Concept of Operations (ConOps) for the Advanced Transportation Controller Cybersecurity Standard

August 8, 2023

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In addition to the SDOs the ATC Cybersecurity WG voting members, and SMEs, there were many others that contributed to the development of this standard as non-voting WG members. Their input and assistance was critical to the final product.

Recognition is also given to the United States Department of Transportation that sponsored this effort and also provided guidance and support.

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Section 1
General Information [Informative]

1.1 Purpose

This Concept of Operations (ConOps) has been developed for the Advanced Transportation Controller (ATC) Cybersecurity Project under the United States Department of Transportation (USDOT) Contract # DTFH61-16-D-00055, Work Order # 19-0403. The purpose of the project is to identify and address cybersecurity needs in the ATC family of standards comprising the ATC 5201 ATC Standard, the ATC 5401 ATC Application Programming Interface (API) Standard, and the ATC 5301 ATC Cabinet Standard. The ATC standards are being developed and maintained under the direction of the ATC Joint Committee (JC), which is composed of representatives from the American Association of State Highway and Transportation Officials (AASHTO), the Institute of Transportation Engineers (ITE) and the National Electrical Manufacturers Association (NEMA).

This ConOps has been prepared by the ATC Cybersecurity Working Group (WG), a technical subcommittee of the ATC Cybersecurity Committee. It establishes a common understanding of the user needs for the cybersecurity elements to be applied to the three ATC standards for the following:

a) The local, state, and federal transportation agencies who specify and use ATC equipment;
b) The manufacturers, software developers and integrators who create equipment, software, and systems that use ATC equipment; and
c) The public who benefits from the deployment of ATC equipment and who directly or indirectly pays for these products.

1.2 Scope

The ATC family of standards provide an open architecture hardware and software platform that can support a wide variety of Intelligent Transportation Systems (ITS) applications including those for traffic management, safety, and security. It is expected that many of the cybersecurity issues addressed for the ATC standards will also apply to other ITS standards and specifications.

The project follows a systems engineering process. Its interim deliverables are a ConOps, a Systems Requirement Specification (SRS), and a System Design Description (SDD) (to be determined, design material may be in individual standards) for the cybersecurity areas of concern for the three ATC standards. The primary deliverable of the project is the ATC Cybersecurity Standard.

This ConOps provides high level background material on how transportation field cabinet systems (TFCSs) operate and descriptions of the three current ATC standards. This aids participants in the ATC Cybersecurity Project who may be less familiar with such equipment and provides context when identifying cybersecurity needs.

1.3 References

1.3.1 Normative References

Normative references contain provisions that, when they are specifically referenced in other sections of this document, constitute provisions of this standard. At the time of publication, the versions indicated for the references were valid. All references are subject to revision. Parties using this document are encouraged to investigate the possibility of applying the most recent versions of the references listed.

Identifier	Title
ATC 5201 v06A	Advanced Transportation Controller (ATC) Standard Version v06A, AASHTO / ITE / NEMA, 29 July 2020.
ATC 5301 v02	Advanced Transportation Controller (ATC) Cabinet Standard Version v02, AASHTO / ITE / NEMA, 18 March 2019.
ATC 5401 v02B	Application Programming Interface (API) for the Advanced Transportation Controller (ATC), AASHTO / ITE / NEMA, 16 February 2023.

1.3.2 Other References

The following documents and standards may provide the reader with a more complete understanding of transportation architecture, ITS field equipment, communications, and security; however, these documents do not contain direct provisions that are required by the ATC Cybersecurity Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision. Parties to agreements based on the ATC Cybersecurity Standard are encouraged to investigate the possibility of applying the most recent editions of the standard listed.

Identifier	Title
ARC-IT 9.1	Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT), USDOT, https://arc-it.net
Caltrans TEES 2020	Caltrans Transportation Electrical Equipment Specifications (TEES), California Department of Transportation, 5 November 2020.
CIS Controls v7.1	Implementation Guide for Industrial Control Systems, Center for Internet Security, 2019
CTI 4001 v01	Roadside Unit (RSU) Standard v01, AASHTO / ITE / NEMA / SAE, 11 November 2021.
CTI 4501 v01	Connected Intersections Implementation Guide v01, AASHTO / ITE / NEMA / SAE, September 2021.
ISO/IEC 15408-1:2022	Information security, cybersecurity and privacy protection — Evaluation criteria for IT security — Part 1: Introduction and general model, ISO/IEC. 2022
ISO/IEC/IEEE 29148:2011	Systems and software engineering — Life cycle processes — Requirements engineering
ISO/IEC 9899:2018	Information technology -- Programming languages -- C, ISO/IEC, 2018
ITS Cabinet Standard v01	Intelligent Transportation System (ITS) Standard Specification for Roadside Cabinets v01.02.17b, AASHTO / ITE / NEMA, 16 November 2006.
NEMA TS 1-1989	Traffic Control Systems. National Electrical Manufacturers Association, 1989
NEMA TS 2-2016	Traffic Controller Assemblies with NTCIP Requirements—Version 03.07, National Electrical Manufacturers Association, 2016.
NEMA TS 8-2018	Cyber and Physical Security for Intelligent Transportation Systems (ITS), National Electrical Manufacturers Association, April 2020.
NIST CSRC Online Glossary	NIST Computer Security Resource Center (CSRC) Online Glossary, https://csrc.nist.gov/glossary/
NIST SP 800-53 Rev. 5	Security and Privacy Controls for Information Systems and Organizations, National Institute of Standards and Technology, 2019
NTCIP 9001 v04	The NTCIP Guide v04, AASHTO / ITE / NEMA, July 2009.

1.3.3 Contact Information

1.3.3.1 Architecture Reference for Cooperative and Intelligent Transportation

The Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) may be viewed online at:

https://arc-it.net

1.3.3.2 FHWA Documents

Documents from the USDOT Federal Highway Administration (FHWA) (with designations FHWA-JPO-…) are available at the USDOT National Transportation Library, Repository & Open Science Access Portal (ROSA P):

https://rosap.ntl.bts.gov/

1.3.3.3 IEEE Standards

Standards from the Institute of Electrical and Electronics Engineers (IEEE) standards may be purchased online in electronic format or printed copy from the following:

Techstreet
6300 Interfirst Dr.
Ann Arbor, MI 48108
(800) 699-9277
www.techstreet.com/ieee

1.3.3.4 Internet Documents

Request for Comment (RFC) electronic documents may be obtained from several repositories on the World Wide Web, or by “anonymous” File Transfer Protocol (FTP) with several hosts. Browse or FTP to the following:

www.rfc-editor.org
https://www.rfc-editor.org/retrieve/

1.3.3.5 ISO/IEC Standards

Standards from the International Organization for Standardization / International Electrotechnical Commission (ISO/IEC) may be purchased online in electronic format or printed copy from the following:

Techstreet
6300 Interfirst Dr.
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1.3.3.6 ITE Standards

Standards from the Institute of Transportation Engineers (ITE) may be obtained from the following:

Institute of Transportation Engineers
1627 Eye Street, NW, Suite 550
Washington, DC 20006

(202) 785-0060
https://www.ite.org/technical-resources/topics/standards/

1.3.3.7 NIST Standards

Standards from the National Institute of Standards and Technology (NIST) may be obtained from the following:

National Institute of Standards and Technology
100 Bureau Drive
Gaithersburg, MD 20899
301-975-2000
https://csrc.nist.gov/publications/

1.3.3.8 NTCIP Standards

Standards that are a part of the National Transportation Communications for ITS Protocol (NTCIP) family of standards may be obtained from the following:

NTCIP Coordinator
National Electrical Manufacturers Association
1300 17th Street North, Suite 900
Arlington, Virginia 22209
www.ntcip.org
e-mail: ntcip@nema.org

1.4 Terms

The following terms, definitions, acronyms, and abbreviations are used in this document.

Term	Definition
2070	A traffic signal controller that meets the California Department of Transportation (Caltrans) Transportation Electrical Equipment Specifications (TEES) for a Model 2070.
API Managers	API Software that manages an ATC resource for use by concurrently running application programs.
API Software	The body of software that conforms to the API Standard. This software includes API Managers, API Utilities, the functions defined in this standard, and any libraries necessary to implement the standard.
API Utilities	API Software not included in the API Managers that is used for configuration purposes.
Application Program	Any program designed to perform a specific function directly for the user or, in some cases, for another application program. Examples of application programs include word processors, database programs, Web browsers and traffic control programs. Application programs use the services of a computer's OS and other supporting programs such as an application programming interface.
ATC Device Drivers	Low-level software not included in standard Linux distributions that is necessary for ATC-specific devices to operate in a Linux OS environment.

Term	Definition
ATC Unit	The term used for a traffic signal controller that conforms to the ATC 5201 Standard.
Availability	Ensuring timely and reliable access to and use of information. Source: *NIST CSRC Online Glossary*.
Bus Interface Unit	A transportation cabinet device which is used for SDLC communications within NEMA TS 2 cabinet systems.
Board Support Package	Software usually provided by processor board manufacturers which provides a consistent software interface for the unique architecture of the board. In the case of ATC units, the Board Support Package also includes the OS.
Connected Intersections (CI)	An infrastructure system that broadcasts signal, phase, and timing (SPaT) information, mapping information and position correction data to On-Board Units and Mobile Units. Source: *CTI 4501*.
Confidentiality	Preserving authorized restrictions on information access and disclosure, including means for protecting personal privacy and proprietary information. Source: *NIST CSRC Online Glossary*.
Cybersecurity Risk	An effect of uncertainty on or within information and technology. Cybersecurity risks relate to the loss of confidentiality, integrity, or availability of information, data, or information (or control) systems and reflect the potential adverse impacts to organizational operations (i.e., mission, functions, image, or reputation) and assets, individuals, other organizations, and the Nation. Source: *NIST CSRC Online Glossary*.
Data At Rest (DAR)	Data that is not actively moving from device to device or network to network such as data stored on a hard drive, flash drive, or archived/stored in some other way.
Data In Transit (DIT)	Data that is actively moving from one location to another such as across the internet, through a private network, or between devices. Also, called Data in Motion.
Interchangeability	The capability to exchange devices of the same type on the same communications channel and have those devices interact with other devices of the same type using standards-based functions. Source: *The NTCIP Guide*
Interface	A shared boundary across which information is passed. Source: *IEEE Std 610.12-1990, IEEE Standard Glossary of Software Engineering Terminology, 1990.*
Integrity	Guarding against improper information modification or destruction, and includes ensuring information non-repudiation and authenticity. Source: *NIST CSRC Online Glossary*.

Term	Definition
Interoperability	The ability of two or more systems or components to exchange information and to use the information that has been exchanged. Source: *IEEE Std 610.12-1990, IEEE Standard Glossary of Software Engineering Terminology, 1990.*
Mobile Unit (MU)	A device used to wirelessly communicate with other devices for safety and mobility purposes carried by a pedestrian, bicyclist, work zone worker, or other traveler. Source: *RSU Standard v1.0.*
Operational Scenario	A scenario is a step-by-step description of how the proposed [system] should operate and interact with its users and its external interfaces under a given set of circumstances. Operational Scenarios help readers understand how all pieces of the system interact to provide operational capabilities. Source: *IEEE 1362-1998.*
Roadside Unit (RSU)	A transportation infrastructure communications device located on the roadside that provides vehicle-to-everything (V2X) connectivity between OBUs/MUs and other parts of the transportation infrastructure including traffic control devices, traffic management systems, and back-office systems. Note: Devices that are not part of the transportation infrastructure, such as cellular base stations or satellites, are not RSUs. Source: *RSU Standard v1.0*.
Robustness	Degree to which a system or component can function correctly in the presence of invalid inputs or stressful environmental conditions. Source: *ISO/IEC/IEEE 24765:2017 Systems and software engineering-Vocabulary*
Serial Interface Unit	A transportation cabinet device which is used for SDLC communications within ATC cabinet systems.
Synchronous Data Link Control (SDLC)	A protocol that is used for transferring synchronous, code-transparent, serial-by-bit information over a communications line. Transmission exchanges can be duplex or half-duplex over switched or nonswitched lines. The configuration of the connection can be point-to-point, multipoint, or loop. Source: *IBM Documentation https://www.ibm.com/docs/en*.
Transport Layer Security (TLS)	A cryptographic protocol that provides secure communication over a computer network. It can be implemented in any application or protocol that requires secure communications. The latest version, TLS 1.3, is faster and more secure than previous versions.
Transportation Field Devices	Devices and electronic systems that monitor and control traffic operations on a roadway.

1.5 Abbreviations

The abbreviations and acronyms used in this document are defined below.

AASHTO	American Association of State Highway Transportation Officials
ADU	Auxiliary Display Unit
API	Application Programming Interface.
APIRI	API Reference Implementation
APIVS	API Validation Suite
ARC-IT	Architecture Reference for Cooperative and Intelligent Transportation
ASARP	As Secure As Reasonably Practicable
ATC	Advanced Transportation Controller
BBS	Battery Backup System
BIU	Bus Interface Unit
BSM	Basic Safety Message
BSP	Board Support Package
C2C	Center-To-Center
C2F	Center-To-Field
CI	Connected Intersection
CIS	Center for Internet Security
CMU	Cabinet Monitor Unit or Conflict Monitor Unit
CPS	Cabinet Power Supply
ConOps	Concept of Operations
CV	Connected Vehicle
DAR	Data at Rest
DCS	Distributed Control System
DIT	Data in Transit
DRAM	Dynamic Random Access Memory
DTLS	Datagram Transport Layer Security
ECLA	External Control Local Application
FHWA	Federal Highway Administration
FIPS	Federal Information Processing Standards
FPGA	Field Programmable Gate Array
HDLC	High-level Data Link Control
HDSP	High-Density Switch Pack
HSM	Hardware Security Module
IEEE	Institute of Electrical and Electronics Engineers
I/O	Input/Output

ICS	Industrial Control System
IOO	Infrastructure Owner/Operator
I-SIG	Intelligent Traffic Signal
ISSA	Infrastructure Standards Security Assessment
IT	Information Technology
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation System or Systems
JC	Joint Committee
Kbps	Kilobits per second
MAC	Media Access Control
MMU	Malfunction Management Unit
MU	Mobile Units
NCHRP	National Cooperative Highway Research Program
NEMA	National Electrical Manufacturers Association
NIST	National Institute of Standards and Technology
NRTM	Needs to Requirements Traceability Matrix
NTCIP	National Transportation Communications for ITS Protocol
OBU	On-Board Units
OS	Operating System
OSS	Open Source Software
PCB	Printed Circuit Board
PLC	Programmable Logic Controller
RA	Registration Authority
RAM	Random Access Memory
RSU	Roadside Unit
RTC	Real-Time Clock
SBOM	Software Bill of Materials
SCADA	Supervisory Control and Data Acquisition
SCMS	Security Credentials Management System
SDD	System Design Description
SDO	Standards Development Organizations
SDLC	Synchronous Data Link Control
SE	Systems Engineering
SEP	Systems Engineering Process

SIU	Serial Interface Unit
SNMP	Simple Network Management Protocol
SPaT	Signal Phase and Timing
SRAM	Static Random Access Memory
SRS	Systems Requirement Specification
SSE	Systems Security Engineering
SU	Sensor Unit
TEES	Transportation Electrical Equipment Specifications
TFCS	Transportation Field Cabinet System
TLS	Transport Layer Security
TMS	Traffic Management System
TSC	Traffic Signal Controller
UPS	Uninterruptible Power Supply
US	United States
USB	Universal Serial Bus
USDOT	United States Department of Transportation
V2X	Vehicle-to-Everything
VAC	Volts Alternating Current
VDC	Volts Direct Current

Section 2
Concept of Operations [Normative]

2.1 Tutorial [Informative]

In systems engineering, the different stages of the definition and design process are captured in documents specific to the stage of development of the system (or device). A ConOps is a document that describes characteristics for the proposed system from the user's perspective. The goal is to have a common understanding between the users of the system and the developers of requirements for the system. User needs for the system are identified via collaboration of a broad base of stakeholders and some are drawn from existing documents. Each user need is captured in the ConOps in a formal manner along with the rationale which justifies the inclusion of the need and may also provide other clarifying information so that the user need is understood in subsequent stages of development.

This ConOps has been prepared as part of the development of the ATC Cybersecurity Standard. The terms “Normative” and “Informative” are used to distinguish parts of this ConOps that must be conformed to (Normative) and those that are there for informational purposes (Informative). It is possible for a section to be identified as Normative but have subsections that are identified as Informative. If a section is identified as Normative, then all of its subsections are to be considered Normative unless identified otherwise.

The remaining sections of this ConOps are as follows:

- **Section 2.2 Background [Informative].** This section provides background information on how transportation field cabinet systems operate and descriptions of the three current ATC standards.
- **Section 2.3 Current Situation and Problem Statement [Informative].** This section describes the current situation and the need for an ATC Cybersecurity Standard.
- **Section 2.4 ATC Cabinet Operational Architecture [Informative].** This section describes the operational architecture of an ATC Cabinet in relation to other systems and devices.
- **Section 2.5 ATC Cybersecurity Scope [Informative].** This section provides the scope for the ATC Cybersecurity Standard and identifies areas being addressed.
- **Section 2.6 Architectural Constraints [Informative]**. This section identifies constraints on the architecture for the ATC Cybersecurity Standard.
- **Section 2.7 ATC Cybersecurity Needs [Normative].** This section identifies the cybersecurity user needs for ATC equipment.
- **Section 2.8 Operational Policies and Constraints [Normative]**. This section describes any operational policies and constraints that apply to the system or situation.
- **Section 2.9 Operational Scenarios [Informative].** This section provides any operational scenarios identified for the system.
- **Section 2.10 ARC-IT and Security [Informative].** This section provides security resource information available on the Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT).

2.2 Background [Informative]

2.2.1 General Description of Transportation Field Cabinet Systems

Starting in the 1970s, standards and specifications emerged for actuated traffic signal control. These standards and specifications defined systems that are located in cabinets at signalized intersections. Since that time, these standards and specifications have evolved, and new national standards have been developed to add capabilities and features while preserving the same general concepts as their predecessors.

There are six major TFCS standards and specifications. From oldest to newest, they are:

- "NEMA TS 1 Traffic Control Systems," National Electrical Manufacturers Association (NEMA). Commonly called a "TS 1 Cabinet." This standard was originally published in 1976 and last published in 1989.
- "Caltrans Transportation Electrical Equipment Specifications (TEES)," California Department of Transportation. Commonly called the "Model 332 Cabinet" or "Model 33x Cabinets" to refer to other cabinets of the same general style. This specification was originally published in 1978 and last published 2020.
- "NEMA TS 2 Traffic Controller Assemblies," NEMA. Commonly called a "TS 2 Cabinet" or "TS 2 Type 1 Cabinet." The standard also provides some feature enhancements for the older TS 1 Cabinet, called a "TS 2 Type 2 Cabinet." This standard was originally published in 1992 and last published in 2016.
- "Intelligent Transportation System (ITS) Standard Specification for Roadside Cabinets," ATC Joint Committee. Commonly called the "ITS Cabinet." The standard was published in 2006.
- "ATC 5301 Advanced Transportation Controller (ATC) Cabinet Standard," ATC Joint Committee. Commonly called the "ATC Cabinet (ATCC)." A successor to the ITS Cabinet, the ATCC has significant additional features and design changes. This standard was originally published in 2016 and last published in 2019.

The general elements of a TFCS are described below and illustrated in Figure 1.

- **Inputs** supply information to the Controller from external (field) sensors in the form of on/off states. There are numerous sensor technologies including inductive loops, video, radar, and magnetometers. Most commonly, Inputs consist of "sensor units" or "detectors" housed in a "detector rack," "input assembly," or "input file" (terms are synonymous). Cabinets can also include additional input functionality capable of receiving information from additional sources.

- The **Controller** is a field hardened computer that runs the signal control application and other applications. The signal control application associates Inputs with movements through the intersection. The Controller reads the Inputs, determines how to safely provide right of way to road users, and switches signal indications (reds, yellows and greens) via the Outputs. Not shown, Controllers will also communicate with a Roadside Unit (RSU) to support a connected intersection (CI) environment.

- **Outputs** are switches grouped in components called "switch packs" or "load switches" (terms are synonymous) that are switched by the Controller to enable or disable the flow of electricity to signal indications, turning them on and off. Switch packs/load switches may be plugged into a "cabinet back panel," "load bay," or "terminal and facilities area" (terms are synonymous); or in an "output assembly," "output rack," or "output file" (terms are synonymous). Cabinets can also include additional output functionality capable of driving auxiliary devices.

- The **Monitor** (or signal monitor) ensures that the signal indications are non-conflicting by comparing them to pre-configured safe states programmed by the user using either hardware "program cards" or in software programmable flash memory devices (e.g., "data keys"). If conflicting signal indications are sensed, the monitor transfers the TFCS to a fault state, which changes the signal indications from normal operation to flash. Depending on the type of TFCS, the monitor may also be able to validate that the Controller is operating, and that internal cabinet and output voltages are within allowable parameters. Depending on the type of TFCS, the

Monitor may be called a Conflict Monitor Unit (CMU), Malfunction Management Unit (MMU), or Cabinet Monitor Unit (CMU). Monitors may have auxiliary communication ports.

- The **Power Supply** provides power for the devices internal to the TFCS.

- The **Internal Bus** interconnects the Input, Output, Controller, and Monitor elements. Older TFCSs (e.g., TS 1, Model 33x) have “parallel buses” with discrete electrical wiring between the elements. More modern TFCSs (e.g., TS 2, ITS, ATCC) have “serial buses” that use synchronous data link control (SDLC) communications to exchange data between the elements.

- The **Enclosure** includes the cabinet housing, doors, latches/locks, hinges and door catches, gasketing, ventilation, lighting, internal assembly mounting, and external mounting (e.g., foundation/base, pole, or pedestal).

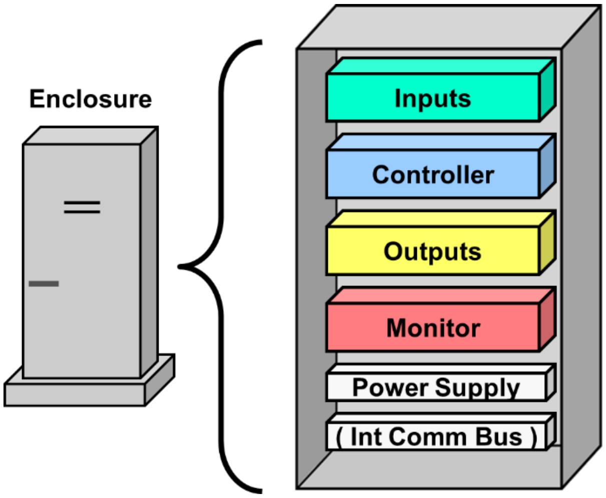


Figure 1. Elements of a Transportation Field Cabinet System.

Figure 2 illustrates the basic operation of a TFCS. Steps are as follows:

1) Field sensors detect vehicles which are provided as inputs to the controller.
2) The controller determines which movements should receive right of way according to its programming.
3) The controller determines the signal indications and turns them on or off via the outputs.
4) The outputs switch power to the signal indications according to the commands from the controller.
5) At the same time, the monitor verifies that the signal indications are not in conflict and that the other elements of the TFCS are operating correctly. If they are not, the monitor transfers the TFCS to a fault state.
6) For NEMA TS 2 Cabinets, ITS Cabinets, and ATC Cabinets, the monitor sends the status of the outputs to the controller (voltage in TS 2, voltage and current in ITS and ATCC).

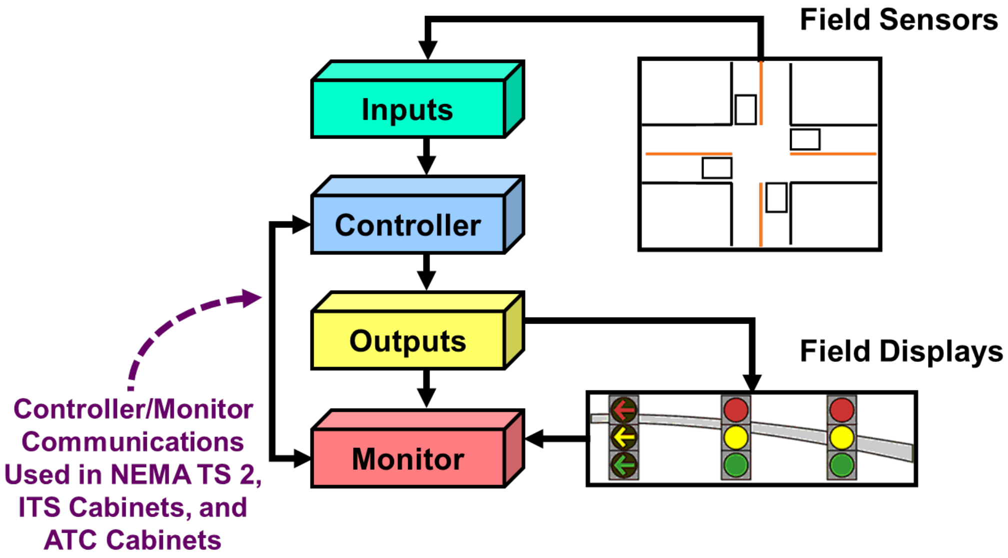

Field Sensors
Inputs
Controller
Outputs
Monitor
Field Displays
Controller/Monitor Communications Used in NEMA TS 2, ITS Cabinets, and ATC Cabinets

Figure 2. Basic operation of a Transportation Field Cabinet System.

TFCSs typically have additional equipment that is not defined by ITS standards such as:

- **Networking Equipment** including switches, routers, Ethernet, Wi-Fi, fiber optics, and cellular devices.
- **Advanced Detection Systems** that typically have dedicated processors including non-intrusive detectors installed above or beside the roadway (e.g., radar, video, and lidar) and sophisticated intrusive detectors (e.g., magnetometers). They may actuate inputs via sensor units in the detector rack or they may connect to the serial bus. Their processors may have Ethernet ports for remote management, monitoring, and configuration.
- **Priority and Preemption Systems** implement transit signal priority and emergency vehicle preemption using equipment in TFCSs that receives data from vehicles and sends requests to the controller inputs via either sensor units in the detector rack or the serial bus.
- **Clock Sync Devices and GPS Time Sources** connect directly to controllers via USB, asynchronous serial (EIA-232), or Ethernet. These devices may set the controller’s clock or the controller may poll them at regular intervals to update its clock.
- **Battery Backup Systems (BBSs) and Uninterruptible Power Supplies (UPSs)** are used at some TFCSs to sustain signal indications during power outages. These devices typically have Ethernet ports for remote management, monitoring, and configuration.
- **External Control Local Application (ECLA) Devices** are used at some TFCSs to modify the controller’s operation by changing its timing plan (pattern), adjusting its timing parameters, and issuing it real-time signal control commands such as holds, force-offs, and omits. ECLA devices often run adaptive control programs from a manufacturer other than the controller manufacturer. ECLA devices have Ethernet ports for remote management, monitoring, and configuration.
- **Connected Vehicle (CV) Processors / Coprocessors** are devices that offload processing demands for connected intersections (CIs) from the main processor of the controller or an RSU. They may perform some of the processing required to provide Signal Phase and Timing (SPaT) messages, process incoming messages such as BSMs, or other functions of a connected intersection (CI). These devices can be co-processors within the controller or separate devices within the cabinet system. These devices may have Ethernet ports for remote management, monitoring, and configuration.

2.2.2 Description of ATC Standards

The Advanced Transportation Controller (ATC) family of standards provide an open architecture hardware (HW) and software (SW) platform that can support a wide variety of Intelligent Transportation Systems (ITS) applications including traffic management, support for connected vehicles (CVs), specialized data collection, safety, security, and other applications. The ATC standards are being developed and maintained under the direction of the ATC Joint Committee (JC) which is made up of representatives from the American Association of State Highway and Transportation Officials (AASHTO), the Institute of Transportation Engineers (ITE), and the National Electrical Manufacturers Association (NEMA).

Historically, the transportation industry has had a relatively slow growth in controller computing power compared to edge products in other industries. Some of the factors were as follows:

- Controllers were viewed as single application devices. Controllers evolved from mechanical timers in the 1940s. Early microprocessors and the cost and size of memory seemed marginally bigger than the needs of the signal programs.
- Some standards and specifications identified specific processors for controllers that were obsolete soon after the documents were published. When these standards and specifications were in development, it was important to be able to purchase the controller hardware and the application software from different manufacturers and developers. The solution at the time was to identify a specific processor within the standard. However, it was underestimated how long such documents took to develop and the reluctance to change things once they were adopted. For instance, there are controllers being bought new in the United States today that are based on 1980s technology.
- Some standards treated the controller as a closed architecture device which meant that only software produced by the manufacturer could run on the controller.

The ATC Standards Program was started help mitigate these factors.

The ATC Program concept for a controller (including OS and enabling software) was to define a general-purpose field computing platform for transportation applications. The design goals were:

- Open architecture – Any manufacturer or developer can build a controller that meets the internal architecture defined in the standard.
- Modular – This means that the internal structure of the controller has a separation in subsystems or assemblies and flexibility in the way they are combined. Modularity can increase the maintainability of a system, the utility of a system, and the testability of a system.
- Multi-process / Multi-application – Multi-process means that the controller can run multiple application programs at the same time. Multi-application means these programs may be used for different purposes.
- Application Portability – Portability means that there is low effort required for applications to run on ATC units from different vendors.
- Grow in Capability – The standard allows controllers to evolve with better processors and memory and still conform to the standard.
- Upgrade Legacy TFCSs – The controller can provide contemporary performance and capabilities for all of the nationally recognized TFCSs being used in the United States.

The ATC Program also set out to create a new TFCS standard based on lessons learned and technology improvements over the legacy TFCS standards. The design goals were the following:

- Focus on increasing value to end users – This means providing more capability for the same or reduced cost.
- Flexibility within the standard for innovative designs – This means that the placement of the assemblies and components is not set within the standard. The size of components is not specified unless interchangeability is intended.
- Higher density – Able to put more inputs and outputs in a smaller space.
- Increased technician safety – Protect technicians.
- Increased public safety – Protect the public.
- Enhanced monitoring functionality – Monitor more aspects of the TFCS and provide more information to the end user.

- Increased cabinet power efficiency – Potential power conservation.
- Provide LED signal compatibility – Potential power conservation and alternative power sources.

The ATC 5201 ATC Standard and the ATC 5401 ATC Application Programming Interface (API) Standard were developed to meet the goals for ATC units. The ATC 5301 ATC Cabinet Standard was developed to meet the goals for a new TFCS standard.

2.2.2.1 ATC 5201 ATC Standard

ATC 5201 Advanced Transportation Controller (ATC) Standard Version v06A is the latest version of ATC 5201. The standard specifies a controller architecture where the computational components reside on a 5” x 4” printed circuit board (PCB), called the “Engine Board,” with standardized connectors and pinout. The Engine Board contains the following items:

a) CPU
b) Linux Operating System (OS) and Device Drivers
c) Non-Volatile (Flash) Memory
d) Dynamic and Static RAM (DRAM and SRAM)
e) Real-Time Clock (RTC)
f) Two Ethernet ports (manufacturers add Ethernet switches outside of the Engine Board to make more external Ethernet connections available on a controller)
g) One Universal Serial Bus (USB) port that is used for a portable memory device
h) Seven serial ports (some are designated for special interfaces and others general purpose).

The Engine Board plugs into a “Host Module” that supplies power and physical connection to the I/O devices of the controller. While the mechanical and electrical interfaces to the Engine Board are completely specified, the Host Module may be different shapes and sizes to accommodate controllers of various designs. Figure 3 shows how the Engine Board can be used to create ATC units that work within different families of traffic signal controller equipment. This concept also allows more powerful Engine Boards to be deployed in the future without changing the overall controller and cabinet architecture.

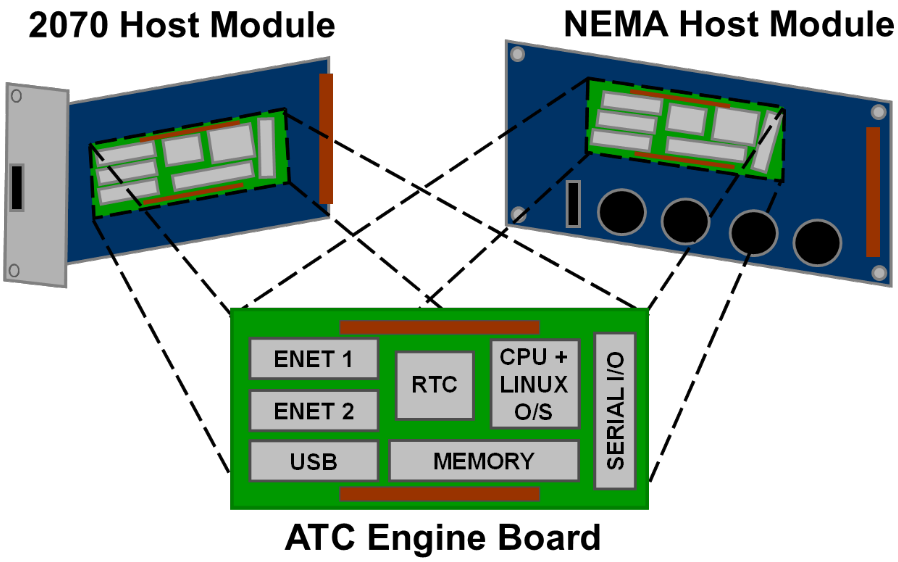
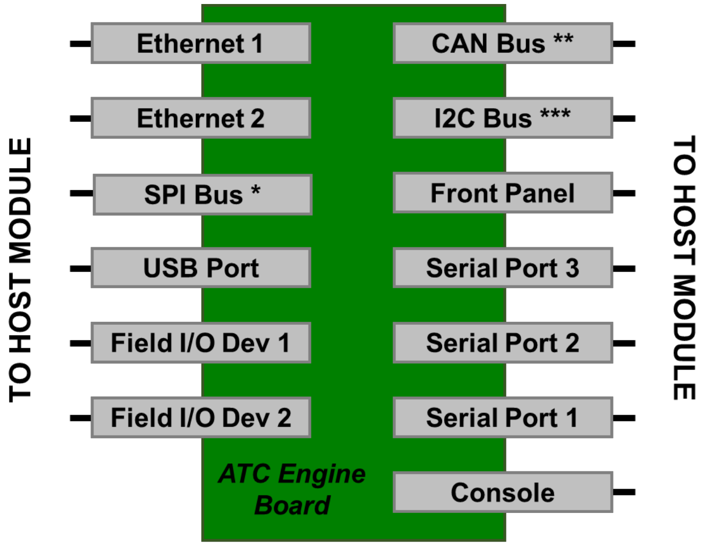


Figure 3. ATC Engine Board is used to support different families of controllers.

ATC 5201 specifies a minimum level of processing capability for the Engine Board. It also specifies the minimum physical and communication requirements for the Host Module. The Engine Board communication ports and their typical functions are illustrated in Figure 4 (not all named ports are required for different configurations). In the configuration shown, Serial Ports 1-3 are for general use.



*	Serial Peripheral Interface Bus – Used for optional removable memory devices (e.g., Datakey, EEPROM, SD Card)
**	Controller Area Network Bus (optional)
***	Inter-Integrated Circuit Bus (optional)

Figure 4. ATC Engine Board communications ports and their functions.

A controller that conforms to ATC 5201 alone usually runs a single application program. While Linux is a multi-process OS, ATC 5201 does not provide for multiple applications running concurrently from different software providers. This is because there is no capability to share the resources of the front panel and the TFCS internal communications. This capability is addressed in ATC 5401 as described in Section 2.2.2.2.

2.2.2.2 ATC 5401 ATC Application Programming Interface Standard

ATC 5401 Advanced Transportation Controller (ATC) Application Programming Interface (API) Standard Version v02A is the latest version of ATC 5401. ATC 5401 defines API Software that enables application programs to share access to the front panel of the controller and the field I/O devices of the TFCS. The API Software has “managers” for the front panel and field I/O devices that are active when the controller is operating. Application programs interact with these managers through functions specified in ATC 5401 using the C programming language. These functions are implemented in the source code of the API Software. ATC 5201 requires that manufacturers provide the libraries and build chain required to create programs for their ATC hardware. Portability of application programs to ATC Engine Boards from different manufacturers is achieved by application developers compiling and linking their application source code and the API Software source code for the targeted manufacturer. See Figure 5.

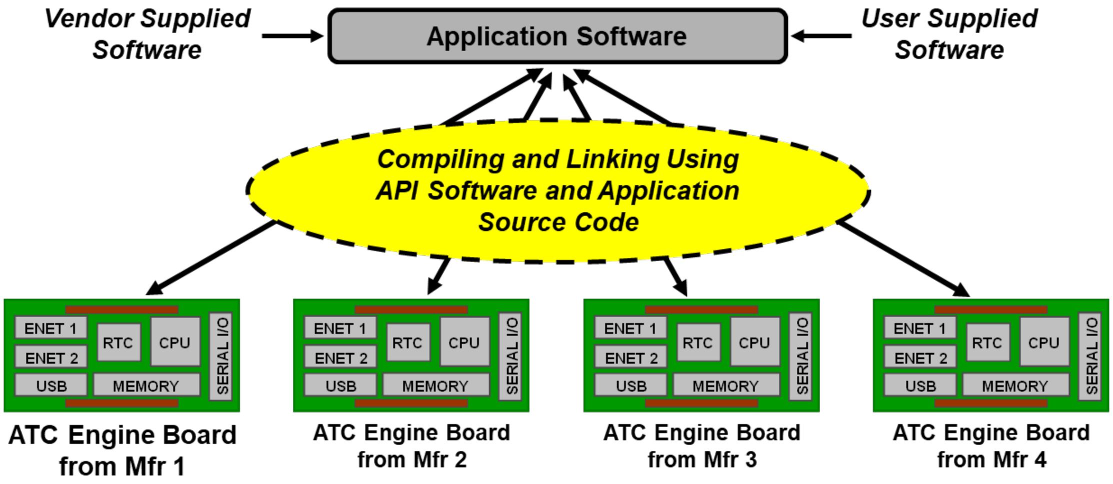

Vendor Supplied Software
Application Software
User Supplied Software
Compiling and Linking Using API Software and Application Source Code
ENET 1
ENET 2
RTC
CPU
USB
MEMORY
SERIAL I/O
ATC Engine Board from Mfr 1
ATC Engine Board from Mfr 2
ATC Engine Board from Mfr 3
ATC Engine Board from Mfr 4

Figure 5. Application portability through compilation and linking of source code.

Figure 6 illustrates the organization and layered architecture of ATC software. The "Linux OS and Device Drivers" reflects a specification of the Linux OS defined in the ATC Board Support Package (BSP) in ATC 5201. This includes functions for things typical in any computer system such as file I/O, serial I/O, interprocess communication, and process scheduling. It also includes the specification of the device drivers necessary for the Linux OS to operate on the ATC hardware. "API Software" refers to the software specified ATC 5401. As shown in Figure 6, both users and application programs use the API Software to interface to ATC units.

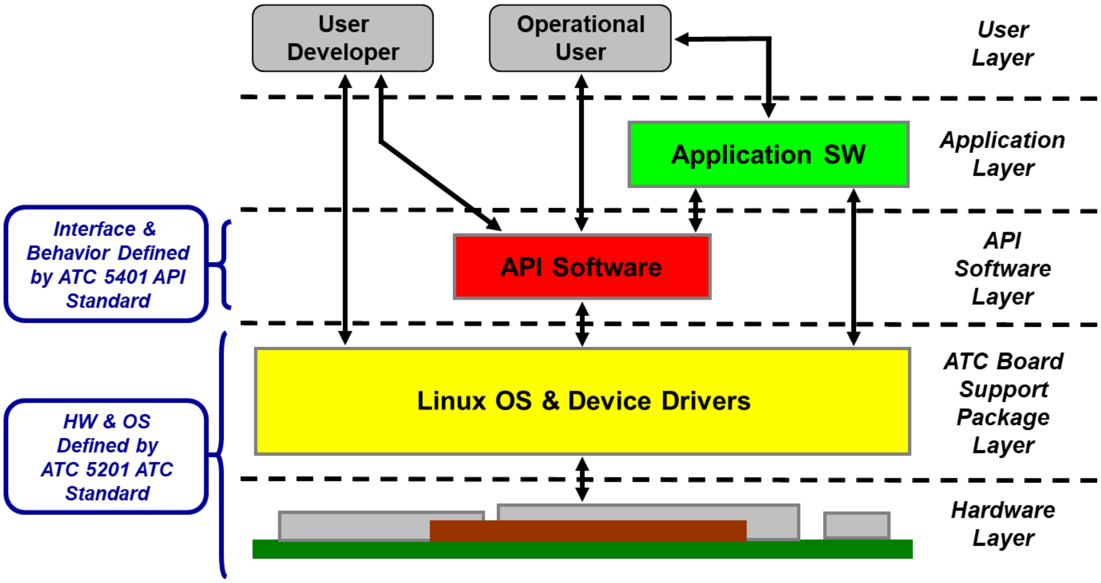
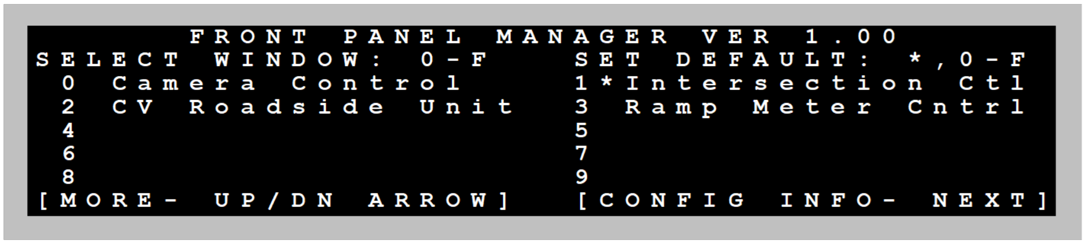

User Developer
Operational User
User Layer
Application SW
Application Layer
Interface & Behavior Defined by ATC 5401 API Standard
API Software
API Software Layer
HW & OS Defined by ATC 5201 ATC Standard
Linux OS & Device Drivers
ATC Board Support Package Layer
Hardware Layer

Figure 6. ATC software layered organization.

The division of the ATC software into layers helps to ensure consistent behavior of the software environment between ATC architectures and also provides a migration path to new ATCs in the future. The relationship between the Hardware Layer and ATC BSP Layer is maintained, for the most part, by the Linux operating system community of users and the manufacturers of the Engine Board. Linux source code licenses are free to the public and there are strong market incentives for Linux users to maintain the

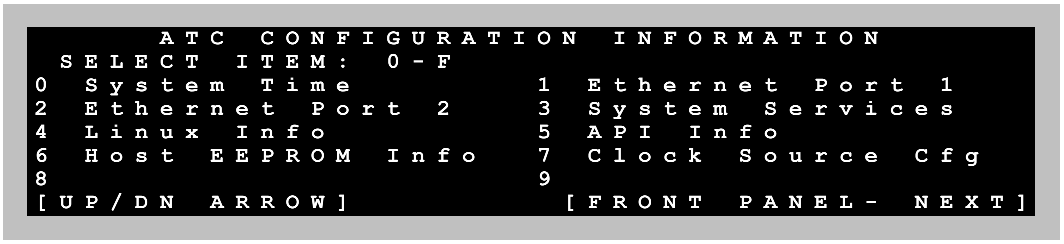
Linux standard and ensure consistent functionality of the Linux commands for the operating system. The relationship between the ATC BSP Layer and the API Software Layer is maintained by the transportation community through the ATC standards. Functions in the API Software Layer access the ATC unit through the functions in the ATC BSP Layer. If programs written for the Application Layer only reference the ATC unit through the functions specified in the API Software Layer and ATC BSP Layer, they will be able to operate on any ATC provided the source code is recompiled for the target ATC's processor. Users of the API Software are: a) the operational users that interact with the application programs and the technicians or engineers who configure the system settings (e.g., system time, Ethernet ports, systems services) and b) the user developers who use the API Software to develop applications.

Figure 7 shows an example of the Front Panel Manager window that allows users to select which application program running on the ATC unit to display on the screen. In this example, there are four application programs running: Camera Control, Intersection Control, CV Roadside Unit, and Ramp Meter Control. The application program with the asterisk next to its name is the default application to be displayed when the controller is powered up. Figure 8 shows an example of the ATC Configuration Information window. Users use this window to set and view systemwide parameters (e.g., system time, Ethernet ports).



```
      FRONT PANEL MANAGER VER 1.00
SELECT WINDOW: 0-F     SET DEFAULT: *,0-F
 0  Camera Control     1*Intersection Ctl
 2  CV Roadside Unit   3  Ramp Meter Cntrl
 4                     5
 6                     7
 8                     9
[MORE- UP/DN ARROW]    [CONFIG INFO- NEXT]
```

Figure 7. Front Panel Manager allows users to select an application program to put in view.



```
     ATC CONFIGURATION INFORMATION
 SELECT ITEM: 0-F
0 System Time         1 Ethernet Port 1
2 Ethernet Port 2     3 System Services
4 Linux Info          5 API Info
6 Host EEPROM Info    7 Clock Source Cfg
8                     9
[UP/DN ARROW]          [FRONT PANEL- NEXT]
```

Figure 8. ATC Configuration Information allows users to set and view systemwide parameters.

The USDOT sponsored a project to develop an open source software (OSS) reference implementation of the API Software called the API Reference Implementation (APIRI) and an OSS validation software called the API Validation Suite (APIVS). They are publicly available at https://github.com/apiriadmin/APIRI and https://github.com/apiriadmin/APIVS respectively.

2.2.2.3 ATC 5301 ATC Cabinet Standard

ATC 5301 Advanced Transportation Controller (ATC) Cabinet Standard Version v02 is the latest version of ATC 5301. Figure 9 illustrates an example ATC Cabinet System (ATC Cabinet). It must be emphasized that not all ATC Cabinets will have this configuration. The components of the cabinet are color coded in a similar fashion to the general TFCS description in Section 2.2.1.

- The **Controller** is shown as an ATC unit. This refers to the Advanced Transportation Controller unit that conforms to ATC 5201 and ATC 5401 (multi-application support option). ATC units from different manufactures will have a different appearance, size, and shape.

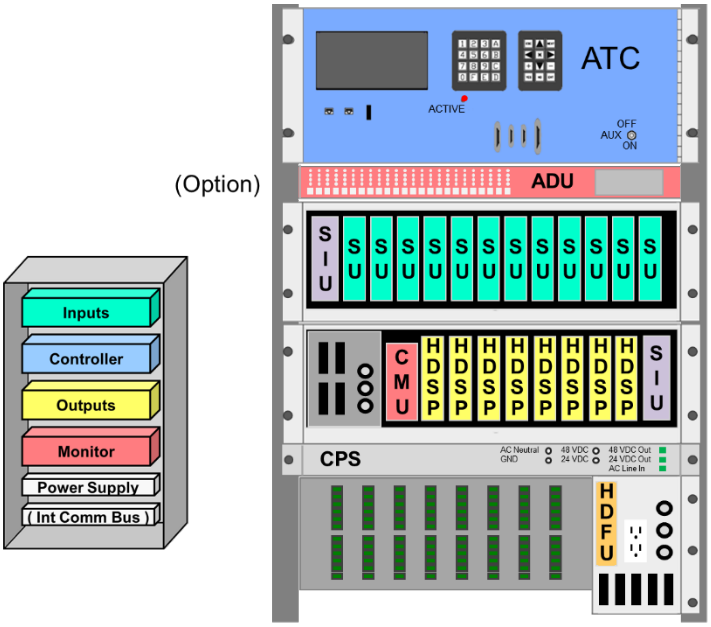
- **Inputs** is shown as an Input Assembly containing Sensor Units (SUs) to perform on-street detection and a Serial Interface Unit (SIU) to communicate the sensor data to the ATC unit. The SUs can be double or quad density detectors that support two or four input channels for each SU. Input assemblies can be different sizes and shapes.

- **Outputs** is shown as an Output Assembly containing High-Density Switch Packs (HDSPs) to control power to signals and other devices, a Cabinet Monitor Unit (CMU) to ensure that there are no conflicting signals (and other monitoring), and an SIU to allow the ATC unit to command the states of the HDSPs. HDSPs can control two output channels for each HDSP. HDSPs also come in high voltage (120 VAC), very high voltage (220 VAC), and low voltage (48 VDC) models. The HDSPs are unique to the ATC Cabinet architecture because of the support for two channels and multiple voltage options. The output assembly can be various shapes and sizes.

- The **Monitor** is shown as a CMU and an optional Auxiliary Display Unit (ADU). The ADU allows technicians to easily see the status of the cabinet system. The ADU may have various designs or the ADU functionality may be achieved through a laptop, handheld device, or the ATC unit. In the latter case, a technician may plug a laptop or handheld device into the CMU or the ATC unit may have a utility to see the status of the cabinet system. The CMU performs load current monitoring which can be used to detect dark signal heads. CMUs come in high voltage (120 VAC), very high voltage (220 VAC), and low voltage (48 VDC) models. The load current monitoring and multiple voltage options are unique to the ATC Cabinet architecture. A removable memory device is used to set the allowable signal state combinations allowed for an intersection in the CMU.

- The **Internal Bus** uses SDLC communications at 614 Kbps (kilobits per second) between the SIUs on the output and input assemblies, the CMU, and the ATC unit.

- The **Power Supply** is shown as the Cabinet Power Supply (CPS). There are several models of CPSs in ATC 5301 and manufacturer-specific designs are also allowed. The CPS converts service power to 48/24/12 VDC to power devices in the ATC Cabinet.



ADU	Auxiliary Display Unit
ATC	Advanced Transportation Controller
CMU	Cabinet Monitor Unit
CPS	Cabinet Power Supply
HDFU	High Density Flasher Unit
HDSP	High Density Switch Pack
SA	Service Assembly
SIU	Serial Interface Unit
SU	Sensor Unit

Figure 9. ATC Cabinet System and Components.

2.3 Current Situation and Problem Statement [Informative]

The United States Cybersecurity and Infrastructure Security Agency (CISA) has identified the US roadway transportation system as one of “16 critical infrastructure sectors whose assets, systems, and networks, whether physical or virtual, are considered so vital to the United States that their incapacitation or destruction would have a debilitating effect on security, national economic security, national public health or safety, or any combination thereof.” It is fundamental to the US economy to be able to transfer goods to market and allow people to go to work and conduct business. The roadway infrastructure is a critical resource in responding to natural disasters, contributing to national security across the country, and generally providing quality of life for the US population. There are over 4 million miles of interstate highways, strategic highways, arterial roadways and intermodal connectors. There are approximately 350,000 signalized intersections.

For most of the computer age, the roadway transportation infrastructure has been protected by its relative obscurity compared to financial institutions, large corporations, and non-transportation government entities. In the middle 1990s, when other sectors were using high-end workstations, fiber networks, and Internet protocols; most of the roadway networks of the transportation sector had single application traffic signal controllers with proprietary operating systems, low-end processors, and used proprietary communications over serial lines. This was due to many factors such as the high cost of replacing infrastructure, the long and complex effort needed to acquire large project funds, and the internal resistance to change by practitioners who maintained such systems. Today, however, this is no longer the case. Most transportation agencies have fiber networks and use Internet protocols. Older traffic signal controllers are being replaced by ATC units that are Linux computers. Operationally, they may be used for different applications and run multiple application programs concurrently.

The exponential rise in the number and sophistication of cyber threats affects all of the US critical infrastructure sectors. IOOs can no longer depend on obscurity to protect the roadway infrastructure. Large transportation agencies are thwarting tens of thousands attacks a day. About one third of state transportation agencies have reported cyber incidents. Traffic delays in metropolitan areas may cost a region hundreds of thousands of dollars per hour. There are demands for more and better data that may expose agencies to more risk. Important societal and economic efforts such as Smart Cities and multimodal transportation depend on improved collection, analysis, and distribution of transportation information. Safety efforts such as the Connected Vehicle (CV) program depend on accuracy, precision, and timing where an intrusion could be more detrimental than an all-out failure of the system. Transportation infrastructure may communicate with external systems outside of an agency including cloud services. All of these developments inevitably increase both the vulnerability of the transportation infrastructure and the urgency to include cybersecurity measures in the latest transportation field cabinet systems and subsystems.

2.4 ATC Cabinet Operational Architecture [Informative]

This section identifies the operational architecture of an ATC Cabinet in the field. The description of how TFCSs operate and the introduction to the ATC Cabinet, Controller and API standards have already been provided in Section 2.2 and its subsections. Generally, the internal configurations of an ATC Cabinet will be similar at a subsystem level (e.g., inputs, controller, outputs) but will vary based on the applications being supported, the roadway characteristics, and the connections to other systems. Figure 10 illustrates ATC Cabinet connections to external devices and systems that may exist . This illustration is not intended to be exhaustive. All of the external connections shown are network-type connections except for those used by traditional signal detection and displays which use power from the input and output devices in the cabinet to perform their function (e.g., loop detectors, signal displays, beacons, simple changeable message signs).

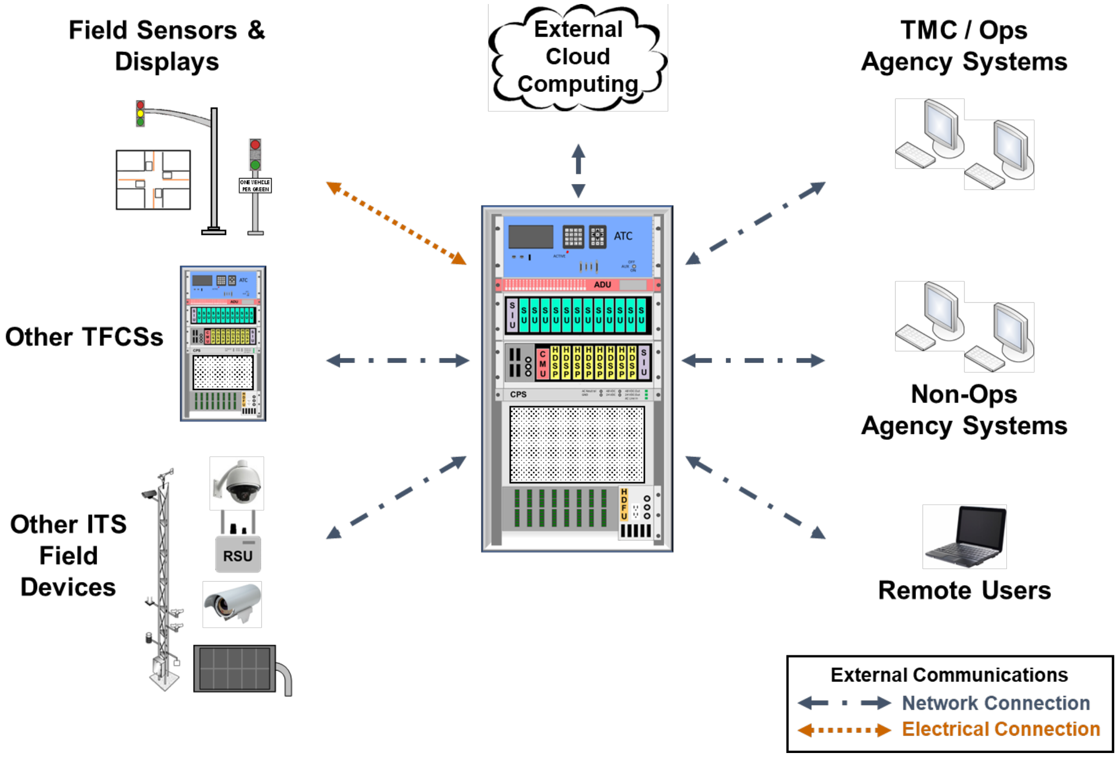


Figure 10. ATC Cabinet with external operational connections.

2.5 ATC Cybersecurity Scope [Informative]

Cybersecurity evaluations for an ATC Cabinet focus on all equipment and communications within cabinet, and all communications with devices and systems that are external to the cabinet. The external systems and devices themselves are not a subject of this ConOps but the communications with them are. This is illustrated in Figure 11. Figure 12 provides an internal view of the ATC Cabinet with areas identified for discovery of ATC cybersecurity needs and requirements.

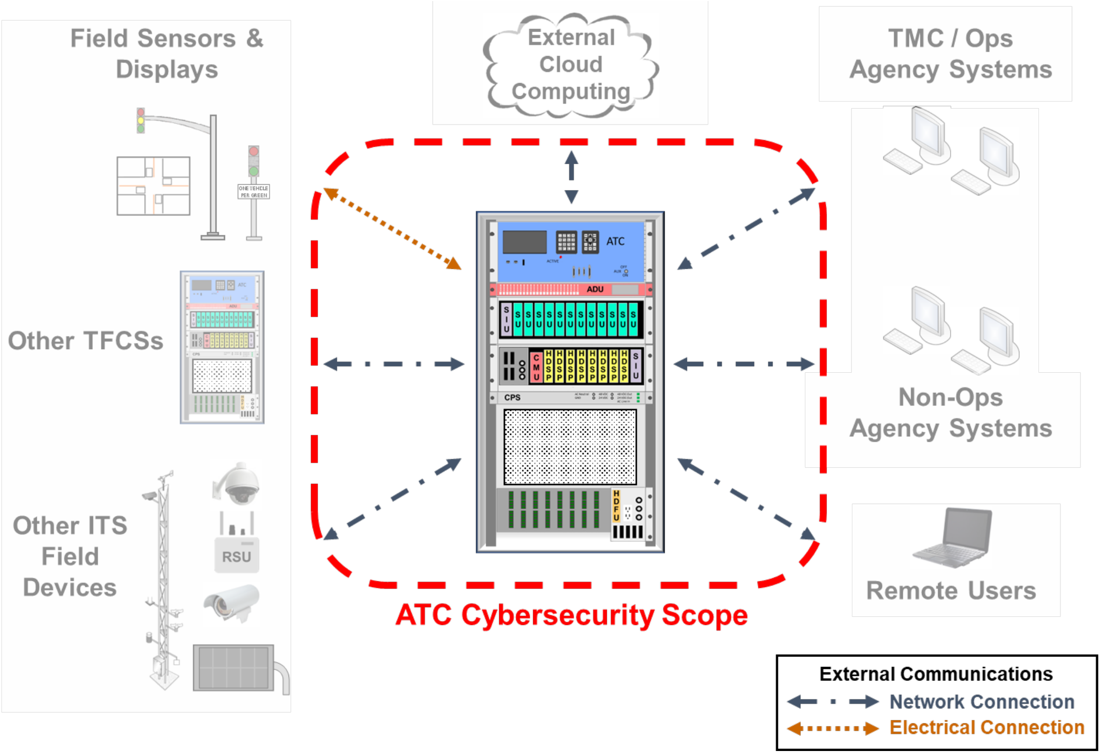


Figure 11. ATC Cybersecurity Scope includes needs and requirements for the ATC Cabinet system and external communications.

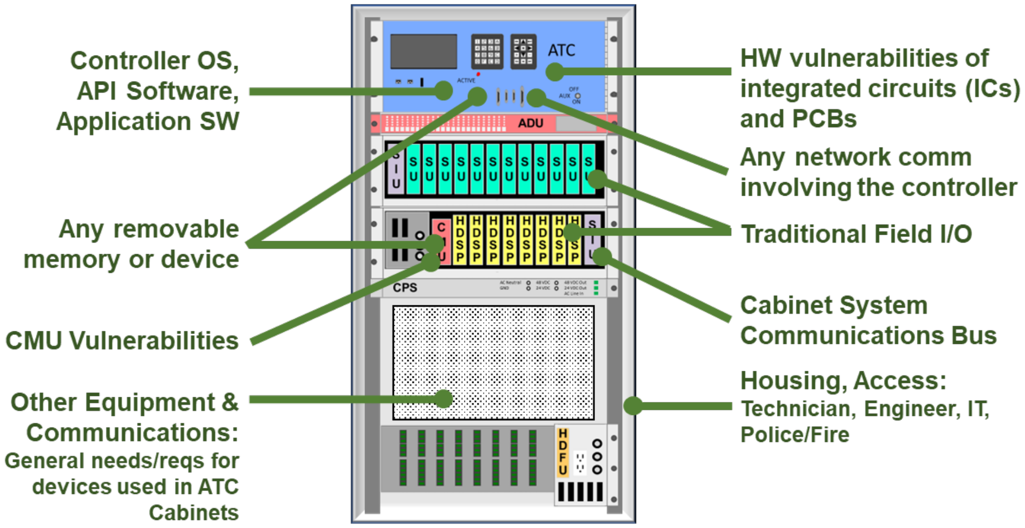

Controller OS, API Software, Application SW
Any removable memory or device
CMU Vulnerabilities
Other Equipment & Communications:
General needs/reqs for devices used in ATC Cabinets
HW vulnerabilities of integrated circuits (ICs) and PCBs
Any network comm involving the controller
Traditional Field I/O
Cabinet System Communications Bus
Housing, Access:
Technician, Engineer, IT, Police/Fire
ATC
ADU
CPS

Figure 12. Areas for discovery of ATC cybersecurity needs and requirements.

2.6 Architectural Constraints [Informative]

This ATC Cybersecurity Standard applies to the ATC family of standards. Attempting to impose requirements on non-ATC TFCS designs is out of scope. Therefore, ATC units in cabinet systems that do not conform to ATC 5301 are not formally covered by this ConOps but may still benefit from most of its content.

2.7 ATC Cybersecurity Needs [Normative]

This section identifies the cybersecurity needs to be included in the ATC Cybersecurity Standard. As a system, the needs are assigned to the ATC Cabinet. During requirements development, however, it is expected that requirements will reflect the subsystems, devices, communications or software to which they apply. Each need has a unique number (section number) and title, a sentence stating the need, and a rationale (typically 1-4 sentences) which states the reason for the need and may contain additional clarifying information.

In addition, each need is followed by initial implementation priorities set by the ATC Cybersecurity WG to help plan the requirements phase of development. They are bracketed and written in italics (e.g., *[Implement Now]*). The options are as follows:

- Implement Now – the need is implementable using the current generation of ATC equipment and it is a priority to do so.
- Desired Now – the need may or may not be implementable using the current generation of ATC equipment or it is a lower priority than those identified as Implement Now.
- Next Generation – the need is to be deferred to a new generation of ATC equipment due to the technical requirements or the time needed to carry it out.

The implementation priority is Informative and may change during the development of the ATC Cybersecurity Standard.

2.7.1 Physical Security

This section identifies needs that concern physical security.

2.7.1.1 Control Physical Access

The ATC Cabinet needs to control physical access to the cabinet system. This may include authentication, monitoring, and reporting physical access to the cabinet system. Physical access control helps to protect the system from tampering and modified operation.
[Implement Now]

2.7.1.2 Cabinet Monitor Bypass

The ATC Cabinet needs to prohibit the CMU from being bypassed or disabled. The CMU is a critical safety device for traffic signal control applications.
[Implement Now]

2.7.2 Inventory and Control of Assets

This section identifies needs that concern inventory and control of assets.

2.7.2.1 Facilitate Physical Inventory

The ATC Cabinet needs to facilitate the inventory and control of physical devices within the system. This may include support for identifiers such as the model, version, manufacturer, serial number, MAC address (if it is a network capable device), or universally unique identifier (UUID). This is to support asset and

configuration management by users. It is intended to be retrievable electronically. The identifying information will vary depending on the device.
[Implement Now]

2.7.2.2 List of Vulnerable Components

The ATC Cabinet needs its physical devices within the cabinet to come with a list that identifies the components of the device that may impose cybersecurity risks. Examples include microcontrollers, microprocessors, and field programmable gate arrays (FPGAs). This is to support supply chain risk management (SCRM).
[Implement Now]

2.7.2.3 Facilitate Software Inventory

The ATC Cabinet needs to facilitate the inventory and control of any software that is used on a programmable device. Software may include driver software, OS, libraries, a board support package (BSP), file system, middleware, application software, and scripts. Identifiers may include the software name, version, publisher, install date, and other identification. It is intended to be retrievable electronically.
[Implement Now]

2.7.2.4 Software Bill of Materials

The ATC Cabinet needs any software that is to be used on a programmable device to come with a software bill of materials (SBOM). An SBOM is a nested inventory of the software components for a given software item. It allows users to respond to security, license, and operational risks that come with software including open source and third-party components present in a codebase.
[Implement Now]

2.7.2.5 Inventory Tool Support

The ATC Cabinet needs a means to supply the identifying information of its devices electronically. Identifying information may include the current location of the device. This is to allow users to use automated tools for asset management.
[Next Generation]

2.7.2.6 Notice of Unsupported Software

The ATC Cabinet needs vendors to provide notices of end of life (EOL) or otherwise unsupported software. Notices may include EOL, expected end of support, or if a delivered software is not a production release (e.g., Beta Version Release). This is typically performed at procurement but it may be a part of an ongoing relationship with the software provider.
[Implement Now]

2.7.2.7 Asset Tracking

The ATC Cabinet needs to include asset tracking capabilities for selected components. Asset location technologies can help ensure that critical assets (especially ATC units and CMUs but could include other equipment) remain in expected physical locations.
[Desired Now]

2.7.3 Continuous Vulnerability Management

This section identifies needs that concern continuous vulnerability management.

2.7.3.1 Validate Software Is Authorized

The ATC Cabinet needs a mechanism to ensure only authorized software is installed in the system. Software may include driver software, OS, libraries, a board support package (BSP), file system, middleware, application software, and scripts. Identifiers may include the software name, version, publisher, install date, and other identification. This is to protect against the unauthorized loading of software.
[Implement Now]

2.7.3.2 Vulnerability Scanning

The ATC Cabinet needs to continually check for unauthorized changes to software components including additions and removals. Unauthorized manipulation is logged and reported.
[Implement Now]

2.7.3.3 Intrusion Detection

The ATC Cabinet needs to detect in a timely manner when a cyber intrusion has been attempted or occurred. Intrusion includes malware activity. The detection capability can be updated with the latest known threats.
[Desired Now]

2.7.4 User Accounts and Controlled Use of Administrative Privileges

This section identifies needs that concern user accounts and controlled use of administrative privileges.

2.7.4.1 Uniquely Identify Authorized Users

The ATC Cabinet needs to be able to uniquely identify authorized users of the system. The system may use passwords or multi-factor authentication. The purpose is to verify that the user is authorized.
[Implement Now]

2.7.4.2 User Account Management

The ATC Cabinet needs to support the addition, change, and removal of user accounts. This allows the agency to manage access to the entire system.
[Desired Now]

2.7.4.3 User Access Control

The ATC Cabinet needs to provide user based access control. The ability to use features and operations (user privileges) can be tailored and restricted for logins and may be time limited. Access and operations may be role-based. This protects the operation and security of the device.
[Desired Now]

2.7.4.4 Default Passwords

The ATC Cabinet needs to protect against the use of weak or discoverable default passwords. Default passwords are a security risk.
[Implement Now]

2.7.5 Logging, Monitoring, and Reporting

This section identifies needs that concern logging, monitoring, and reporting.

2.7.5.1 Consistent and Accurate Time

The ATC Cabinet needs to maintain consistent and accurate time among all of its devices. Consistent and accurate time is necessary to analyze logs and perform forensics after a cybersecurity event.
[Desired Now]

2.7.5.2 Account Logging

The ATC Cabinet needs to log and report any changes to the accounts on the system or application in a fashion that prevents tampering (unauthorized modification). This is to detect the changes made as soon as they happen as well as in later analysis.
[Desired Now]

2.7.5.3 Security Event Logging

The ATC Cabinet needs to perform security event logging. For example, denial-of-service, port scans, temporary changes due to an attack, etc. Logging needs to be enabled by default and securely stored so that it is accessible to privileged accounts only.
[Desired Now]

2.7.5.4 Support Security Audits

The ATC Cabinet needs to support the secure auditing of the cabinet system. For example, adding a user or changing the configuration. This provides historical and forensic support.
[Desired Now]

2.7.5.5 Security Monitoring

The ATC Cabinet needs to provide security monitoring of the system operation. This includes automated tools, alerts, and notifications. This may be through a front panel display or a message sent to another device.
[Implement Now]

2.7.5.6 Operating Software Reporting

The ATC Cabinet needs to report all currently running software when queried. This can confirm proper operations and can protect the system from unauthorized software.
[Desired Now]

2.7.5.7 Network Service Status

The ATC Cabinet needs to provide the current status of the network features. This allows agencies to understand the device’s capabilities that are enabled and disabled. Network features may include the webservices provided, the protocols supported (e.g., HTTP, HTTPS, SSH2, FTP, SFTP), and the ports used.
[Implement Now]

2.7.6 Networks, Protocols, and Services

This section identifies needs that concern networks, protocols and services.

2.7.6.1 Secure Remote Access

If remote access is supported by the system, the ATC Cabinet needs to provide secure connections and communications. For example, Internet proxy. This reduces the attack surface.

[Implement Now]

2.7.6.2 Wireless Security

The ATC Cabinet needs to employ secure wireless protocols when using wireless communications. This is to secure data in transit. For example, WPA3. Wireless communications are to be secure by default. This reduces the vulnerabilities associated with wireless communications.
[Implement Now]

2.7.6.3 Disabled Protocols, Services, and Ports

The ATC Cabinet needs to contain network capable devices that have protocols, services, and ports disabled by default. This means that users will configure what they need and will be less likely to expose services unintentionally.
[Implement Now]

2.7.6.4 Manufacturer-Stated Network Services

The ATC Cabinet needs to have the network features of all network-capable devices documented by the manufacturer. This allows agencies to understand the device's capabilities, how to configure them, and how to maintain them.
[Implement Now]

2.7.6.5 Boundary Protection

The ATC Cabinet needs to restrict or prohibit unauthorized network traffic to critical components. This includes the support of monitoring and control of network communications at managed interfaces. Managed interfaces include the use of gateways, routers, firewalls, guards, and other network management methods. Support the use of VLANs or multiple physical networks. This allows a LAN to be configured to only connect devices of similar security sensitivity.
[Implement Now]

2.7.6.6 Denial-of-Service Protection

The ATC Cabinet needs to protect against denial-of-service (DoS) attacks. This ensures the applications running within the cabinet system perform their required operations in the expected fashion. Mitigations may be boundary protection devices and increased network capacity and bandwidth. Possibly automated rate limiting of devices.
[Implement Now]

2.7.6.7 Use of Cloud Services

The ATC Cabinet needs to continue to operate safety critical applications (e.g., traffic signal control) without interruption due to the loss of cloud services. Non-critical features that rely on cloud services may not be available. This protects the ATC Cabinet system from failed or compromised cloud services.
[Implement Now]

2.7.7 Data At Rest Protection

This section identifies needs that concern data at rest protection.

2.7.7.1 Secure Data At Rest

The ATC Cabinet needs to have all sensitive data at rest encrypted and integrity protected. This extends to all of the systems that the ATC Cabinet uses including cloud services. This protects the operation of the system.

[Desired Now]

2.7.7.2 Removable Storage Security

If removable storage is supported, the ATC Cabinet needs to protect sensitive data at rest on removable storage devices. Examples may be to require that the user has privileges to access devices and encrypt/decrypt files. Ports are to be disabled when not in use.
[Desired Now]

2.7.8 Data in Transit Protection

This section identifies needs that concern data in transit protection.

2.7.8.1 Secure Data in Transit

The ATC Cabinet needs to utilize secure communications between network capable devices. At a minimum, use secure (encrypted), up-to-date protocols such as TLS 1.3, SFTP, SSH2, and SNMPv3. This extends to all systems that the ATC Cabinet uses including cloud services. Unencrypted protocols are not secure.
Note: SDLC communications may be exempted for current generation ATC equipment.
[Desired Now]

2.7.8.2 Valid Credentials

The ATC Cabinet needs to ensure that it uses up-to-date, valid credentials to send and receive information securely (e.g., TLS certificates between devices). This extends to all systems that the ATC Cabinet uses including cloud services and any services used by those cloud services. Communications with invalid credentials are not secure.
[Desired Now]

2.7.9 Authentication, Authorization, and Accounting

This section identifies needs that concern the authentication, authorization, and accounting of users and devices.

2.7.9.1 Configure Centralized Point of Authentication

ATC Cabinet needs to provide facilities for remote authentication of users (e.g., active directory, RADIUS, IEEE 802.1x). This allows centralized credential management. This extends to practices employed by all systems that the ATC Cabinet uses including cloud services. For example, when a person leaves the agency, their credentials can be removed from the domain.
[Desired Now]

2.7.9.2 Authentication Protection

The ATC Cabinet needs to protect the authentication capability of the system. Locally stored user credentials and privileges are stored in a secure fashion. This extends to practices employed by all systems that the ATC Cabinet uses including cloud services. Allow configurable expiration of credentials. Secure storage of locally stored credentials and privileges helps protect against unauthorized access to the system.
[Implement Now]

2.7.9.3 Key Material Protection

The ATC Cabinet needs to protect the cryptographic material (e.g., private keys for TLS certificates) of the system. Locally stored cryptographic material is stored in a secure fashion. This extends to practices

employed by all systems that the ATC Cabinet uses including cloud services. This could be a security module. Secure storage of locally stored cryptographic material helps protect the system from unauthorized use.
[Next Generation]

2.7.9.4 Secure Authenticated Sessions

The ATC Cabinet needs to provide best practices for authentication. Use Public Key Infrastructure (PKI) for bidirectional cryptographic authentication, locking accounts after too many failed authentication attempts, and terminating inactive sessions. This extends to practices employed by all systems that the ATC Cabinet uses including cloud services. This inhibits the ability of bad actors to gain access to the system.
[Desired Now]

2.7.9.5 Trustworthiness

The ATC Cabinet needs to ensure that it does not exchange data to/from devices that are no longer trustworthy. This extends to practices employed by all systems that the ATC Cabinet uses including cloud services. The system may halt communications with a device due to expired certificates, lack of responsiveness, excessive network traffic, and other tests. Communications with a device that is not trustworthy is not secure.
[Desired Now]

2.7.10 Operating Platform and Applications

This section identifies needs that concern the operating platform for ATC units and the application programs that run on them.

2.7.10.1 Application and Process Isolation

If the ATC Cabinet is running multiple applications, then the resources used by the applications need to be isolated, controlled, and privileges restricted. This extends to applications running on all systems that the ATC Cabinet uses including cloud services. If one application is compromised or malfunctions, it will not affect the other applications.
[Desired Now]

2.7.10.2 Application Reporting

The ATC Cabinet needs to provide a capability for applications to report faulty operation. This extends to applications running on all systems that the ATC Cabinet uses including cloud services. This could be used by application programs to identify safety and security risks.
[Desired Now]

2.7.10.3 Application Logging

The ATC Cabinet needs to provide a capability for applications to perform logging. This extends to applications running on all systems that the ATC Cabinet uses including cloud services. This could be used by application programs to identify safety and security risks.
[Desired Now]

2.7.10.4 Application Portability

TFSC needs to facilitate application portability. Application portability and the ability to reconstitute on different platforms increase the availability of mission-essential functions. For example, mission critical software on a compromised ATC unit from one manufacturer could be reconstituted on a non-

compromised ATC unit from another manufacturer. Also, portability of application programs allows new security solutions to be used to secure the system.
[Desired Now]

2.7.10.5 Separation of System, Security, and User Functionality

The ATC Cabinet needs to separate user functionality, including user interface services, from system management functionality. The separation of user functions from system and security management functions may be physical or logical and may be separated by using different computers, instances of operating systems, central processing units, or network addresses. This extends to practices employed by all systems that the ATC Cabinet uses including cloud services. This prevents the misuse of privileged functions.
[Implement Now]

2.7.10.6 Facilitate System Software Updates

The ATC Cabinet needs to provide tools to ensure the timeliness and completeness of patching firmware, operating system, and middleware. This extends to practices employed by all systems that the ATC Cabinet uses including cloud services. These tools include options for manual and automated updates. Only allows valid software to be installed and includes the removal of previous versions of the software.
[Desired Now]

2.7.11 Resiliency

This section identifies needs that concern resiliency.

2.7.11.1 System Backup

The ATC Cabinet needs to provide a method for system backups. Backups may include system state information, operating system software, middleware, application software, licenses, user and system documentation, and data. This extends to practices employed by all systems that the ATC Cabinet uses including cloud services. This is to facilitate recovery from an attack or failure.
[Desired Now]

2.7.11.2 System Safe Mode

The ATC Cabinet needs to provide a safe mode of operation. It may be activated automatically or manually. It restricts the operations that systems can execute when conditions such as an unauthorized intrusion, a failure, or other conditions are encountered. Examples could be disabling network capabilities, front panel display, keyboard, and others.
[Implement Now]

2.7.11.3 Secure System Restore

The ATC Cabinet needs to allow an authorized user or trusted installer to revert to a trusted configuration. This may be a recovery method from unauthorized software being installed or a trusted environment that has become corrupted.
[Desired Now]

2.7.11.4 Power Interruption Response

The ATC Cabinet needs to provide a method for continued operations when there are service power interruptions. This may provide for orderly shutdown of the system or a transition to an alternate power source. This protects system devices and may continue operation of the system.
[Implement Now]

2.8 Operational Policies and Constraints [Normative]

There are no operational policies or constraints identified for this ConOps.

2.9 Operational Scenarios [Informative]

There are no operational scenarios identified for this ConOps.

2.10 ARC-IT and Security [Informative]

The Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) is the reference architecture for intelligent transportation systems in the United States. It allows planners and engineers to conceive, design and implement systems using four “Views” (viewpoints) of a system that are all tied to the common reference architecture. It also provides “Services” which represent elements of the Physical View that address specific ITS services along with their functional objects and information flows. Security applies to all physical objects and information flows, impacts all enterprise objects, and affects the structure and content of communications profiles. See Figure 13.

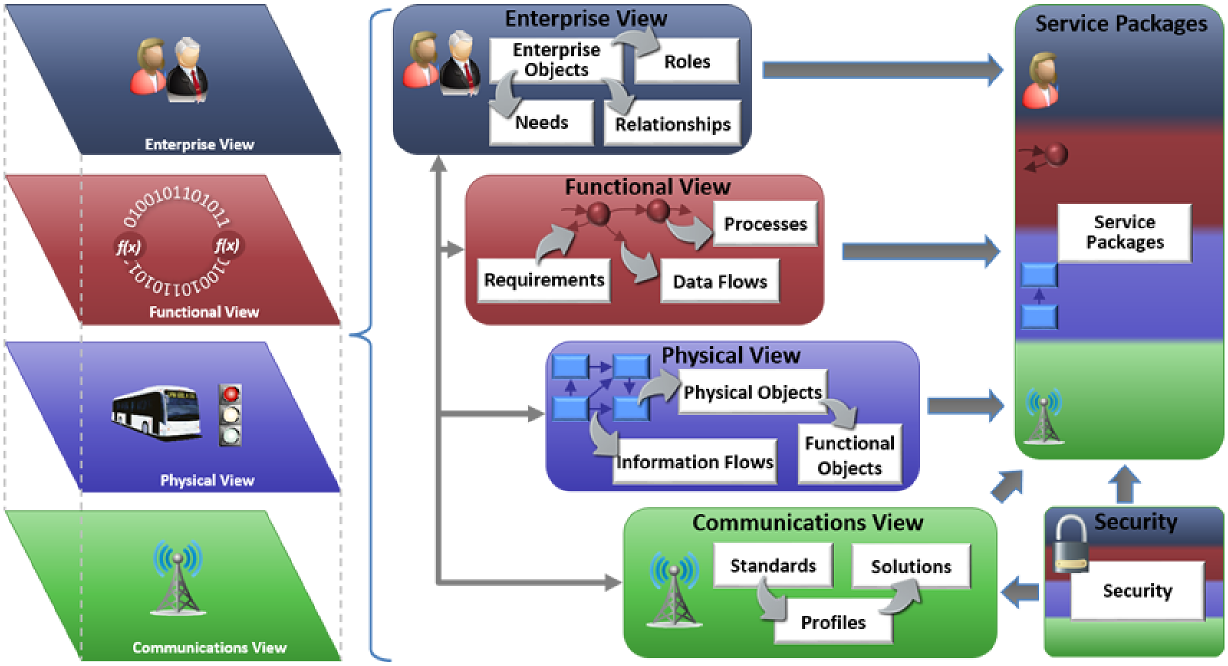
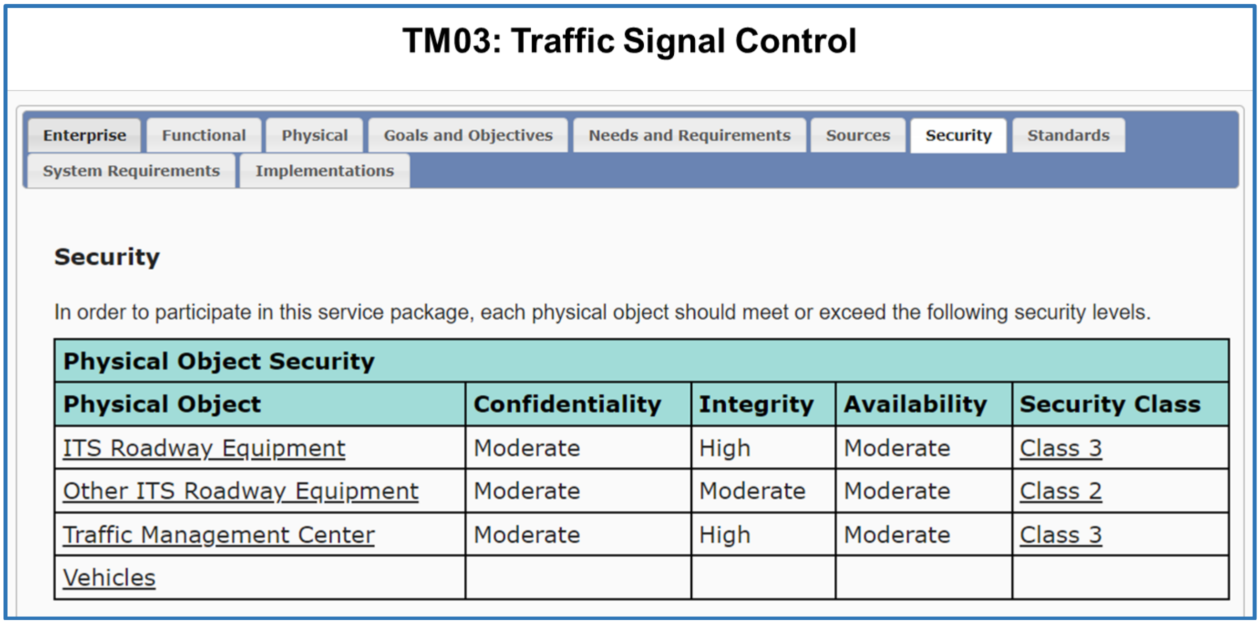


Figure 13. ARC-IT’s interconnected components are organized into four views of the reference architecture.

ARC-IT defines five physical device security classes (also called “device classes” or “classes”) based on the requirements for Confidentiality, Integrity, and Availability for the device. The classes are a collection of security controls from which security requirements can be developed. Class 5 devices have the highest level of security controls. Every physical object represented in ARC-IT is covered by a device class that matches or exceeds its security requirements. The control documentation for ARC-IT is largely sourced from NIST SP 800-53r3 Security and Privacy Controls for Information Systems and Organizations. The most common starting point when using ARC-IT is through the Services. Figure 14 is a portion of the screen from the Security tab of the Traffic Signal Control service. This shows that ITS Roadway Equipment is Class 3. Selecting Class 3 and then subsequently "Detailed Controls," will list the NIST controls that ARC-IT has identified for Class 3 devices. The ATC standards specify devices and software that fall under this class. A separate analysis of NIST SP 800-53r5 was also performed as part of this ConOps development (see Annex A).



TM03: Traffic Signal Control

Security

In order to participate in this service package, each physical object should meet or exceed the following security levels.

Physical Object Security

Physical Object	Confidentiality	Integrity	Availability	Security Class
ITS Roadway Equipment	Moderate	High	Moderate	Class 3
Other ITS Roadway Equipment	Moderate	Moderate	Moderate	Class 2
Traffic Management Center	Moderate	High	Moderate	Class 3
Vehicles				

Figure 14. Physical object security for the ARC-IT Traffic Signal Control service. ATC standards are a part of ITS Roadway Equipment Security Class 3.

Annex A
Requirement Resources from NIST SP 800-53r5 Controls [Informative]

A.1 Introduction

During the development of the ConOps, an analysis was performed of the security controls found in NIST SP 800-53 Security and Privacy Controls for Information Systems and Organizations. This was in order to discover additional user needs and to identify controls that could serve as a resource for requirements to be developed for the ATC Cybersecurity Standard. As discussed in Section 2.10, NIST SP 800-53 serves as the security resource for ARC-IT.

NIST SP 800-53r5 organizes security controls into 20 families (see Table 1). The families contain base controls and control "enhancements" which either add functionality or specificity to a base control or increase the strength of a base control. There are a total of 1006 controls and enhancements in NIST SP 800-53r5 of which 206 have been initially identified as resources for requirements development.

Table 1. NIST SP 800-53r5 Security and Privacy Control Families

ID	Control Family	ID	Control Family
AC	Access Control	**PE**	Physical and Environmental Protection
AT	Awareness and Training	**PL**	Planning
AU	Audit and Accountability	**PM**	Program Management
CA	Assessment, Authorization, and Monitoring	**PS**	Personnel Security
CM	Configuration Management	**PT**	PII Processing and Transparency
CP	Contingency Planning	**RA**	Risk Assessment
IA	Identification and Authentication	**SA**	System and Services Acquisition
IR	Incident Response	**SC**	System and Communications Protection
MA	Maintenance	**SI**	System and Information Integrity
MP	Media Protection	**SR**	Supply Chain Risk Management

A.2 User Needs and NIST SP 800-53r5 Controls

Table 2 lists the user needs identified within the ConOps and the NIST controls and enhancements that may serve as resources for requirements development. The controls and enhancements have the form "*ID-n(e)"* where *ID* is the family, *n* is the base control number, and *e* is the enhancement number. During requirements development, it is recommended that the controls and enhancements listed are reviewed along with any related controls referenced within the descriptions. Table 2 is not intended to be exhaustive.

Table 2. ATC Cybersecurity User Needs and Supporting NIST SP 800-53r5 Controls

UN #	User Need Title	NIST Controls and Enhancements
2.7.1	**Physical Security**	
2.7.1.1	Control Physical Access	CM-3(8), CM-5(1), IA(11), PE-2(1), PE-3(1), PE-3(4), PE-4, PE-6(1), AC-2(11), AC-2(12), IA-11
2.7.1.2	Cabinet Monitor Bypass	CM-3(8), PE-3(5), PE-4, PE-6(1)
2.7.2	**Inventory and Control of Assets**	
2.7.2.1	Facilitate Physical Inventory	CM-7(9), CM-8
2.7.2.2	List of Vulnerable Components	SR-3, SR-3(3), SR-4, SR-4(1), SR-4(2), SR-4(4), SR-5
2.7.2.3	Facilitate Software Inventory	CM-8
2.7.2.4	Software Bill of Materials	SR-3, SR-3(3), SR-4, SR-4(1), SR-4(2), SR-4(4), SR-5
2.7.2.5	Inventory Tool Support	CM-8, SA-10(3), SA-10(6)
2.7.2.6	Notice of Unsupported Software	SA-22, SA-5
2.7.2.7	Asset Tracking	PE-20
2.7.3	**Continuous Vulnerability Management**	
2.7.3.1	Validate Software Is Authorized	CM-7, CM-7(1), CM-7(2), CM-7(4), CM-7(5), CM-7(7), IA-9, SI-7, SI-7(1), SI-7(2), SI-7(5), SI-7(6), SI-7(8), SI-7(9), SI-7(10), SI-7(12), SI-7(15)
2.7.3.2	Vulnerability Scanning	CM-11(2), CM-11(3), SI-3, SI-3(4), SI-3(8), SI-7(2), SI-7(6), SI-7(8)
2.7.3.3	Intrusion Detection	CM-11(2), CM-11(3), SC-7, SC-7(3), SC-7(4), SC-7(5), SC-35, SI-3, SI-3(4), SI-3(8)
2.7.4	**User Accounts and Controlled Use of Administrative Privileges**	
2.7.4.1	Uniquely Identify Authorized Users	AC-4(17), AC-2(1), AC-2(3), AC-2(4), AC-2(7), AC-2(12), AC-3, AC-3(8), AC-24, AC-24(1), AC-24(2), IA-2, IA-2(1), IA-2(2), IA-2(5), IA-2(6), IA-2(13), IA-5, IA-5(1), IA-5(5), IA-5(7), IA-7, IA-8, IA-10, IA-11
2.7.4.2	User Account Management	AC-2(1), AC-2(3), AC-2(4), AC-2(7), AC-2(11), AC-2(12), AC-3, AC-3(8), AC-3(13)
2.7.4.3	User Access Control	AC-2(7), AC-2(11), AC-2(12), AC-3(7), AC-2(7), AC-3(8), AC-3(13), AC-6(10), AC-7(4), AC-24, AC-24(1), AC-24(2), CM-3(8), CM-5(1), CM-11(2), SC-4
2.7.4.4	Default Passwords	AC-7(4), IA-5(5)
2.7.5	**Logging, Monitoring, and Reporting**	
2.7.5.1	Consistent and Accurate Time	SC-45, SC-45(1), SC-45(2)
2.7.5.2	Account Logging	AU-2, AU-3, AU-3(1)

UN #	User Need Title	NIST Controls and Enhancements
2.7.5.3	Security Event Logging	AU-2, AU-3, AU-3(1), AU-12(3), CM-3(5), CM-5(1), SI-11
2.7.5.4	Support Security Audits	AU-3, AU-3(1), AU-4, AU-4(1), AU-5, AU-5(1), AU-5(2), AU-7, AU-7(1), AU-8, AU-9, AU-9(3), AU-9(6), AU-12, AU-12(3) AC-6(9), CM-3(8), CM-3(5), CM-5(1)
2.7.5.5	Security Monitoring	SI-4, SI-4(2), SI-4(5), SI-4(7), SI-4(14), SI-4(22), AC-9
2.7.5.6	Operating Software Reporting	CM-6, CM-8, SA-10(1), SI-11
2.7.5.7	Network Service Status	CM-6, SI-4, SI-4(2), SI-4(22)
2.7.6	**Networks, Protocols, and Services**	
2.7.6.1	Secure Remote Access	AC-3, AC-17(1), AC-17(2), AC-17(3), AC-17(10), AC-20, AC-20(1), AC-20(2), AC-20(3), IA-2(13), IA-3, MA-4(4), SC-7(8), SC-7(11), SC-7(15), SC-10, SC-11
2.7.6.2	Wireless Security	AC-18, AC-18(1), AC-18(3), AC-18(4), SC-7(3), SC-7(5), SC-11, SC-40
2.7.6.3	Disabled Protocols, Services, and Ports	AC-18(3), CM-6, CM-7, CM-7(1), SA-4(5), SC-7(5), SC-41
2.7.6.4	Manufacturer-Stated Network Services	SA-5
2.7.6.5	Boundary Protection	AC-3(5), AC-4, AC-4(1), IA-5(2), SC-4, SC-5, SC-7, SC-7(3), SC-7(4), SC-7(5), SC-7(8), SC-7(11), SC-7(12), SC-7(13), SC-7(15), SC-7(16), SC-7(18), SC-7(21), SC-7(23), SC-7(28), SC-7(29), SC-11, SC-47, SI-3
2.7.6.6	Denial-of-Service Protection	SC-5, SC-5(1), SC-5(2), SC-5(3), SC-6, SC-7
2.7.6.7	Use of Cloud Services	AC-3(5), AC-20, AC-20(1), AC-20(3), AC-20(4)
2.7.7	**Data At Rest Protection**	
2.7.7.1	Secure Data At Rest	AC-3(11), AC-20(2), AC-20(4), MP-2, MP-7, SC-4, SC-13, SC-28, SC-28(1)
2.7.7.2	Removable Storage Security	AC-20(2), AC-20(5), AC-3(11), MP-2, MP-7, SC-4, SC-28, SC-28(1), SC-41
2.7.8	**Data in Transit Protection**	
2.7.8.1	Secure Data in Transit	AC-17(2), AC-17(3), SC-8, SC-8(1), SC-13
2.7.8.2	Valid Credentials	IA-9
2.7.9	**Authentication, Authorization, and Accounting**	
2.7.9.1	Configure Centralized Point of Authentication	AC-3(11), AC-3(12), AC-3(13)
2.7.9.2	Authentication Protection	AC-3(5), IA-5(7), IA-7, IA-5(13), IA-5(14), IA-6, SI-10(5)
2.7.9.3	Key Material Protection	AC-3(5), IA-5, IA-5(1), IA-5(2), IA-7
2.7.9.4	Secure Authenticated Sessions	AC-7, AC-2(5), AC-11, AC-12, AC-12(1), AC-12(3), IA-3(1), IA-5(14), IA-7, SC-17, SC-21, SC-23, SC-23(1), SC-23(3), SC-23(5)
2.7.9.5	Trustworthiness	AC-4, CM-3(5), IA-3, SI-10(5)

UN #	User Need Title	NIST Controls and Enhancements
2.7.10	**Operating Platform and Applications**	
2.7.10.1	Application and Process Isolation	SC-2, SC-2(1), SC-5, SC-6, SC-7(21), SC-18, SC-39, AC-3(12), AC-6(4), AC-6(10), SI-16
2.7.10.2	Application Reporting	AU-2, SI-4, SI-4(7), SI-11
2.7.10.3	Application Logging	AU-2, AU-3, AU-3(1), AU-12(3), CM-5(1), SI-11
2.7.10.4	Application Portability	SC-27
2.7.10.5	Separation of System, Security, and User Functionality	SC-2, SC-2(1), SC-3, SC-3(1), SC-3(2), SC-3(3), SC-3(4), SC-3(5), AC-6(8), AC-6(10) SC-7(21)
2.7.10.6	Facilitate System Software Updates	SI-2(4), SI-2(5), SI-2(6), SA-10, SA-10(1), SA-10(3), SA-10(6)
2.7.11	**Resiliency**	
2.7.11.1	System Backup	CP-9
2.7.11.2	System Safe Mode	CP-12, SC-7(18), SC-24, IR-4(5), SI-7(5), SI-17
2.7.11.3	Secure System Restore	CP-10, IR-4(5), SA-8(24), SI-17
2.7.11.4	Power Interruption Response	PE-11, PE-11(1), SI-17

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