Standardizing Non-Standard Intelligent Transportation Systems: A Migration Methodology

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In recent years, the strategic ITS vision of fully interoperable transportation and information services is becoming a reality through the coordinated planning and application of the National ITS Architecture, development and application of ITS, ISO and industry standards (hardware, data structures and protocols), the emergence of real ITS markets and the cooperative response of a broad offering of conforming ITS products and services by industry supplier(s).

New ITS projects and systems inherently have the benefits that come with up-front application of established ITS principles (architecture), practices and standards. These benefits include: standardized, interchangeable components on a conforming ITS architecture; open standard data structures, protocols and communications interfaces; interoperable functional interfaces and information exchanges, and reduced system maintenance and life cycle support costs.

However, older, pre-ITS Architecture systems and installed infrastructures do not necessarily share these valuable benefits. Furthermore, the enormous capital investments already made to deploy these older systems have made additional capital improvement funding more difficult to secure in order to overhaul these systems into standardized, fully-compliant, ITS Architecture configurations.

Hence, alternative system "standardization" and "migration" approaches that incorporate "interoperability bridges" with other conforming and non-conforming ITS Architecture systems, services and functions on a regional level become natural and fiscally responsive options. These approaches leverage and couple the vast legacy investment with select system configuration changes and interface upgrades to facilitate opportunities for ITS system/service interoperability. These approaches also enable the identification and characterization of system interfaces that facilitate interoperability opportunities. These interfaces, whether conforming or non-conforming, are thoroughly analyzed for standard characteristics and assessed for their application as interoperability bridges. The process by which this analysis takes place is derived from systems engineering. Maintenance and supportability factors are also considered to determine the viability of the selected interface. Once the analysis is performed, an interoperability concept, or solution, is developed. The existing configuration and conceptual solution enables the development of a migration path. Development of this migration path identifies the actions required to implement the conceptual solution. These actions are converted into action plans with assigned responsibilities and due dates. Opportunities to assign these actions as part of planned system maintenance/life cycle repair and retrofit programs should be explored in addition to definition of capital improvement projects.

INTRODUCTION

This paper describes a standardization and migration methodology whereby system owners, service operators, and system maintainers can schedule and systematically upgrade key subsystems and components to facilitate system standardization and service interoperability with other similar or complementary systems and services. This methodology identifies a process to formulate standardization and interoperability goals and objectives, to identify candidate subsystems and components, to define the applicable standards to be employed (including architecture), to implement a configuration management program, to develop an upgraded system configuration, and to develop a migration plan of action that considers a number of implementation factors (i.e., migration schedule, implementation cost estimates, configuration management, and potential funding sources). This "standardization migration plan" provides an implementation roadmap to transform non-standard systems into open, cost-effective, interoperable ITS Architecture-conforming systems, and to potentially prolong the useful operational life of non-conforming intelligent transportation systems.

The following methodology described in this paper is based upon an approach used to develop the Caltrans TMC Standardization Plan (1), published in January 1999. This TMC Standardization Plan was developed through a sequence of facilitated technical and consensus-building workshops and the inexhaustible efforts of Caltrans representatives from Headquarters, TMC Districts and Department specialty programs (Operations, Maintenance, New Technology). Other standardization projects, (e.g., TravInfo Standards Migration Plan, GCM Gateway TIS, etc.) were also reviewed for methodology considerations.

ASSUMPTIONS

Successful application of this methodology assumes the following pre-conditions and attitudes are prevalent:

- The commitment and vision of those directing the standardization effort fully endorse the development, negotiation/mediation and execution of the standardization/migration action plan.
- The willingness to participate in the process is endorsed by all organizations, whether or not they are affected.
- The willingness to think "outside the box" to foster change to the "business as usual" mentality is a critical attitude to negotiate action plan compromises.
- The resources (personnel and funding) required to develop AND execute the action plan are readily available for this effort.

METHODOLOGY OVERVIEW

This methodology was derived from selected engineering activities specified in the Systems Engineering (2) process specification and tailored to focus on addressing system interoperability through standardized interfaces, processes and procedures. Figure 1 provides an overview of this methodology as a means to provide a roadmap through the process.

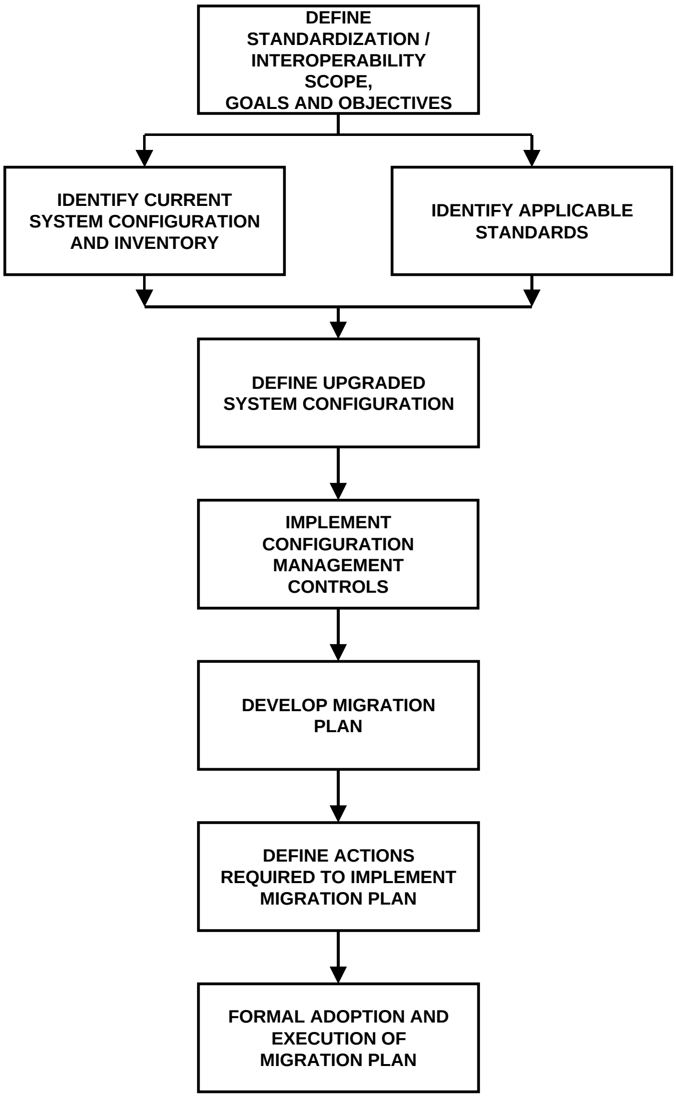

Figure 1. Standardization Migration Process

The primary objective of this methodology is to develop a standardization migration plan that defines the standardization goals and objectives, defines standardized system architecture configurations, levels and degrees of standardization, the timeline goals in which standardization is to be achieved, and an action plan that defines the tasks needed to meet the goals and objectives. A natural by-product of this process is a standardized system specification that that serves as the "target" of the migration plan. This specification prescribes the coordinated system framework on which field elements, communications interfaces, protocols and networks, computer systems, operational procedures, and functional, performance and standardization requirements are to be implemented. In addition, the system specification defines the quality requirements, integration, testing and acceptance requirements, maintenance and support requirements, configuration management, and design practices to be used in executing the migration plan.

Although, consolidating all these requirements into a single specification may appear to be overwhelming, some, if not most, requirements already exist for most systems and should be documented in the initial set of specifications. This "migration system specification" should be written to specify references to other specifications that already exist. The real challenge to developing this specification is determining the elements to "standardized", and to formulate and configure the target system that facilitates a cost-effective migration path. Figure 2 illustrates this system specification content-by-reference approach.

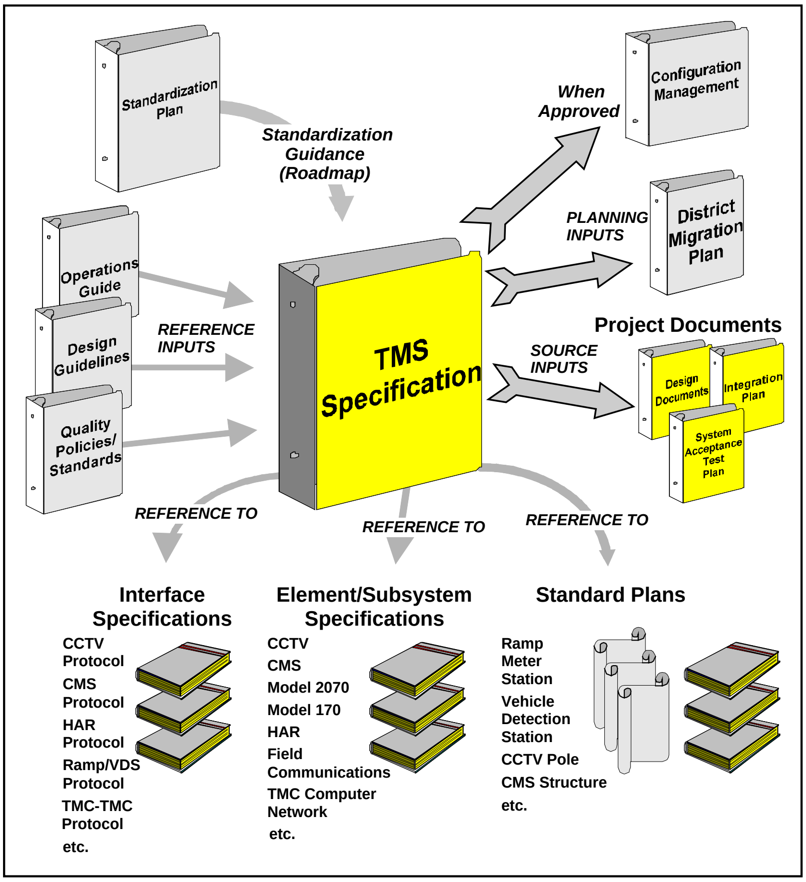

Figure 2. System Specification – By Reference

DEFINE STANDARDIZATION / INTEROPERABILITY SCOPE, GOALS AND OBJECTIVES

Standardization Goals and Objectives

To initiate this process, specific goals and objectives for the standardization study effort MUST be defined. These key elements provide the focus and criteria to shape migration decisions for standardization level(s), system architecture configuration, field components, communication and networking interfaces and methods, system management applications and procedures, system interoperability, support functions and migration timelines. Examples of standardization goals and objectives include:

Goals

- Realize increased levels of operational efficiency and interoperability

- Develop a standard, technical baseline for system maintenance and adaptation / insertion of emerging technologies
- Support conformance with agency requirements and mandates
- Leverage and better utilize other resources to deliver services

Objectives

- Develop a Standardization Migration Plan that identifies the system elements, migration strategies and the action plan that provides cost-effective solutions to promote interoperability with other similar or complementary systems
- Standardize systems, operations, and facilities to achieve uniform functionality
- Standardize systems to streamline maintenance and support requirements and costs
- Standardize select systems, operations and facilities to facilitate regional interoperability
- Reduce system support and maintenance costs through standardized components and multi-vendor products
- Establish a regionalized structure to provide an open framework for integrated management
- Enhance public and private partnerships that promote multi-modal transportation interoperability, activities and services

Standardization Scope

To maintain the focus of this effort, the scope of the standardization effort MUST be defined. This key definition provides the focus for the entire effort and provides the boundaries for formulating migration decisions. Without a clear definition of, and adherence to, the defined scope, the effort can easily increase, become convoluted and place achieving the stated goals and objectives at risk. The scope must include the following, at a minimum:

- Definition of system standardization
- Definition of a minimum set of standardization documents (specifications, manuals, practices, operating procedures, design and development processes, drawings, etc.)
- Institutional adoption of published and internal standards
- Definition of systems interoperability and redundancy
- Identification of functions and services to be transparent to users
- Definition of common terminology
- Definition and implementation of a system-wide change control process (standards, specifications, components, procedures, authority, etc.)

Define Standardization Levels

A challenge to the standardization effort is deciding the level, or levels, at which to standardize. Four basic levels can be categorized:

- Components (identical make and model (series))
- Interfaces (physical, functional)
- Applications (data/information exchange)
- System Architecture / Market Package (National ITS Architecture)

Identify System Elements to Standardize

The most critical challenge to standardization is the identification of those elements to standardize. The following criteria can be used to facilitate identification:

- Supports regional interoperability
- Supports compliance with ITS and industry-wide standards
- Level of criticality as related to operations
- Overall benefits for more efficient operations, maintainability and support
- Scale of economy and availability benefits of from multiple vendors

Define Standardization Priorities

Once standardization elements are identified, priorities need to be established in accordance with the needs of users or area being serviced. These priorities consider:

- Regional interoperability
- System maintainability and supportability
- Satisfaction of critical agency requirements and mandates
- Cost impacts to current and future operations

Define Time-phasing of Standardization Efforts

Critical to the rollout and implementation of standardization efforts is the time phasing of the implementation. Time phasing considers:

- Synergy with on-going system upgrade projects
- Evolution of available and emerging technologies
- Cost impacts and funding constraints
- Regulatory milestones
- Availability of appropriate resources to implement, operate and maintain

Develop Standardization Outreach Plan

Success of the standardization efforts also involves an institutional component. Outreach efforts to adopt and accept the resulting standards and migration approaches facilitate the functional deployment of the standards and migration approaches. Outreach efforts also help forge cooperative efforts between agencies so that the full benefits of the standardization effort can be realized.

IDENTIFY CURRENT SYSTEM CONFIGURATION AND INVENTORY

The initial activity to developing a standardization plan is capturing the state of the current system assets and operations. This inventory process provides a basis to review the composition of the systems assets, their distribution and remaining useful life. For organizations with multiple peer-level systems, this activity also provides a view of the commonality and differences between systems. This activity also produces the basis from which all standardization migration efforts will be initiated. Inventory categories include:

- System Architecture
- Field Elements
- Field Communications Infrastructure
- System Networking
- Operations Management Systems (computer systems)
- Operational Administration (SOPs, inter-agency agreements, etc.)

- System Maintenance Administration (maintenance functions, facilities, inventory controls, software development environments, etc.)

Utilization of a database management tool is recommended to capture the inventory information. Figure 3 illustrates a representative database design using an entity relationship diagram (ERD) to show the key relationships between the various tables.

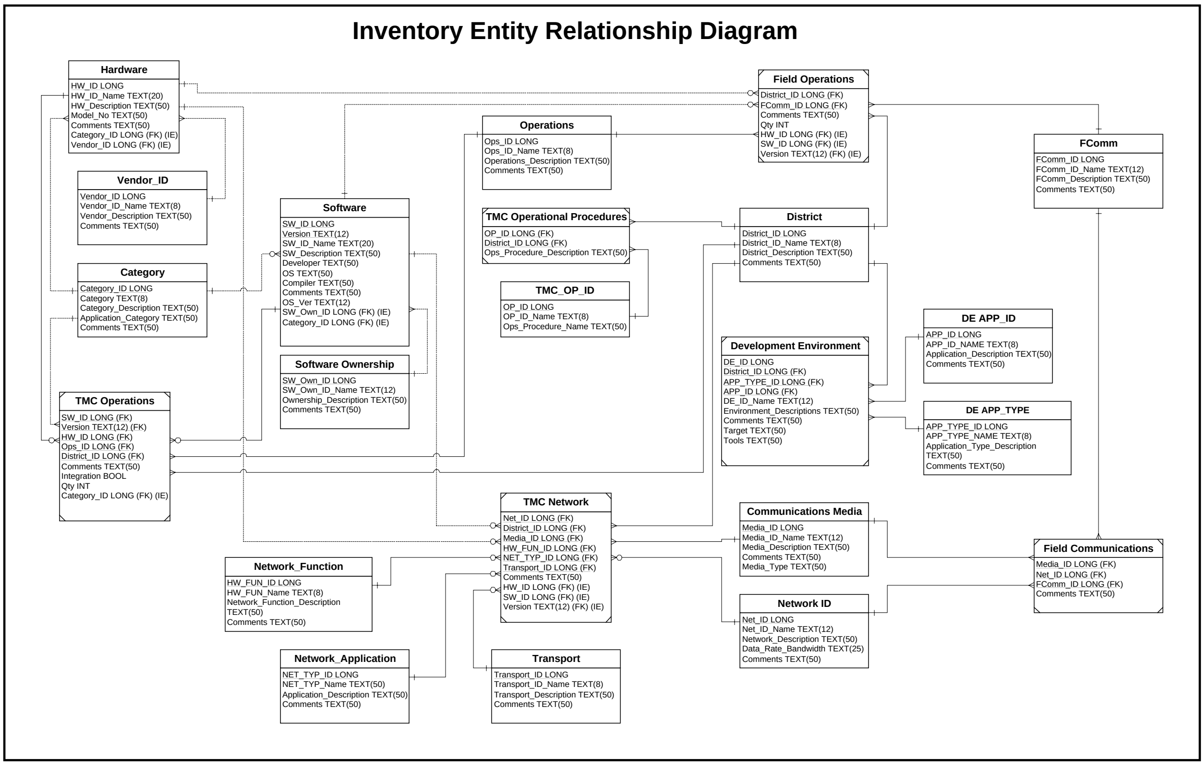

Figure 3. Representative Inventory Database Content (ERD)

Additionally, use of a common diagramming tool to capture system architectures, communications, networking and computer environments provides a common format from which to view and relate architectures and layout configurations.

Document System Architecture(s)

Documenting existing system architecture provides a high-level view of the system. The system view at his level can be used to compare differences with other peer systems or a comparable National ITS Architecture (3). Whether conformance with the National ITS architecture or modifications to expand functional capabilities are target objectives, a comparable architecture will need to be developed to identify the modifications. With these modifications, a migration approach can then be developed and assessed. Use of a diagramming tool to document the current and target architectures will aid identification of specific upgrade modifications for the migration plan.

Document Field Component Inventory

Documenting the field component inventory produces a clear view of the deployed investment of the system. This view can be used to evaluate different standardization strategies as well as migration costs. This view also provides an opportunity to identify the types of components that are candidates for standardization. For instance, if 90% of the system's CCTV camera inventory is of a certain make and model series, one can expect that this component will be established as the system standard, barring any critical support or functional performance issues. System components categorized as field elements include:

- CCTV Cameras
- Changeable/Variable Message Signs (including Extinguishable signs)
- Highway Advisory Radio Stations
- Vehicle Surveillance/Detector Stations
- Ramp Meter Stations
- Traffic Signal Systems
- Weather Stations
- Electronic Toll Systems (including transponders)

Specific field element information to document into the inventory database include:

- Hardware manufacturer and model
- Software application and version (if any)
- Quantity of units
- Physical communication media and link type
- Communications protocol
- Owner
- Operational application
- Conforming standards
- Estimated unit cost to implement
- Estimated design life
- Estimated remaining useful life

<u>Document Communications Infrastructure Inventory</u>

Documenting the communications infrastructure inventory can be divided into two types: data and video. This division provides a fundamental allocation based upon the bandwidth required for each. Voice communication is included with data since bandwidth requirements are nominal. Communications are further identified by link type, that is, by the type of field component it is connected to and connection type and the protocol used for communications. Data communications can largely vary from dial-up telephone service using standard networking protocols, to dedicated fiber optic networks using proprietary protocols. Video communications tend to have fewer options due to relatively high bandwidth requirements, but also range from standard protocol, dial-up options to proprietary protocol, fiber optic options.

Specific information to document for each communications link type include:

- Physical communication media and link type
- Communications protocol
- Nominal bandwidth
- Hardware manufacturer and model
- Software application and version (if any)
- Quantity of units
- Owner/service provider

- Communications application
- Conforming standards
- Estimated unit cost to implement
- Estimated design life
- Estimated remaining useful life

Document System Networking Inventory

Documenting system networking inventory is a critical part of the standardization process. This inventory assessment can make visible opportunities for using networking to consolidate communications. Networking protocols have been developed for different applications at various levels of the network, that is, local area networks (LAN), campus/metropolitan area networks (MAN), and wide area networks (WAN). Correspondingly, each network level usually prescribes a specific communications architecture along with protocols best suited for the level. A benefit of networking is that most any type can be adapted to provide communications for data, voice and video; however, the networking overhead and protocol must be carefully considered to achieve cost-effective, quality service.

Specific information to document for each network type include:

- Physical networking architecture
- Networking protocol
- Nominal bandwidth
- Networking function
- Hardware manufacturer and model
- Software application and version (if any)
- Number of network nodes
- Owner/service provider
- Conforming standards
- Estimated unit cost to implement
- Estimated design life
- Estimated remaining useful life

Document Operations Management Systems

Of all the system elements, documenting operations management systems tend to be the most fragmented. Over time, legacy systems have been implemented through a collection of separate management systems. Most tend to have separate computer systems, co-located in the same facility. Some provide a level of integration where different management applications can be executed on the same computer system, however, the look and feel of the user interface are not similar and may not conform to industry coding standards.

Specific information to document for operations management systems include:

- Hardware manufacturer and model
- Software application and version
- Number of platforms
- Operations application
- Operating system
- Owner
- Conforming standards

- Estimated unit cost to implement
- Estimated design life
- Estimated remaining useful life

Document Operational Administration

Operational administration elements, incl. standard operating procedures (SOPs), inter-agency cooperative agreements (MOAs/MOUs), provide a current view of the level of system operations performed by personnel and the level of operational cooperation and interoperability between agencies. These elements indicate the level at which operations are performed on a manual basis, and provide the basis to analyze operations for automation opportunities.

Specific information to document for operational administration include:

- Operations application
- Specific procedures
- Owner
- Interfacing entities

Document Maintenance Administration

Maintenance Administration elements provide a view of the system support capabilities of the organization. These capabilities include maintenance functions, facilities, inventory controls, software development environments and other support functions. Documenting these elements produce system life cycle related requirements to be included in the upgraded system configuration.

Specific information to document for operations management systems include:

- Host hardware manufacturer and model
- Software development tool and version
- Number of platforms
- Operations application
- Operating system
- Target platform
- Owner
- Conforming standards
- Configuration control tools
- Estimated unit cost to implement
- Estimated design life
- Estimated remaining useful life

IDENTIFY APPLICABLE STANDARDS

Applicable standards to be considered should facilitate open system designs, promote component interchangeability, systems interoperability and systems integration. For standardization migration activities, a superset of standards must also be considered. This superset of standards encompasses those developed from several different industries that ITS builds upon or incorporates. These other industries include computer hardware, networking, video, telecommunications and software development. Application of these standards enables a level of migration planning flexibility to accommodate a multiple standardization configurations.

This step in the standardization process requires the organization to establish agreement for those system areas to standardize AND identify the standards to apply in the upgraded, standardized system configuration.

These standards enable component interchangeability, new technology adaptation and simplified maintenance support and training. Principal benefits from the use of standards (1,4) include:

- Expandability: Open ended – Allows upgrading to take advantage of continued evolution in technology
- Interoperability: Machine independent (end-to-end functionality) – Allows the largest possible markets for service deployment.
- Compatibility: Noninterference – Various devices within the same system must be able to operate without interfering with the operation of other devices:
- Interchangeability: Vendor independence – Devices from different manufacturers that perform the same functions with the same interfaces.
- Open: Nonproprietary – All interface design elements are known and available to be used by others. Promotes rapid deployment and reconfiguration as required.
- Scaleable: Flexible/Expandable – Configurable to accommodate various system sizes specified by functional requirements and local conditions.
- State-of-the-art: Uses the latest available standards to maximize functionality and performance while avoiding technological stagnation and evolution constraints.
- Adaptable: Opportunities to adapt and test new and emerging technologies through standard interfaces.

The development of standards has been a major factor in the rapid deployment of new products and services by the worldwide computer and telecommunications industries during the past several decades. Standards organizations are of two types: treaty-based and voluntary.

The treaty-based organization is the International Telecommunication Union (ITU), founded under the International Telecommunications Convention (ITC). ITU membership consists of Japan, Australia, Canada, the United States and all nations currently involved in ITS in Western Europe. This Geneva-based organization acts through two technical organizations - the International Consultative Committee for Telegraph and Telephone (CCITT) and the International Consultative Committee for Radio (CCIR).

The voluntary organizations are the International Standards Organization (ISO) and the International Electromechanical Commission (IEC). These organizations, also based in Geneva, work in close cooperation with the CCITT and CCIR. Most industrialized countries are members of these voluntary standards organizations and are represented by their national standards body, trade associations, professional associations and government representatives. The American National Standards Institute (ANSI) serves as the voting member of ISO for the United States.

The three major international bodies actively developing standards for computers and communications are the ISO, Institute of Electrical and Electronic Engineers (IEEE) and CCITT. ISO and IEEE develop standards for use by computer manufacturers, while CCITT develops standards for connecting equipment to different types of national and international public networks. As the overlap between the computer and telecommunications industries increases, however, there is of necessity an increasing level of cooperation between these organizations.

In the United States, the following trade and professional organizations are contributing to the development of ITS standards:

- National Electronics Manufacturers Association (NEMA)
- Society of Automotive Engineers (SAE)
- Electronic Industries Association (EIA)
- Institute of Electrical and Electronic Engineers (IEEE)
- Telecommunication Industries Association (TIA)
- VMEbus International Trade Association (VITA)
- ITS America - Standards and Protocol Committee
- ITE ITS Council Standards Committee
- American Association of State Highway and Transportation Officials (AASHTO)
- American Society for Testing and Materials (ASTM)
- Institute of Navigation (ION)

It should also be noted that the National ITS Architecture does not prescribe standards and protocols; rather, it identifies where they are needed to achieve the stated objectives. The Architecture provides an open system framework that supports a multi-vendor component environment allowing adaptability, compatibility, interoperability and interchangeability.

The identification and application of standards need careful attention due to the evolutionary nature of some industries, namely video, telecommunications, and ITS. Established industry standards tend to be more mature and are readily adopted for application in components and systems; however, emerging standards need to be carefully assessed to ensure mechanisms are in-place for long-term support (i.e., government funding provisions, mandates, strong consumer product demand, or industry association support). Although future planned standards may be in committee, conceptual or review stages, products and components developed along this evolutionary path need to be considered for future application and/or adaptation when system upgrades become necessary. Based on these considerations, one can categorize standards according to maturity: Established, Emerging, and Future.

Established Standards

Established standards provide a proven and known technical base on which systems may be upgraded or developed and encompass a broad range of institutional and technical areas, as well as associated industries. These include (but limited to):

- Computer technology and networking
- Telecommunications
- Video Encoding

- Geo-location and Referencing

Computer Technology and Networking

Established computer hardware and software technology standards can be found in many different platform types and at various levels. Most all high-end computer hardware platforms tend to be of a proprietary design; however, overlying software operating systems and applications tend to bridge this gap to accommodate certain standards and functional services. Low to moderate computer hardware platforms begin to show levels of standardization with the x86 PC, NEMA, Type 170/2070 and VME computer platforms. Several other computer technology standards include:

Hardware
- Disk drive interfaces (e.g., IDE, DMA, SCSI-x, RAID, Fiber Channel, etc.)
- Component interfaces (e.g., PCI, SCSI, ISA, AGP, etc.)
- Peripheral device interfaces (e.g., EIA RS-232, RS-12xx, RS-13xx, Centronics, PCMCIA, SCSI, USB, etc.)
- Networking interfaces (e.g., IEEE 802.3 -10BaseT, 802.3u – 100BaseT, FDDI, etc.)
- Networking protocols (e.g., TCP/IP, UDP/IP, etc.)
- High capacity ROM media (e.g., digital versatile disc (DVD), DVD w/ MPEG-2, Fiber Channel, etc.)

Operating Systems
- UNIX System V
- Microsoft Windows™

Software Development
- ANSI-C, C++, COBOL, FORTRAN, LISP
- JAVA, HTML, UML, XML

Database Management Systems
- Structured Query Language
- Relational DBMS
- Object-oriented DBMS

Networking (OSI-RM) (5)
- Physical Layer (e.g., IEEE 802.3-Ethernet 10BaseT, 802.3u-Ethernet 100Base (electrical and optical), 802.5 Token Ring; ANSI X3T9.5-FDDI, etc.)
- Network Layer Services (e.g., ARP, IP, ICMP, etc.)
- WAN routing protocol (e.g., EIGRP, etc.)
- Transport Layer Services (e.g., TCP, UDP, etc.)
- Application Layer Network Services (e.g., DNS, FTP, SMTP, SNMP, RIP, TELNET, DHCP, TACACS+, RADIUS, etc.)

Telecommunications

Established telecommunications standards capitalize on mature, proven information transmission methods. These include both electrical digital hierarchy (EDH DSx) and optical carrier level standards (OC-x). Currently, SONET and ATM provide additional levels of standardization to promote interoperability and fault-tolerant data transmission. Applicable national and industry transmission standards include:

- POTS, Bell 201/202T, DDS, DSx/TX
- EIA/TIA-232, EIA/TIA-422/485, EIA/TIA-449/423, EIA/TIA-530
- NTSC TV
- ISDN-BRI/PRI, X.25, Frame Relay
- SONET OC-x
- ATM
- V.32, V.32 bis, V.42, V.42 bis, V.90 (56k), V.11, V.24, V.35, xDSL
- PPP/SLIP/PMPP
- SDLC, HDLC
- RF-spread spectrum
- PCS-TDMA/IS-136 Cellular, PCS-CDMA/IS-95 Cellular
- IS-54/136 TDMA-DQPSK Cellular, IS-95-CDMA-QPSK Cellular
- DTMF (dual-tone, multiple frequency)

Video Encoding

Standards for video image encoding and transmission are mainly comprised of those developed for teleconferencing (e.g., H.261, H.320) and broadcasting (NTSC TV). Numerous video encoding standards currently exist (i.e., MPEG-1, MPEG-2, motion JPEG, JPEG, etc.) and are presently being implemented into commercially available products. In addition, many of these products adhere to standard DSx interface specifications to be used with the telecommunications infrastructure. Industry video encoding/transport standards include:

- NTSC TV Standard (525 lines, interlaced, 30 frames/sec)
- JPEG (640x480 resolution, secs/frame)
- Motion JPEG (640x480, 30 frames/sec, 600k – 45Mbps)
- MPEG-1 (352x240, up to 30 frames/sec, 1.5 Mbps)
- MPEG-2 (720 x 480 resolution, up to 30 frames/sec, 3-20 Mbps)
- H.261/H.320 (352x288, 176x144, on ISDN or switched 56k)

<u>Geo-location and Referencing</u>

Standards for geo-location and referencing (i.e., geospatial) are numerous depending upon application. For worldwide global positioning, the Geodetic Latitude, Longitude and Height system provides the most common format to indicate position on or about (under/over) the earth's surface (latitude, longitude, and altitude). Systems using Global Positioning System (GPS) products use this format in conjunction with time. A common format for aircraft navigation is the World Geographic Reference System (GEOREF). Other formats (e.g., TIGER) are used for census and land use planning. Others still, have been developed for local use and are based upon local landmarks.

Emerging Standards

Emerging standards provide a migration path that facilitates systems integration, interchangeability and interoperability for communications, networking, digital video, ITS, and among equipment. The following identify emerging standards to consider for migration planning:

Telecommunications and Networking

- IEEE 802.3z - 1000BaseFX (optical) Gigabit Ethernet switching
- Token Ring Switching
- FDDI Switching
- ATM LAN / Metropolitan Area Network (MAN) (25Mbps to 622Mbps)
- Digital Subscriber Line (HDSL, ADSL)
- OC-384+ (19+ Gbps)
- Dense wavelength division multiplexing (DWDM) (100+ Gbps)
- ATM (OC-48/192 - 2.5 to 9.6 Gbps switching)

Digital Video

New digital video standards currently adopted by the Advanced Television Standards Committee (ATSC) will eventually replace the NTSC TV standard at several levels. In addition, other industry bodies have developed video encoding standards to address the need to manage video transport within newer telecommunications and networking environments. Some of these new emerging standards include:

- ATSC HDTV (ISO13818 digital video (1920x1080, 1280x720), 30 frames/sec))
- ATSC SDTV (ISO13818 digital video (720x480, 640x480, 30 frames/sec))
- MPEG-2 (720x480, 30 frames/sec)
- MPEG-4 (from H.263 SQCIF (128x96) up to 4CIF (704x576), up to 30 frames/sec.)
- H.261/H.321 (352x288, on ATM networks)
- H.261/H.322 (352x288, on IEEE802.9a isoEthernet with QoS)
- H.261/H.323 (352x288, on Ethernet 802.3, Token Ring, or other packet-switched networks, no QoS, PC video conferencing)
- H.261/H.324 (352x288, on V.34 and POTS, very low bit rate)

ITS Standards

The National ITS Architecture provides the guiding framework necessary to allocate subsystem functions and standard interfaces. A key objective of the National ITS Architecture project is to achieve national/regional interoperability of certain ITS services; this requires the establishment of standards. Thus far, the National Architecture Program has examined 72 interfaces for possible standardization; 28 interfaces have been identified as deserving a high priority for standardization; and, with the passage of TEA-21, conformance with the National ITS Architecture will be under tighter scrutiny for federal aid to ITS projects. Standards currently being developed under the ITS umbrella are categorized as emerging for the purposes of this paper. Applicable ITS standards (6) includes (but are not limited to):

- NTCIP series
- TCIP
- TMDD and Message Sets
- ATIS DD and Message Sets
- DSRC
- ITS Architectures and Practices

NTCIP

The National Transportation Communications for ITS Protocol (NTCIP) series of standards define the manner in which ITS centers communicate with field devices (CCTV cameras, traffic controllers, CMSs, HAR, weather stations, and other centers). The emerging NTCIP suite of protocols will provide the communications framework to interface to various elements; however, NTCIP needs to be applied with other ITS standards (e.g., TMDD, ATIS DD, message sets) to facilitate interoperability between interfacing systems.

Future Standards

Future standards will provide insight for the migration planning process. Future standards will tend to specify new application of existing standards-based products and components. Examples of these standards to consider include CCTV cameras that output ATSC digital video rather than NTSC TV video; future local area networking application standards will include ATM at the desktop PC; and developing nation deployment of wireless telephone technologies rather than the traditional wireline technology and infrastructure.

In general, future standards should be considered for cost-effective deployment of new services, achieving architecture conformity, easing systems integration complexity, and facilitating regional interoperability and service deployment.

DEFINE UPGRADED SYSTEM CONFIGURATION

Defining the upgraded, standardized system configuration requires the understanding of current system functional capabilities, equipment inventories and application of the agreed-to standards. To leverage existing ITS resources, this activity should begin the standardization focus on those existing elements rather than configuration of a wholly new design, unless absolutely warranted.

For most legacy ITS systems, field components, communication protocols, and computer systems tend to be somewhat tightly coupled and do not readily offer "openness" to alternative configurations. In these cases, the system functional and physical components and interfaces need to be analyzed and (re) grouped into functional and physical "black box", building block elements. This approach employs a philosophy that given equal functionality for a given (set of) component element(s), the focus is not on the "design" that is evident within the box; rather, the focus is on the interfaces used to integrate the component with the rest of the system.

In cases where the objective is to achieve National ITS Architecture conformity, current infrastructure, services, and institutional stakeholders must be identified as the starting point. Once identified, a conformity assessment must be performed to identify those non-conforming elements. This can be performed using the methods specified by the Architecture training course. For those non-conforming elements, equivalent architecture configurations (e.g., market packages and subsystems) can be defined and configured as a "black box".

The "Black Box Approach"

The "black box" approach employs a methodology that identifies modular, functional and physical building blocks within a given system. The goal of the approach is to define a functionally complete building block element that conforms to the desired standards. A key to determine the boundaries of the functional "black box" is to ask the question: "Where can this component element provide an open and standards-based interface that is not dependent upon other interfacing elements to provide the desired functionality?" Once these building block elements are defined, decisions for their integration must be made. If the migration approach is to upgrade the communications infrastructure, then standards-conforming communications components can be identified and incorporated into the upgraded system configuration. If budgetary constraints do not permit wholesale communication upgrades, then interface and protocol adapters at field level, communications transport level, and computer system levels may be incorporated. Criteria to determine the black box boundaries and perform standardization decision making are derived from the goals and objectives of the standardization effort. Criteria categories include:

- ITS Architecture Conformity
- Level(s) of Standardization
- Level of Interoperability (local, regional, national, international)
- State and Quantities of Current System Inventory
- Applicable National and Industry Standards
- Applicable Organization Standards

Employing this approach facilitates adherence to the agreed-to standards, provides a greater potential for component interchangeability, and offers long-term supportability inherent in the multiple vendor supplier base. For transportation management systems, the black box approach can be applied to any of the following six major functional elements to configure the upgraded system configuration:

- Field Element Configurations
- Communications Infrastructure Configurations
- Computer Network Configurations
- Computer System Configurations
- Transportation Operations
- Development and Support Environments

Standardizing the latter two elements tends to be synergistic with the computer network and system configurations.

IMPLEMENT CONFIGURATION MANAGEMENT CONTROLS

Successful implementation of the standardization effort is the controlled maintenance of the system documentation used to track the system configurations through each phase. The formal mechanism used to provide this control is configuration management (CM), or a change control process. A key requirement to successful migration and achievement of standardization goals and objectives is the institution of a formal CM process over the duration of the standardization period, at a minimum. Currently, most all low-level, discipline-oriented system development activities (e.g., software, hardware, standards, etc.) institute a change control process to manage and control the evolution of the system or product. Once a design (configuration) is accepted, or released for production, all development related documentation is “frozen” and placed under configuration control by a document control function to capture the state. The document control function enforces the configuration control rules established by the CM process. This same process needs to be implemented throughout the standardization migration effort to ensure each subsequent upgrade phase builds upon the known configuration. This management discipline requires the integration and systematic execution of a process component and an institutional component. Figure 4 is a simplified CM process flow used to illustrate the change control mechanisms that provide the configuration control of all system elements. Bolded boxes are activities typically performed by a document control function.

The minimum set of system documentation used to represent the system configuration for each phase is suggested in the following list. These documents are used in conjunction with the CM process to capture and control system requirements, deployed system and subsystem designs, system and subsystem testing activities and procedures, and operational and maintenance procedures. This set includes the following:

- User Service Needs/Concept of Operations
- System Requirements Specifications
- Requirements Traceability Matrix
- Subsystem Requirements/Functional Specification(s)
- Interface Specifications (Internal and External)
- System Design Specification(s) (Preliminary and Detailed)
- Software Component Design Specification(s)
- System Integration Plan
- System Acceptance Test Plan
- System / Software Users Manual
- System Operations Manual
- System Training Material
- System / Software Maintenance Manual
- System Configuration Document
- System Maintenance/Work Order Log
- Facilities Specifications
- As-built and Standard Plans & Specifications and Actual Implementation Costs
- Standardization Migration Plan
- System Inventory Listing

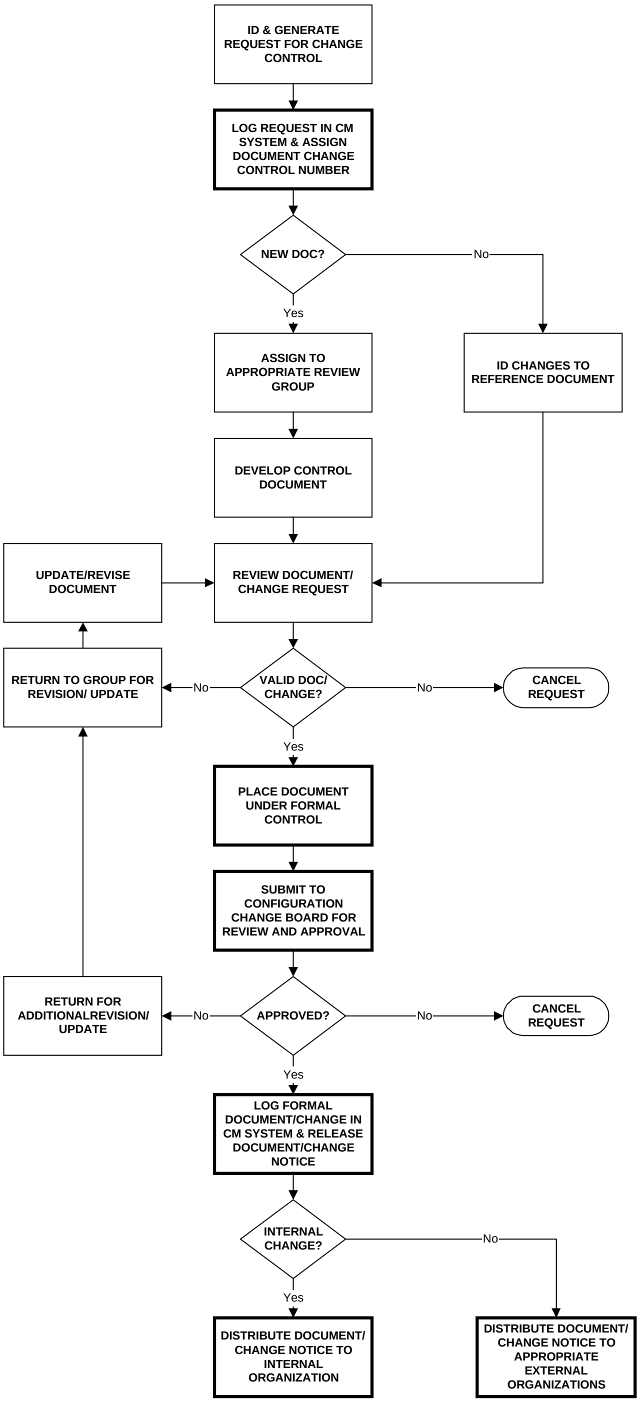

Figure 4. Configuration Management Process Flow

DEVELOP MIGRATION PLAN

Migration from the existing system configuration to the upgraded, standardized system requires careful technical and program planning and timely implementation. Migration provides the gradual, systematic transition from the existing configuration. The Standardization Migration Plan provides the guideline and implementation reference for the detailed upgrade projects to be programmed. If allowed, parts of the plan could also be used for pre-planned maintenance upgrades to capitalize on technology evolution and standards adoption.

The Migration Plan should be organized for each of the six major functional elements as defined in the upgraded standardized system configuration:

- Field Element Configurations
- Communications Infrastructure Configurations
- Computer Network Configurations
- Computer System Configurations
- Transportation Operations
- Development and Support Environments

For each major functional element section, the following subsections should be defined to address the specific migration elements to be employed.

- <u>Migration Strategy</u> - Identification of migration strategies from the current configuration to the standardized configuration.
- <u>Considerations</u> – Identification of considerations that contribute to successful system migration.
- <u>System Architecture Changes</u> – Highlight system architecture changes needed (if any).
- <u>Timeline and Milestones</u> - List of key dates and project milestones.
- <u>Implementation</u> - Implementation approaches to achieve the migration strategy.
- <u>Configuration Management</u> - Configuration management elements that need to be updated.
- <u>Migration Implementation Cost Estimates</u> – General overall and unit cost estimates (design and unit install/test cost) to implement the recommended migration strategy.
- <u>Potential Funding Sources</u> – Identify any potential migration funding sources for subsequent action assignments.

These subsections provide the framework to assure consistent migration planning and implementation. It should also be noted that for organizations that plan to standardize multiple peer level systems, this Migration Plan also assumes no new, non-coordinated system elements or components will be used once the Migration Plan has been adopted. It should be noted that, once adopted, the Standardization Migration Plan should be treated as a “controlled” document to ensure all affected organizations can be notified of any updates. Any major updates should be approved through a process similar to one that created the initial document.

Migration planning should consider leveraging other internal planning processes to execute the migration implementation plans. It should also note that full implementation of a migration plan may need to be achieved in multiple phases. One example is where the formal standard is still in development and a “organization standard” is used as an emergency, interim solution. Once the formal standard is published and product become available, completion of the standardization effort can be accomplished.

DEFINE ACTIONS REQUIRED TO IMPLEMENT MIGRATION PLAN

Once the migration strategies, timelines and estimated costs are defined, and action plan/list and timeline summary should be developed to shape the standardization migration effort into a form where a standardization program, or set of projects/programs, can be established, funded and assigned. The timeline summary provides a high-level schedule of the scope and status of the entire standardization effort over time. Contents of the action plan/list should include the action recommendations defined from the migration strategy and be organized in the following format:

- Action Number
- Action Category
- Action Description
- Assignee
- Required Completion Date
- Dependencies

The final steps in the development of the Standardization Migration Plan is to receive formal adoption by those participating organizations and place the plan under configuration management control.

CONCLUSIONS/CONSIDERATIONS

In conclusion, application of this standardization migration methodology can provide the initial roadmap to transform non-standard (ITS) systems into those that conform and can reap the benefits that come with standardization. Standardization benefits, such as open system architectures, interchangeable components, long-term component support, systems interoperability, new technology adaptation and extended system life, are some of many tangible attributes that can help systems be adaptable to meet the changing needs of their environment. This methodology was developed from the application of systems analysis and engineering principles as a means to functionally distill system components for functional integration of new technologies and to expand capabilities.

Identifying standardization opportunities and related actions needed to develop a migration plan are logical, follow-on extensions to facilitate the transformation of non-standard (ITS) system(s), interfaces and components into standardized elements. An equally challenging effort is execution of the Action Plan to accomplish the standardization / interoperability goals and objectives.

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Mr. Fukuda is a Project Manager/Principal Systems Engineer with Parsons Transportation Group in Newport Beach, California. He has over 17 years experience in the design and deployment of large-scale, transportation management and information processing systems designed to interoperate (at multiple levels) with other “existing” and proprietary systems. His background and experience includes project manager / principal (ITS) systems engineer for numerous ATMS, ATIS and ETC projects (including National ITS Architecture and Caltrans TMC Standardization Plan), involvement with several ITSA and USTAG/TC204 committees (assisting the development of ITS standards), and experience with the development of secure command, control, communications and intelligence (C2/C3I) systems for the Department of Defense.

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END NOTES

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