interface needs to other systems and agencies.

In terms of objectives, a common question is what are the uses or applications of video that a prospective project will deliver? Video can be used in support of many high-level transportation management goals. Common goals include:

- Increase the safety of the transportation network.
- Improve mobility within the network.
- Increase the efficiency of the transportation network.
- Improve network user productivity and satisfaction.
- Deliver a positive impact upon energy consumption and environmental quality.

The project under development will likely address several of the broad goals listed above. Working within these goals, video can be applied in areas such as:

- incident detection, verification, and response support;
- traffic flow monitoring, disabled vehicle detection, or abnormal driving;
- roadway hazards, and roadway condition monitoring (ice, snow, high wind, flood waters);
- winter weather roadway management support;
- infrastructure security, trespasser detection, and identification; and
- ITS equipment (sensors, DMS, ramp meter, traffic signals) operation verification.

Another useful product of the regional architectures is the identification of the region's stakeholders. The stakeholders are the potential partners and benefactors of a new project. Some are transportation system operators, system users, and system managers. The list can become lengthy in an urban region. Some example stakeholders are:

- TxDOT;
- Department of Public Safety (state police);
- Federal authorities (Coast Guard, Border Patrol, Customs, etc.);
- Cities;
- Counties;
- Toll authority;
- Transit operators (including school districts);
- Large traffic generators (military bases, airports, universities, ports of entry, etc.);
- Emergency dispatch (police, fire, EMS, 911); and
- Media (television, radio, websites, private sector Information Service Providers (ISPs).

The stakeholders will bring resources to the project, and the project will help address the stakeholders' needs. An example might be a city or county providing a critical fiber-optic link to fill a gap in current systems and in return receive beneficial video images from an area where they otherwise would have no coverage. Stakeholders should review project objectives and define their roles and responsibilities within the project.

The project development team should view the new effort in the context of its surroundings. Unless a newly proposed system is truly stand alone, its inputs, outputs, and operation will have to interact with other systems and users. Projects with multiple stakeholders will require more interaction. Stakeholders should define the interfaces and information to be exchanged. The definition should be detailed enough to provide a beginning set of integration requirements for the proposed project. From a video standpoint, one stakeholder may require full motion video, and it must be displayed on a traditional analog monitor. Another stakeholder may only need infrequent digital video streams or snapshots displayed on a computer monitor.

Along with the integration study, a parallel discussion can be to identify known constraints. Available infrastructure may be a constraint if a project is unable to completely fund new infrastructure. Communication systems are an excellent example. A stakeholder may be able to share fiber but require that all new activity meet their operational rules. A partner may have available network bandwidth but the protocols and security requirements limit its use for the proposed applications. Considering the video stakeholder case above, the digital video partner may not have sufficient bandwidth, staff, or space and, therefore, must require video or video images to be displayed on a computer monitor instead of an analog feed. Funding constraints should be identified and understood. Different funding sources may be used for different aspects of the project due to their use rules. Stakeholders should discuss the staffing, administration, and technical support needs that the new project will require.

Readers are reminded that the regional architecture is not meant to be an absolute blueprint for the future. The architecture should be a 'living' document and there is room to add or modify the architecture as opportunities arise or area needs change. As the new project takes shape, revisit the architecture, and update it to reflect the new activity.

3.3. Feasibility Study

The regional architecture identified the needs, objectives, resources, and stakeholders. In this stage of the SEP, planners are essentially creating a business case for a project, by analyzing the technical aspects, the economic considerations, the political climate necessary to support the project, and any key risks. Planners may also create several alternative concepts to address the above issues and identify, which, if any, of the concepts make the most sense for moving forward with the project.

Concept definition should be kept at a reasonably high level but provide enough detail to make judgments regarding the concept's viability. The goal is to determine the project's technical, operational, economic, and political feasibility. The assessment should answer questions similar to the following:

- Are there several ways to address the needs?
- Are some needs or solutions unrealistic due to costs?
- Can the project be operated and maintained long term given budget constraints?
- What are the benefits and the costs?
- Which way delivers the best product for the price?
- What are the risks?
- Is there sufficient institutional interest and support to pursue and see the project through?

Each concept should be fundamentally different, not just a variant of another concept. The focus should be on providing concepts of high quality, not merely a high quantity of concepts. The concepts should be defined using clear, technology neutral, terms. The description should be easily understood by all those involved.

It can be confusing to discuss concepts now and also in the next step, identified as the concept of operations. At this stage of the process, the focus is on concept development or exploration. Concept exploration is generating multiple ideas that will fulfill the objectives, or stated another way, a broad assessment of different alternatives. This allows the project team to ultimately select a preferred concept to move forward, at which time the concept of operations will be developed to provide significant additional detail on how the project will operate.

As an example, consider a case in which the objective (need) is to increase the surveillance on a section of roadway. One concept may be to install a group of CCTV cameras viewable back to a TMC. Another option would be to deploy traffic detectors along the project area. Is deploying video the best option or will traffic detectors provide the needed information? Video may be a popular solution with many benefits but if the true need is simply to identify the level of congestion, traffic sensors alone can address the need.

An evaluation criteria should be established which will be used to determine the success or failure of the concept. To create good criteria, the problem needs to be clearly defined and understood by all parties. Cost and funding constraints should be known and incorporated. Consider how effectively each proposed concept addresses the needs for the expected cost. A 'do nothing' option should be included in case none of the other concepts are viable either technologically or economically.

The proposed concepts should then be evaluated on technical benefit, economic impact, operational feasibility, life-cycle costs, and any associated risks. These evaluations may take place using workshops, benefit cost information, or other software tools pertaining to decision-making analyses. The results of each evaluation should be documented for use by other decision makers later.

3.4. Concept of Operations

A concept of operations (COO) should contain sections pertaining to:

- Scope
- References
- Operational Description
- Operational Needs
- System Overview
- Support Environment
- Operational Scenarios

As the next step in the process, the COO establishes a shared understanding of the traditional questions of who, what, why, where, when, and how, associated with the selected alternative. This understanding is shared by system owners, operators, and maintainers. The use of the COO as a tool for defining the overall system is fundamental to the success of the SEP.

At a minimum, the COO should contain sufficient detail to provide a broad overview of the proposed project to anyone reading the document. The recommendation is for the following minimum sections:

- Scope – The scope of the COO communicates a description, purpose, and audience. Each one of these sections is generally short, perhaps one to two paragraphs.

- References – The references section identifies and documents any resources used in the preparation of the COO or that are needed for reference.
- Operational Description – This section of the COO provides a description of the operation of the system. This information can be communicated both pictorially and with text. Some systems may have a description of the system from multiple audience viewpoints.
- Operational Needs – One use of this section is to identify weaknesses or shortcomings in existing systems that will be overcome with the implementation of the proposed system. Another use is to specify the high-level list of features required to implement this system. These features may then serve as a first-level input into the development of functional requirements.
- System Overview – The overview should summarize the boundaries of the proposed system, the users, the interfaces to other systems or components, goals and objectives, and a high-level architecture.
- Operational and Support Environment – This section describes the environment in which the system will operate including information about facilities, equipment, hardware, software, personnel, operating procedures, and more.
- Operational Scenarios – This section of the COO is used to describe how the planned system or enhancement would be used in various situations, such as normal conditions, stress of high activity conditions, failure conditions, etc. In essence, this is the "story" aspect of the document, describing how each individual, or more accurately, position within the agency, that is affected by this project would use it, from their perspective. It is from this section of the document that systems designers or developers will likely gain the most information about how to design functions or aspects of the system to satisfy the different users.

Overall, developing the COO for the project will enhance stakeholder consensus, reduce risk, and improve the quality of operations for the system. The COO may make heavy use of tables cataloging information or diagrams illustrating various uses and/or capabilities of the systems. The document may contain several diagrams, each from the perspective of a different user.

3.5. Cited Sources and Bibliographical References

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4. THE FUNCTIONAL REQUIREMENTS PHASE

4.1. Introduction

A clear statement of requirements is often the most important attribute in a successful project. However, this step is often seen as the most difficult. Many times, the initial list of 'requirements' resembles more of the jumbled wish list, combined with project or technology preferences. It takes time and effort to develop a comprehensive set of good requirements.

The starting point for requirements should be the stakeholder needs identified in the Concept of Operations. These needs should be reviewed, analyzed, and transformed into requirements that define *what* the system will do. At this point in the process, the emphasis should not be on *how* the system will do it.

The starting point for requirements is stakeholder needs.

When complete, the attributes of a good set of requirements include the following:

- Necessary – Each requirement should trace back to a specific stakeholder need or a parent requirement.
- Clear – Each requirement should be explicit in the needs listing, avoiding words and phrases that are subject to interpretation, such as "optimum" or "user-friendly".
- Complete – Every stakeholder or need should trace to at least one requirement.
- Correct – Requirements must accurately describe functionality and performance to be delivered without conflict to other requirements.
- Feasible – Requirement must be feasible, or able to be met by system developers. Avoid word like 'instantaneous' which specify an unreasonable requirement.
- Verifiable – Can meeting the requirement actually be demonstrated and confirmed? If so, then the requirement is verifiable.

4.1.1. Specify What, Not How

Be sure to keep the definition of a requirement in mind as you develop your system requirements. Many documents contain statements that are not requirements. One of the most common pitfalls is to jump to a design solution and then write "requirements" that define how the system will accomplish its functions. Specify what the system will do in the system requirements step, and explain how the system will do it in the system design step.

Requirements specify "what" the system does, not "how".

The best way to start writing requirements is to use just two words: a verb and a noun. For example, the user requirement "monitor road weather conditions" would yield system requirements such as "shall detect ice," "shall monitor wind speed," and "shall monitor pavement temperature." Performance requirements would define the different kinds of ice conditions and the range of wind speeds and pavement temperatures.

4.2. Development

The functional requirements discussed in this chapter are organized into 16 topics as follows:

- Systems User
- Camera Control
- Distribution of Camera Images
- Image Quality
- User Interface
- Control Room Issues
- Communications Infrastructure
- Security
- System Reliability and Redundancy
- System Operation Parameters
- System Administration
- Field Equipment
- Standards/Testing
- System Expansion
- System Maintenance
- System Users

The topics are a subset of those found in Questions to Help Define CCTV System Operations *(1)*. The questions in the document provide a comprehensive point to think about when considering a new CCTV system or expansion of an existing system.

In the following clauses, each topic is expanded upon by listing some of the relevant questions, followed by a brief technical discussion about the topic. Each discussion is followed by a number of sample user need statements and then as a number of sample requirement statements.

In this report, the original set of questions was reorganized so that it is more relevant to Video over IP. Also, some of the questions do not lead directly to requirements but rather lead to derived requirements. Some of the questions in the Questions document are not addressed here and the ones that have been included have been paraphrased to some extent.

Also note that some of the user needs were copied with permission from a Michigan DOT User Needs Memorandum *(2)*.

4.3. System Users

- Who are the users (TxDOT, DPS, city, county, transit, 911, media, website, etc.)?
- What are the uses of the video images by the users?
- Any special needs from the users (mobile access, mobile feed, format, etc.)?

When considering users, it is not just the operators who will use the video images. Any type of emergency responders may find video images helpful. Dispatchers could use video to judge the severity of an incident and send the appropriate services. The Department of Public Safety could use real-time wide angle images of a scene to use for better incident managements. City engineers could use archived video to conduct pedestrian and vehicle counts at intersections. County engineers could also use archived video for crash analysis purposes. Transit management can achieve significant returns on most of its safety and security investments by deploying a video assessment system that leverages an agency's other safety and security assets. Since initial notifications often come from motorists, could the TMC be a user of video coming from a camera cell phone? Don't forget the public likes to use the broadcast media and website so that they can plan trips accordingly. With more and more emergency vehicles having onboard cameras, the TMC could be a user of this type of video. If one of the local agencies has surveillance aircraft, live video from it could prove useful to a number of users.

When considering the needs for system users, you need to think about how many users will there be and how they will use the video. Control room operators typically use video for incident detection and dispatch. If the operators will also be responsible for incident management, the number of operators increases. How video is used also varies by operator's responsibility. Incident detection tends to use wide angle images, whereas the incident management may require resolving characteristics of individual vehicles.

Are all operators and users in the same facility? DOT, DPS, transit, and media operators can be located in a centralized control room. If not, the number of external users and the amount of video can have a significant impact on the communications video infrastructure.

Is it possible that you will need to import images from mobile sources? For example, think of a scenario where a law enforcement officer has the role of an on-site incident manager, and the police cruiser is equipped with a camera. Would you want to receive and use images captured by the officer's camera? Most cell phones capture video or take still photos. Would there be any merit in receiving or using images from the general public? Using a caller's image may be useful in validating the severity of an incident in an area where no agency camera is available.

Will you need to distribute images for television or web-based broadcast? If you plan to offer images to commercial broadcasters, will your images be compatible with the new digital format? Is there any concern about high definition (HD)? For web-based broadcasting, lower definition is better for reasons of viewing speed.

4.3.1. Sample User Needs Statements

A. All external stakeholders need to access at least one video image that may be different from those that are sent to other stakeholders.
B. Individual TMC operators need to see to focus on the details of an incident and on the overall status of traffic around that incident.
C. The system needs to import images from mobile sources.
D. Need to provide advanced information about incident conditions (injury, severity, etc.).
E. Need to provide information available via the Internet.
F. Media outlets need to be able to obtain user rights to view live video anywhere in the state without having to request special permission for each viewing instance.

4.3.2. Sample Requirement Statements

A. The [stakeholders] shall have access to at least one real-time image available in the TMC.
B. Cameras shall be able to capture an image of an entire roadway section in one direction down to an individual vehicle at a maximum of 500 feet. Close-ups of an individual vehicle shall occupy at least 95 percent of a display.
C. The system shall be capable of displaying images from cell phone users.
D. The system shall be capable of exporting live video to a webpage.
E. All media outlets shall sign a copyright and distribution agreement prior to the use of any video.

4.3.3. Sample Protocol Requirements List

Traceability is an important concept linking needs, requirements, and ultimately, testing and verification.

One of the critical tasks in matching user needs to functional requirements is the construction of a protocol requirements list (PRL). The PRL matches up the needs with requirements, identifies them as mandatory (M) or optional (O) and highlights any discrepancies or holes. This process is called traceability and can be continued across the

"Vee" diagram into the testing stage to ensure that testing requirements are matched to specific functional requirements.

Table 4-1 below shows the traceability between user needs and functional requirements for the section labeled 'system users support'. The table is a standard form to map the connection between the need and requirement. In this particular example, user need 4.3.1.D. cannot be traced to a particular functional requirement, which is highlighted by the lack of traceability in the table.

Table 4-1. Sample Protocol Requirements List (PRL) Table.

User Need ID	User Need	FR ID	Functional Requirement	Compliance	Project Requirement	Additional Project Requirements
4.3.	System Users Support			M	Yes	
4.3.1.A.	All Users Need Access			M	Yes	
		4.3.2.A.	User access to ≥ 1 image at a time	M	Yes	
4.3.1.B.	Need images that focus on details and on overall scene			M	Yes	
		4.3.2.B.	Capture both entire roadway and one vehicle at distance of 500 feet	M	Yes	
4.3.1.C.	Need to import images from mobile sources			O	Yes / No	
		4.3.2.C.	System shall be able to display cell phone images	O	Yes / No	
4.3.1.D.	Need incident metadata					
		4.3.2.?				
4.3.1.E.	Need to provide info to public via Internet			M	Yes	
		4.3.2.D.	Shall export video to webpage	M	Yes	
4.3.1.F.	Media need access and use rights			M	Yes	
		4.3.2.E.	Use of video requires agreement	O	Yes / No	

4.4. Camera Control

- Who will have access (all partners, some partners)?
- What will the control hierarchy be?
- What will the rules be for operation/notification/presets/view blocking for privacy?
- Will there be a need for a Graphical User Interface (GUI) control or a joystick?
- Will there be a need for camera tours?
- What are the requirements for camera/image specifications (motion speed, presets, view blocks, tours, multi-vendor, etc.)?

Will the system need to limit access of some users? For example, if a TMC operator is focusing in on the details of an incident, is it okay for that image to be sent to the broadcast media? What if an individual is recognizable, and it is an accident scene?

What control of camera images do the various users need and who should have view-only access. Generally, TMC operators might need to control pan, tilt, or zoom at all times, while others might need to see the images but are not authorized to change a camera's perspective. For example, a public information officer might be given access to whatever image he or she wants but they might not be allowed to change the pan, tilt, and zoom setting of that camera creating that image. If the broadcast media has access to images, are they also allowed to change the perspective of that image?

Is there a need to know who is controlling which images? For example, if one operator is changing the orientation of a camera, should other operators be locked out during the change process? There may also be a need for operators to know at a glance who else is viewing images so they can respond cooperatively with other agencies. System administrators might need a record of viewers for historical data purposes.

When one operator is actively using an image, he or she would not want the orientation to change. The same situation would apply to an external user, such as a TV news program, who might want to zoom in on an incident. The access management policy needs to consider everyone's needs and the hierarchy of control.

To manage some incidents effectively, an operator may need to focus on a select group of images. From a management perspective, some TMC operators may only be responsible for specific areas under surveillance. Does the system need functionality to support this?

When considering users needs and requirements, consider how good images have to be. Some users may only need low resolution or snap shots of conditions; whereas others my want the highest frame rate and resolution possible. When displaying images on a webpage, resolution is usually set low to accommodate low speed access. When rebroadcasting to the media, the station may be broadcasting in high-definition.

4.4.1. Sample User Needs Statements

A. System managers need a mechanism to limit a user's access to images.
B. Users need to be able to identify if another user is controlling the display characteristics of an image.
C. The system needs to incorporate a means of restoring a camera's preferred image.
D. Some users prefer to use a joystick rather than a GUI control to change the perspective of an image.
E. System managers and operators need to select a subset of images for display.
F. The PTZ change speed needs to be sufficiently responsive.
G. Operators need to be able to view live video from, and control (pan, tilt, and zoom) cameras.
H. Operators need to be able to keep control over a camera despite attempts or requests for control from users with less priority.
I. Operators need to be able to take over camera control from users with less priority.
J. Operators need to know whether a media outlet is accessing camera video.
K. Operators need to be able to see who has control of a particular camera at any given time.
L. Operators need to be able to request control of a camera controlled by a user with higher priority.
M. Operators need to be able to see who is requesting or taking control of a camera.
N. System administrators need to be able to set allowable viewing angles for cameras so they are not used for unauthorized purposes.
O. Operators need to be able to yield control of a camera to a user with less priority who requests control.
P. Operators need to be able to conveniently hide a camera image from public view and replace the video with a message saying the video has been hidden.
Q. Operators need to be able to view multiple camera images at once on their workstation monitors.
R. Operators need to be able to view multiple camera views at once on a large video wall.

S. Operators need to be able to set up camera tours where they can scan views of multiple cameras in standard sequences.

4.4.2. Sample Requirement Statements

A. The system shall implement an access management scheme that limits what users (both external and internal) have access to an image and the control of the image characteristics for resolution and perspective.
B. The access management scheme shall have the ability to have operators/users request access from and grant access to other operators/users.
C. The system shall have the capability of displaying those operators and external users that are using an image.
D. Each camera image shall have at least five presets that define pan position, tilt position, and zoom value.
E. The system shall provide a user with the ability to control a camera's orientation via a joystick and a software icon.
F. The PTZ shall be able to perform a complete 360 degree pan in 15 seconds. The PTZ shall be able to perform a +60 to -60 degree tilt in 15 seconds. The PTZ shall be able to perform a maximum to minimum zoom change in 5 seconds.
G. Each TMC operator console shall be capable of displaying two full-screen sized video images along with the image's ID, location, pan and tilt position, status, and focus and iris values.
H. The control of access hierarchy shall be able to assign up to 10 levels of control for each user. The hierarchy of override or control of access to the images shall be the same as access.
I. The system administrator or designated user shall have the ability to define two sets of allowable viewing horizontal and vertical angles for cameras so that sensitive images are not displayed.
J. The system will provide all users with an indication when another user has control over an image.
K. Operators shall be able to define camera tours of 16 video images and the time spent on the image.
L. A room-sized display shall be capable of displaying 32 images broken down into 4 X 4 quadrants so that an image can be displayed across multiple cells of a quadrant.

4.5. Distribution of Video Images

- Matrix of users and allowable cameras
- How many channels (simultaneous views) are needed per user? (all videos?)
- Blocking certain users from sensitive scenes (e.g., media, web)
- Text overlay: copyright, ownership stamp agreement, time/date stamp?

- Can users redistribute? (web, internal within entity, media, etc,)
- TMC access to video from other entities and rights of use
- Distribution of snapshots, video clips

The first thing to think about in terms of video image distribution is whether the system needs to limit user access and control of the images. For example, if a TMC operator is focusing in on the details of an incident, is it okay for that image to be sent to the broadcast media? What if an individual is recognizable, and it is an accident scene?

Most CCTV systems allow you to add a text label somewhere on the image or in a linked file. However, the number of characters in the label or the number of items you can include might be limited.

The physical location where information is entered may constrain what is possible to add or remove. If a text label is entered at the camera itself, chances are that it cannot be removed or altered in retransmission. Labeling images at the management center gives you flexibility in removing or changing them prior to retransmission.

Labeling images at the management center gives you flexibility in removing or changing them prior to retransmission. This ability might be important, for example, if the label initially recorded on the image is cryptic but meaningful to transportation staff yet could be confusing or meaningless to broadcast viewers. As another example, having an agency logo on images used in the control center does not serve a useful purpose, but adding a logo on an exported image might.

Full-sized, full-motion video requires higher communications capabilities to exchange than snapshots (still pictures) or some other types of images. A snapshot can be transmitted over a dial-up modem in seconds. Do you need to be able to capture and use snapshots, streaming video, or other types of images in addition to full video?

Consider the scenario where several supervisors in an HOV headquarters 10 miles away from the control center are required to verify that reversible lane barriers have been moved before motorists are allowed to use the lanes. Do the supervisors need full motion video or would snapshots do the job?

Image copyright is a complex issue. Should you copyright your system's video images? If licensed broadcast media or private information service providers use your images, it may be necessary to copyright images so that others do not alter them or rebroadcast them without permission. In other cases, agency policy might not permit you to apply for or retain copyright to materials. Applying for a trademark on a logo may also be against policy. Will a user be entitled to alter an image or add additional information to an image? Instead of making images freely available, could they be a revenue opportunity?

You will need to determine what options regarding copyright are open to the organizations operating your CCTV system. Once you determine what options you have, then consider what rights you want to retain, how you want to publicize them, and how you will handle breaches of copyright.

There may be cases where an outside user wants permission to redistribute or archive your images for future use. Is that allowable? Is such a user required to give credit to the agency?

Regardless of what you decide regarding copyrighting images, you will want to develop a distribution policy on how images may be used. Decide what you want to cover in your distribution policy, especially with stakeholders and outside agencies. Create a permission statement if you want users to include one. As part of the permission line, you will probably want to include a statement that public funding provides the information. An agreement that prohibits adding additional information to images may preclude the need for full copyright language.

Will there be a difference in the way you handle copyright for images received from different sources or used by different viewers? If your system accepts video or snapshot input from other sources, can they be redistributed or rebroadcast?

In order to effectively manage images, a video image needs to include some type of label that identifies the source, for example "I-81 SB at US 11." When planning your system, determine what information you need to be able to include on your images. While general location information is static, knowing that a camera is facing north might be helpful if camera direction is changeable. Is there a need to add other information such as direction, iris settings, or zoom settings? Are cardinal or ordinal directions sufficient or is absolute azimuth needed? If you plan to record and archive your images, time and date labeling is usually necessary.

4.5.1. Sample User Needs Statements

A. Need the ability to collect and disseminate real-time traffic conditions information. System managers need a mechanism to limit a user's access to images.
B. Need to be able to identify if another user is controlling the display characteristics of an image.
C. Need to incorporate a means of restoring a camera's preferred image.

D. Need to meet user's desire to use joystick or GUI control to change the perspective of an image.
E. Need to allow system managers and operators to select a subset of images for display.
F. Need the ability to collect and disseminate real-time traffic conditions information.
G. Need to provide incident responders/dispatchers with advanced information about an incident to send the right personnel and/or to avoid sending personnel unnecessarily.
H. Need to provide incident responders advanced information about the condition of a collision and status of people involved (e.g., Are they walking around or is it likely an injury accident?).
I. Need to provide real-time incident information at 911 centers and in vehicles.
J. The system shall be able to provide information that is relevant to travelers.
K. Provide sharing of freeway information with adjacent jurisdictions.
L. Operators need to be able to keep control over a camera despite attempts or requests for control from users with less priority.
M. Operators need to be able to share frames from video streams with responders or other operators, as well as to include with incidents and events.
N. Operators need to be able to reference devices by MDOT standard naming conventions.
O. Transit agencies need to be able to view live video and receive incident information from the system.
P. Other agencies need to be able to view live video and receive incident information from the system.
Q. Need to include viewing direction to eliminate confusion about orientation and direction.
R. Need to show image time and date information so that there is no confusion about whether image is live or recorded.
S. Need images distributed to and received from commercial television and web-based broadcast media in common format to enable information exchange and comprehensive responses.

4.5.2. Sample Requirement Statements

A. The system shall implement an access management scheme that limits what external users have access to an image and the control of the image characteristics for resolution and perspective.
B. A control room display shall be capable of displaying up to 32 images simultaneously.
C. Each operator console shall be capable of displaying up to 2 images simultaneously.

D. The software shall implement an access management scheme that limits what TMC users have access to an image and the control of the image characteristics for resolution and view.
E. The system shall have a mechanism for adding a copyright mechanism notice prior to any image exported to the TMC.
F. The system shall provide a mechanism for recording and then allowing access to only external users that have signed a copyright and redistribution agreement. The agreement shall automatically lapse on a yearly basis.
G. Each camera shall have the ability to add a user definable text overlay/and a time/date stamp to an image. The text overlay/ time/date field shall be at least 20 characters.

4.6. Image Quality

- Minimal acceptable video quality based on applications and users
- Frame rate, compression (adjustable by users?)
- Acceptable rate, quality, resolution for snapshots/video
- Different quality settings for Internet distribution

There are two aspects to image quality. Subjective quality is what a person perceives to be a good picture. Objective quality is whether an image meets quantifiable metrics for quality. In the first case, a person looking at a winter image with snow falling might consider it to be poor quality. On the other hand, that same image may meet all specifications for broadcast video and objectively be of high quality.

Frame rate is the number of unique consecutive "still" images, called frames, that an imaging device produces during a set period of time. If the rate is high enough, the human eye will blend the images so that there is no observable flicker between them. Full-motion video is approximately 30 frames per second and is what you see on television or in the theater.

Samples of different frames rates are on the enclosed CD.

In considering user needs and requirements, you should determine what frame rate is acceptable for your system's needs and whether one size fits all. Images will appear to flicker as you reduce the frame rate toward 15 frames per second. Below 15 frames per second, you might start missing a car traveling at freeway speed. To get a good sense of what different frame rates look like, see the samples on the accompanying CD.

While lower frame rates require less communications bandwidth, not all users will be satisfied with stop-and-go video. Could frame rates be automatically adjusted based upon how long a camera is pointed in a particular direction? Could frame rates be adjusted by each individual user?

There are considerations to think about that apply specifically to broadcast media regarding import and export of images. Will you need to distribute images for television or web-based broadcast? If you plan to offer images to commercial broadcasters, will your images interface with the different types of commercial broadcast media?

Commercial broadcast television signals are now sent in a digital format. Some signals are high definition (HD). CCTV equipment that operates in a format compatible only with the older analog signal format will not be compatible with the new format. If your images are made available to the broadcast media, will the non-digital format be acceptable for rebroadcast? If you plan to import images, will television images that meet new broadcast requirements be compatible with your system display hardware and software?

Image quality criteria with CCTV is subjective but measurable and therefore it is important for the design team to ascertain from stakeholders using demonstrations and workshops the quality achievable using network-based technology comparing them directly with analogue technology that most user representatives are accustomed to.

When planning your CCTV system, consider topics related to image quality. User needs for image quality will depend on a variety of issues such as the intended uses for images or interaction with transmission and display equipment. The sections below provide information for making these types of decisions. Many of the considerations for image quality interact closely with operational, transmission, and field considerations.

There are two aspects to image quality. Subjective quality is what a person perceives to be a good picture. Objective quality is whether an image meets quantifiable metrics. In the first case, a person looking at a winter image with snow falling might consider it to be poor quality. On the other hand, that same image may meet all specifications for broadcast video and objectively be of high quality.

Users tend to measure quality subjectively, and one needs to consider whether everyone will be satisfied with a common definition of "quality." As long as one starts with an image of a quality acceptable for required purposes, resolution can be modified to meet lower communications requirements.

Several factors affect the capability to acquire acceptable image quality. For example, scenes need to be adequately lighted. Daytime lighting, even on cloudy days, is usually sufficient to maintain image quality, but nighttime lighting needs special attention to ensure it meets minimum levels. As another example, the distance between a camera and objects will determine whether images will be useable in foggy conditions.

Some people have the impression that Video over IP only produces poor quality images. Good quality IP-based cameras (or network cameras) have exactly the same high quality image sensors and optics as analogue cameras. Don't confuse professional products with those meant for public consumers. A $25 webcam will not produce a quality image.

Actually "digital" cameras are much higher resolution than analog. Analog cameras were in fact limited to less than .5 megapixels because of the NTSC encoding standard that they operated on. By contrast, a low-end digital network camera can deliver 1.3 megapixel images or more.

Analog technology solved many problems with high-quality cameras, matrix switchers, and monitors. It has limitations, however, with regard to distance and video playback. These two factors are resolved by IP network-based video transmission and cost-effective digital recording.

Other IP technology can be useful in addressing expansion. Instead of stringing new analog cable, a video stream can be pumped to multiple uses via a technique called multicasting.

4.6.1. Sample User Needs Statements

A. The system needs a method of defining a set of video quality parameters for different types of users.
B. Operators need to be able to override day/night settings on cameras in order to select the setting that provides the best image.
C. Operators need to have the ability to select higher resolutions when needed.
D. Along with users monitoring and controlling requirements, there is a need to ascertain their recording requirements.
E. Operators need to be able to override day/night settings on cameras in order to select the setting that provides the best image.
F. Reduce congestion by identifying and determining the nature of incidents so that they can be quickly cleared.
G. Improves safety and reduces congestion.
H. Modern IP systems use MPEG-4, which makes more efficient use of the network than M-JPEG. For occasions when lower quality would be sufficient and help control the amount of storage used, IP gives you the ability to customize the quality of the video output based on your viewing needs and storage capacity.

4.6.2. Sample Requirement Statements

A. The system shall incorporate a mechanism for assigning a set of video quality parameters for each type of user.

B. Operators shall have a mechanism to override automatic selection of iris aperture.
C. Operators shall be able to temporarily upgrade the set of video quality parameters assigned to them.
D. A set of video quality parameters shall be set for recording purposes but operators may temporarily upgrade the set of video quality parameters established for recording.
E. When an image is distributed to the Internet, it shall be assigned a default set of video quality parameters.
F. There is then the issue of what image resolution (target size) is required in order to fulfill specific functions in these three key areas. These resolutions have been classified for us by the Police Scientific Development Branch (PSDB, now HOSDB) using a 1.6 m high "target" as: Control & Monitoring (target occupies a minimum of 5 percent of the display device), Detection 10 percent, Recognition 50 percent and Identification 120 percent.

4.7. User Interface

- Different levels of user interface with different functionality
- Totally different interfaces for different users
- GUI or joystick (software vs. hardware)

When considering the user needs of different users is there one common interface that fits all users or should each type of user have a customized interface? Consider a scenario where "system" operators are responsible for incident detection and identification. In this case, should the operator have full control over an image's perspective? Once an incident has been identified, the "system" operator could pass the image over to a "dispatch" operator to send and coordinate the appropriate responders. Other that selecting an image, should their interface allow for control over an image's perspective?

In another scenario, assume that freeway management and HOV operators each have consoles in a TMC. Do HOV operators need to have control of all cameras in the system or should their control be limited to those related to HOV lanes?

Another consideration could be to provide a customizable interface. Some users prefer to use a joystick to control a camera's perspective whereas, others prefer a GUI control. Should the system support a user selection of one or the other?

4.7.1. Sample User Needs Statements

A. The system needs a single, common interface so it can easily operate in different tasks or regions without retraining.

B. The user interface shall be configurable on an individual user basis.
C. Minimizes or eliminates freeway breakdown conditions during peak periods.
D. Maximizes the utilization of physical capacity.
E. Increases vehicle throughput.
F. Rapid detection and clearing of accidents will reduce congestion and secondary collisions that frequently result and cause additional delays.
G. The best CCTV systems enable users to view video via both PC and analog monitors.
H. Operators need an interface where all functions are integrated in a common user interface.
I. Operators need an interface that complements their workflow, i.e., is event-oriented rather than device-oriented.
J. Operators need an interface that is intuitive and easy to use.
K. Operators need a system that validates data entry to minimize typographical errors.
L. Operators need a single system with a common interface so they can easily operate in a different region without retraining.
M. Operators need to be able to view all spatial information on a single system map.
N. Operators need to be able to view field device status on the map by their icon, i.e., whether they are operational, partially operational, or failed.
O. Operators need to be able to zoom and scroll the map using familiar controls.
P. Operators need to be able to select a device on the system map to view more detailed device information.
Q. Operators need to be notified of system or device malfunctions.
R. Operators need to be able to alert maintenance personnel of device malfunctions.
S. Operators need to be notified when malfunctioning devices have been repaired.
T. Operators need to be able to override day/night settings on cameras in order to select the setting that provides the best image.
U. Need a common system software package to access remote field devices (traffic signals, DMS, CCTV, RWIS).
V. Provide immediate description of hazardous materials.

4.7.2. Sample Requirement Statements

A. The system administrator shall be able to define what functionality is available for a control room operator on his or her user interface.
B. The operator user interface shall be customizable on a per user basis, as to which cameras locations are shown, a joystick or icon control of camera pan and tilt, and access to submenus.

C. The operator interface shall have a control to toggle between live video and a snapshot.

4.8. Control Room Issues

- Number of simultaneous video streams needed
- Will there be a variety of video formats or just one (NTSC, RGB, etc.)?
- Image sizing and resolution needs for viewability on a video wall, monitor, PC
- Is a video wall required?
- Is a video switch needed or use digital switching?
- Need for complex video display capability (stretching across multiple monitors)

Looking at a system simplistically, an analog system with 250 cameras requires 250 communications channels to bring back the images. This is true if there are only 10 displays. In a Video over IP system, you only need as much communications bandwidth to support the maximum number of displays. This has a significant impact on the communications infrastructure requirements.

Any issue about analog formats such a NTSC or RGB only becomes an issue when analog components are used. If a camera has an IP interface and all displays are essentially computer displays, any issue about analog formats is completely irrelevant.

If you are willing to consider only the most popular compression techniques, interoperability issues almost disappear. The vast majority of network cameras support MPEG-2 and/or MPEG-4. If you want to encode analog signals, the vast majority of encoders support NTSC input. They provide support for most encoding algorithms.

In terms of video wall resolution, one only needs to consider the lowest resolution of only one "cube." An individual cube could have an individual resolution of 1024 X 768. When displayed on a 4 X 2 cube matrix of the same type of cube, the overall resolution is effectively 4096 X 1536. With the advent of digital TV in the home, the large wall displays are significantly dropping in price. Moving to a Video over IP has also decreased the complexity of these devices.

Operators can use a video display wall to visualize an incident that spans multiple cameras. The wall display is also invaluable as a public relations tool. On the other hand, providing two monitors at each operator console and running image tours on one of them might be more cost effective and allow each operator more latitude to see what he or she is interested in.

Unless you are dealing with integration issues, Video over IP eliminates the need for video switches.

A complete Video over IP system (network ready cameras as opposed to analog camera signals converted to digital, then converted back to analog) should be given serious consideration. Video over IP involves fewer components, reduces the overall complexity of the system, and reduces the total cost of deployment and maintenance. Consider Table 4-2, which compares traditional system components to those used in video over IP.

Table 4-2. Comparison of Analog vs. Digital System Components.

Traditional System Component	Video over IP component
Video Decoder in Equipment room	Software on workstation
Video Switch	Software on workstation
Analog Monitor	Software on workstation
PTZ Controller	Software on workstation
Video signal coax	Ethernet jack on workstation
PTZ Communication wiring	Ethernet jack on workstation

4.8.1. Sample User Needs Statements

A. Need a common system software package to access remote field devices (traffic signals, DMS, CCTV, and RWIS).
B. The choice of switching hardware is directly dependent upon determining the potential number of simultaneous flows across the network. With reference to Figure 2 below, which represents a conceptually simple view of data flow across the network for a single user; the projected Day 1 data flows for multiple sets of users over the network infrastructure need to be quantified taking into account all cameras and scenarios.
C. Operators need to be able to access the system from outside the TMC from any computer with access to the State of Michigan network.
D. Operators need to be able to record camera video in digital format either manually or according to a schedule.

4.8.2. Sample Requirement Statements

A. The CCTV system shall support the display of up to 48 simultaneous live video images.
B. All displays within the TMC control room shall have DVI-I and HDMI connections.
C. Image resolution on a TMC control room display shall be a minimum of 1280 X 1024 with 32 bit color.
D. Routers shall serve as a backup in preventing video images from being sent to anyone but authorized users.

E. A “Video Wall” is required, and it shall be capable of being segmented into 24 individual displays. Adjacent individual monitors shall be combinable so as to create one large display, a half screen, a quarter screen, an individual screen, and combinations thereof.

4.9. Communications Infrastructure

- Management of infrastructure bandwidth (all videos ‘ON’ all the time, multicast)
- Connection and streaming costs for leased line video links
- Leased line infrastructure costs charged to video user? (metering leased services)
- Integration of analog, SONET, Ethernet, leased line video systems
- Codec issues (interchangeability, multiple vendors, standards based)
- Administration
- Standards
- Policy Impacts

Video over IP can decrease complexity and increase the efficiency of the communications infrastructure. Video over IP eliminates the need for video switches. The video switches are replaced by computer network switches and routers. In a Video over IP system, video does not need to be transmitted all the time but rather on-demand (enabled and transmitted only when needed). If there were 200 CCTV cameras in the system, and the control room has the capability of displaying any one of them on 48 different monitors, what is the maximum number of video signals that have to be carried by the communications infrastructure? It is only 48 and not 200.

Auditing software can track who, what, where, and when. If this sort of information is available, external users could be charged a usage fee.

In Video over IP systems, video and PTZ can use the same physical connections. Whereas analog cameras used coax for video signals, a separate signal had to be decoded for PTZ signals. This is not the case with Video over IP because many PTZ units incorporate an IP interface.

Most video technicians consider “codecs” (video encoders/decoders) as being proprietary hardware designs. While there are performance issues to consider, many encoders support “industry” standards and can be decoded using commercial off-the-shelf software. Apple’s QuickTime” is one such example.

Most of the standards relevant to communications infrastructure are dictated by the use of IP as the network layer protocol. If the services are supplied following the guidelines for classes of service defined in IEE802.1, then many of the attributes guaranteed in the service level agreement can be measured to demonstrate a specific level of service (QoS).

Upgrade all Communications Group Management capabilities that allow for remote monitoring, configuration, fault isolation, and methods to remotely resolve issues/problems; this is to save costs in productivity, public safety, transportation and resolution time and improve the services provided to customers.

4.9.1. Sample User Needs Statements

A. Need a common system software package to access remote field devices (traffic signals, DMS, CCTV, and RWIS).
B. Need a flexible interface path to the existing hybrid mix of CCTV systems.
C. Re-use existing infrastructure to reduce costs.
D. Provide sharing of freeway information with adjacent jurisdictions.
E. Even dedicated CCTV networks can get crowded periodically. With Bosch, users can choose how to adjust to accommodate temporary traffic surges. The frame rate can drop temporarily while the sharpness of each image is maintained, or, conversely, the same number of frames can be recorded but at a lower resolution. Each encoder can also be programmed so that the bandwidth it uses is allowed to rise and fall as necessary to preserve both the frame rate and resolution. Or the user can fix a maximum threshold to ensure that even if every encoder on the network became active, the system would still not exceed the total bandwidth allocation. Bosch provides the flexibility to choose which option is best for a particular application.
F. Eliminate the need for dedicated wiring.
G. System administrators need to be able to monitor bandwidth utilization and control bandwidth allocation to lower priority functions to protect the performance of core functions.
H. System administrators need the system to be efficient in its use of bandwidth so it does not bog down the State Wide Area Network (WAN).
I. The use of the existing communications infrastructure needs to be coordinated with the [Agency] network information system group.
J. All external users need to sign a distribution and copyright agreement.
K. The communications infrastructure needs to be monitored in order to assure users are not experiencing excessive delays, poor quality, and service interruptions.
L. Elimination of traffic delays at cross-jurisdictional boundaries.

M. Data sharing between agencies for improved traffic management and planning.
N. New/revised maintenance measures for ITS technologies.
O. Real-time information needs to be exchanged between emergency operations centers (EOC's) during a major emergency.
P. There needs to be dissemination of real-time disaster information (i.e., floods, wildfires).
Q. There needs to be enhanced emergency operations for major fires, snows, floods, and potential dam failures.
R. There is a need to inform all regional fire agencies (keep in mind that some service areas overlap) about planned traffic signals to facilitate the inclusion of fire pre-emption in the design of the traffic signal.

4.9.2. Sample Requirement Statements

A. The CCTV communications infrastructure shall be compatible with the existing computer networking infrastructure.
B. The total cost of ownership shall be minimized by leveraging existing network infrastructure and equipment.
C. The system shall incorporate an audit trail of "who-did-what-when" and monthly summary reports as to when external users use video streams.
D. Live Video shall only be transmitted when selected for display.
E. For the next 5 years, the contractor shall perform a cost analysis of the communications infrastructure (hardware and any leasing arrangements), maintenance, and replacement.
F. The contractor shall demonstrate that video decoders are not sole sourced.

4.10. Security

Security is an important concept to consider in any network or communication system design.

- What is the security risk if hacked into?
- Is a formal policy required? What is on or touching a public network?
- Who administers/monitors system security
- Use of credentials by users – rules/administration
- Different classes of system users (view only, view/control, all)
- Ability to rapidly cut video feeds to sensitive material quicklyEncryption requirements

The security risk with CCTV cameras is that someone might attempt to point the camera at a sensitive scene. Hackers could damage cameras by exposing the image sensors to strong light and manually override iris settings. The transmission of inappropriate video is a more sensitive issue. While such a display within a TMC would be embarrassing, any retransmission to the media might have repercussions.

The current recommendations on security suggest that a complete IP security solution implements IPSec, Internet Key Exchange (IKE), and IP Payload Compression Protocol (IPPCP). These protocols define the use of public-key encryption, data compression, symmetric key encryption, and authentication to implement a security solution. While this solution provides the best security at a business level, all these operations are computationally intensive and, depending on the bandwidth needed, may require hardware acceleration. From a TMC CCTV system perspective, what level of security is required?

With Video over IP, most solutions to Internet security can be applied to the video network. Using a commercial-off-the-shelf security monitoring tool is an economical and effective solution.

User passwords should always be "Strong" and renewed regularly. For any group, accounts access for administrative purposes and shared passwords for those accounts is required (e.g., "Root" or "Administrator" accounts), the passwords must always be "Strong" and frequently and immediately upon any personnel change within the group.

With all their data encrypted, secure IP networks are more robustly protected than analog systems ever were. If the appropriate protection is used (firewalls, VPN, and password protection), the Internet can safely transfer all kinds of sensitive information. Keep in mind that banks and financial institutions use the Internet as the medium for global money transactions. It is very easy for third parties to tap into the cables of an analog system and gain access to supposedly secure video transmissions. Access is more difficult with secure IP networks.

4.10.1. Sample User Needs Statements

A. Some users feel that they need to store video. Such video, needs to only be available to authorized users.
B. Network-based systems need to ensure that the security and integrity of the system and data flowing across it are maintained.
C. The system needs to provide an audit trail of "who-did-what-when."
D. Any connection through a non-agency communications link needs to provide a level of security equal to or greater than VPN.
E. System administrators need to be able to provide different levels of access to different users based on user roles.
F. System administrators need a system with good virus protection.
G. System administrators need to ensure users accessing the system via non-secure PCs do not expose the system to unauthorized individuals (e.g., by timing out from inactivity, rotating passwords, etc.).
H. The system needs to enforce the use of "Strong Passwords."

I. Any access to the Internet needs to be isolated completely from the TMC computer/video network.

4.10.2. Sample Requirement Statements

A. Access to Internet has to be provided to each Control Room operator but only as a virtual terminal to a non-TMC networked computer.
B. The method of authentication shall be equivalent to or better than Extensible Authentication Protocol-Transport Level Security (EAP-TLS).
C. Use of Password Authentication Protocol (PAP), Shiva Password Authentication Protocol (SPAP), or Challenge Handshake Authentication Protocol (CHAP) is permitted to be used for access control on the profile of any remote access policy, but it must be documented. Any alternatives require the preapproval of the agency TMC project manager.
D. IP security shall at a minimum implement IPSec, Internet Key Exchange (IKE), and IP Payload Compression Protocol (IPPCP).

4.11. System Reliability and Redundancy

- Evaluation definition for video (% time video is unusable).
- Should all videos have same qualifications or tailored to option (analog, MPEG)?
- Are certain video streams high priorities and thus need to be highly reliable?
- Redundancy requirements for portions of the system (e.g., main network switch).
- Hot or cold standby for backup systems (e.g., redundant equip, UPS, etc.).
- Is this a function of TMC operator hours?

With Video over IP, the signal passes over the data network. As such, one should expect the network to be available between 99.99 percent and 99.9999 percent of the time. That equates to less than one hour of downtime a year to less than one minute of downtime a year. But keep in mind that network needs downtime for component maintenance and system upgrades *(3)*.

While using a single technology (reduces complexity and simplifies maintenance), it is very possible to mix the analog and digital together. Cameras can be analog or digital. An encoder can convert the analog camera signal to digital for transmission or a decoder can convert the digital camera to analog for transmission over existing communications infrastructure. This principle can be applied anywhere along the entire path to the computer monitor or analog monitor.

Video over IP is quite easy to integrate with or expand existing systems. One simple solution is to use data communications as an extension cord. Take the analog output of a camera, encode it as a protocol stream, send it over the data network, and then decode it back to an analog signal. This signal can be treated as any other analog signal going to a matrix switcher, video tape recorder, or analog monitor.

If a particular camera is characterized as being high priority, the best solution is to incorporate redundancy in the networking components. If something goes wrong, the network can be set up to automatically reroute information.

Depending on who's in control of the data network, IP network providers use classes of service or priority queues to manage the flow of multiple services across their networks. Real-time video traffic should be given a high priority class of service. The IEEE 802.1p standard established eight priority levels for service *(4)*. Many of the attributes guaranteed in the service level agreement can be measured to demonstrate a specific QoS.

By their very nature, networked systems feature more built-in redundancy and resilience than the older analog systems. Modern networks support alternate routing and redundant network links connecting the network switches and routers. This provides back-up paths in the event of a failure of either equipment or a cable. It is possible to design a network that would continue working even in the event of multiple failures. Data networks are usually designed with multipath connections. Network routers and bridges can easily reroute data with a path that is no longer available. Even workstations can have multiple Ethernet connections on them.

Most TMCs have secondary (generator) and tertiary (battery) power systems. This power is typically distributed throughout a building via special orange colored outlets. It is normal for the entire communications equipment room to be powered by this type of circuit. The problem is that sometimes the operator consoles are overlooked. Another consideration is that the field equipment and any satellite communications hubs need backup, as well.

4.11.1. Sample User Needs Statements

A. The system needs to encompass a common system software package that accesses all types of remote field devices (traffic signals, DMS, CCTV, and RWIS).
B. The operation of the system needs to build and maintain credibility with the motoring public.

C. The system software needs to create a more reliable security system.
D. The system needs to automatically redirect video traffic to a backup storage system in the event of a power failure or network outage.
E. Any single operator needs to be able to monitor remote and wireless cameras from anywhere on the network. The control of video storage needs to be able to be managed remotely, as well. The system needs to integrate surge protection that protects against transient on the power and data lines.
F. System administrators need to be able to maintain operations capability even if a region's system goes down.
G. System administrators need to be able to take over operations capability even if another region's system goes down.
H. System administrators need to be able to perform point-in-time backup and restore operations.
I. System administrators need a system that is stable and reliable (i.e., it does not crash), especially under peak load, which is when the system is needed the most.
J. The communications infrastructure shall have an emergency backup policy in place.

4.11.2. Sample Requirement Statements

A. The CCTV communications infrastructure shall maintain a 99 percent uptime.
B. The expansion of the CCTV system shall use digital technology but be integrated with the current analog components.
C. The contractor is required to work with the network information system personnel to coordinate assignment of video to the highest possible priority. The contractor shall develop a test procedure that demonstrates the priority scheme.
D. The CCTV system design is required to incorporate secondary communication paths for all sources of video images.
E. The TMC contractor shall provide backup power to the operator console equipment.

4.12. System Operation Parameters

- Latency parameters, camera movement speed
- Presets, fine/coarse control
- Use of true azimuth, elevation, zoom, instructions
- Video image switching speed, selection of a bad video (blank, blue, noise, etc.)

When the NTCIP standard for CCTV was being developed, there was a lot of discussion about pan speed and how accurately a camera could be positioned. If you are moving a camera 2 degrees left, pan speed is usually not a concern. However, what if an operator needs to move a camera 180 degrees? Operators may not like the fact that it takes 5 minutes to move a camera to the opposite direction.

In analog and digital video, image quality includes resolution, frame rate, and color rendition. In video over IP applications, the communications network must be capable of maintaining a throughput required to deliver a video stream without breakup. This measure is referred to as quality of service (QoS). Another measure is latency, which refers to the delay between when a frame is transmitted and when it is received. If latency is constant, it is usually not a problem unless someone is moving a camera. An operator may attempt to pan left, but when nothing happens, he or she may overcorrect before effects of the movement are visualized. Another associated QoS parameter is jitter, which is the variation in that delay from one frame to the next. When jitter is present, a video stream appears to break up, and some frames are lost.

Most CCTV systems support a number of presets where value set for pan, tilt, zoom, and possibly other parameters can be saved as return values. The concern in terms of requirements is whether all cameras will support the same minimum number, whether all cameras support the "other" parameters, and whether the camera returns to the preset positions with sufficient accuracy.

One advantage of specifying conformance to standards is that operation of different makes and models of camera and PTZ units do not require an operator to learn different operating procedures. For example, NTCIP 1205 – Object Definition of CCTV Camera Control, normalizes a number of parameters. Some PTZ units may expect a pan position to be expressed in whole degrees while other manufacturers' units expect it to be expressed in tens of a degree. While it always good to have a complete set of operating manuals, they do not have be part of each operator's console library.

Another feature of NTCIP 1205 conformance is that it allows directions to be specified in different ways and ensures that any device conformant to the standard support the different modes, For example, one can say move the camera 5 degrees to the left or move it to 30 degrees from the north.

While it may sound like an obscure point, operators need to be able to tell the difference between good video, poor video due to visual impairments, and lack of video due to hardware problems or failures. For example, in dense fog or a heavy snowstorm, a video image may appear blank yet its video electrical parameters might be perfect. Internally, a camera's imager may fail but the communications channel may be working just fine (Video over IP allows a check for this.). A video stream may be received at the TMC perfectly but when retransmitted to the broadcast media, all they see is snow.

While general location information is static, knowing that a camera is facing north might be helpful if camera direction is changeable. Is there a need to add other information such as direction, iris settings, or zoom settings? Are cardinal or ordinal directions sufficient or is absolute azimuth needed? If you plan to record and archive your images, time and date labeling is usually necessary.

4.12.1. Sample User Needs Statements

A. The system operators need to be able to adjust pan and tilt speed.
B. The system needs to be able to define a number of presets so that operators can always return to a specific view.
C. The system interface for PTZ needs to be consistent across all makes and models of units.
D. Operators need to be able to tell if a blank or noise-filled display is due to weather conditions or equipment failure.

4.12.2. Sample Requirement Statements

A. The speed at which a camera pans and tilts shall be operator programmable.
B. The PTZ shall be able to perform a complete 360 degree pan in at least 10 seconds. The PTZ shall be able to perform a +60 to -60 degree tilt in at least 5 seconds. The PTZ shall be able to perform a maximum to minimum zoom change in 2 seconds. The PTZ shall have variable speed controls such that the aforementioned movements are completed in half the specified value.
C. Each camera image shall have at least 5 presets that define pan position, tilt position, and zoom value.
D. Control room displays shall display a message when a video signal going to the display is lost.

4.13. System Administration

- What features are needed (log of camera operations?)
- Review of who viewed what to ensure compliance
- Report generation
- Automatic alarms for error events
- Automatic reports for system errors and maintenance issues
- System configuration support and tracking
- Software licensing
- System emergency recovery

Logging has often been a touchy subject for some. Since recording can require a significant amount of hardware resources, one needs to ask what aspects of logging needs be incorporated in the system. Recording high resolution digital video from hundreds of cameras requires terabytes of storage space. If there appears to be a need to record incidents, can that be on an as-needed basis? In other words, a TMC operator could declare when an incident has occurred, and the image on his or her console is then recorded. Remember also that in video is not necessarily available all the time. Using an On-Demand approach will save a significant amount of communications bandwidth.

Related to this is data surrounding the use of video. Date and time are a given. Do the PTZ, iris, and other camera parameters need to be recorded as well? What about operator actions? Is it important to record what operator made adjustments to the camera or PTZ unit?

In most TMCs only a small portion of the video images are displayed at any one time. Even thought an image is not displayed, it would be nice to know if a hardware problem occurred. In Video over IP, this is more of a communications problem that can be resolved by commercial off-the-shelf network monitoring software. Conformance to the NTCIP 1205 standard which is based on SNMP allows the operator to monitor the functionality of a camera or PTZ Unit and generate reports without even having to look at the video.

When considering configuration support and inventory control, keep in mind that this information may need to be shared by stakeholders. Consider the situation in Dallas/Fort Worth. Each city has its own TMC. Even though Dallas would not normally view video images from cameras in Fort Worth, would there ever be a need to? What if there is a major incident just between the two cities. Does there need to be a way to share inventory and status between the two TMCs? The ITS Architecture and the Traffic Management Data Dictionary describe this type of information flow between centers.

There have been lessons learned about software licensing and intellectual property rights. The FHWA's Lessons Learned Knowledge Resource has several topics that need consideration. The advice is to, "Facilitate the participation of private sector technology companies in the deployment of ITS by using creative approaches to address the assignment of intellectual property rights."

Video plays an important role in terms of being used for interagency coordination in support of emergency and special event management and disaster recovery. For a Video over IP - CCTV system, consider the needs of emergency recovery of the "system." Are the current system software and any configuration files backed up? Is there backup communications infrastructure or routing capability?

4.13.1. Sample User Needs Statements

A. System administrators would like a record of what camera images are being displayed on the wall display and those being observed on each user's console(s).
B. From an ease of use point of view, CCTV camera operator usage, system alarm, and system error reports shall be integrated with reports on other TMC-controlled devices (DMS, CCTV, RWIS) as well as the communication network components.
C. Managers need to see standard performance measure reports at regular intervals (e.g., weekly) from data gathered by the system log.
D. Operators need thorough and accessible user manuals.
E. To ensure the long-term survivability of the system, the administrators need the source code for all software installed and or used by the system.
F. The communications infrastructure needs to include redundant components to ensure that recovery from a disaster is possible.

4.13.2. Sample Requirement Statements

A. All selection of video that is to go to a display shall be recorded. The record shall include operators making the selection, the identifier of the display that the image is being sent to, date, and time.
B. An event recording mechanism shall be provided. Records of other subsystems shall be integrated.
C. The event reporting mechanism shall have the ability of generating reports on a weekly and monthly basis. The mechanism shall support a minimum of 10 programmable and preconfigured reports.
D. Any outside enclosure shall generate an alarm whenever the door or access cover is opened.
E. The contractor shall supply user manuals for every component used in the system. In the case of multiple units of the same device, there shall be one for every 10.

F. Wherever possible, the contractor shall purchase the source code rights for all software used within the system, in lieu of this, source code shall be placed in escrow.

4.14. Field Equipment

- View needs drive lens selection (how much near roadway, how much zoom)

- Mounting and environmental issues with field cameras (heaters, faceplate wipers)
- Camera and movement (vibration) allowance
- Maintenance issues
- Physical location access, maintenance support software
- Field control of camera, bucket truck reach, staff training

Specifying the focal length of a lens is relatively straightforward using a field of view calculator. Small hand-held light meters can used to measure the ambient illumination reaching the camera lens during daytime and nighttime conditions from natural or artificial lighting sources. Optical test equipment is used to test the functionality of fiber-optic transmission systems and to measure cable continuity and attenuation, and fiber-optic connector and splice coupling efficiencies. In addition to test tools, there are others that can be used during the initial design, installation, operation, and maintenance of the digital (or analog) video equipment.

A field of view calculator can be a software program or hand-held wheel such as illustrated in Figure 4-1 and Figure 4-2.

Figure 4-1. Field of View Wheel.

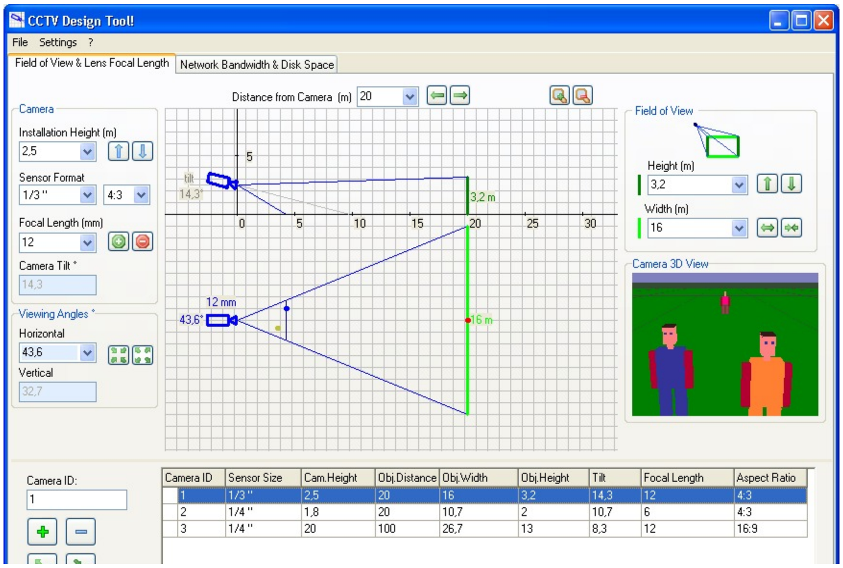

Figure 4-2. Field of View Software.

Assuming that you want to use both panoramic and close-up views, one calculates the focal length for widest object width at some distance and the smallest object width at the same distance. Using a ½ inch imager with a camera 500 feet away from the scene you want to capture, an image 40 feet wide requires about 80 MM. A wide angle shot covering 400 feet of roadway requires about an 8 MM lens. An 8-80 MM zoom lens is readily available. In addition to field of view calculators, network bandwidth and storage calculators are also available *(5)*.

If a camera is pointed directly at the sun, the imager could be damaged. Even when a camera is pointed at the sun's approximate position, such as at dusk or dawn, the sun's brightness may saturate the imager and make details impossible to discern. For this reason it is advisable to ensure that some sort of sunshade is provided. Depending on its design and color, a sunshade can also keep a camera cooler and keep rain/snow/ice off of the camera faceplate. While today's cameras don't typically require a heater except in extreme conditions, a small faceplate heater can prevent condensation from building up. A hermetically sealed housing pressured with nitrogen can ensure that there is no inside condensation, it does present potential maintenance issues. Faceplates do require regular cleaning but to keep them clean (and free of cobwebs) the period between maintenance cycles can be longer if the faceplate glass has a hydrophilic coating. This type of coating repels water, oils, and dust.

If a camera is mounted on a structure such as a bridge or gantry, vibrations may be an issue especially in windy conditions or if the roadway has any washboard ripples. If the camera is mounted at the end a pole, it can exaggerate the problem. Stabilized lenses can remove significant image vibration (blurring) in cameras that are buffeted by wind or the motion caused by the moving vehicle.

In some situations, cameras are mounted on an overhanging traffic signal mast arm. The swaying of a traffic signal on the end of a mast arm may not bother a motorist but a swaying camera image may be ineffective and hard to watch in the control center.

CCTV systems require periodic maintenance. The FHWA's Guidelines for Transportation Management Systems Maintenance Concept and Plans suggests that measurements of raw video, peak white, color burst, synch pulse, might image, and connector integrity be checked every week *(6)*. Raw video and connector integrity require camera measurements and typically entail a bucket truck.

4.14.1. Sample User Needs Statements

A. Need images that are free of shake and jitter so that details in the scene are discernable.
B. Need a common system software package to access remote field devices (traffic signals, DMS, CCTV, RWIS).
C. Need to have complete visual coverage of underpasses.
D. Travelers need access to visual images of roadway conditions.
E. Provide advanced information about rail crossings being occupied for fire response and/or during an evacuation.
F. Improve safety in work zones, in high-incident locations, and in rural areas.
G. Located on both sides of freeway between interchanges, at approximately 1 mile spacings.
H. Provide continuous freeway monitoring.
I. Port-of-entry (POE) bypass capability for trucks with proper credentials.
J. Railroad-highway grade crossing.
K. Need to monitor high accident locations for incidents.
L. Need real-time information available in emergency vehicles.
M. Field equipment should be upgradeable.
N. Software that allows the end users, operators, supervisors, or administrators to be able to view, control, configure, and manage the system. Cameras + CODECs and their video streams need to be managed. Camera controls need to have priorities applied in a multi-user environment. There will be linkages developed and applied in the system to enable cause and effects, e.g., if event "A" occurs then camera "B's" image must display on "C's" display and associated recording must start and finish thus.
O. Operators need to be able to monitor ramp metering lanes.

P. Operators need to be able to train on a non-production instance of the system.
Q. Trainees need to be able to run scenarios on a non-production instance of the system for mock drills or simulation exercises.
R. Students need to be able to create and save reports from the production system.
S. Managers need to be able to track maintenance activity by asset for budgeting purposes.

4.14.2. Sample Requirement Statements

A. Cameras shall be able to capture an image of an entire roadway section in one direction down to an individual vehicle at a maximum of 500 feet. Close-ups of individual vehicle shall occupy at least 95 percent of a display.
B. The camera housing shall be such that it prevents internal condensation. The faceplate aperture shall incorporate a coating that prevents rain, dust, and other particulates.
C. The camera shall incorporate a mechanism that stabilizes an image when it is subjected to vibration and movement.
D. Field installations shall incorporate a mechanism to view video and control PTZ locally at ground level.
E. The contractor shall supply three sets of tools needed to perform the weekly, quarterly, and twice yearly maintenance procedures defined in the FHWA's Guidelines for Transportation Management Systems Maintenance Concept and Plans. The contractor shall document customized procedures that relate to the specific equipment provided. The contractor shall develop training material, class syllabus, and power point presentation on how to perform the maintenance procedures.
F. As part of this contract, the contractor shall provide mobile equipment suitable for accessing CCTV cameras and other devices that are mounted above 6 feet.

4.15. Standards/Testing

- Use of NTCIP or other well-documented protocol
- Vendor-specific control protocols and multi-vendor protocols
- Digital video coding (MJPEG, MPEG1-2-4, Wavelet, H-2xx) for interoperability
- Demonstration of interoperability by multiple vendors
- Development of a list of test/qualification requirements and procedure
- Who will carry out testing and reporting?

When developing a regional architecture for a CCTV System or subsystem, keep in mind that the National ITS Architecture references the

AASHTO/ITE Traffic Management Data Dictionary (TMDD) and Message Sets (TMDD) standard and several AASHTO/ITE/NEMA National Transportation Communications for ITS Protocol (NTCIP) standards. Numerous elements of the North Texas ITS Architecture developed for the Dallas and Fort Worth districts also reference these standards.

These standards prescribe how information is defined, encoded and how it is to be exchanged. By specifying how systems and components interconnect, the standards promote interoperability between components and foster interchangeability of devices.

There ARE several sources for test procedures related to CCTV Systems. For example, TxDOT Project 0-5003, Testing for Compliance to NTCIP Standards, contains test procedures for CCTV cameras and PTZ units that can be used to verify conformance to the standards. Those procedures, when applied to products from multiple vendors, verify interchangeability. Testing an NTCIP conformant traffic signal control on the same physical sub-network verifies interoperability.

There are two appendices in the TxDOT 0-5003 Report that may prove helpful when defining requirements. Appendix A is a slightly modified version of TxDOT 2004 Special Specification 6025 – CCTV Field Equipment. The specification was modified to refer to NTCIP Requirements. Because TxDOT's approach is to define NTCIP externally, Appendix B defines a draft Special Specification that deals specifically with the details of NTCIP for CCTV Equipment.

Chapter 4 of the TxDOT report and the testing chapter of this document look at two approaches as to how to carry out testing. Within TxDOT, there are two approaches to carrying out testing. One follows an internal processor carried out by TxDOT personnel. The other follows a more external process where the physical testing is carried out by a contractor, but a TxDOT engineer is in the loop and signs off on the various steps.

4.15.1. Sample User Needs Statements

A. Need a common system software package to access remote field devices (traffic signals, DMS, CCTV, RWIS).
B. Need ITS devices to be specified for NTCIP protocol so multiple vendors can provide products that are accessible via a single software package.
C. System administrators need to be able to add devices from different manufacturers without writing new drivers, to the extent possible. Therefore, the system must conform to ITS standards.
D. System administrators need a system made up of components that are widely deployed and tested, which implies commercial off-the-shelf components to the extent possible.

E. System administrators need to be able to test and develop system upgrades on a development instantiation of the software.

4.15.2. Sample Requirement Statements

A. The CCTV devices and control software shall comply with all mandatory objects of the mandatory conformance groups as defined in NTCIP 1205v01.08a – Object Definitions for Closed Circuit Television (CCTV) Camera Control as follows:

    1. CCTV Configuration Group
    2. Extended Functions Group
    3. Motion Control Group
    4. On-Screen Menu Control Group
    5. Configuration Conformance Group
    6. Security Group

B. The CCTV devices and control software shall comply with all the following optional objects defined in NTCIP 1205 v01.08a – Object Definitions for Closed Circuit Television (CCTV) Camera Control, as follows:

    1. positionQueryFocus
    2. positionQueryIris

C. The CCTV devices and control software shall comply with all mandatory objects of the mandatory conformance groups as defined in NTCIP 2301: 2001 – Simple Transportation Management Framework – Application Profile:

    1. System Group
    2. SNMP Group

D. The CCTV control software shall use the NTCIP objects described above.
E. The transport layer protocol used at the camera interface shall be TCP/IP and conform to the applicable NTCIP standards
F. A single video encoding scheme shall be used throughout the entire system. (The scheme can use multiple encoding algorithms but all devices shall use have the same set of algorithms.)
G. Even if only a single vendor's equipment is supplied for field use under this contract, equipment from at least two other vendors shall be supplied for the purposes of testing for interoperability and for training.
H. Contractor shall provide tools that implement the test procedures as defined in Testing for Compliance to NTCIP Standards. The

testing tools used to perform system acceptance and maintenance shall also be provided.

I. The testing associated with this contract shall follow the "contractor" approach as defined in Testing for Compliance to NTCIP Standards.

4.16. System Expansion

- Technical migration issues with software/hardware
- Infrastructure limitations
- Extension to partners

On average, cameras with a built-in IP interface cameras are less sensitive under low-light than high-end analog security cameras, and migration to newer cameras must take this into account. An underpass may have sufficient light for an analog camera but may not have enough for a given IP camera. The rule is that cameras with larger image sizes (⅓ versus ¼ inch) and larger pixel pitch (distance between pixels) have better low-light sensitivity. The larger, individual pixels allow each pixel to gather more light.

With analog cameras, the video displayed at an operator's console could be expected to be of a similar quality to that coming directly from a camera. With digital systems, compression and decompression of the video stream cause wide variations in video quality at an operator's console. In order to provide an operator with quality video, this means that:

- Video cannot be too compressed in order to save network bandwidth (high levels of compression make objects harder to identify by an operator).
- An operator cannot experience excessive latency, especially with PTZ (Pan/Tilt/Zoom) surveillance cameras because video and PTZ motion must seem to occur in real-time to an operator.

In 2008, even low-end computer monitors have 1024 X 768 pixel resolution. Even with a fair amount of compression, it is not unusual to see network bandwidths at 12-15 Mbps depending on camera settings. Existing data networks may have problems handling this bandwidth. Granted that tradeoffs can be made with lower resolution cameras, higher compression, or lower frame rates, the effectiveness of the system and utility of the images needs to be taken into consideration. While an agency can install camera to TMC infrastructure to meet its needs, sending video to a remote partner or the broadcast media may entail leasing arrangements.

Analog technology solved many problems extremely well with many high-quality cameras, matrix switchers, and monitors. Its limitations, however, in regard to distance and video playback, are still there. These two factors are resolved by IP network-based video transmission and cost-effective digital recording.

Other IP technology can be useful in addressing expansion. Instead of stringing new analog cable, a video stream can be pumped to multiple uses via a technique called multicasting.

4.16.1. Sample User Needs Statements

A. Supply easy migration of existing CCTV and future expansion.
B. Implementation of the infrastructure is needed for long-term ITS enhancements of a freeway system.
C. IP networks offer improved flexibility for enlarging a CCTV system. It is not only easy to add cameras, but also to add storage space and distribute it across the network. Plus, IP networks are uniquely able to support multiple viewers. In the same way that an e-mail server can send the same data to multiple people at the same time, the network switch has the ability to clone the video and use the same data multiple times.
D. System administrators need to be able to easily maintain, upgrade, configure, and add software and devices to the new system.
E. System administrators need to be able to add, remove, and configure devices in the system.
F. System administrators need good documentation for upgrades, configuration, troubleshooting, and general maintenance.
G. The system needs to be scalable to the number of cameras that are planned for the future.
H. Need to expand the TMC to include additional jurisdictions, provide active control of systems and information, and to coordinate activities.
I. Need to integrate systems between local transportation and emergency agencies.

4.16.2. Sample Requirement Statements

A. The system shall be scalable to provide for management of a minimum of 500 cameras. This capability shall be demonstrable by a means approved by the project engineer.
B. The system's communications infrastructure shall be capable of handling 50% more video transmissions then what are currently required by this project. This capability shall be demonstrable by a means approved by the project engineer.
C. The system shall provide management and control by a minimum of 48 control room operators. This capability shall be demonstrable by a means approved by the project engineer.

D. The system shall provide management and control by a minimum of 48 control room operators. This capability shall be demonstrable by a means approved by the project engineer.
E. The system shall be capable of providing twice as much external video importing and exporting capability than what is physically required under this contract. This capability shall be demonstrable by a means approved by the project engineer.

4.17. System Maintenance

- Life-cycle costs (life expectancy, annual maintenance estimate)
- Availability of replacement equipment
- End of life issues with technology
- Custom software maintenance (TMC control packages)
- Maintenance procedures for equipment

In terms of life-cycle costs, implementing a digital system does not require throwing away those trusted (and already paid for) cameras. With a Video over IP system, you can still use all the cameras, lenses, and cables in place through a step-by-step migration to digital technology. Consider any recording devices. Traditionally these systems are highly labor intensive because of the need to change tapes and perform system maintenance. Tape wear and tear is an ever-present problem. Furthermore, the actual quality of the images recorded is often unsatisfactory, because recording speed is set to maximize how much can be recorded. With digital video recorder (DVR) technology, the storage media are no longer dependent on operator intervention or tape quality. With Video over IP, there is no real distinction between a video server and network server.

There is a myth that you have to be an IP specialist to install and maintain Video over IP systems. The reality is that there is no mystery to IP CCTV, especially with the training available on the Internet and that from manufacturers. Although Videoover IP offers better image quality, accessibility and ease of use, a number of issues remain the same.

What is the purpose of the system? Where and how will the cameras be located? What is the correct angle of view? How will the camera signals be transmitted? What information should be recorded and archived? How will the system operate? These are all the same questions that CCTV people have had to deal with for years. The challenge now is to find ways to get up to speed on how IP networks work.

When maintenance issues arise, the traditional IT guys may be much more helpful than you realize. Back in 1994, a communications consultant fired by the FHWA suggested that one of the standards groups look at a new idea in communications technology. One group looked at a protocol called the Simple Network Management Protocol (SNMP). It seems like every device that connects to the IP network uses this protocol to manage the network. Every switch, bridge, router, and any other device on this new communications technology called the Internet, supported SNMP. Video over IP cameras now support SNMP. Thanks to the FHWA's insightful choice of a consultant, new ITS traffic signal controllers, dynamic message signs, system sensors, on-street masters, and a whole bunch of other equipment supports SNMP, as well. In the transportation domain, you may have heard of NTCIP. For all practical purposes, if you know one, you know the other. If you need some help managing your Video over IP network or your traffic controller network see your IT Department.

4.17.1. Sample User Needs Statements

A. Maintenance personnel need to view camera images from around the municipality to more effectively dispatch snowplows.
B. Traffic personnel can use the cameras to investigate signal trouble calls remotely.
C. System administrators need a highly modular system with a well-defined and documented application programming interface (API) or protocol interface to facilitate integration with external systems, including COTS components.
D. System administrators need to be able to easily maintain, upgrade, configure, and add software and devices to the new system. Maintenance technicians need to be able to test and diagnose problems remotely.
E. Maintenance technicians need to be able to test and diagnose problems remotely.

4.17.2. Sample Requirement Statements

A. In the preparation of the proposal for this RFP, the bidder shall provide an analysis on the life expectancy and annual maintenance expense estimate for the equipment that the bidder is proposing.
B. Even if only a single vendor's equipment is supplied for field use under this contract, equipment from at least 2 other vendors shall be supplied for the purposes providing the availability of replacement equipment.
C. As part of this contract, the contractor shall provide five semi-annual yearly reports on any end-of-life issues related to technology over the next 10 years.
D. The system shall come with a five year maintenance agreement. The maintenance agreement shall cover a yearly review and report of the any component that may be affected by end-of-life cycle issues. The availability of replacement components shall also be reviewed and reported.

E. The system shall be delivered with a set of documents covering maintenance procedures for all hardware components.

4.18. System Users

- User Interface
- Control Room Issues (owning agency)
- Security
- Administration
- Policy Impacts

If the TMC has users representing different stakeholders, will all users interact with the system in the same way? Will one common interface fit the needs of all users or should each type of user have a customized interface? A service dispatcher who uses CCTV to gauge the appropriate response to an incident might not want the same system user interface as a freeway management operator who uses cameras for incident detection. Would the user interfaces for a freeway management operator be the same as the one for an HOV operator? Do HOV operators need to have control of all cameras in the system or should their control be limited to those related to HOV lanes?

Another consideration could be to provide a customizable interface. Some users prefer to use a joystick to control a camera's perspective whereas, others prefer a GUI control. Should the system support a user selection of one or the other?

Once a TMC is established, it often becomes a major source of information on highly visible transportation resources. The various stakeholders and surrounding communities become dependent on that information. If the system does not work well, it can have a negative impact on the media's and local citizen's credibility. Control room policies and procedures, and scenario planning must be addressed to ensure that the system works well.

Another consideration related to control room issues is whether the CCTV system will ever be used for criminal identification and crime prevention. Any usage for Homeland Security should be spelled out in appropriate usage agreements and policies.

In a CCTV system, there are two aspects related to security. One is related to authorized access and use of the control software and images and the other relates to non-authorized access.

Security issues can come into play when one considers the legal liability of monitoring certain areas. If an operator moves a camera so that he or she can look into an apartment window, would the first reaction of a tenant be to sue for invasion of privacy? Is the programming and setup of prohibited areas conducted at an appropriate supervisor level? Are there policies and operator training to ensure that everyone knows what is and what is not the appropriate use of the system?

Security also becomes important when dealing with people who are trying to break into the system surreptitiously. This is a popular subject in the computer and networking domain. However, there has been a gap in information about security issues in transportation systems until recently. *Transportation Infrastructure Security Utilizing Intelligent Transportation Systems* has a whole chapter devoted to Securing ITS *(7)*. It is recommend reading.

Who is authorized to access camera images? Who is authorized to control the PTZ of an image? Will some users have restrictions on the movement of a camera? When considering control room operators, their questions are not difficult to resolve. A system administrator can have a list of control room operators, and he or she can enter any constraints.

When you factor in broadcast media access, however, it gets a little more complicated. Should a system administrator be the only one to define access? Should an operator be able to block access in cases where a screen image is not suitable for public display? What about one level of control room user being able to block another control room user?

The overall functioning of a CCTV system may be impacted by policies that define what system users have access to and how they intend to use the system. Will some CCTV system users ever utilize the system for criminal identification and crime prevention? Would there be any circumstances when Homeland Security would want to use the system? The policies of who, what, where, when, and why need to be defined in appropriate usage agreements so as to understand any impact on other users.

When considering general administrative issues, consider whether any limitation on the number of hours that the TMC is staffed has an impact? There was a situation in Florida where CCTV cameras were installed over a heavily traveled portion of I-95. The TMC was very active in freeway management: however, one significant event was overlooked. On one weekend, fog lead to a multicar pileup. Because the TMC personnel were not working that weekend, it was several hours before anyone started to divert traffic due to the 10 mile backup. The TMC was not manned on weekends.

4.18.1. Sample User Needs Statements

A. As technology develops and opens up numerous possibilities in the application of CCTV surveillance, one of the key requirements of legislation is that the use of the system is proportionate, adequate, relevant, and non-excessive. From the point of view of data storage, even if storage is cheap and accessible, an organization should consider whether there is are privacy considerations in keeping data.
B. Video magnification for visually impaired.
C. Storage.
D. System administrators need to be able to administer the system remotely.
E. Source code needs to be provided, with data models, e.g., Unified Modeling Language (UML) diagrams.
F. System administrators need to be able to create, remove, and make changes to user accounts.
G. System administrators need to be able to grant or restrict permission to different system functions and modules by user or user group. Suggested permission levels include:

    - CCTV viewing only (other agency use)
    - View all functions with read-only access (selected agencies)
    - CCTV, DMS and VSS viewing and modification ability (typical operator setting)
    - Full administrative rights (system administrators)

H. Operators need to be able to easily identify and select cameras by type on the map, such as by a mouse click, mouse-over, or by the icon.

4.18.2. Sample Requirement Statements

A. A mechanism shall allow a system administrator or shift supervisor to select a camera by location or name and then define or display programming information that includes:

    - Name
    - Location
    - Camera type
    - Lens Type
    - Maximum Number of Labels
    - Label Color
    - Maximum Pan Left Limit
    - Maximum Pan Right Limit
    - Pan Home Position

- Maximum Tilt Up Limit
- Maximum Tilt Down Limit
- Zoom Limit
- Iris Limit
- Minimum Pan Step Angle
- Minimum Tilt Step Angle
- Maximum Tilt Speed
- Current Tilt Speed
- Maximum Pan Speed
- Current Pan Speed
- Access Code
- Communications Logical Address
- IP Network Address and Mask

B. The contractor shall develop a Control Room operations manual as derived from the roles and responsibilities of the stakeholder's TMC operators.

C. The system shall support a mechanism for the supervisor to enter user names, their access rights within the systems, and other restriction such as viewing angles. The system shall support a user re-definable "strong" password that the user is forced to change periodically.

D. The contractor shall develop a systems operations manual for the system that contains any letters of understanding between the stakeholders, and the roles and responsibilities of each the stakeholder.

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5. THE SYSTEM DESIGN PHASE

5.1. Introduction

A quick look at the history of different technologies will show that in virtually every field, old technologies will eventually be replaced by newer, more advanced options. The eight track was replaced by cassette tapes, compact discs came along and both tapes and records were no longer used, and DVD players quickly overtook VCRs as the preferred method for distributing video. The same thing is starting to happen in the video transmission world, as improvements in digital technologies are leading to digital video transmission starting to overtake analog transmission as the preferred method. In fact, in June 2009 all full-powered television stations in the U.S. are required by the government to stop analog transmissions and go to digital. As the move from analog to digital takes place, it is important to understand how digital video is transmitted. This section of the guidebook will focus on what digital video is and the different methods used to transmit digital video over an Internet Protocol network.

5.2. Video Properties

5.2.1. Introduction

Analog and digital video transmissions are very different from each other. Analog video uses a continuous electrical signal, which varies in voltage depending on the image being displayed. This signal is created when a camera turns an image into an electrical signal. This electrical signal is then transmitted over some medium to a monitor, such as a television, or a storage device such as a VCR. The most common medium used in analog transmission is coaxial cable, or coax. One thing that must be considered in transmitting an analog signal is degradation of the signal. Coax cable can only transmit a signal a few thousand feet before it begins to degrade. Other cables, such as fiber optic, can carry a signal much farther before the signal begins to suffer. Digital video does not use a continuous signal. A digital video signal is actually a series of sampled values from an analog signal. Sampling is the process of taking measurements at a given interval of time. This series of numbers, which represents the actual analog video, can then be stored or transmitted to digital devices, such as computers, where they can be viewed.

There are many reasons to go from analog to digital. Digital signals can be stored and retrieved with no change from the original signal. Analog signals can degrade over time, introducing artifacts to the video that were not originally there. Digital signals can also outperform analog signals in many ways, including a wider range in sound on digital sound versus analog. While technologies are advancing and making digital video more widely used, it is not perfect. Digital video can be very large to transmit and store and therefore must be compressed to be useful in most cases. This compression can lead to the loss of some original information, and lead to artifacts being introduced into the video. The process of compressing, and then decompressing, the video is the main key in transmitting digital video. That process will be discussed in greater detail in later sections.

5.2.2. Video Characteristics

Every video feed, whether it is analog or digital, shares common characteristics. These characteristics shape what users see when they view the video. By knowing what each characteristic is, and how it affects the video, one can be better prepared to know what steps may be taken to improve the quality of the video they are seeing.

5.2.2.1. Frame Rate

Samples of different frame rates are on the enclosed CD.

The process of transmitting video from one source to another is accomplished by sending one still image after another. Each successfully transmitted image is known as one frame of video. The frame rate of a video feed is the number of frames per second that are captured and sent for viewing. When a series of still images are shown rapidly in succession, the illusion of movement is created for the viewer. In order for a human to see this illusion and perceive it as full motion, a frame rate of 25-30 frames per second (fps) must be used. Some applications may not require full motion video, and a lower frame rate may be used, but it is important to note that this may not be seen as full motion at the viewing location.

5.2.2.2. Resolution and Aspect Ratio

Samples of different resolutions and an illustration of pixels per inch are on the enclosed CD.

The resolution of a video can be thought of as a measurement of how clear the image is when displayed on a monitor. It is measured in terms of horizontal and vertical lines that are displayed. A resolution of 800 x 600 has 800 horizontal lines and 600 vertical lines. As the resolution of an image increases, the clarity of the image will increase. Digital resolution is a little different, as it refers to pixels instead of lines. A pixel is the smallest amount of information that can be stored for an image.

The higher the number of pixels the more detailed an image is. A digital resolution of 800 x 600 is 800 pixels wide and 600 pixels in height.

The aspect ratio is the ratio of width versus height on a monitor or TV screen, and is written as width:height. The two common aspect ratios used in video today are 4:3 and 16:9. Standard definition television uses an aspect ratio of 4:3, and high definition uses the 16:9 aspect ratio. The following figure illustrates some different resolutions and their aspect ratios, along with some examples of technologies that use those settings. The technologies will be further discussed in a later section.

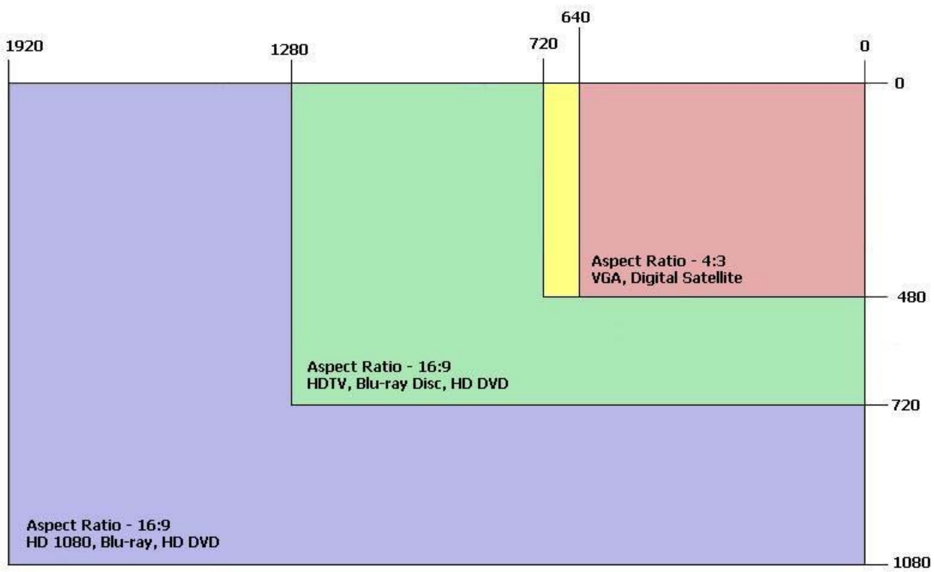

Figure 5-1. Common Video Resolutions

5.2.2.3. <u>Luminance and Chrominance</u>

The luminance and chrominance refer to the black and white and color aspects of the image, respectively. The luminance describes the dark and light values in the picture. The darkest value is pure black, and the brightest is pure white. Most of the resolution that a human eye sees in an image is contained in the luminance part of the image (1, 13). The chrominance of an image describes the color portion of the signal. Chrominance contains two measurements, hue and saturation. Hue is the actual color we see such as red and blue. A stop light, for example, has three hues, red, green, and yellow. The saturation refers to the intensity of the hues in the image. A light green color has a different saturation than a dark green. An intense color is said to be saturated, while a weak color is said to be pale, or pastel.

5.2.2.4. Color Depth

Samples of different color depths are on the enclosed CD.

The color depth of a picture is the number of bits of information used to represent the color of a pixel. Each bit is presented in Base 2, so 1 bit is 2^1 or 2 colors total, black and white; 3 bits of information, 2^3 provides 8 colors total; 8 bits of information, 2^8 provides 256 colors total, which was used on early computer systems. Higher color depth implementations, like 24-bit, 30-bit, or 32-bit color provide for millions of possible colors with the goal of presenting the video image in true color.

5.2.2.5. Contrast Ratio

The contrast ratio is the difference between the lightest and darkest values in an image. Generally a high contrast ratio produces the best display, but this is not always the case, and at times a lower ratio will produce a more desired display.

5.2.2.6. Signal to Noise Ratio

Noise in a video signal is best described as unwanted information mixed in the desired signal. Noise has many different causes including interference from other equipment, poor circuit design, over amplification of signal, or many other possible causes. The ratio of noise in a signal to the usable signal is known as signal to noise ratio, or SNR. While humans tend to have a high toleration of noise, and can generally distinguish between noise and usable content, computers do not respond well to noise. Digital video with lots of noise will cause data to have to be resent to its intended location, which can slow down a network and affect the efficiency of the system. The SNR is more of a measure of the equipment, lower quality equipment can introduce more noise than high quality equipment, than a measure of the video signal itself.

5.2.3. Signal Characteristics

While some characteristics deal with the video, other characteristics that affect the final product affect the signal itself. These characteristics can improve, or degrade, the video as much or more than any of the video characteristics.

5.2.3.1. Bit Rate

The bit rate, sometimes described as data rate, is the number of bits sent over a network in a given amount of time. Bit rates are measured in terms of bits per second. With the amount of bandwidth available today bit rates are generally written in terms of megabits (1,000,000 bits) per second, written as Mbit/s, or gigabits (1000 megabits) per second, Gbit/s. The bit rate that is used in video feeds is usually determined by the available bandwidth in the network. A higher bit rate will produce better quality video, at the expense of using more bandwidth. Video streams used today range from 2.0 Mbit/s for VHS quality up to 27 Mbit/s for high definition video.

Samples of varied bit rates for different encoding schemes are on the enclosed CD.

5.2.3.2. Compression

Compression is the process of removing extra, or redundant, information from a signal. By removing the data it makes the signal smaller, and can therefore be transmitted using less bandwidth, or recorded with less storage space required. There are many different algorithms that are used in order to accomplish the desired compression. The algorithms attempt to remove as much data as necessary without changing the content. Some of the more commonly used compression algorithms, such as MPEG, MPEG-2, and H.264 will be discussed in more detail later.

Samples of different compression, or encoding schemes, are on the enclosed CD.

5.2.3.3. Latency

Latency is another way to describe delay. Latency can be affected by the speed of the media used to transmit the data, how far the transmission must go, or one of many other factors. In some instances the latency will not affect the quality of the video. If the video is simply being recorded for later use, a small latency can be acceptable. However, some applications require real-time video, and a significant delay can hurt their performance.

5.3. Video Distribution Using IP

5.3.1. Introduction

Distributing video across a network requires communication between the sending and receiving device. With the growing capacity in networks to handle large amounts of bandwidth, IP-based video transmissions have become more and more popular. IP is a low-level networking protocol used by computers and other hardware to communicate across networks. Today it is common to see

IP referred to as TCP/IP. TCP, which stands for Transmission Control Protocol, and IP are actually two different protocols that belong to a large number of Internet protocols. However, TCP/IP has become known in the industry to stand for the family common Internet protocols. The protocols stem from a Defense Advanced Research Projects Agency (DARPA) project dealing with the interconnection of networks in the late 1970s. By 1983 it was mandated for all United States defense long-haul networks. Over time, TCP/IP became accepted throughout the world and is now an internationally known and supported protocol, becoming the most important protocol used by the Internet.

IP works as a “messenger” protocol – its functions are to address and send data packets. The IP protocol contains three pieces of information: the IP address, subnet mask, and default gateway. The IP address, which is the identity of each node on the network, is 4 bytes long, each separated by a dot. It contains two pieces of information, the node’s network ID and the system’s host ID. The subnet mask, also 4 bytes separated by dots, is used to extract the network and host ID from the IP address. The default gateway is the entrance point to the nodes network.

TCP/IP is the most complete networking protocol available. Because of this it has also become almost universally accepted and can be utilized in virtually any networking environment. In addition to supporting the protocol, the source code is also available on many operating systems. This has made it much easier over time to extend the suite of protocols. In addition to the software source code, virtually every piece of network software produced has TCP/IP support. TCP/IP packets are actually “encapsulated” or surrounded by the network protocol in use, such as Ethernet, Frame Relay, ATM, etc. Because TCP/IP is so universal, it can be used to provide functionality and communications across disparate networks.

5.3.2. Video Encoding and Decoding

5.3.2.1. Introduction

Video signals, in their original state, are much too large to transmit over a network using IP. In order to transmit the video the signal must be altered in some manner. Video encoding and decoding is the process of altering a signal, making it smaller, in order to transmit the video over a network. A video source is first encoded at its source, making the video capable of being sent over the network. The video is then sent, using the IP protocol, to its intended destination(s). Once it reaches its destination, it must be decoded back to its original format so it can be viewed. Encoding and decoding the video introduces some level of quality loss to the signal depending on the algorithm used. These algorithms are known as codecs, which comes from combining the "co" from compressor and "dec" from decompressor. Some of the more common codecs are discussed in detail in later sections.

5.3.2.2. Hardware vs. Software

There are two types of encoders and decoders in use today, hardware and software. Hardware encoders/decoders are stand-alone pieces of equipment, designed specifically for the purpose of transmitting video. The video source is connected directly to the encoder, which is also connected to a network. The video is then encoded and transmitted through the network to a corresponding decoder located somewhere else on the network. The decoder will then output the video to some viewing device, whether it be a television, VCR, DVD player, or other device. Theoretically any encoder can be paired with any decoder that utilizes the same codec. This, however, may not always be the case as some vendors will have slight variations to the standard codec that will only allow it to connect to a device by the same vendor.

Software encoding and decoding works in a similar way, but runs off of a PC, instead of a separate piece of equipment. Software encoding consists of software that runs on the PC, which encodes video into a format that can be transmitted over a network, or stored on the PC as a file. The video can then be viewed by anyone with a PC that has the corresponding decoding software. With the continued improvement of networking capability software encoding has become very popular over the internet, with many companies using streaming live and recorded video on their websites. This has lead to the development of multiple software options.

5.3.2.3. RealVideo

RealVideo, developed by RealNetworks, is an architecture that was designed for transmitting live video over the Internet. RealVideo was first published in 1997 and uses a proprietary codec. The standardized Real Time Streaming Protocol (RTSP) is used by RealVideo to set up and manage a connection for streaming, but all the data is sent using the proprietary codec. This makes interoperability across software hard with RealVideo, making the player available from RealNetworks, RealPlayer, the main player used to view RealVideo feeds. The player can be downloaded for free and is available for multiple operating systems, making sharing the video with other users relatively simple. RealVideo also supports both regular IP and multicast connections for sharing with a large number of users at one time without increasing the necessary bandwidth.

Until recently RealVideo only used a constant bit rate for encoding. This ensured that a set amount of data was sent out each second. RealNetworks has since introduced a variable rate form, called RealMedia Variable Bitrate (RMVB), which allows for better quality in transmission. This could cause problems if the video requires more bandwidth that is available on the network, which would lead to an interruption in the video stream. When being compared to other similar encoding schemes, RealNetworks claims that the newest version of RealVideo, RealVideo 10, can reduce the bandwidth needed for streaming video by as much as 80 percent when compared to other codecs *(1)*.

5.3.2.4. QuickTime

QuickTime, developed by Apple, is a multi-platform software architecture that synchronizes video, audio, text, graphics, and music. QuickTime does not use a proprietary codec and supports standardized codecs such as MPEG-4 and H.264. The QuickTime streaming software supports both unicast and multicast connections for distributing video. Apple does offer a free QuickTime Player to view QuickTime streams. Since it uses standardized formats, video streamed via QuickTime can be viewed by any media player that supports the required software. QuickTime is also viewable by many standard compliant devices, such as mobile phones, making it possible to reach a wider audience. While the streaming software was designed to run on Mac OS X, there is an open source server available to run on both Windows and Linux.

5.3.2.5. Windows Media Services

Windows Media Services is the streaming media software developed by Microsoft. Windows Media Services transmit video using several proprietary video codecs developed by Microsoft. There are a few different options available for streaming video, including Windows Media Encoder. Although the codecs used are proprietary, there are many options available for viewing media streams in this format. Sharing video from

Windows Media Services is generally an easy process. PCs that come with a Microsoft operating system have a player preinstalled that will allow the user to view media services feeds, this lessens the amount of complications that could arise from attempting to share the video.

5.3.2.6. Advantages/Disadvantages

There are advantages and disadvantages to both the hardware and software methods. Hardware encoding/decoding can be expensive. Each location where video needs to be encoded requires its own encoder, and similarly each location where video needs to be viewed must have its own dedicated decoder. Software, on the other hand, can be cheaper than hardware, especially when there are multiple destinations for the video. Generally, the decoding software is available free of charge for anyone to use. If there is one video feed that needs to be shared with 10 separate locations, you only have to purchase one piece of software to encode the video. While it may be cheaper than hardware, software can be very intensive on the PC. You must have a PC capable of handling the load required for the video encoding, and often this will lead to the PC being dedicated solely for the purpose of encoding the video. It must also be pointed out that some hardware encoders do have software decoders available for viewing. This setup can be very helpful when the viewing of video will take place on PC(s) but the video encoding requires a hardware encoder.

5.3.2.7. Transmission Output

When setting up a video distribution system it is important to understand the different transmission outputs available, multicast and unicast. A multicast broadcast is a one to many relationship, where one source can be viewed at many different destinations. Multicast works by using an IP address that is not specific to one location. Instead the encoder sends out the transmission on multicast addresses. Multicast addresses are then forwarded by routers to any destination that requests the feed. A unicast feed works as a one-to-one relationship between one source and one destination. When set up for a unicast feed, the encoder's destination is the IP address of the decoder and no other destinations are able to receive the feed. Unicast feeds are desirable in some instances, but if the feed is going to be viewed at more than one destination a multicast feed is more efficient than having multiple unicast feeds.

5.3.3. Video Format Types

5.3.3.1. Introduction

There are few topics more confusing or misunderstood to the lay person than multimedia. The term multimedia is a very broad and encompassing topic that can include all video, audio, analog, and digital. Part of the misunderstanding is the belief those terms and definitions are understood when in reality they are not. When trying to explain different topics of multimedia it is important to break down all definitions and acronyms into their true individual parts. Multimedia sound bites pass along the general idea about a topic but not very much useful information. MPEG-4 video is a good example of a multimedia term that is used very often but is generally misunderstood. In product literature and brochures, a company may say its product recodes and plays in the MPEG-4 format, as opposed to AVCHD, or MPEG-2. The MPEG-4 referred to is, in reality, the H.264/MPEG-4 AVC standard, which is actually a collection of standards, specifications, audio formats, video formats, audio compression and decompression, video compression and decompression, and stream types, all wrapped in a container format called MPEG-4. Each of the aforementioned items has its own set of guidelines that make up the MPEG-4 format. It is easier to simply say the video camera records in the MPEG-4 format than to list all its individual components. The following list of multimedia formats covers the general usage in the marketplace from the past to the future. Multimedia format types cover both physical hardware such as camcorders, cameras, videotapes, and hard drives as well as software types like container formats and video settings.

5.3.3.2. AVCHD

AVCHD is a new format of high-definition recording developed or used by Sony, Panasonic, and JVC for use in digital tapeless camcorders. The recorded data can be stored in multiple ways depending on the camera manufacturer and model. Internal hard drives, 8 cm DVD disk, SD/SDHC, and memory stick cards are the dominant available options. The digital data can be copied onto a computer directly off the camera via IEEE 1394 (FireWire), at high speeds of up to 50 Mbytes per second. Compared to the HDV format with its MPEG-2 TS compression, AVCHD camcorders achieve higher compression and lower data rates with comparable image quality. Another major difference is the HDV format requires real-time playback of the tape via IEEE 1394 (FireWire) connection to a computer.

AVCHD is a container format that is a suite of standards that includes video compression in the MPEG-4 AVC/H.264 format. Audio compression is in AC-3 or PCM format, and the system stream type is MPEG-2 Transport stream (TS). Technology in the consumer market of HD has still not advanced to the point of 100 percent full HD of 1080p resolution. The latest AVCHD cameras (as of August 2008) are still only capable of 1080i interlaced video maximum. A significant point of fact to consider with AVCHD when editing and converting media files is the considerable computer power required. Editing AVCHD files requires the very latest multi-core processors with gigabytes of RAM and hard drive space. Just standard video playback can be impossible for old computers.

5.3.3.3. Blu-ray

The Blu-ray disc is an optical digital storage media format in addition to being a format type. Its three primary functions are high-definition video, PlayStation 3 console games, and data storage. The physical dimensions of the disc are the same as a standard CD or DVD. The high capacity of the Blu-ray disc allows it to hold full-length motion pictures in high definition 1080i/p along with interactive content. All current Blu-ray players are manufactured to be backward compatible, enabling them to play both DVDs and CDs. The Blu-ray names comes from the fact the laser used to read and write to the disc is in the 405nm wavelength of blue-violet. Blu-ray discs are available in both single and dual layer configuration. The single layer design holds 25 gigabytes of data. The dual layer stores 50 gigabytes. A dual layer Blu-ray disc holds approximately 5.9 times more data than a dual layer DVD disc, which holds 8.54 gigabytes of data. The Blu-ray disc became the sole winner of the high definition optical disc format war when Toshiba officially announced it would stop manufacturing and developing HD DVD. The HD DVD standard was a rival format to Blu-ray with similar video, audio, and near data storage capabilities.

5.3.3.4. Container Format

A container format is a computer file that contains other files. The files it contains depend on the container format itself. Older container formats, like AVI, can contain a limited set of data such as audio and video but not still images and menu structures used in DVDs. A container format is analogous to TCP/IP and packages received in the mail. TCP/IP are wrappers for data transmitted in networks. The TCP/IP itself does not contain the data. They contain the instructions on how the files are to be assembled and the paths they are to take when traversing the network. In the package at home analogy, the package received in the mail is not important, it is the contents of the package that are of value. The outside package was simply a means of transporting, storing, and protecting the contents. Depending on the contents to be sent the container may be different. If a letter is sent it will have a different container than a fragile chandelier. For PCs the container format does not define what compression formats (codecs) the files will take but how the audio, video, and possibly other data is stored. If more than a single audio or video file is contained, the container format interleaves the different data types, which can include audio and video support for multiple subtitles, meta-data, and still images. Some container formats are exclusive to audio, such as AIFF and WAV. Some container formats are exclusive to still images, such as Flexible Image Transport Systems (FITS), and Tagged Image File Format (TIFF). Other multifunction container formats have the ability to hold many types of audio, video, and meta-data. Some of the more recognizable ones are 3gp (used by many mobile phones), AVI (the standard Microsoft Windows container), MPEG-2 transport stream (standard container for digital broadcasting; typically contains multiple video and audio streams, and an electronic program guide) and program stream (PS), MP4 (standard audio and video container for the MPEG-4 multimedia suite), MOV (QuickTime video container from Apple Inc.), Real Media (container for Real Video and RealAudio).

5.3.3.5. Digital8

Digital8 is a discontinued digital tape media recording in the DV format. Digital8 uses the same digital codec as MiniDV, while using older technologies, such as 8mm and Hi-8 analog tapes as the medium. Digital8 camcorders allow recording in a digital format with backward capability with the older prerecorded tapes. Digital8 has a horizontal resolution of 500 lines and high quality PCM 16bit/12bit mode digital stereo sound. The Digital8 format consumes tape at a higher rate than the analog versions giving it only a 130 minute maximum recording length.

5.3.3.6. Digital Video Format (DV)

Digital Video Format, also referred to as DV or DV25, is a digital video format and compression, not a media. The DV25 (DV for short) format is a limited container format that uses cassette tapes in the "L-size" which is the largest available, with a dimension of 120 × 90 × 12 mm. The most widespread use of the DV format is with the MiniDV in consumer digital cameras. It has a form factor size of 65 x 48 x 12mm. The maximum record time on the MiniDV tape is 120 minutes. The DV format calls for a higher video resolution of 520 lines of resolution compared to Hi-8's resolution of 480, or 8mm and VHS at 250 lines of resolution. DV uses Intraframe Discrete Cosine Transform (DCT) which is similar to MPEG, but it is comprised solely of I-frames, meaning there are no predicted frames. The I-frames are compressed within each frame, yet have no relation to other frames. Each I-frame is a self-contained unit. DV is compressed at a fixed bit rate of 25Mbps in addition to the audio at a 1.5 Mbps bit rate, plus approximately 9Mbps of subcode data, error detection, and correction, totaling roughly 35 Mbps. Thirty-five Mbps is the equivalent of approximately 19 Gigabytes per hour on a computer hard drive. The DV format has two audio options. The first and most common is two digital (stereo) audio channels at 16 or 12 bit resolution and a 48 kHz sampling rate. The second option is 4 digital audio channels at 12 bit resolution and 32 kHz sampling rate. The DV format has a fixed compression ratio of 5:1 whether the images are pure black or fast moving data. DV has a color ratio of 4:1:1. This ratio shows how often the luminance is sampled compared to how often the color is sampled. Nearly all DV cameras have an IEEE 1394 (FireWire) interface and analog composite video and Y/C outputs. High-end DV recorders allow the recording of video back through the IEEE 1394 and composite and Y/C outputs. With a FireWire connection the camcorders can be controlled via editing software on a personal computer.

5.3.3.7. DVD

The DVD disc is an optical digital storage media format, in addition to being a format type. Its primary functions are standard definition video playback and data storage. The physical dimensions of the disc are the same as a standard CD or Blu-ray disc. The DVD format is based upon some of the same basic technologies as the CD. The high capacity of a dual layer DVD disc allows it to hold full-length standard definition motion pictures at a resolution of 720 x 480 at 29.97fps. Interactive content can also be included in this double layer configuration. DVD uses a red laser diode in the 650nm wavelength while a CD works in the 780nm wavelength. Smaller wavelengths allow smaller pits to be etched on the media surface, giving it a larger capacity. The DVD disc is available in both a single layer and dual layer configuration. Single-sided and double-sided discs are also available, which double the discs' storage capacity versus a single-sided disc. A single-sided single layer DVD holds 4.7 gigabytes of data while a dual layer double-sided disc holds 17 gigabytes. In comparison the smallest DVD holds approximately 6.7 times more data than a standard CD. There are many types of DVDs, including DVD-ROM, DVD,-RAM DVD-R, DVD+R, DVD-RW, and DVD+RW. The extension after DVD describes the way in which data is recorded onto the disc. As an example, DVD-ROM contains data that can be read, but not written, whereas DVD-RW is a disc that can be written to, read, erased, and written to again and again.

5.3.3.8. High Definition DVD (HD-DVD)

The HD-DVD disc is an optical digital storage media format in addition to being a format type. Its primary functions are storage and playback of high-definition video and data storage. The physical dimensions of the disc are the same as a standard CD or DVD. The HD DVD format is based upon the same basic technologies as the DVD. The high capacity of the HD DVD disc allows it to hold full-length motion pictures in high definition 1080i/p as well as interactive content. The HD DVD disc is available in both a single layer and dual layer configuration. A single layer disc can hold 15 GB of data, and a dual layer disc can hold 30 GB. In comparison, an HD DVD dual layer disc holds approximately 3.5 times more data than a dual layer DVD. On February 19, 2008, HD DVD conceded the format wars to Blu-ray, a rival high-definition format with similar video, audio, and data storage capabilities. On this date Toshiba officially announced it would stop manufacturing and developing HD DVD players.

5.3.3.9. High Definition TV (HDTV)

HDTV is a format type and physical hardware. The current television system in America started in 1939. Standard Definition Television (SDTV) has 525 lines of resolution at 60 hertz with an aspect ratio of 4:3. This is being replaced by a 1080 lines of resolution 16:9 aspect ratio, or HDTV. In the United States, HDTV has been around since 1981 when it was first demonstrated. In America the conversion to HDTV officially began in 1996 when Congress mandated the conversion to digital broadcasting. The conversion to digital transmission will free radio spectrum use for other public uses such as public safety, fire, police, and other commercial services. The digital television transition concluded on June 12, 2009, when all full power public televisions stopped transmitting in analog and began transmitting only in digital. Without an analog to digital converter, analog televisions are unable to view programs transmitted over the air. Cable and satellite transmission subscribers will not be affected. HDTV has taken so long to come to the retail market because in its early analog form, too much valuable radio frequency spectrum was consumed. Several HDTV systems have been proposed and demonstrated in the United States as the new HDTV format, including the Japanese MUSE system. Eventually they were all rejected by the FCC because they all consumed more bandwidth than presently being used for standard SDTV broadcast. The new American HDTV standard was required to transmit within a lower bandwidth than presently used with SDTV. Analog transmission of HDTV is not possible within the bandwidth of SDTV. Presently the SDTV system uses approximately 6 megahertz of the VHF radio spectrum per second for a complete television picture transmission. HDTV, using the same analog equipment, consumes approximately 26 megahertz of the VHF radio spectrum per. Digital transmission of an HDTV signal with a very high compression ratio is the only way possible to transmit more data with less data bandwidth available for use. The FCC adopted the ATSC, the Advanced Television Systems Committee. The United States has three different formats of HDTV, which are 720p, 1080i, and 1080p. Each format is either interlaced or progressive. Interlaced and progressive define the way the TV screens are continuously drawn. The interlaced (i) format draws one half the image on the screen skipping every other line, from top to bottom, then starts over at the top, beginning with the missed line. The progressive (p) format draws an entire image on the screen in one pass. Computer monitors are progressive screens. The 720p format has a screen resolution of 1280x720. The true HDTV formats are 1080i and 1080p with a screen resolution of 1920x1080. Currently HDTV terrestrial broadcast transmits in 1080i. To get the full 1080p resolution, a different video source is required. Blu-ray, Sony's Playstation3, and Microsoft's Xbox360 currently offer full 1080p output.

5.3.3.10. High Definition Video (HDV)

HDV is a new format of high-definition recording for use in digital cameras similar to AVCHD. The HDV format uses MPEG2 TS compression format to fit HD content onto the same DV, or MiniDV, tapes previously used in the DV format of digital record for standard definition. Using a prior generation tape media has both advantages and disadvantages. The major advantage is the reduced cost of the tapes compared to solid state media. The second advantage is that the tapes themselves are a master archive. Solid state memory has no backup, and if the hard drive or solid state memory fails without a backup, all is lost. The HDV format came to the marketplace before AVCHD and, as of August 2008, still commands a larger share of the market. HDV is considered a transition format to HD video recording. The first HDV cameras only used the SD MiniDV tapes to record video. With improved electronics, the HDV format is able to compress 1080i HD video onto MiniDV tapes at the same speed as the SD recordings. HDV records at a slightly higher bit rate of 25 Mbps for the MPEG2 TS compared to AVCHD, which uses MPEG-4 AVC/H.264 compression and a maximum of 24Mbps. Even with a higher bit rate, HDV video quality is still comparable to AVCHD, since AVCHD can compress the video and audio more efficiently. The major disadvantage of HDV compared to AVCHD is that HDV requires a tape system. With tapes, in order to edit the master on a PC, it must be played in real time via an IEEE 1394 (FireWire) connection to the PC. An AVCHD does not have this restriction because the storage medium is some form of digital media. With AVCHD, digital data can be copied onto a computer directly off the camera via FireWire, at high speeds up to 50 Mbytes per second. Since the first HDV format was introduced, a major advance in the recording format has been made. A few modern HDV cameras have hard drives for the storage medium and not tapes. The use of hard drives brings with it the same advantages and disadvantages that AVCHD has had with hard drives. HDV, with its I-Frame compression is easier to edit on a PC then AVCHD. The hard drive space to store the master edit files is approximately the same as AVCHD, but the actual editing of data is less demanding.

5.3.3.11. <u>Video CD (VCD)</u>

VCD is a digital format for storing standard definition audio and video on a standard CD. The VCD specification calls for an image quality comparable to standard VHS tapes. Typically CDs are formatted in CD-ROM mode 1 which has approximately 700 MB of data storage available. In CD-ROM mode 2 a CD has approximately 800 MB of data per disc for VCD recording. This equates to approximately 80 minutes of standard audio and video. The VCD specifications call for a MPEG-1 Codec, a resolution of 352x240, a 4:3 aspect ratio, a frame rate of 29.97, and a constant bit rate of 1,150 Kbit/sec.

The audio specified is 224 Kbit/sec MPEG-1 Layer2 Audio. This bit rate equates to a minute to minute ratio listed on the CD. If the CD states it's an 80 minute CD, it can hold 80 minutes of VCD recording. A 74 minute CD holds 74 minutes of video. The CD standard operates in the near infrared with laser diodes in the 780 nm wavelength. Unlike the SVCD standard, the VCD format is compatible with the DVD specification. At SIF resolution (352x240) the VCD is ½ the resolution of a NTSC signal. Modern DVD players are usually backward compatible with older technology like VCDs. Most new standalone and computer-based DVD and CDR players have the ability to play VCDs in their native format.

5.3.3.12. Super Video CD (SVCD)

SVCD is a digital format for storing standard definition audio and video on standard CD. The SVCD specification calls for an image quality better than standard VCD and VHS tapes with the ability to store a minimum 35 minutes per CD. If a longer video playback time is desired, video quality must be lowered. The specifications for a SVCD are an MPEG-2 Codec, a resolution of 480x480, a frame rate of 29.97, and a constant bit rate of 2,600 Kbp/sec. The audio specified is 44100Hz and 32 -384 Kbit/sec MPEG-1 Layer2 or MPEG2 Audio with up to 2 Audio Tracks. SVCD has aspect ratio abilities of 4:3 and 16:9. The SVCD standard is incompatible with the DVD-Video standard due to resolution differences. Modern DVD players are generally backward compatible with older technology such as SVCD. Most new standalone, computer-based DVD players have the ability to play SVCDs in their native format.

5.3.3.13. MiniDV

MiniDV, also referred to as Consumer DV or Regular DV is the most common DV format. MiniDV tapes, which are universal to all DV devices, are a digital tape media and not a format type or specification. MiniDV cassettes have a dimension of 65 × 48 × 12 mm and hold either 60, 90, or 120 minutes of video depending on whether the video is recorded at Standard Play (SP) or Extended Play (called Long Play on some recorders). Uncommon and more expensive 80 minute tapes use thinner tape and can record 120 minutes of video in EP/LP mode. These tapes sell for as little as US $6.00 each at retailers as of August 2008. DV recorded in SP mode has a helical scan track width of 10 micrometers, while EP mode uses a track width of only 6.7 micrometers. MiniDV tapes were originally designed for recording digital SDTV. Newer HDV camcorder use MiniDV tapes as their storage medium. Through higher compression they record in the same 25 Mbps tape speed using the MPEG-2 Video compression.

5.3.3.14. MOD and TOD

MOD and TOD are common names of tapeless video recording formats. Because they are tapeless, they are generally used in hard drives, memory cards, and SD memory. MOD files are used solely for standard definition video files, while TOD files are used for high definition files. There is no official name for the file extensions used. MOD and TOD formats are file-based and are stored using random-access media. Directory structure and naming convention are identical except for extensions of media files. MOD Standard Definition video is stored in MPEG-2 program stream (PS) container files. It is possible to change the file extension from MOD to MPG in computer editing software to be compatible. MPG and MPEG are the standard file extensions used in other formats. TOD high definition video is stored in MPEG-2 transport stream (TS) container files. It is possible to change the file extension from TOD to M2T in computer editing software to be compatible. M2T is the standard file extension used in other formats. One big advantage of the MOD video format is that it can be watched on a computer with a player capable of reproducing MPEG-2 video. MOD files can easily be created for watching on a DVD player without transcoding or recompression because they are fully compliant with the DVD standard. The high definition HD TOD format is comparable with AVCHD, but cannot be directly played on consumer computer video equipment. To be watched directly, the camera has to be connected to the television. To be watched from a source other than the camera, such as Blu-ray, the files have to be transcoded and edited with an authoring program on a computer.

5.3.3.15. Video Home System (VHS)

VHS is an analog tape media. In 1976 JVC launched the full size ½ inch (12.7 mm) VHS tape. In 1982 VHS' smaller form factor brother VHS-C (Video Home System – Compact) using exactly the same ½ inch (12.65 mm) wide magnet tape was introduced. VHS tapes have a bandwidth of approximately 3 MHz, giving the modern 4 Head VCR an output of 230 to 250 lines of resolution, depending on tape speed recording. As a general rule the faster the tape moves across the recording heads the higher the quality. With the 230 to 250 lines of resolution, the VHS system records at a slightly lower resolution than 8MM. The standard T-120 VHS tape has a recording time of 2 hr, and the standard T-30 VHS-C tape has a recording time of 30 minutes. The only difference between the VHS and VHS-C is the size of the cassette, with the ½ magnet tape being the same. The VHS cassette tape has dimensions of 7 3/8″ wide, 4″ deep and 1″ thick (187 mm x 103 mm x 25 mm). The smaller form factor VHS-C cassette tape has dimensions of 92 mm wide x 58 mm deep x 20 mm thick. Studio movies are no longer made for the VHS format, and its popularity has diminished drastically with the introduction of higher resolution options such as the DVD.

5.3.3.16. 480i

480i is a shorthand term used to describe a video resolution. The 480 stands for 480 lines (pixels) of vertical display resolution. The "i" stands for interlaced video. 480i at a 4:3 or 16:19 aspect ratio is considered SD television. Interlacing is a method of improving the picture quality of a video signal largely on Cathode Ray Tube (CRT) devices without consuming extra bandwidth. Interlacing is the process whereby a single frame of video is split into two equal horizontal parts to be displayed on an output device. Interlacing uses two fields to create a single frame. One field contains all the odd lines in the picture while the other contains all the even lines. The scan starts at the top left of the screen on the first line and proceeds to the bottom right skipping every other line. After the scan reaches the bottom right it starts again at the top left on the second line. A field is an image that contains only half of the lines needed to make a complete picture. CRT screens differ from LCDs in several major ways. A CRT by the nature of its construction has a phosphor afterglow. This persistent glow along with human vision results in two fields being perceived as an uninterrupted image. This exploitation of our human vision deficiencies enables the viewing of full horizontal detail with half the bandwidth required for a full progressive scan image. CRTs are the only devices that can natively display interlaced video directly without flickering. Interlacing can cause problems on non CRT output devices such as LCD projectors, and plasma screens. To properly display interlaced images on these devices requires some form of de-interlacing to properly display the image.

5.3.3.17. 480p

480p is a shorthand term used to describe a video resolution. 480p is not considered to be high definition but enhanced definition. The 480 at the beginning stands for 480 lines (pixels) of vertical display resolution while the "p" stands for progressive scan video. Progressive scan is the process whereby an entire frame of video is displayed on an output device in a single pass. The field pattern is started at the top left on the first line and drawn consecutively line by line to the bottom right then started again at the top left. Progressive scan can have a variable field rate of 30 or 60 frames per second. The field rate when displayed is written with the number of field refreshes per second after the "p" such as 480p30 and 480p60. The 30 and 60 denote how many times per second the entire screen is refreshed.

5.3.3.18. 720p

720p is a shorthand term used to describe a video resolution. The 720p specification is the lowest format that is considered HDTV. Presently, over the air broadcast at 1080p with 30 frames per second is the (official) highest resolution with the new American HD ATSC standard. Changes to the ATSC standard are in flux and have been changed many times in the past few years. It is anticipated that 1080p60 will eventually be the ATSC standard with even higher resolutions still possible. The new HD specifications of 720p, 1080i, and 1080p all assume a widescreen aspect ratio of 16:9 vertical resolutions with varying vertical resolutions. The 720p horizontal resolution of 1280 pixels gives it a total pixel count of 921,600. The ATSC 720p specification has the two frame rates of 720p24 and 720p60 available. The p24 is 24 frames per second and mainly used for movies (which use a film speed of 24fps) and the p60 which is normal HD ATSC broadcast. Three points of fact need to be mentioned about the 720p and 1080p specification, which is discussed later. The first point is that both 720p and 1080p are directly compatible with the newer flat-panel technologies of LCD and plasma displays because they are progressive in construction and must perform de-interlacing to display 1080i signals. The second point is that progressive scan reduces flickers and combing effects in images because it does not have to combine two slightly time shifted images to get the whole picture. The third fact is that 720p and 1080p signals must be scan-converted for display on CRT televisions, which are, by and large, interlaced display devices.

5.3.3.19. 1080i

1080i video resolution has 1080 lines (pixels) of vertical display resolution and uses interlacing to display video. Human vision has a persistence effect; if an object flashes fast enough it can be perceived as a single object. This exploitation of our human vision deficiencies enables the viewing of full horizontal detail with half the bandwidth required for a full progressive scan image. 1080i also implies a horizontal resolution of 1920 pixels combined with the 1080 vertical pixels, which give a ratio of 1920 × 1080 and about 2.07 million pixels. Most new LCD technology has the ability to receive at different frame rates. The standard rates for 1080i are 1080i24 for movies, 1080i30 for standard HD video, and 1080i60 for HD fast movement images.

5.3.3.20. 1080p

1080p is a video resolution with 1080 lines (pixels) of vertical display resolution that uses progressive scan to display the video. The 1080p specification can be referred to as full HD, full high definition, or native 1080p capable to differentiate it from other HDTV video modes. Early model HD equipment capable of displaying both 720p and 1080i may not have the ability to display 1080p or 1080i material at full resolution. It is common practice for this video material to be downscaled to the native device capability of the equipment. New HD specifications of 720p, 1080i, and 1080p all assume a widescreen aspect ratio of 16:9 vertical resolutions with varying vertical resolution. In the United States, the ATSC standard presently allows support of 1080p24 and 1080p30 video (24 and 30 frames per second) with a MPEG-2 codec. The ATSC is contemplating amending the standard to allow more advanced codecs such as H.264/MPEG-4 AVC. Increased resolution and frame rates, such as 1080p60, can only be accomplished using more bandwidth or the more advanced codes. An important fact to remember is audio and video content can be encoded in one format but transmitted in another format. The only way presently to receive full HD (1080p60) is with an external output device having a component video or HDMI output. The output and input connectors are one determining factor in SDTV or HDTV. Composite video, S-Video, and Coax are only capable of SDTV and EDTV. 1080p60 encoded movie titles have been released in the past on Blu-ray Disc, DVD, and HD DVD.

5.3.4. Video Comparison of Different Media Types

Table 5-1 listed below contains a comparison of past and present analog and digital video format measurements along with traditional analog, digital, standard, and HD TV lines per picture height for various recorded media. The list only includes standard (widespread) formats that were available and does not include the exotic or uncommon formats. The resolutions listed below are for the NTSC (National Television System Committee) system, which is the color encoding television system used in the United States, Canada, Mexico, Japan, and a few other countries. Phase Alternating Line (PAL) is the color encoding system used in broadcast television systems in the majority of the remaining countries not covered by NTSC. The PAL screen and line resolutions are slightly different to NTSC owning to the fact Alternating Current (AC) of 50 cycle per second are used as opposed to 60 cycle per second used in the NTSC regions. Some of the numbers below have been rounded for clarification. Multiple video formats and line resolutions are possible with some media depending on the recorded speed. As an example D-VHS recorded at LP has a 1280 x720 capability but when recorded in SP mode it can record at 1920 x 1080.

Table 5-1. Video Format Measurements.

Horizontal x Vertical Maximum (Rounded)	TV Lines Maximum (Rounded)	Devices
350×240	250 lines	Video CD
330×480	250 lines	Betamax, VHS, Video8 (8mm)
400×480	300 lines	Super Betamax, Betacam
440×480	330 lines	Analog TV Broadcast
720×480	400 lines	Widescreen DVD (anamorphic)
560×480	425 lines	Hi-8, Laserdisc, Super VHS
640x480	480 lines	EDTV (Enhanced Definition TV) normal
640x480	480 lines	Digital satellite broadcast
670×480	500 lines	Enhanced Definition Betamax
700×480	500 lines	SDTV (Standard Definition TV) maximum
720×480	520 lines	DVD, Digital8, Digital Betacam SP, miniDV
1280×720	720 lines	HDTV, Blu-ray Disc, D-VHS, HD DVD, HDV (miniDV)
1920×1080	1080 lines	HDTV, Blu-ray Disc, D-VHS, HDCAM SR, HD DVD

5.3.5. Audio and Video Standards, Compressions, and Formats

Standards are typically defined as documented agreements which contain technical specification and precise criteria covering the characteristics of the product, process, or service.

The two organizations that oversee broad audio and video standards and their development are the International Organization for Standardization (ISO) and the International Telecommunications Union (ITU). The ISO is the world's largest developer and publisher of international standards. The ISO is a network of the national standards institutes comprised of 157 countries with a Central Secretariat in Geneva, Switzerland, that coordinates the system. The ITU has gone through several name changes since it became a United Nations specialized agency in 1947. It started out as the CCITT, from the French name "Comité Consultatif International Téléphonique et Télégraphique." As of 2008 this CCITT acronym is still on many product identification labels. In 1993 it was renamed ITU-T. ITU-T is the leading United Nations agency for information and communication technologies. As the global focal point for governments and the private sector, ITU's role in helping the world communicate spans three core sectors: radio communication, standardization, and development.

Digital compression is the process of reducing the size of digital files to take less storage space or to require less bandwidth for transmission. Compression of digital files is done with codec (COding DECoding). The type of codec used generally depends on the type of content that needs to be encoded. Audio, video, and data content can all have different types of codec. Container formats are codecs that can encode and decode more than one type content at a time. A codec, as the name implies, performs the actual encoding and decoding of the raw data, while the data content itself is stored in a file with a specific structure and information. There are three major divisions into which all codecs fall. Uncompressed codecs offer virtually no compression. Lossless codecs offer some compression, with lossy codecs offering the most compression of data.

Formats are different methods used to encode content for storage in digital form. MPEG-2, Divx, JPEG, and AVI are a few examples of common formats. Formats can be engineered to store specific types of content such as audio or video only. Formats can also be engineered to be a container format (catch all), that can store audio, video, and data. RealMedia, Windows Media, QuickTime, H.264/MPEG-4 AVC are all container formats.

5.3.5.1. Adobe Flash

Prior to being purchased by Adobe Systems, Adobe Flash was called Shockwave Flash and Macromedia Flash. The Adobe Flash software has become the de-facto industry standard tool for creating interactive content of all types (Audio, Video, and Animation) for multiple device types. Adobe Flash is used for adding interactive options to websites, advertising, games, mobile devices, cell phones, and PDAs.

5.3.5.2. Advanced Television System Committee (ATSC)

"The Advanced Television Systems Committee, Inc. is an international, non-profit organization developing voluntary standards for digital television. The ATSC member organizations represent the broadcast, broadcast equipment, motion picture, consumer electronics, computer, cable, satellite, and semiconductor industries. ATSC creates and fosters implementation of voluntary Standards and Recommended Practices to advance terrestrial digital television broadcasting, and to facilitate interoperability with other media." (http://www.atsc.org/)

5.3.5.3. Audio/Video Interleave (AVI)

AVI is the original multimedia container format for Microsoft's Video for Windows multimedia framework. AVI files can contain both audio and video data in a file container, which allows synchronous audio and video playback. AVI is not designed around a single format or standard, hence the container does not include as much information about the video being stored as more specialized containers like MPEG or MP4. AVI files do not contain pixel aspect ratio information. AVI files may have square pixels, which can give frames a stretched or squeezed appearance when played back. DV-AVI is a type of AVI file where the video has been compressed to conform to the DV standards. Most DV camcorders capture video in this format.

5.3.5.4. DivX

DivX is a combination of a container format and a codec. DivX is a digital media format for video similar to the MP3 format for audio. DivX technology compresses video to a fraction of its original size using the lossy MPEG-4 ASP compression. DivX balances image and audio quality against file size for an efficient storage on storage media and is easily shared via e-mails, web pages, and removable media.

5.3.5.5. Elementary Stream (ES)

An ES is basically the raw output of an encoder and contains no more than is essential for a decoder to approximate the original picture, data, or audio. An elementary stream is defined by the MPEG communication protocol and contains only one kind of data, e.g., elementary stream picture, elementary stream audio, or elementary stream data for closed caption. The MPEG protocol does not define the codec, leaving that to the manufacturer of the encoders and decoders. The format of the elementary stream depends upon the codec or data carried in the stream, but will often carry a common header when packetized into a packetized elementary stream (PES).

5.3.5.6. H.261

The H.26x families of video coding international standards are in the domain of the ITU-T Video Coding Experts Group (VCEG). The MPEG families of video coding standards are in the domain of the ISO/IEC Moving Picture Experts Group (MPEG). These two international standards bodies have worked closely and in collaboration on H.261/MPEG-1, H.262/MPEG-2, and H.264(AVC)/MPEG-4. H.261 was the first truly functional digital video coding standard and, in fact, all subsequent video coding standards that followed H.262 to H.264 are based off the H.261 standard. The original H.261 standard coding algorithm was designed to operate at a video bit rate between 40kbs to 2Mbs. The original video frame size was 176x144 and 352x288. These specifications, while inferior to present-day standards, were more than adequate to start the video revolution we see today on the Internet and digital media.

5.3.5.7. H.262/MPEG-2

H.262 is an ITU-T digital video coding international standard, and it falls under the direction of ITU-T VCEG. It is maintained in partnership with the ISO/IEC MPEG. H.262 is identical to the video part of the ISO/IEC MPEG-2 standard. This standard was developed in a joint partnership between the ITU-T and ISO/IEC. H.262/MPEG-2 is a published standard of both organizations with the documents being completely identical in all respects. For a technical reference see MPEG-2 below.

5.3.5.8. H.263

H.263 is a video codec international standard originally designed as a low bit rate compressed format for videoconferencing. It was developed by the ITU-T VCEG. H.263 was built on the H.261 and H.262 specifications. H.263 has been used in internet video files and websites. MySpace, Google Video, YouTube, and Flash Video content is encoded in this format. Where practical, video content in the H.263 format is being converted to the newer, more efficient, and higher quality H.264 format.

5.3.5.9. H.264/MPEG-4 AVC/MPEG-4 Part 10

H.264 is an international standard for video compression. It is known by many names, such as MPEG-4 Part 10, MPEG-4 AVC, H.264/MPEG-4 AVC, H.264, or Advanced Video Coding (AVC). The reason for multiple names arises from the fact that the standard is the product of two international standards organizations' collaboration efforts in a partnership effort know as the Joint Video Team (JVT). H.264 is the latest block-oriented motion-compensation-based codec standard developed by the ITU-T VCEG together with the ISO/IEC MPEG. H.264 is comparable and in competition with the VC-1 standard. The goal of the H.264/AVC standard was to create a standard capable of providing good video quality at substantially reduced bit rates than previous standards without increasing the complexity of design so much that it would be impractical to implement. A secondary goal was to provide enough flexibility to allow the standard to be applied to a large variety of networks on a wide variety of systems and a large variety of applications. The standard needed to include low and high bit rates, and low and high resolution video. The standard also needed to operate at half or less the bit rate of MPEG-2 and H.263.

5.3.5.10. Motion Joint Photographic Experts Group (JPEG)

In motion JPEG, still images are compressed into smaller sizes using the JPEG compression method. This method removes color change information from a still picture that the human eye normally cannot see. This trimming of non-useful information allows storage of the still picture using fewer bytes than the original image. Motion JPEG takes advantage of these compression savings by encoding individual video frames into JPEG frames and then sending the sequence of JPEG frames as a video stream. The advantage of motion JPEG is that it requires the least amount of equipment complexity to encode and decode. Therefore, motion JPEG equipment tends to cost less than other types of video encoding equipment. The disadvantage is that it does not compress video as well as the other MPEG routines, and it requires the most bandwidth to transmit a video stream.

5.3.5.11. Moving Pictures Experts Group 1 (MPEG-1)

MPEG-1 takes the compression savings provided by Motion JPEG a step further by introducing compression techniques that eliminate redundant picture information between adjacent frames in a video sequence. The advantage of MPEG-1 is that it is well established as a standard. More products can decode and use an MPEG-1 stream than any other standard mentioned here. The disadvantage is that MPEG-1 does not have a large variety of options compared to other MPEG standards. Additionally, because MPEG-1 is designed to compress progressive-scan video, interlaced television signals are difficult to compress using MPEG-1. It does not easily encode higher quality video streams such as HDTV.

5.3.5.12. Moving Pictures Experts Group 2 (MPEG-2)

MPEG-2 inherited the benefits of Motion JPEG and MPEG-1, but went further to correct the functional limitations of MPEG-1. The advantage of MPEG-2 is that it is scalable and allows better picture quality than MPEG-1. It supports interlaced video encoding by design. It is used in many applications including DVDs, HDTV, satellite television distribution, and personal video recorders such as TiVo®. The disadvantage of MPEG-2 video streams is that they require more CPU power to decompress than MPEG-1. When encoding video at lower resolutions, the advantages MPEG-2 has over MPEG-1 are diminished.

5.3.5.13. Moving Pictures Experts Group 3 (MPEG-3)

MPEG-3 is no longer used and has been dropped from use. MPEG-3 primary purpose was for HDTV with specifications for 1,920 x 1,080 at 30 frames per second. The bit range for the standard was 20 to 40 Mbps. MPEG-1, 2, and 4 standards with a little modification work well in the HDTV range.

5.3.5.14. Moving Pictures Experts Group 4 (MPEG-4)

MPEG-4 is the newest standard, and commercial products that use it are just now populating the market. MPEG-4 is designed to deliver close to MPEG-2 quality video at lower data rates and use smaller file sizes. Where previous MPEG development was aimed at television and HDTV encoding, MPEG-4 was developed in response to industry demands to deliver quality video streams over a variety of devices, ranging from bandwidth-limited cell phones to broadband video providers. The newest standard to the ATSC television system is H.264/MPEG-4 AVC, which allows HD transmission in the MPEG-4 format. The main advantage of MPEG-4 is that it was designed to handle low-bandwidth video transmission that had been previously processed or encoded. If a network suffers from bandwidth limitation, more parallel MPEG-4 streams can be placed on that network than other MPEG methods.

5.3.5.15. Packetized Elementary Streams (PES)

Packetized Elementary Streams (PES), like TS, is defined by the MPEG communication protocol that permits an ES to be broken into packets. For realistic purposes, the continuous ES carrying video, data, and audio from encoders needs to be broken into packets. These packets are identified by headers that encapsulate time stamps for synchronizing. One method of transmitting ES video, data, or audio from an encoder is to first create PES packets from the ES and then to encapsulate these PES packets inside transport stream TS packets or PS packets. PES packets can be used to create TS or PS. The TS packets can be multiplexed and transmitted using the ATSC and DVB standards, or multiplexed into PS for distribution on media.

5.3.5.16. Program Stream (PS) and MPEG-PS

Program Streams and MPEG-2 PS are the same product and are in point of fact not streams, but containers used to store most MPEG-2 video, data, and audio streams. PS commonly uses the extensions .MPG or .MPEG. Program streams are one method of combining several PESs, which have a common time base, into one single stream. Program streams are a container format for multiplexing digital video, data, and audio. Similar to TS, PSs are defined by the MPEG-1 and MPEG-2 communication protocols. PSs are designed for comparative reliable media such as disks or point to point video, in contrast to TS which is for data transmission in which loss of data is probable. Program streams have variable size packets compared to TS which have fixed packet sizes. PS are used on DVD, HDV, and the defunct HD DVD video discs. Blu-ray discs use a TS format with additional time code added to the beginning of each packet. Program stream packets should not be confused with transport-stream packets, which are smaller and of fixed size.

5.3.5.17. QuickTime

QuickTime, one of the oldest container formats still in use, is a proprietary container format used by Apple's encoding and playback software. It uses an extension of .MOV. QuickTime is based on an early specification of the MP4 container format. QuickTime, unlike Microsoft's AVI, has been constantly updated throughout the years. QuickTime 7 features state-of-the-art codec H.264/MPEG-4 with audio typically being AAC. QuickTime 7 Pro offers HD play and recording.

5.3.5.18. RealMedia

RealMedia, like QuickTime, is one of the oldest container formats still in use. RealMedia is a proprietary container format used by RealNetworks encoding and playback software RealPlayer, RealDVD, and Rhapsody. RealMedia typically uses an extension of .rm and is typically used for streaming content (audio, video, data, movies, TV) over via Internet. Like Apple's QuickTime, RealMedia has been constantly updated throughout the years. RealMedia 11 the latest version and as of August 2008 has been updated with state-of-the-art codec and has the ability to encode and play back both variable and constant bit rate streams.

5.3.5.19. Transport Stream (TS, TP, MPEG-TS, or M2T)

The Transport Stream (TS) container is designed to deliver multiple sets of PES together, which would normally be delivered as separate files. The TS can carry many different PESs, and each may use a different compression factor and bit rate that can change dynamically, although the overall bit rate stays constant. Like ES and PS, TS are defined by the MPEG-1 and MPEG-2 communication protocol and generally have an extension of .TS. TS has features for error correction for transportation over unreliable media and is used in broadcast applications such as ATSC. In addition to broadcast digital TV systems, TS is used for satellite television such as DirecTV and Dish Network.

5.3.5.20. Windows Media

Windows Media is a software suite package for multimedia creation and distribution for Microsoft Windows. It consists of a software development kit with several application programming interfaces and a number of prebuilt technologies. Windows Media is a container format that is a combination of three core software programs of Windows Media Player, Windows Media Encoder, and Windows Media Services. The latest version of Windows Media as of August 2008 is version 11. Versions 10 and 11 are software upgrades and end-user enhancements. Windows Media 9 implemented the most recent change to updated VC-1 video codec. Windows Media Video 9 is Microsoft's implementation of VC-1, a standard that delivers high-definition quality with highly efficient compression rates. The VC-1 standard defines three complexity profiles, simple, main, and advanced. Windows Media Audio and Video codecs support both variable and constant bit rate encoding.

5.3.5.21. VC-1 Video Codec

VC-1, initially developed by Microsoft, is a video codec specification that has been standardized by the Society of Motion Picture and Television Engineers (SMPTE) and implemented by Microsoft as Microsoft Windows Media Video 9. VC-1 is an alternative to the latest ITU-T and MPEG video codec standard known as H.264/MPEG-4 AVC. The VC-1 codec is designed to achieve state-of-the-art compressed video quality at bit rates that may range from very low to very high. The VC-1 codec specification has been implemented by Microsoft in the form of 3 codecs: WMV3, WMVA, and WVC1. The WMVA codec (included in Windows Media 10) is a deprecated codec because it is not fully VC-1 compliant. The VC-1 standard defines three complexity profiles of simple, main, and advanced. WMV3 supports simple and main profiles and WVC1 supports the advanced profiles. The difference between profiles is the level of sophistication and options offered. As an example, B Frames are not part of the simple profile but are with the main and advanced profiles.

5.3.5.22. Xvid

Xvid is a video codec library following the MPEG-4 standard. Xvid features MPEG-4 advanced simple profile features such as b-frames, global and quarter pixel motion compensation, luminance masking, trellis quantization, and H.263, MPEG and custom quantization matrices. Xvid is a direct competitor with Divx. Xvid is free software and published under the GNU GPL license while Divx is a proprietary format that has to be purchased for the encoder.

5.4. Design Considerations

5.4.1. Introduction

Modern communications utilize protocols that provide the backbone for the Internet. Additional specialized protocols enable specific functions to take place. SMTP (Simple Mail Transport Protocol) is an example of a specialized service. Without SMTP no e-mail traffic could take place. Typically these specialized protocols run on top of the IP. For example, the World Wide Web (WWW) applications use HTTP. It is not possible to use HTTP alone. HTTP also requires a base-level protocol such as TCP/IP in order to provide the basic transfer capabilities. HTTP provides specialized functionality to either improve information transfer or to improve the existing transfer capability. Awareness of these protocols is important for ITS deployments, as they are commonly used by equipment manufacturers to transmit information and control equipment in networks.

5.4.2. Protocols Used in IP Video

One of the most basic concepts in telecommunications is the concept of protocol. In essence, a protocol is a standardized method of taking any type of information and breaking it up into discrete units that can be sent along the media. Although it sounds somewhat complicated, a protocol is really nothing more than a set of rules for handling and exchanging information. There are hundreds of protocols in existence today. While some work independently, others work cooperatively with other protocols. Readers should also realize that protocols can be implemented in both hardware and software. The following list identifies some of the most common protocols and the functionality they provide.

5.4.2.1. <u>Transmission Control Protocol/Internet Protocol</u>

TCP/IP is a low-level networking protocol used by computers and other hardware to communicate across networks. In reality, TCP and IP are two separate protocols that are part of a large number of Internet protocols. TCP/IP has, however, become known to the industry to stand for the family of common Internet protocols. Over time, TCP/IP became accepted throughout the world and is now an internationally known and supported protocol.

5.4.2.2. <u>Internet Protocol</u>

IP works as the “messenger” part of the TCP/IP protocol – its functions are to address and send data packets. The IP protocol contains three pieces of information, the IP address, subnet mask, and default gateway. The IP address, which is the identity of each node on the network, is 4 bytes long, each separated by a dot. It contains two pieces of information, the node's network ID and the system's host ID. The subnet mask, also 4 bytes separated by dots, is used to extract the network and host ID from the IP address. The default gateway is the entrance point to the nodes network.

5.4.2.3. Transmission Control Protocol

TCP is a reliable connection-oriented protocol. TCP is a connection-oriented protocol, meaning that it establishes a communications pathway, or connection, between two devices before sending data. Once the connection is established, TCP begins sending data, broken into packets of information across the network to the intended recipient. TCP numbers each packet as it is sent so that the receiving end knows the correct order in which to reassemble them as they are received. TCP also verifies that the data is received correctly. This is done using a "checksum" calculation on both the sending and receiving ends. If the calculation is the same on both ends then an acknowledge response is sent to the sender, verifying that the data was properly received by the intended target. If the results do not match, a request to resend is sent by the recipient, and the sender resends the necessary data.

5.4.2.4. DHCP

Dynamic Host Configuration Protocol (DHCP) is a TCP/IP protocol that enables PCs and workstations to get temporary or permanent IP addresses from a centrally administered server. DHCP allows a server to dynamically assign IP addresses to workstations on the fly.

5.4.2.5. Domain Naming System (DNS)

DNS is a mechanism used in the Internet and on private intranets for translating names of host computers into address. The DNS allows you to use the internet without remembering a long list of numbers, for example instead if typing in an IP address, users simply type in a name of a location they would like to go to like Google or Microsoft.

5.4.2.6. Ethernet

Ethernet began as a Local Area Network (LAN) standard used to connect computers, printers, and workstations within a small area, usually a building or campus. Ethernet runs on layer 2 of the OSI model, providing services at the DataLink layer. Other protocols, such as TCP/IP, run on top of Ethernet. Adding features enhances the overall performance and capabilities. As with other protocols, the Ethernet protocol is a set of rules on how to construct frames or small packets of information. Each frame is required to have a source and destination address. When a frame is sent via the medium, each node on the medium sees that frame. If a node sees a frame that is not intended for it, the frame is simply ignored, but if a node receives a frame that has its address as the destination address, it reads the frame. While this is the same basic task done by other protocols, ethernet accomplishes it in different ways, with different sized payloads of data, and with different performance characteristics. Today, ethernet networks can be 10 Mbps, 100 Mbps, 1000 Mbps (1 Gbps), or 10,000 Mbps (10 Gbps) in bandwidth.

5.4.2.7. File Transfer Protocol (FTP)

FTP lets users quickly transfer text and binary files to and from a remote or local PC, list directories, delete, and rename as well as a few other features. FTP is an application layer extension of the TCP/IP protocol suite, and was originally developed for transfers of large files of 50 Kb or more.

5.4.2.8. Hypertext Transfer Protocol (HTTP)

HTTP is the standard way of transferring information across the internet and the World Wide Web. It supports a variety of media and file formats across a variety of platforms.

5.4.2.9. Network Time Protocol (NTP)

NTP is a protocol used to ensure accurate synchronization of clock times in a network of computers and devices. Intranets can have NTP servers in addition to the internet time protocol servers.

5.4.2.10. Simple Mail Transfer Protocol (SMTP)

SMTP is a protocol for sending electronic mail messages between servers. Virtually all e-mail systems that send mail via the internet use SMTP to send their messages.

5.4.2.11. User Datagram Protocol (UDP)

UDP is part of the TCP/IP protocol suite. UDP provides for exchange of datagrams without acknowledgements or guaranteed delivery. UDP is a transport layer, connectionless mode protocol, providing a datagram mode of communication for delivery of packets to a remote or local use. UDP is one-way transmission of datagram packets.

5.4.3. Technology Considerations

The task of designing a network to handle IP video communications is not a simple process. There are many different factors that must go into the decision making. What technology to use, what equipment will work well on the chosen technology, and how to monitor the network are just some of the decisions that must be made. The following sections will cover some of the different options that are available.

One of the most important characteristic of any technology is its available bandwidth. In communications, the term 'bandwidth' refers to how much data can be transmitted in a certain amount of time. In most situations, bandwidth is expressed in terms of bits. The larger the number of bits that any given technology can transfer in the same amount of time, the larger its bandwidth. In essence, bandwidth is a measure of the size of the pipe.

Bandwidth is often expressed in terms of its ultimate capacity. However, like many situations, the ultimate capacity is rarely achievable. Inefficiencies in the system tend to grow and create a practical limit to how much bandwidth can actually be achieved with any given technology.

There are many different options that are available when setting up a network. Some technologies, like serial and Plain Old Telephone Service (POTS) generally do not have adequate bandwidth to carry video data. There are also technologies that are not specifically designed for large networks, and therefore may not be right for networks that will transmit video over IP. The following sections provide a quick overview of some of the different options that are available for networks.

5.4.4. Plain Old Telephone Service (POTS)

5.4.4.1. <u>Introduction</u>

POTS is the standard telephone service that has been around for decades. POTS can carry both analog and digital signals. Although the technologies for carrying calls over long distances have changed, little has changed for what is known as the 'last mile,' which is the final connection between the central office and a home or business. This last mile connection is almost always analog. A typical telephone connection uses a single twisted pair.

5.4.4.2. Capabilities

Because there are limitations on the amount of information that can be transmitted, POTS is mainly suitable for low-bandwidth applications. The speed of the modem is the primary factor in how fast information can be transferred. In practice, a phone line can accomplish many of the typical ITS data transfer needs. For example, a dynamic message sign (DMS) message is typically around 1000 bytes, or 1 Kb. That transmission can easily be handled by a phone line.

However, video applications are not well suited for phone lines. Because the amount of information that has to be transferred in video applications is far larger than data applications, most phone line solutions can only handle, at best, 1-2 frames of video per second. In reality, a more typical expectation would be 1-2 seconds per frame. The exact capabilities vary widely depending on the size of the video, the encoding mechanism, and the quality of the phone line, but generally POTS would not be used to transmit video.

5.4.5. Integrated Services Digital Network (ISDN)

5.4.5.1. Introduction

Another technology that runs on a standard phone line is ISDN. The "Integrated" part of ISDN refers to the ability to combine voice and data services over the same phone wire. Although the physical cabling is the same as that for POTS, the infrastructure that supports it at either end and at the phone company is substantially different. The main advantage of ISDN is that it is an all-digital system. The use of all digital increases the available bandwidth because there is no analog conversion process.

5.4.5.2. Capabilities

An ISDN connection transmits digital information on a single telephone twisted pair. The connection provides a raw data rate of 144 Kbps. To better suit its use for voice applications, the 144-Kbps channel is generally partitioned into three channels. Two of the channels are 64 Kbps and are labeled B, for *bearer*. The third channel is 16 Kbps and is labeled D, for *data*.

Generally, the D-channel is unavailable for an end-user to transmit data. This channel is used for administrative and call control data that the phone companies transmit; however, each B-channel can carry a separate telephone call and usually has its own telephone number. Through a process called bonding, the two B-channels can be merged together to form a single 128-Kbps channel for end-user use.

There are two types of ISDN:

Basic Rate Interface (BRI) – BRI is the basic ISDN configuration as described above, with two B-channels at a rate of 64 Kbps and one D-channel at a rate of 16 Kbps, which carries call-control information.

Primary Rate Interface (PRI) – PRI is a type of ISDN service designed for larger organizations. PRI includes 23 B-channels and one D-channel.

5.4.6. Digital Subscriber Line (DSL)

5.4.6.1. Introduction

DSL is a technology for bringing high-bandwidth capabilities to homes and small businesses over ordinary copper telephone lines. There are numerous implementations of DSL that provide different upload and download speeds. Collectively, these technologies are referred to as xDSL.

5.4.6.2. Capabilities

There are many different types of DSL service, with the main difference being speed. Like ISDN, xDSL services are distance limited. A main advantage of xDSL over ISDN is that the connection is always on and there are no dial-up connections to establish and maintain. Additionally, DSL service is typically easier to configure and install.

5.4.7. Cable Modem

5.4.7.1. Introduction

The term ‘Cable Modem’ is actually an abbreviation of two words. Cable is short for Cable TV Network (CATV) and Modem is modulator-demodulator. A cable modem is an end-user device for sending and receiving data over the infrastructure originally designed and installed for cable television. The term modem is somewhat of a misnomer because there is no dialing or connection time involved in cable modem service. Cable modem connections are constantly on.

5.4.7.2. Capabilities

Cable modem service is not distance limited like DSL and ISDN technologies. It is therefore typically available to a wider customer base. However, the upload and download speeds can be widely variable, as they depend on many factors. Typical speeds are shown below.

- Download – Rates range from 1 to 5 Mbps.
- Upload – Rates range from 128 Kbps to 1 Mbps.

Cable modem service is typically targeted at either home or business use. Business use may have additional features such as a guarantee of minimum levels of service and bandwidth. The business class of service almost always costs more than the home use.

5.4.8. T-1/T-3 Services

5.4.8.1. Introduction

T-1 (or Trunk Level 1) is a digital transmission link with a total signaling speed of 1.544 Mbps. Since the development of T-1, it has become the building block of dedicated voice and data service in North America. T-1 is also known as Digital Signal 1 (DS-1).

T-1 service can be delivered to the end-user in either a channelized format or an unchannelized raw bit stream. North American carriers typically deliver T-1 service split into twenty-four 64-Kbps channels. Each channel is often referred to as a DS-0 and can be used to transmit voice (typically one conversation per channel) or data across a network. The provision of T-1 alone provides no specific services to a location, only a means of transmitting data or voice services from a network into the office.

T-3/DS-3 is a higher multiple of T-1/DS-1 that has been joined (also known as bonded or multiplexed) together. A T-3/DS-3 is composed of 28 individual T-1/DS-1 lines.

5.4.8.2. Capabilities

T-1/T-3 services are not distance limited. Both services can be provided over twisted pair copper wiring or fiber-optic wiring.

The list below details some of the typical capabilities of these services.

- T-1/T-3 services can be broken out into channels – voice and data can run side by side on the same circuit, but different channels.
- DS-0 = 64 Kbps = 1 channel.
- T-1/DS-1 = 1.544 Mbps = 24 channels.
- T-3/DS-3 = 44.736 Mbps = 28 DS-1/T-1 = 672 channels.
- Each channel can be used for data services or a single phone call.
- Fractional T-1 service is available in some areas, with standard rates of 256, 384, 512, and 768 Kbps.

5.4.9. ATM

5.4.9.1. Introduction

Asynchronous Transfer Mode (ATM) is a high-bandwidth, low-delay technology that is capable of very high transmission rates. ATM is a packet switching technology that uses a fixed packet size. Along with a fixed packet size, ATM has long provided for the concept of Quality of Service, which is the guaranteed delivery of packets in the right order, without delay. In the initial days of ATM, these characteristics provided significant advantages to applications requiring continuous streams of data, such as video. Today, other technologies can often provide the same reliability at a fraction of the cost.

5.4.9.2. Capabilities

ATM services are not distance limited. ATM service is provided over fiber-optic wiring. The list below details some of the typical capabilities of ATM.

- ATM is a packet switching technology that divides upper-level data units into 53-byte cells for transmission over the physical medium.
- Each individual ATM cell consists of a 5-byte cell header and 48 bytes of information encapsulated within its payload.
- ATM is a connection-oriented technology, which means it requires a channel to be established between the sender and receiver before any messages are transmitted.

- ATM creates these pathways, called virtual circuits.
- ATM can allocate bandwidth on demand as services requirements change.
- ATM can interface with SONET and Ethernet technologies.
- Typical ATM bandwidth is 1.54 to 622 Mbps.
- ATM features characteristics such as low delay and quality of service, which is a guaranteed delivery feature.

5.4.10. SONET

5.4.10.1. Introduction

Synchronous optical network (SONET) is a standard for optical telecommunications transport formulated by the Exchange Carriers Standards Association (ECSA) for ANSI, which sets industry standards in the U.S. for telecommunications and other industries.

5.4.10.2. Capabilities

SONET can provide bandwidths from 51.84 Mbps to 39.812 Gbps. Each level of SONET is called OC, for Optical Carrier. Table 5-2 lists the typical OC levels that can be obtained in SONET installation.

Table 5-2. Optical Carrier Rates.

Optical Carrier Level	Data Rate
OC-1	51.84 Mbps
OC-3	155.52 Mbps
OC-12	622.08 Mbps
OC-24	1.244 Gbps
OC-48	2.488 Gbps
OC-192	10 Gbps
OC-256	13.271 Gbps
OC-768	39.812 Gbps

5.4.11. Ethernet

5.4.11.1. Introduction

Ethernet was invented as a project to connect computers, printers, and workstations within a small area. Ethernet was designed to run on top of the TCP/IP protocol for the base transmission and added features on top of that to enhance the overall performance and capabilities.

5.4.11.2. Capabilities

Ethernet has evolved more rapidly than perhaps any other technology. From simple beginnings with low speeds just 30 years ago, Ethernet now boasts speeds of 10 Gbps and features such as Quality of Service. It is estimated that 85%–90% of all networks are Ethernet-based networks. Table 5-3 lists the current levels of Ethernet and their usable capacity.

Table 5-3. Standard Ethernet Speeds.

Name	Speed (Mbps)	Usable Capacity (%)
Ethernet	10	Approx 30–50
Fast Ethernet	100	Approx 50
Gigabit Ethernet	1000	Approx 80
10 Gigabit Ethernet	10,000 (10 Gbps)	Approx 80

5.4.12. Bandwidth Overview

Table 5-4 shows both a theoretical and typical or usable bandwidth, as many technologies have overhead or constraints that limit the availability of the full theoretical bandwidth.

Table 5-4. Bandwidth Listing by Protocol.

Protocol	Bandwidth			
	Theoretical Typical		(Usable)	
Serial	Up to 115.2 Kbps		19.2 Kbps	
POTS	56 Kbps		40 – 45 Kbps	
ISDN	BRI – 128 Kbps PRI – 1.544 Mbps		BRI – 128 Kbps PRI – 1.544 Mbps	
DSL	Downstream	1.544 – 52.8 Mbps	Downstream	1 – 8 Mbps
	Upstream	128 Kbps – 4 Mbps	Upstream	128 Kbps – 1 Mbps
Cable Modem	Downstream	1 – 8 Mbps	Downstream	1 – 4 Mbps
	Upstream	128 Kbps – 4 Mbps	Upstream	128 Kbps – 1 Mbps
T-1/T-3	1.544 – 44.736 Mbps		1.544 – 44.736 Mbps	
ATM	1.54 – 622 Mbps		Up to 500 Mbps	
Ethernet	10 Mbps		4 – 5 Mbps	
	100 Mbps		40 – 50 Mbps	
	1000 Mbps		800 Mbps	
	10,000 Mbps		8000 Mbps	
SONET	51.84 Mbps – 39.812 Gbps		51.84 Mbps – 39.812 Gbps	

5.4.13. Network Monitoring

Once a network is designed and installed, the work is not over. Maintaining a network, like any other large system, can be time consuming and expensive. In order to ensure the network continues to run properly, each device on the network must be constantly monitored for potential problems. Monitoring a network manually is virtually impossible. Verifying that each device is working 24 hours a day 7 days a week is just not feasible. Fortunately there are options available that will monitor a network and alert you when a problem persists. Finding the right network management software and ensuring that the devices placed on the network are compatible are extremely important in ensuring that you can successfully monitor a network once it is deployed.

5.4.13.1. Simple Network Management Protocol (SNMP)

SNMP is an IP-based protocol that was designed to help manage network applications. Today it is the most widely used protocol when dealing with network management. In fact today a device is considered a managed device only if it is SNMP compliant. SNMP management software works by querying devices on the network using a supported Management Information Base, or MIB. An MIB is basically a database of information that is stored within a device, which relates to its performance. Once a managed device receives a query for information, it returns the appropriate response. Network management software can send out and monitor these query responses in order to ensure the network device is properly functioning. If a bad response, or no response at all, is received, the software can notify the appropriate persons who can then attempt to diagnose and repair the problem.

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6. THE TESTING AND SYSTEM ACCEPTANCE PHASES

6.1. Introduction

When most people view the “Vee” diagram, they assume that testing activities only take place on the “right” or “integration and recomposition” side of the diagram. However, testing activities actually take place on both sides of the “Vee” diagram. During the concept of operations phase, thought must be given to the development of a testing plan with roles and responsibilities considered. One should also keep in mind that, in some cases, testers are also users. During the systems requirements phase, each requirement needs to be analyzed as to whether it is testable. During the high-level and detailed design phases, the initial testing activity centers around traceability back to requirements. As the designs start to reach completion, the activity is a review to identify deficiencies before they become errors and omissions that present themselves in subsequent testing phases.

While an agency is not likely to be involved in the software/hardware development phase, a number of agencies perform sample or qualified products list unit testing. Even if they do not perform their own unit testing, they need to understand and review how unit testing is performed by the vendor. The same situation applies to subsystem verification. An agency may perform the verification testing or monitor and review how an integrator or contractor conducts it. Either way, there may be a significant effort to verify compliance to subsystem requirements and how a component interfaces with others. During system verification and deployment phases, acceptance testing is primarily the responsibility of the agency. The agency needs to verify that the system complies with the specifications. At this point, even though the agency owns the system the testing activities do not stop. Operation and maintenance include support activities. When new versions of software become available, testing looks at whether new features or bug fixes work properly. Regression testing also determines whether the new features and fixes have created other problems.

To understand how testing can apply to all cycle phases, consider these basic techniques *(1)*:

- Inspection
- Analysis
- Certificate of Compliance
- Demonstration
- Test (Formal)

Inspection can apply to the system planning documentation and the delivered product. Analysis can look at simulation to determine if a design is even feasible. Past performance of a system can also help determine if a scaled up version of a system will work. Asking for any certificates during the design can help make decisions about alternatives. Demonstrations can also help during alternative analysis but primarily come into play while exercising a system under actual conditions. These techniques can be applied before any formal testing takes place. Formal testing is used to evaluate whether a component, subsystem, or system meets a requirement under some type of real or simulated conditions.

6.2. Test Planning

As mentioned in the introduction, test planning should start early in the life cycle of a project. Some concept of what to test and how to conduct the test needs to be considered during the initial development of a project plan. The best guidance on developing a test plan can be found in Institute of Electrical and Electronics Engineers (IEEE) Std 829 - IEEE Standard for Software Test Documentation *(2)*. Although the term software is used, the principles apply equally to hardware.

The IEEE document suggests that an overall plan, one or more test design specifications, and test case specifications be developed before any details of test procedure are defined.

The overall plan should convey the scope, approach, resources, and schedule of testing activities. It is used to present a high-level view of the project to inform all interested parties.

The test design specifications provide a more detailed view of the testing project. A test engineer's supervisor and any group such as a project monitoring committee can use the test design specifications to make sure that a test engineer understands the project and is addressing what is needed. This serves as part of the validation step in the project development. The test case specifications are then defined to outline individual test cases that verify specific features or functions of the system or its elements.

The test case specifications provide additional oversight but primarily help a test engineer organize and plan the specifics of each test case before committing to code or formal definition. While some people consider all this up-front documentation a waste of time, it may actually save time in doing the job correctly the first time.

6.3. Testing Activities

6.3.1. Concept of Operations Testing

Testing activities during the concept of operations focuses on the concept of operations development process and should include "testers" as one of the stakeholders. The "testers" or system analysts need to start on the test plan. After the user needs are assembled and documented, there needs to be a series of reviews conducted with stakeholders and users. The testers need to ask the questions as to whether the appropriate steps in the development of the concept of operation have been followed.

There are no checklists or templates for a concept of operation. However, the FHWA report Developing and Using a Concept of Operations in Transportation Management Systems defines the core functions of a Concept of Operations as *(3)*:

- establishes scope;
- identifies reference resources;
- develops a user-oriented operational description;
- establishes or identifies operational needs;
- provides a system overview;
- describes the operational and support environment; and
- incorporates operational scenarios.

An inspection or analysis test performed on the Concept of Operations could be to verify whether the functions are addressed.

The test plan documentation should start during or just after this phase. The plan is used at this point to inform the users and stakeholders of who is going to be involved in testing activities and what their roles and responsibilities will be.

A draft of a 2008 version of IEEE 829 now referred to as S IEEE Standard for Software and System Test Documentation lists the following testing activities during the Concept of Operations phase *(4)*:

- Review concept of operation so that tester understands the user needs.
- Review the requirement documentation.
- Develop initial requirements to test case traceability matrix.
- Identify integrity level (describes the importance of the need to the user).

6.3.2. Functional Requirements Testing

The testing task, during or after the functional requirements phase, is the review of the documentation. The following requirements review checklist appears to be well suited for reviewing the functional requirements *(5)*.

- Are all external interfaces of the system explicitly stated?
- Does each requirement have a unique identifier?
- Is each requirement atomic and simply stated?
- Are requirements organized into coherent groups?
- Are the requirements prioritized?
- Are potential unstable requirements marked as such?
- Is each requirement verifiable?
- Are all requirements consistent (non-conflicting)?
- Are the requirements sufficiently precise and unambiguous?
- Are the requirements complete? Can everything not explicitly constrained indeed be viewed as developer freedom? Is a product that satisfies every requirement indeed acceptable? (No requirements missing.)
- Are the requirements understandable?
- Are the requirements realizable within budget?
- Do the requirements express actual customer needs rather than solutions?
- Does the Requirements Traceability Matrix (RTM) indicate that every requirement has been addressed by the design?
- Does every design element address at least one requirement?

The 2008 draft version of IEEE 829 lists the following minimum testing activities during the Requirements phase:

- Develop acceptance test plan.
- Develop system test plan.
- Review testability of software and interface requirements.
- Update integrity level.
- Update requirements to test case traceability matrix.
- Identify risk(s) (test).
- Identify security issues (test).

6.3.3. System Design Testing

During the system design phase, the role of testing is to perform design reviews. The reviewers should ask:

- Are the design details well-documented?
- Do the details of the design trace to requirements definitions?
- Are boundaries and interfaces of the system clearly identified?
- Is there a process for configuration control?

Several system designers have suggested the following design checklist of questions to help evaluate any design *(6)*:

- What indicates that this design can be implemented and tested with the planned amount of time and effort?
- What makes this design understandable?
- Does the design suggest reasonable implementation tasks?
- How have concerns been separated and addressed in distinct modules?
- Can new features be easily added later?
- What makes this system easy to test?
- Does the system consume an acceptable amount of time, storage space, bandwidth, and other resources?

The 2008 draft version of IEEE 829 lists the following minimum testing activities during the Design phase:

- Update Acceptance Test Design
- Update System Test Design
- Develop Component Integration Test Plan
- Develop Component Integration Test Design
- Update integrity level
- Update requirements to test case traceability matrix,
- Update risk(s), and
- Update security issues.

6.3.4. Software/Hardware Development Testing

Equipment vendors are responsible for the software/hardware development phase testing. An agency, however, should ask for and review the vendor's documentation. What tests did they run to ensure the equipment meets the requirements? If a third party performed any testing, those test reports should be reviewed.

6.3.5. Unit and Subsystem Testing

For CCTV systems, the individual units and subsystems can be partitioned as follows:

- Camera subsystem
    - Camera and lens

    - Housing
    - Pan/tilt/zoom unit
- Transmission subsystem
    - Encoder
    - Internet Protocol (IP) network
    - Decoders
    - Routers
    - Switches
- Headend subsystem
    - Video multiplexers
    - Wall displays
    - Computer consoles
    - Recorders

Section 4.4 covers a number of test procedures that can be used to qualitatively and quantitatively test these units and subsystems. As these components are delivered, they should be subjected to receiving inspections and functional testing as detailed in the procurement specification. Conditional acceptance can be given with respect to delivered quantities, but final acceptance should not be given until the subsystems are fully integrated and they pass the formal acceptance tests.

Integration testing can take place if the transmission subsystem and one of the other subsystems are complete. For example, the camera subsystem can initially be integrated with the transmission subsystem. If one connects a laptop to a switch at the management center, one should be able to check to see if images are available. If a test pattern can be fed into an encoder, one should be able to see it on the wall displays or computer consoles.

When all the components of a system are connected together, tests are performed to ensure that the system operates as a whole. During this testing phase, the system could be subjected to stresses and abnormal conditions that it might encounter during its expected life cycle.

The 2008 draft version of IEEE 829 lists the following testing activities that would apply to the Unit and Subsystem Testing phase:

- Execute Component Integration Tests
- Evaluate Component Integration Test results
- Prepare Component Integration Test Report

6.3.6. System Acceptance Testing

System acceptance refers to testing a complete system that brings together all the hardware and software components and subsystems. Whereas unit and subsystem testing is primarily derived from functional requirements, acceptance testing also relates to non-functional requirements such as ease of use and reliability. Testing specific to this phase also relates to the environment that the system will operate within.

Normally, acceptance testing is the responsibility of the agency and is the last opportunity to make sure that the system's equipment and software meets the agency's performance and operational needs and is in full compliance with all the requirements identified throughout the project. From the vendor's standpoint, satisfactory completion of the acceptance test and approval by the agency means that the vendor has completed its contractual obligation to the agency and is due final payment.

The 2008 draft version of IEEE 829 lists the following testing activities that should apply to the System Acceptance Testing phase:

- Perform installation/checkout.
- Evaluate installation/checkout.
- Prepare installation/checkout report.
- Perform the system and acceptance tests.
- Evaluate the system and acceptance test results.
- Prepare the system and acceptance test reports.

6.3.7. Operations and Maintenance Testing

Operations and maintenance testing is a system life-cycle process that is often overlooked in the planning phase. The FHWA's Guidelines for Transportation Management Systems Maintenance Concept and Plans refers to "a series of methodical, ongoing activities designed to minimize the occurrence of systemic failures and to mitigate their impacts when failures do occur *(7)*. These activities include replacing worn components, installing updated hardware and software, tuning the systems, and anticipating and correcting potential problems and deficiencies. Maintenance includes the development and implementation of action plans for responding quickly, efficiently, and orderly to systemic failures. It also includes an infrastructure and procedures for measuring and monitoring maintenance activities."

A test plan should document what operation and maintenance activities will be conducted and who will carry them out. For example, how often should an image be checked to see if it has degraded? If a component fails, what procedures will be used to ensure that its replacement is working properly? If system software is updated to add new features, what regression tests should be run to ensure that other parts of the system are not affected? When new software is intended to correct errors (bug fixes), unforeseen interaction with part of the system working properly may occur.

The 2008 draft version of IEEE 829 lists the following testing activities that should occur during the Operations Testing phase:

- Evaluate operating procedures.
- Perform ongoing operational tests.
- Evaluate operational test results.
- Prepare operational test report.

The 2008 draft version of IEEE 829 discusses the following testing activities that may occur during the Maintenance Testing phase:

- Evaluate system as to conformance to updates standards.
- Perform problem and modification analysis.
- Evaluate new software releases and perform appropriate regression test.

6.4. Test Procedures

6.4.1. Camera Subsystem

For the purposes of discussion, the camera subsystem is defined as any component associated directly with the camera. This includes the:

- camera,
- lens,
- housing,
- heater,
- wiper,
- pan/tilt/zoom unit,
- mounting hardware, and
- interface cabinet.

6.4.1.1. <u>Camera</u>

6.4.1.1.1. Subjective Testing

There are a number of test charts that can be used for subjective testing of a video image. One source offers a set of charts that can be used for measuring:

- resolution,
- registration,
- back focus,

- color reference, and
- gray scale charts.

An example of the gray scale test chart is shown in Figure 6-1. It is designed to assess whether the system can differentiate between contrast steps all the way from black to white, but particularly at the extremes of the chart where contrast limitations are most apparent. For example, the two large white rectangles in the figure should actually be two smaller bars. If a monitor only show eight bars, it is not adjusted correctly or something is wrong.

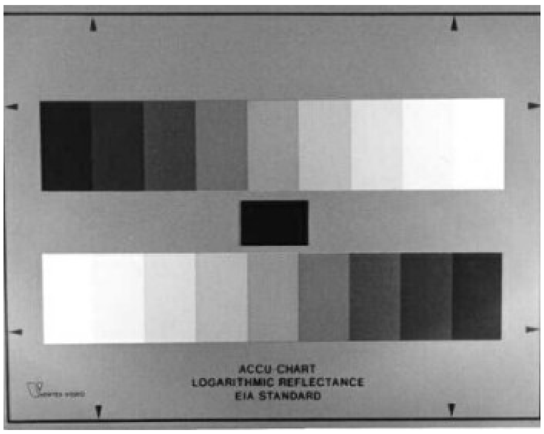

Figure 6-1. Gray Scale Test Chart.

The various charts are meant to be placed in front of a camera, and the resulting image is viewed on a monitor or display. Although the charts rely on personal perceptions to interpret the image, they permit an individual to make judgments about the quality of the system. One should also keep in mind that operative word is "system," where a system consists of camera, transmission system or cable, and a display or monitor.

6.4.1.1.2. Objective Testing

A set of 18 objective test procedures have been defined in a European Broadcast Union Standard that is available on the internet *(8)*. The document gives details of the measurement procedure for the following characteristics of Charge Coupled Device (CCD) cameras:

- sensitivity,
- maximum sensitivity,
- signal-to-noise ratio (random noise),
- signal-to-noise ratio (fixed-pattern noise),
- horizontal static resolution,
- aliasing,

- registration,
- geometry,
- white shading or white level non-uniformity,
- black shading or black level non-uniformity,
- streaking,
- flare,
- transfer law or gamma correction,
- smearing,
- over-exposure headroom,
- blemishes,
- image format, and
- colorimetric fidelity measurement.

A similar International Electrotechnical Commission (IEC) standard 1146-1 provides another set of procedures for measuring video characteristic *(9)*.

Several Department of Transportation (DOT) agencies have specified CCTV testing procedures that involve a simple to use, hand-held, battery operated meter that measures five characteristics of a National Television System Committee (NTSC) composite video signal *(10)*. The characteristics that it measures are:

- Sync - Video sync output level
- Luminance - Brightness setting
- Composite - Overall level of the video signal level
- Color Burst - Color burst amplitude
- Focus - Best focus setting of a scene

The meter manufacturer's webpage includes three articles on the purposes for the tests and how to conduct them. The webpage also has a form for recording results during periodic maintenance checks.

6.4.1.1.3. Lens

Testing a lens is beyond the scope of most testing labs. However, a subjective test using an Electronic Industries Alliance (EIA resolution chart) Resolution Chart (see Figure 6-2) could point out some problems *(11)*. For example, the chart is placed in front of a lens and the resolution is measured using the four corner resolution circles. They should indicate the same resolution as measured in the center. If they do not indicate the same resolution, the lens may have some sort of aberration.

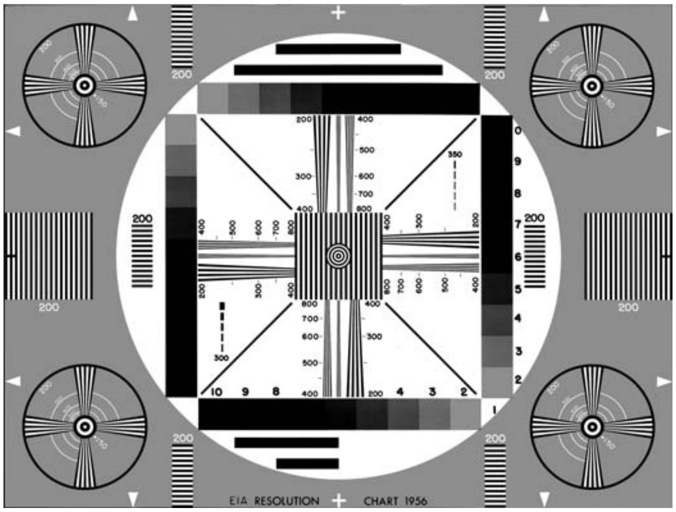

Figure 6-2. EIA Resolution Chart 1956.

IEEE also publishes a similar test chart in a standard on the measurement of camera system resolution *(12)*. In addition to resolution, the IEEE chart can be used as an aid in checking scanning linearity, aspect ratio, interlacing, shading, streaking, and ringing. Sometimes it can also be used for observing aliasing or interference patterns problems. A word of caution when using a chart applies: a camera system consists of a camera, some type of transmission cable, and a monitor. Therefore, the source of a problem is not necessarily the camera itself.

6.4.1.2. Camera Housing

The typical camera housing (or enclosure) should have a National Electrical Manufacturers Association (NEMA) 3R or 4X rating. A NEMA 3R enclosure is described as an indoor or outdoor enclosure that provides a degree of protection against falling rain and sleet; undamaged by the formation of ice on the enclosure. A NEMA 4X enclosure is described as an indoor or outdoor enclosure that protects the enclosed equipment against splashing water, seepage of water, falling or hose-directed water, and severe external condensation; these enclosures are sleet resistant but not sleet proof *(13)*. The reference provides equivalent Underwriters Laboratories (UL) and Canadian Standards Association (CSA) approval designations.

To claim conformance to the various enclosure ratings, a manufacturer would have to comply with the requirements contained in NEMA 250-2003 standard *(14)*. This standard provides a guide to selecting an appropriate rating (for example, 3R or 4X), and it tests to demonstrate conformance to the standard. From an agency's perspective, an inspection of paperwork asserting compliance would constitute an initial test procedure. In use, operators can often tell when an enclosure leaks. When maintenance crews check field equipment, they can check for condensation on the lens.

6.4.1.2.1. Heaters, Wipers, Washers, and PTZ Units

National Transportation Communications for Intelligent Transportation Systems (ITS) Protocol (NTCIP) 1205 - Object Definitions for Closed Circuit Television (CCTV) Camera Control provides a definition of configuration, status, and control information associated with the functions in the camera housing and pan/tilt/zoom (PTZ) units *(15)*. Test procedures have been incorporated in several NTCIP testing tools and can also be found in the Texas Department of Transportation (TxDOT) Report Testing for Compliance to NTCIP Standards *(16,17,18)*.

Appendix B of the previously mentioned FHWA Maintenance Concept and Plans has a section that specifically addresses CCTV preventive maintenance*(7)*. The section provides of list of test procedures that should be performed at the pole level every six months and another list of test procedures that should be performed at any interface cabinet level on a three-month basis.

6.4.1.3. Interface Cabinet

A number of CCTV installations employ a small pole-mounted cabinet for mounting circuit breakers, transient protection devices, and RF filtering components. The cabinet should have NEMA 3R or 4X rating. The cabinet should provide transient and surge protection equivalent to that of a traffic signal controller cabinet. The NEMA Traffic Section (TS) 2 - Traffic Controller Assemblies standard describes appropriate transient protection requirements and testing procedures *(19)*.

6.4.2. Transmission Subsystem

For the purposes of discussion, the transmission subsystem is defined as any component associated with the delivery of the video signal to any displays, monitors, and/or recorders. This includes the:

- encoder (in the camera interface cabinet),
- transmission media,
- decoder (in the management center),
- routers, and
- switches.

Research into what is available in terms of subjective testing of video transmission only reveals one reference. Several authors that discuss subjective testing all reference an International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) standard that deals with multimedia applications *(20)*.

6.4.2.1. Encoders

Objective testing of video encoders is highly technical and specialized. There are two sources of information that cover what is involved. Tektronix, the electronic testing tools manufacturer, provides a detailed application note on the subject *(21)*. Another general source of information provides background information, description of an encoder test, and a comparison of 21 different products *(22)*.

6.4.2.2. IP Network

In a paper discussing the quality of Video over IP, it is suggested that there are five parameters that should be measured and monitored to ensure quality transport of Video over IP *(23)*:

- Inter-packet arrival jitter causing delay;
- Inter-packet arrival jitter causing burst;
- Ethernet packet loss;
- Ethernet inter-packet arrival average drift/deviation from the Moving Pictures Experts Group (MPEG)-2 data transport rate; and
- MPEG-2 quality due to packet corruption on the network, MPEG-2 encoding errors, or MPEG-2 packet loss.

6.4.2.3. Decoders

Subjective testing of video decoders is also highly technical and specialized. As a manufacturer of test instruments to analyze whether a decoder is working, Tektronix, has published an application note on the subject video decoder testing *(24)*.

6.4.2.4. Routers and Switches

Video over IP entails packetizing the video and sending the resulting frames through routers and switches that provide the connections between the camera and display. While in principle, there is no difference between data and video, the transmission of video does place some additional requirements on routers and switchers. For routers, the question is whether the device supports the necessary throughput. Video using MPEG-2 compression has peaks around 10 Mbps. Can the router handle the throughput for multiple streams with and without multiple user data streams? Insufficient throughput results in packet loss. An objective test for this can be done with a protocol analyzer. A subjective test could be looking at a video stream and noting any blank lines.

An Internet Draft Request for Comment (RFC) was created to address additional tests that can be used to evaluate and compare performance when Ethernet switches are used in streaming media applications. The Switch Testing for Streaming Media Applications - Internet Draft describes those tests *(25)*. The internet draft deals with measuring a parameter referred to as media delivery index (MDI). It is an indication of transport communications layer protocol performance that measures delay and loss packets by looking at the network communications layer protocol.

Another source for objective testing of switches can be found in Evaluating Ethernet Switches when dealing with streaming video applications *(26)*. The article describes how to measure a quality of service parameter and switching latency (the time it takes an Ethernet switch to change channels).

For subjective testing, one could be looking at a video stream and note if it has any blank lines or streaks. When a system is initially installed, any test could have been conducted with compressionset to a specific value. Since compression can be configured, any changes to improve image quality may have the negative effect of causing increased pack loss. There are some free tools to help calculate IP Camera Bandwidth *(27)*. With the particular identified tool, you can calculate system requirements with an unlimited number of network cameras or IP video servers.

6.4.3. Headend Subsystem

For the purposes of discussion, the headend subsystem is defined as any component associated with selecting, displaying, or recording a video signal in a management center. This includes:

- video multiplexers,
- wall displays,
- operator consoles, and
- recorders.

6.4.3.1. Video Switches (Multiplexers)

If video is converted to analog prior to being multiplexed to displays and recorders, NTCIP 1208 - Object Definitions for Closed

Circuit Television (CCTV) Switching provides a definition of configuration, status, and control information associated with switching *(28)*. Although there does not appear to be a set of NTCIP test procedures for that standard, generic commercial-off-the-shelf (COTS) testing tools can be used to check support for the objects *(29,30)*.

If video is not converted to analog, the digital signal has to pass through Ethernet switches. If that is the case, and there is a desire to do subjective testing of switches, then the previous section on routers and switches would be relevant.

6.4.3.2. Wall Displays

When it comes to wall displays, you are usually dependent on the vendor for any objective test procedures. Most wall displays have the ability to show test screens that can help with subjective testing. For example, a wall display could show a set of color bars similar to what is shown in Figure 6-3. If you have a professionally produced color reference chart, the colors on the screen should match the colors on the chart. The quality control on the inks and dyes used to manufacturer color test charts is very precise, and a properly adjusted display should match almost perfectly.

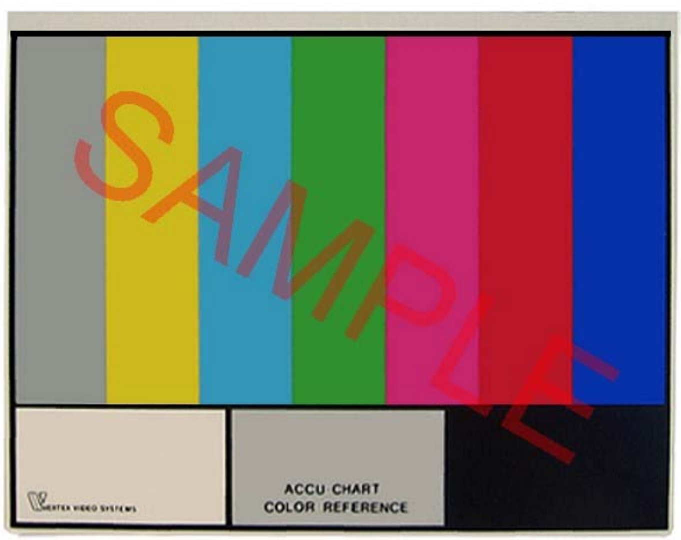

Figure 6-3. Color Reference Chart.

If a wall display does not have built-in test screens, putting a color reference, registration, or resolution charts in front of a camera and showing the image on the display can provide a means of subjective testing.

6.4.3.3. Operators Consoles

There are a number of ways to carry out subjective comparisons and testing. At the formal level, a method of subjective testing is presented in International Telecommunication Union - Radiocommunication Sector (ITU-R) BT.500 "Methodology for the subjective assessment of the quality of television*(31)*." The method recommends categorizing the quality of video on a five-point scale:

1 – very annoying
2 – annoying
3 – slightly annoying
4 – perceptible, but not annoying
5 – perceptible, imperceptible

The grading of video quality can also be expressed as a percent from 0 to 100. The ITU-R standard includes a detailed description of test environment, test methodologies, and results processing. Other methods and tools can be found on the internet *(32)*.

For objective testing, the previously mentioned Appendix B of Guidelines for Transportation Management Systems Maintenance Concept and Plans also contains a list of camera preventive maintenance tests that are applicable to the control center and conducted on a weekly basis *(6)*. It suggests that a waveform monitor be used to measure:

- raw video,
- peak white,
- color burst, and
- synch pulse.

These tests can also be run on the hand-held device mentioned the Objective Testing section.

6.4.3.4. Recorders

The advent of digital recorders and new compression algorithms has changed the methods and the techniques of how video is recorded *(33)*. Correct playback and recording of video is only ensured if recorders write discs that are compliant with the Digital Video Disc + Read/Read Write (DVD+R/RW) Video specifications. A sample specification and a fully documented test procedure are available on the internet *(34)*.

6.5. Applying Test Procedures

6.5.1. Testing Approaches

TxDOT documents and specifications generally describe two testing approaches. One approach defines an internal TxDOT process that is used primarily for traffic signal controllers. The alternate describes a more general testing process that is the responsibility of a contractor to perform. Currently, most TxDOT special specifications that relate to CCTV reference the contractor approach that is defined in TxDOT Special Specifications 6504 - Testing, Training, Documentation and Warranty *(35)*.

6.5.2. Contractor Testing Process

Figure 6-4 illustrates the steps in the contractor testing process. During *design approval* testing, the contractor either runs environmental tests directly or has an independent testing laboratory conduct them. As part of this step, the contractor is to submit design approval test procedures to the TxDOT engineer, 60 days prior to the tests for the engineer's approval.

During *demonstration* testing (conducted prior to installation), the contractor performs a physical inspection of the equipment and performs operational tests to ensure compliance to the specifications. Similar to the previous step, the contractor is to submit a copy of the demonstration test procedures to the TxDOT engineer, 60 days prior to the tests for the engineer's approval.

After the contractor installs the equipment but before connection to any other components of the system, the contractor performs *stand-alone* testing to verify functional operations. Prior to actual execution, the contractor is to submit the stand-alone test procedures for the engineer's approval.

After connection, but before conducting the actual tests, the documentation for the system integration needs to be submitted for the engineer's approval. System *integration* testing should demonstrate that all control and monitor functions are operating properly.

TxDOT personnel do not perform the tests in these four steps, but a reserve clause in the specification allows someone from TxDOT to observe the tests. The TxDOT engineer is responsible for overall approval and final acceptance.

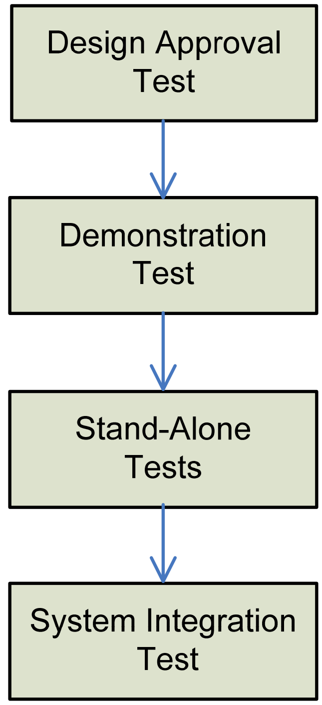

Figure 6-4. Contractor Testing Activities.

6.5.3. TxDOT Acceptance Testing

A number of other TxDOT Special Specifications define an additional step referred to as *final system acceptance*. This is a period where the system must run continuously and successfully for some time period with a minimum amount of downtime.

For new systems, initial performance and system acceptance testing can be performed one of three ways – by the vendor, by the installation contractor or system integrator, or by the owning agency. Each method has advantages and disadvantages. Allowing a vendor to conduct performance testing means that the system will be tested, and any obvious problems will be quickly repaired. However, vendor tests can be incomplete when problems are identified because some of the components may not be provided by the vendor. This sometimes results in finger pointing but not the final resolution of the problem.

Finger pointing may be eliminated when the installation contractor or system integrator is responsible for the "system." However, the interfaces between components can fail and instead of fixing them, the contractor may claim that this was not part of the original scope and may claim the problem requires a change order at extra cost.

Finally the owning agency can perform the system test, which most likely is the most thorough, but this takes staff time and resources. By conducting the testing in-house, agency personnel will be familiar with the CCTV system upon completion. If problems arise in the future, they will have the skills to troubleshoot the system. Keep in mind that once a system is installed and running, it requires periodic testing and maintenance to ensure it continues to operate properly.

6.5.4. Configuration Management and Control

Manufacturers are constantly updating their equipment. This invariably leads to the possibility of equipment that once interoperated with other components, no longer does. As an example, consider daylight saving time. The dates for implementing daylight saving time are now different then they were prior to the year 2006. Unless a management application is up-to-date, it will not be able to deal with the new implementation.

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7. THE CONCLUDING PHASES OF THE SYSTEMS ENGINEERING PROCESS

7.1. Introduction

A common misconception of systems engineering is that the process stops when deployment and testing is complete. However, that is not accurate. From the very first systems engineering diagram (refer to Figure 2-1), the SEP was shown to continue into systems operation and maintenance. Additionally, the adaptation of the "Vee" diagram to ITS projects incorporated an additional block for changes and upgrades (refer to Figure 2-2) recognizing the life-cycle aspect of these deployments. These components, which have been maintained in the SEP process for digital video (refer to Figure 2-3), are important aspects of the overall process.

The systems engineering process does not end with deployment. The sections of 'Systems Operation and Maintenance' and 'Changes and Upgrades' are important and on-going components to consider.

7.2. Operations

The overall goal of the operations and maintenance block in the "Vee" diagram is to recognize, and provide for, the activities that are required for the effective use of the system on a day-to-day basis. With respect to operations, these include the following:

- daily operations,
- monitoring the system,
- performance reporting,
- hiring and training staff,
- continued testing, and
- fine-tuning of system installation.

Daily operations are the 'meat and potatoes' of what the system was designed to do. The majority of the user needs and functional requirements were developed to support those day-to-day activities that stakeholders felt were necessary to accomplish their goals.

System monitoring is a critical task that is often overlooked or downplayed in importance. Many deployments do not want to devote the resources to monitoring due to the time and cost that it can take. However, it is only through consistent and thorough monitoring of the system that trends in performance can be ascertained. As an example, consider a video over IP deployment where camera performance is optimal throughout the day except for brief periods at approximately 8AM and 1PM. Monitoring the deployment and the network may provide likely answers, such as the impact of significant additional network traffic as people report to work and return from lunch. System performance monitoring is best considered as part of the overall requirements of the system and not as an afterthought to try to pinpoint problems. Performance reporting follows directly from performance monitoring. Many deployments will have reporting requirements for how the system is working. There may be calculations or information formatting to accomplish to complete the reporting requirements. Performance reporting is best performed on a routine basis and should become a normal part of staff duties.

Some deployments may protest the inclusion of hiring and training staff as part of operations procedures, stating that is the job of Human Resources. While the aspects of job posting, setting up interviews, and arranging for benefits and identification cards typically fall under the auspices of Human Resources, the rest typically falls to the departments where staff will work, in this case, Operations. Existing operations staff or management will be responsible for training new staff on procedures, equipment, responsibilities, and more. Additionally, management will typically create the responsibilities of the job position, for use by Human Resources. Acknowledging this operations need is important to create a balanced and effective workflow.

Testing of systems essentially occurs constantly, whether by design or not. Any time a system is in use, it is effectively being tested. If it works as planned, it passed. If not, the discrepancy should be noted, identified, and resolved. Some deployments have specific testing schedules where every aspect of the system is tested. This testing is useful for those portions that don't get exercised on a regular basis. Record keeping is an important component of testing and should include items such as who, what, when, and the result, especially in the case of abnormalities.

No system is perfect upon installation. Ideas for refinement and fine-tuning often come about through repeated use and more than one set of 'eyes' looking at the situation. In many cases, these ideas can be used to tweak or fine-tune the initial system. Here again, it is important that essential record-keeping procedures be maintained, as these tweaks may refine procedures, testing practices, or may even be used for new or updated requirements in future evolutions of the system.

7.3. Maintenance

Maintenance is a critical need in any system or deployment. The bottom line is that nothing lasts forever, and systems and components fail. The goal of including maintenance in the SEP is to provide an inherent recognition of both the need for maintenance and the importance it plays in prolonging future changes and upgrades. With respect to video deployments, the typical maintenance areas are:

- preventative maintenance,
- reactive maintenance, and
- software maintenance.

Preventative maintenance consists of items such as testing, cleaning, and parts replacement for end-of-life cycles. Preventative maintenance can also cover items such as backing up data and software. Preventative maintenance goes hand-in-hand with the testing component of operations. Performing maintenance on a set schedule is important for consistency in operations, especially for hardware items. In some cases proof of preventative maintenance may be needed for warranty consideration. Regardless, the record keeping aspect of preventative maintenance is an important consideration to ensure that items get done, once, on the proper schedule.

On the other hand, reactive maintenance involves correcting faults or situations when they occur. While the goal should be to minimize problems through preventative maintenance, all deployments will experience situations where something breaks or fails. This forces a reactive mode to restore the system to good working order. If over time, a series of reactive measures are necessary, it may highlight a missing aspect of preventative maintenance or testing. Once again, logging any maintenance measure taken, whether preventative or reactive, is an important task.

The final aspect of maintenance listed above is software maintenance. Depending on the task, modern program code can contain millions of lines. Automated testing of some program aspects is possible, and developers routinely work to debug software components, but 'bugs' or problems in the software code are still common. When they occur, they are typically not able to be addressed by the day-to-day operations and maintenance personnel and must be rolled to either in-house or contracted support. Recording the exact situation and any error codes or messages that resulted in the error will be a time-saver for tracking down and resolving the problem.

7.4. Changes and Upgrades

The objective of this portion of the SEP is to allow the systems owner/ operator to evolve the system over time. This may include updating it to current standards or technologies or adding capabilities beyond the original deployment. Upgrades may also be necessary to remove obsolete parts of the system or evolve the system to new operations. The critical concern of any change is to maintain the system integrity.

Integrity essentially means that integration into the existing system must be both financially and technologically sound, while new components should be supported by the same process used for the overall system, including needs, requirements, design, and testing. Documentation is important for this area, not only to detail new requirements, but to ensure that the changes required for integration into the existing system can be handled by any development team.

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8. PROCUREMENT TO SUPPORT SYSTEMS ENGINEERING

8.1. Introduction

A procurement specification is a statement of needs to be satisfied. Its purpose is to provide potential suppliers a clear, accurate, and full description of an organization's needs. This should allow a supplier to propose a solution to meet those needs. This section is included in this guidebook to provide some information on procurement, including contract types and roles and responsibilities.

8.2. Description of Roles and Responsibilities of Contract Types

There are several ways to describe contract types. The Testing for Transportation Management System: A Technical Handbook looks at them from the perspective of rolls and responsibilities*(1)*. It describes five types as:

- design,
- build,
- design/build,
- system integrator, and
- system manager.

There are several ways of looking at contracts. One common categorization is by the roles and responsibilities, while another is by the financial and risk model they use.

The following subsections provide a summary of how the handbook describes each of them.

8.2.1. Design

A contractor develops the system or detailed design hardware and software requirements. The contractor also produces the procurement specifications, and the unit, subsystem, system verification plans, and procedures. The contractor is usually required to provide support during the testing and system acceptance phases.

The agency has to manage the design contract and review and approve the design documentation and testing plans. The resulting system will depend on the contractor's understanding of the agency's needs and requirements.

8.2.2. Build

A contractor verifies and implements the system design documentation developed during high-level design phase or created by the design contractor. The build contractor is responsible for carrying out the unit, subsystem, and system verification plans. The build contractor may also be required to develop training plans and conduct training.

In the build type of contract, the agency is responsible for managing the construction contract, and for witnessing and approving acceptance testing. The agency is also responsible for approving any training plans.

8.2.3. Design/Build

This type of contract is a combination of the previous two. A single contractor is responsible for the design and documentation aspects and the implementation and testing phases of a project.

The agency is responsible for managing the design/build contract; review and approve the design documents, the test plans and procedures, and with witnessing and approving acceptance testing. The agency also approves training plans.

8.2.4. System Integrator

In the system integrator contract, an integration contractor is hired to provide the oversight of the design and implementation phases. The contractor is usually responsible for reviewing and commenting on the design documents, procurement specifications, training plans, test plans, and procedures. The contractor signs off on the unit and subsystem testing but is usually responsible for conducting the system verification/acceptance tests. System integrators can be contracted for design and implementation services under either separate agreements or a single agreement.

The agency is responsible for managing the system integrator contract, approving documentation, and witnessing and approving acceptance testing.

8.2.5. System Manager

A system manager contract is all encompassing. The contractor is responsible for directing and managing all phases and aspects of the system development and implementation. The system manager works with the users and stakeholders to develop a concept of operations, coming up with functional requirements, and creating the system design documentation and plans. The system manager develops a system design and implements it or contracts with others to provide the services. In some cases, the system manager is asked to be responsible for the operations and maintenance once the system is up and running.

The agency is responsible for approving procurement practices and any major contracts let by the system manager. The agency is also responsible for oversight of contracts, participates in the approval of documentation, and witnesses and approves acceptance testing.

8.2.6. Selection

The Testing for Transportation Management System: A Technical Handbook provides an assessment of the various risks associated with the different types of contracts *(1)*. Table 8-1 details the comparison.

Table 8-1. Risks Associated with Different Management Contracts.

Contract Type	Financial Risk	Technical Risk	Test Program Burden
Design	Low	High	High
Build	Medium	Medium High	High
Design/Build	Medium	Medium	Medium
System Integrator	Medium High	Low	Low
System Manager	High	Very Low	Very Low

8.3. Description of Financial and Technical Risk Contract Types

Another approach to defining contract types is to look at them from a financial and technical risk perspective. The Guide to Contracting ITS Projects looks to define them from that view *(2)*. It defines the four contract types as:

- fixed price,
- cost reimbursable,
- time and materials, and
- incentive.

In the fixed price contract approach, the contractor is paid a set price irrespective of how long it takes to make deliverable and achieve the required performance. Using a cost reimbursable contract, the contractor is paid for actual costs of performing the work but the amount of profit is fixed. In the time and materials contract, the contractor is paid for actual costs of performing the work and a percentage fee to be added. In the incentive contract, the contractor is paid an additional fee or bonus if some characteristic such as an early finish date is met. This bonus is in addition to the three types of previously described reimbursements. Table 8-2 summarizes the financial risks of the three types.

Table 8-2. Risks Associated with Different Financial Contracts.

Contract Type	Contractor Risk	Agency Risk
Fixed Price	High	Low
Cost Reimbursable	Medium	Medium
Time and Materials	Low	High

8.4. Procurement Specifications

The ITS sources on systems engineering provide significant assistance in developing a concept of operation, defining requirements, and what to consider in a design. Procurement specifications are not discussed. For that, you can turn to a document on specification writing that looks like it came out of a systems engineering manual *(3)*. The document covers the definition of a specification, how it was derived from requirements that meet user needs, who was involved in writing them, and, lastly, how to ensure that they are a description of the development process. The procurement specifications, irrespective of whether they are developed by the acquiring agency or under one of the above contract types, must address all the system requirements and acceptance test requirements. The operative word for writing workable procurement specifications is clarity.

The specification writing document provides a checklist of what constitutes a good specification. A good specification is one that:

- states the requirements unambiguously in clear and concise language,
- focuses on the what is needed and not a solution to the need,
- states the criteria for acceptance,
- only states the essential features or characteristics of the requirement, and
- does not describe any proprietary designs.

While one can readily find example specifications for most components of IP-based CCTV systems, DOT camera specifications that deal with cameras with an IP interface are still hard to find on DOT web pages. Several manufacturers that target ITS applications offer IP-based cameras and have posted specification sheets *(4)*. IP camera specifications are very similar to analog camera specifications but now include references to additional items such as:

- video encoding,
- resolution,
- frame rate,
- compression options,
- connection type (unicast or multicast),
- video latency,
- protocol support, and
- configuration and address management.

8.5. Procurement Tools

Even if a CCTV camera and the pan/tilt/zoom unit do not have to be NTCIP compliant devices, the NTESTER Configuration Wizard may be helpful *(5)*. It is primarily meant to configure what NTCIP variables should be tested. However, it indirectly provides a checklist for features in a field device that may be desirable.

8.6. Cited Sources and Bibliographical References

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9. GLOSSARY

480i - 480i refers to “480 interlaced,”, a form of standard definition digital television broadcast that approximates the quality of standard analog television.

480p - 480p refers to “480 progressive,”, a form of standard definition digital television broadcast. 480p is considered enhanced definition TV but not high definition.

720p - The 720p specification is the lowest format that is considered HDTV. The 720p horizontal resolution of 1280pixels gives it a total pixel count of 921,600.

1080i - 1080i is a high-definition television video mode. The term usually assumes a widescreen aspect ratio of 16:9, implying a horizontal resolution of 1920 pixels and a frame resolution of 1920 × 1080 or about 2.07 million pixels.

1080p - 1080p is a video resolution with 1080 lines of vertical display resolution that uses progressive scan to display the video. The 1080p specification can be referred to as full HD.

10 GIGABIT ETHERNET - A form of Ethernet that has a maximum bandwidth of 10,000 Mbps or 10 Gbps.

AES - Auto Electronic Shutter – This is the ability of a camera to compensate for moderate light changes by adjusting the camera shutter speed as opposed to using an auto iris.

AGC - Automatic Gain Control feature adjusts the brightness of a video image to maintain a consistent level.

ANALOG- A device or system that represents changing values as continuously variable physical quantities.

ANGLE OF VIEW - This refers to the range in degrees that a camera can be focused without distorting the image. A close-up is generally a wide angle of view. To focus on a distant object, the angle of view is smaller or narrower.

APERTURE - The opening of a lens which controls the amount of light let into the camera. The size of the aperture is controlled by the iris adjustment. By increasing the f stop number (f1.4, f1.8, f2.8, etc.) less light is permitted to pass into the camera.

ASPECT RATIO - The term pixel aspect ratio is used in the context of computer graphics to describe the layout of pixels in a digitized image. Most digital imaging systems use a square grid of pixels--that is, they sample an image at the same resolution horizontally and vertically.

ATM - Asynchronous Transfer Mode – A network technology that transfers data in units of information that are fixed in size, called cells.

AUTO WHITE BALANCE - A feature on color cameras that constantly monitors the light and adjusts the color intensities to eliminate any color casts. It is what makes flesh tones look correct.

AUTOMATIC IRIS CONTROL - This a lens feature in which the iris (aperture) automatically opens or closes to maintain proper light levels.

AVC/H.264 - This is the latest ratified video coding standard. It emerged as the result of joint development of International Telecommunication Union Video Coding Experts Group (ITU VCEG) and MPEG ISO. This standard is known as H.264 (ITU-T name), or MPEG-4 part 10 (ISO/IEC 14496-10), or MPEG-4 Advanced Video Coding (AVC).

AVCHD - Advanced Video Codec High Definition is a high-definition recording format for use in digital tapeless camcorders.

AVI - Audio/Video Interleaved – Standard that has been designed by Microsoft. AVI is the file format in which the audio and video data are alternated one after another. During playback a sound track is synchronized with video.

BANDWIDTH - The amount of information that is transmitted across a communications system in a certain amount of time. The theoretical bandwidth is the maximum amount of data that can be transmitted across the system

BITRATE - Rate of video/audio data transfer. Measured in kilobit per second. The higher bit rate is, the more space on the disk is occupied.

BLC - Back Light Compensation – This is a feature on newer CCD cameras which electronically compensates for high background lighting so that normally silhouetted image has more detail.

BLOOMING - The defocusing of regions of the picture due to excessive level in a smaller area. When a vehicle is viewed head on at night, a halo effort blurs the two headlights into a single large spot.

BNC - Bayonet Neill Concelman A commonly used connector for audio/video (A/V) applications. After the plug is inserted, it is turned, causing pins in the socket to be pinched into a locking groove on the plug.

BYTE - A larger level of information, generally considered to consist of 8 bits.

C Mount /CS Mount - Two standards for how camera lenses are attached to camera bodies. They are not compatible with each other.

CAT5 / CAT6 - Category 5 &6 cable is a low capacitance type of twisted pair cable that is used in computer networking applications.

CCD - (Charge Couple Device) The device in a camera that coverts light into an electronic image. The size of the CCD chip is normally 1/4, 1/3, or 1/2 inch. As a rule of thumb, the larger the size, the higher the quality of the image produced. However, some of the higher density 1/4 and 1/3 now produce as good an image as many of the 1/3 or 1/2 inch chips.

CIF - Common Intermediate Format – A video resolution with a size of 352 × 288 pixels.

CLOSED CAPTIONS - Textual video overlays that are not normally visible, as opposed to open captions, which are a permanent part of the picture. Captions are usually a textual representation of the spoken audio. In the United States, the official NTSC Closed Caption standard requires that all TVs larger than 13 inches include circuitry to decode and display caption information stored on line 21 of the video signal. DVD-Video can provide closed caption data, but the subpicture format is preferred for its versatility.

CODEC - COmpressor / DECompressor – Technology for transferring data including video across communications media by compressing it for sending and then decompressing it at the receiving end.

COMPRESSION - Is the process of removing extra, or redundant, information from a signal.

CONTRAST RATIO - The difference in brightness between the brightest white and the darkest black within an image.

D-1 - A video resolution with a size of 720 × 576 pixels.

DECODER - A decoder is a device which does the reverse of an encoder, undoing the encoding so that the original information can be retrieved.

DECODING - The process of converting data between formats.

DEMULTIPLEXING - The opposite of multiplexing. In this process a combined audio/video stream will be separated into the number of streams it consists of.

DHCP - Dynamic Host Configuration Protocol is a protocol used by networked devices clients to obtain the parameters necessary for operation in a network.

DIGITAL - There are two main ways of doing things electronically, analog or digital. The digital method is to consider a circuit either on or off. A digital voltage or signal refers to the discrete nature of digital voltage potentials in digital circuits.

DNS - Domain Name System is a mechanism used in the Internet and on private intranets for translating names of host computers into address.

DSL - Digital Subscriber Line – A communications technology that transmits information over existing phone lines.

DTV - Digital Television. DTV can be used to carry more channels in the same bandwidth than analog TV (6 MHz or 7 MHz in Europe) and to receive high-definition TV programs.

DVD - Digital Video or Versatile Disk is a popular optical disc storage media format. Its main uses are video and data storage. Most DVDs are of the same dimensions as compact discs (CDs) but store more than six times as much data.

DVR - Digital Video Recorder – A digital video recorder is basically a computer that converts the incoming (analog) signal from the cameras to digital, and compresses it, and stores it. The DVR replaces the function of a multiplexer (or quad or switcher) and a security VCR. There are many advantages of digital video recorders over their analog counterparts.

ES - Elementary Stream is a single (video or audio) stream without container. For instance a basic MPEG-2 video stream (.m2v or .mpv) is an MPEG-2 ES, and on the audio side we have AC3, MP2, etc. Most DVD authoring programs require ES as input.

ENCODER - An encoder is a device used to change a signal or data into a code suitable for either cryptography or compression.

ENCODING - The process of converting data between formats.

ETHERNET - A communications technology originally designed to connect computer, printers, and workstations within a small area. Ethernet has exploded in use and is the most common networking communications technology in use today. Ethernet is also known as 10BaseT and has a maximum bandwidth of 10 Mbps.

FAST ETHERNET - A form of Ethernet that has a maximum bandwidth of 100 Mbps. Fast Ethernet is also known as 100BaseT.

FIBER-OPTIC CABLING - A type of cabling that transmits light instead of electronic signals

FIELD-OF-VIEW - The angular perspective of a view.

FRAMES PER SECOND - In digital video applications, refers to the number of video images that can be captured, displayed, or recorded in a second. Also referred to as the frame rate or refresh rate. Thirty frames per second is consider full motion video. An image can be displayed at a frame rate that is less than the frame rate of the device displaying the image.

F-Stop - A term used to indicate the speed of a lens. The smaller the f-number, the larger the iris opening and the greater the amount of light passing through the lens. A lower F-stop sacrifices depth of field for having enough light to capture an image.

FTP - File Transfer Protocol – A protocol that defines how to transfer files over the Internet.

GIGABIT-– 1,000,000,000 bits of information. Abbreviated as Gb. When used as a rate of information transfer, abbreviated as Gbps.

GIGABIT ETHERNET - A form of Ethernet that has a maximum bandwidth of 1000 Mbps or 1 Gbps. Gigabit Ethernet may also be referred to as 1000BaseT.

H.261 - is a video coding standard originally designed for transmission over ISDN lines on which data rates are multiples of 64 kbit/s. The standard supports two video frame sizes of CIF and QCIF.

H.262 - The H.262 recommendation is identical to the video specification of MPEG-2.

H.263 - The H.263 is dedicated to video conferencing via H.324 terminals using V.34 modems at 28.8 kbit/s, and to H.323 LAN-based video conferencing. The coding algorithm in H.263 is based on H.261, but has better performance than the H.261.

H.264 - is a standard for video compression. It is also known as MPEG-4 Part 10, or AVC (for Advanced Video Coding). It was written by the ITU-T Video Coding Experts Group (VCEG) together with the ISO/IEC Moving Picture Experts Group (MPEG) as the product of a partnership effort known as the Joint Video Team (JVT).

HD DVD - is a new standard for next-generation optical systems that delivers brilliant, high-definition performance. DVD and HD DVD share the same basic disc structure. In addition to DVDs MPEG-2, HD DVD players also recognize both MPEG-4 AVC and VC-1 based on Microsoft's Windows Media.

HDTV - High-Definition Television, a new type of television that provides much better resolution than current televisions based on the NTSC standard. HDTV is a digital TV broadcasting format where the broadcast transmits widescreen pictures with more detail and quality than found in a standard analog television, or other digital television formats.

HDV - is an inexpensive high-definition video recording format that uses MPEG2 compression to fit HD content onto the same DV or MiniDV tapes

HTTP - Hypertext Transfer Protocol –A protocol that defines how to transmit and display information across networks using a web server and browser.

INTER PREDICTION - The process of predicting blocks of pixels based on temporal dependency between two or more frames. Also referred to as Temporal prediction.

INTERLACED - Is a video storage mode. An interlaced video stream doesn't contain frames but fields with each field containing half of the lines of one frame (all even or all odd lines).

INTRA PREDICTION - The process of predicting blocks of pixels based on spatial dependency (i.e., within the frame). Also referred to as Spatial prediction.

IR Filter - A glass/plastic filter used in front of an imager to remove infrared light. The infrared end of the light spectrum is associated with heat. The iris (aperture or opening) that controls how much light is allowed to pass through the lens. Also see Aperture.

ISP - Internet Service Provider – A company that provides Internet communications services to home and/or business users.

ISDN - Integrated Services Digital Network – An international communications standard for sending voice, video, and data over normal telephone wires.

ISO - International Organization for Standardization, also provides publicly available MPEG standard documents, reference software and conformance streams for free.

INTERNET - The vast collection of interconnected computers that utilize common protocols for sharing information.

JPEG - is a glossy compression technique for color images. Although it can reduce files sizes to about 5% of their normal size, some detail is lost in the compression.

KILOBIT - 1000 bits of information. Abbreviated as Kb. When used as a rate of information transfer, abbreviated as Kbps.

LAN - Local Area Network – A network that typically spans only a small area, such as a building or company.

LATENCY - A communications term for the delay between two points in the system.

LUMINANCE - is the photometric measure of the brightness in a video picture.

LUX - Refers to the amount of light required for a camera to capture a good image. Infrared cameras have a very low lux rating and therefore can produce image when there is low light. The unit of measure is millicandelas.

MEGABIT - 1,000,000 bits of information. Abbreviated as Mb. When used as a rate of information transfer, abbreviated as Mbps.

MINIDV - Mini DV is a video cassette designed for use in MiniDV digital camcorders. The picture quality of digital video (DV) recorded on a Mini DV cassette is basically identical or better to the quality of DV recorded on a Hi8 or 8mm cassette by a Digital8 camcorder. Mini DV can have up to 530 lines of video resolution for some camcorder models

MODEM - MOdulator-DEModulator – A device that enables the transmission of data over physical wiring.

MOV - QuickTime Movie file.

MP3 - It was standardized by the ISO as MPEG Audio Layer III. The majority of music stored digitally is compressed with the .mp3 format.

MP4 - A file format that was designed for storing MPEG-4 data in a file.

MPEG - The Moving Picture Experts Group is a working group of ISO/IEC in charge of the development of international standards for compression, decompression, processing, and coded representation of moving pictures, audio, and their combination.

MPEG-1 - Audio and video compression format developed by Moving Pictures Expert Group. Official description: Coding of moving pictures and associated audio for digital storage media at up to about 1,5 Mbit/s.

MPEG-2 - The MPEG-2 video coding standard is primarily aimed at coding of higher resolution video with fairly high quality at challenging bit rates of 4 to 9Mbit/s.

MPEG-4 - MPEG-4 is a standard for graphics and video compression that is based on MPEG-1 and MPEG-2 and Apple QuickTime technology. Wavelet-based MPEG-4 files are smaller than JPEG or QuickTime files, so they are designed to transmit video and images over a narrower bandwidth and can mix video with text, graphics, and 2-D and 3-D animation layers.

MULTICAST - is the delivery of information to a group of destinations simultaneously using the most efficient strategy to deliver the messages over each link of the network only once, creating copies only when the links to the destinations split.

MULTIMODE - A type of fiber-optic cable that supports the propagation of multiple streams of light at the same time. Multimode fiber has a typical core diameter of 50 or 62.5 µm.

MULTIPLEXING - Usually video and audio are encoded separately. Then you have to join both of them to make a movie that you can play. During multiplexing the audio and video track are combined to one audio/video stream. The audio and video streams will be intermixed together and navigational information will be added.

NETWORK - A system of devices linked together via shared communications.

NTP - Network Time Protocol – A protocol used to ensure accurate synchronization of clock times in a network of computers and devices.

NTSC - National Television System Committee. The NTSC is responsible for setting television and video standards in the United States and Japan (in Europe and the rest of the world, the dominant television standards are PAL and

SECAM). The NTSC standard for television defines a composite video signal with a refresh rate of 60 half-frames (interlaced) per second. Each frame contains 525 lines and can contain 16 million different colors.

PAL - Phase Alternating Line, the dominant television standard in Europe. The United States uses a different standard, NTSC. Whereas NTSC delivers 525 lines of resolution at 60 half-frames per second, PAL delivers 625 lines at 50 half-frames per second.

PDA - Personal Digital Assistant (Pocket PC).

PES - Packetized Elementary Stream consists of a continuous sequence of PES packets of one elementary stream with one stream ID. When PES packets are used to form a PES stream, they shall include Elementary Stream Clock Reference (ESCR) fields and Elementary Stream Rate (ES_Rate) fields.

PIXEL - Picture element. The smallest cell or area of a CCD chip capable of displaying detail on a screen. The greater the number of pixels, the higher the resolution.

POTS - Plain Old Telephone Service is the standard telephone service that most homes and business use.

PRESETS - Predefined positions of pan, tilt, and zoom equipped cameras. These allow the control equipment to define, move to, or return to predefined reference points.

PROGRAM STREAM - The Program Stream is similar to MPEG-1 Systems Multiplex. It results from combining one or more Packetized Elementary Streams (PES), which have a common time base, into a single stream. The Program Stream is designed for use in relatively error-free environments and is suitable for applications which may involve software processing.

PROTOCOL - A set of formal rules describing how to transmit data between two devices.

PSNR - Peak Signal to Noise Ratio

PTZ - Pan-Tilt-Zoom – A mechanism attached to a cameras that allows you to adjust the position (‘pan’ is side-to-side, ‘tilt’ is up-and-down) and focus (‘zoom’) of the camera using a remote controller. Cameras used for vehicle detection do not incorporate PTZ.

QA - Quality Assurance.

QCIF- Quarter CIF with a video resolution of 176 by 144.

QUAD - An analog device used to display four cameras simultaneously on a single monitor.

QUICKTIME - A video and animation system developed by Apple Computer. PCs can also run files in QuickTime format, but they require a special QuickTime driver. QuickTime supports most encoding formats, including Cinepak, JPEG, and MPEG.

RESOLUTION - The screen resolution signifies the number of dots (pixels) on the entire screen. For example, a 1024by-768pixel screen is capable of displaying 1024 distinct dots on each of 768 lines, or about 786,000 pixels.

RG58 - A common coax cable used in networking applications that has an impedance of 50 ohms.

RG59 - A common coax cable used in CCTV applications that has an impedance of 75 ohms.

RTP - RTP is the Internet-standard protocol for the transport of real-time data, including audio and video. It can be used for media-on-demand as well as interactive services such as Internet telephony. RTP consists of a data and a control part. The latter is called RTCP.

RTSP - Protocols for streaming servers, clients, and infrastructure.

SECAM - Systeme Sequentiel Couleurs a Memoire is television standard in Russia and France. SECAM delivers 625 lines at 50 half-frames per second.

SIGNAL TO NOISE RATIO - The ratio of pure signal to extraneous noise, such as tape hiss or video interference. Signal-to-noise ratio is measured in decibels (dB). Analog recordings almost always have noise. Digital recordings, when properly pre-filtered and not compressed, have no noise.

SINGLE-MODE - A type of fiber-optic cable that supports the propagation of a single stream of light at the same time. Single-mode fiber has a typical core diameter of 9 µm.

SMTP - Simple Mail Transfer Protocol – A protocol for sending electronic mail messages between servers.

SNMP - Simple Network Management Protocol – A set of protocols used to remotely manage networks and devices.

SONET - Synchronous Optical Network – An optical interface standard designed to allow multiple vendors products to be networked together.

STREAMING - Data is streaming when it's moving quickly from one chunk of hardware to another and doesn't have to be all in one place for the destination device to do something with it.

SWITCH - A switch will take multiple camera inputs and will show them on the monitor one at a time. Unlike a quad, it will not display them all at once, instead it sequences through them showing one camera at a time.

T-1 - Trunk Level 1 – A dedicated connection supporting data rates of 1.544 Mbps. A T-1 line actually consists of 24 individual channels, each of which supports 64 Kbps. Each 64 Kbps channel can be configured to carry voice or data traffic. A T-1 line can be delivered across both twisted pair copper and fiber-optic cabling.

TCP/IP - Transmission Control Protocol/Internet Protocol – A low-level protocol used by computers and other hardware to communicate across disparate networks.

TOD - are recording formats for use in digital tapeless camcorders. The format is comparable to AVCHD. Because they are tapeless, they are generally used in hard drives, memory cards, and SD memory. TOD files are used solely for high definition video files.

TRANSPORT STREAM - The Transport Stream combines one or more Packetized Elementary Streams (PES) with one or more independent time bases into a single stream. Elementary streams sharing a common timebase form a program. The Transport Stream is designed for use in environments where errors are likely, such as storage or transmission in lossy or noisy media.

UDP - User Datagram Protocol a protocol within the TCP/IP protocol suite that is used in place of TCP when a reliable delivery is not required. UDP provides for exchange of datagrams without acknowledgments or guaranteed delivery.

UNICAST - In computer networks, unicast is the sending of information packets to a single destination. "Unicast" is derived from the word broadcast, as unicast is the extreme opposite of broadcasting. In computer networking, multicasting is used to regain some of the efficiencies of broadcasting.

URL - Uniform Resource Locator.   Can be used to identify the source (IP address) of a video image.

VHS - Video Home System is a ½″ analog tape media. With a maximum resolution of 250 lines, the VHS system records at a slightly lower resolution than 8MM.

VIDEO CAPTURE CARD - Computer cards that you can install on the motherboard of your own computer to create your own video recording computer. Due to compatibility issues with this type of device, we do not sell these separately.

VIDEO DECODING - The process of taking an encoded video signal and converting it back to its original form.

VIDEO ENCODING - The process of taking a video signal and altering it in some manner for transmission to a remote location.

WAN - Wide Area Network – A large network, usually consisting of a collection of several LANs, that spans a large geographic area.

WAV - This is the Windows standard for waveform sound files.

WAVELET - A mathematical function used in compressing images. Images compressed using wavelets are smaller than JPEG images and can be transferred and downloaded at quicker speeds. Wavelet technology can compress color images from 20:1 to 300:1, grayscale images from 10:1 to 50:1.

WORLD WIDE WEB - WWW – A collection of computers that utilize HTTP to share information. The World Wide Web is often referred to as “the web” or even “the Internet,” although this last characterization is incorrect.

ZOOM LENS - A mechanical assembly of lens elements with that can vary the focal length (and thus angle of view), as opposed to a prime lens which has a fixed focal length. This is the typical type of lens used in transportation management applications.