



Connected Corridor Advancement Initiative

ARC-ITS and IFC Integration for Digital Infrastructure

Overview

This document describes how Industry Foundation Classes (IFC) BIM models integrate with Advanced Regional Center (ARC) Intelligent Transportation Systems (ITS) data to create a comprehensive digital infrastructure platform.

ARC-ITS Data Sources

ARC-ITS systems typically provide operational data for:

Traffic Monitoring Devices

- **Detectors/Sensors** - Loop detectors, radar, video detection

- **CCTV Cameras** - Traffic surveillance cameras
- **Weather Stations** - Road weather information systems (RWIS)
- **Travel Time Sensors** - Bluetooth/Wi-Fi readers, probe data

Traffic Control Devices

- **Traffic Signals** - Signal controllers with SPaT data
- **Ramp Meters** - Freeway entrance ramp control
- **Lane Control Signs** - Overhead lane use signals
- **Dynamic Message Signs (DMS)** - Variable message signs

Connected Vehicle Infrastructure

- **Roadside Units (RSU)** - V2X communication infrastructure
- **Signal Phase & Timing (SPaT)** - CV-enabled traffic signals
- **Traveler Information Messages** - TIM broadcasts

Communication Infrastructure

- **Fiber Optic Network** - ITS device connectivity
- **Wireless Communication** - Radio/cellular backhaul
- **Network Switches** - Communications hubs

Integration Architecture

IFC Model Layer (Static Infrastructure)

IFC models provide the **physical infrastructure** layer:

- **Geometry & Location** - 3D position, coordinates, elevation
- **Asset Inventory** - Equipment type, manufacturer, model
- **Physical Properties** - Mounting height, orientation, coverage area
- **Lifecycle Data** - Installation date, warranty, condition
- **Spatial Relationships** - Alignment-based positioning (station/offset)

ARC-ITS Data Layer (Operational)

ARC-ITS provides the **operational data** layer:

- **Real-Time Status** - Device health, online/offline status
- **Live Data Streams** - Traffic counts, speeds, occupancy
- **Control States** - Signal phases, DMS messages, gate positions
- **Alerts & Events** - Malfunctions, maintenance needs
- **Historical Performance** - Uptime statistics, failure rates

Integration Points

The IFC parser identifies where static BIM data should connect to dynamic ARC-ITS feeds:

IFC Entity	ARC-ITS Data Feed	Integration Method
IFCSENSOR	Traffic detector data (NTCIP 1204)	device_id → NTCIP object identifier
IFCACTUATOR (DMS)	Message content (NTCIP 1203)	device_id → DMS controller ID
IFCSIGNAL	SPaT messages (SAE J2735)	signal_controller_id → Intersection ID

IFCCAMERA	Video stream URL (ONVIF)	stream_url property
IFCROADSIDEUNIT	CV data feeds (IEEE 1609)	rsu_id → SCMS certificate ID
IFCWEATHERSTATION	RWIS data (NTCIP 1204)	station_id → ESS identifier

Enhanced IFC Types for ITS

Proposed IFC Extensions

The IFC parser should recognize these ARC-ITS equipment types:

```
// Traffic Monitoring
IFCCAMERA (subtype: traffic_surveillance)
IFCTRAFFICSENSOR (replaces generic IFCSENSOR)
IFCWEATHERSTATION
IFCTRAVELTIMESENSOR

// Traffic Control
IFCDYNAMICMESSAGESIGN (subtype of IFCACTUATOR)
IFCRAMPMETER
IFCLANECONTROLSIGN
IFCGATEDENTRY

// Connected Vehicle Infrastructure
IFCROADSIDEUNIT (RSU)
IFCCONNECTEDSIGNAL (SPaT-enabled)
IFCBEACON (Bluetooth/DSRC)

// Communications
IFCFIBEROPTICNETWORK
IFCCOMMUNICATIONSCABINET
IFCNWORKSWITCH
```

Required Properties for ARC-ITS Integration

Each IFC entity should include properties that enable connection to ARC-ITS operational data:

Core Integration Properties

```
device_id: Unique identifier in ARC-ITS asset management system
device_type: Equipment classification (per NTCIP/IEEE standards)
manufacturer: Equipment manufacturer
model_number: Specific device model
firmware_version: Current firmware revision
installation_date: When device was installed
commissioning_date: When device went operational
```

Network & Communication Properties

```
ip_address: Network IP address (for NTCIP/SNMP devices)
mac_address: Physical network address
communication_protocol: NTCIP, ONVIF, IEEE 1609, SNMP, etc.
data_feed_url: API endpoint for real-time data
control_interface_url: URL for device control
network_segment: Network zone/VLAN
```

Operational Data Properties

```
current_status: online, offline, maintenance, fault
last_communication: Timestamp of last successful poll
uptime_percentage: Device availability metric
maintenance_schedule: Preventive maintenance interval
critical_spare_parts: Inventory items needed for repairs
calibration_due_date: Next calibration requirement
```

Spatial Reference Properties

```
station: Linear reference station (along alignment)
offset: Lateral offset from alignment centerline
alignment_reference: Link to IfcAlignment entity
viewing_direction: Camera pan/tilt/zoom (PTZ)
coverage_area: Detection/communication range polygon
```

Integration Workflow

1. IFC Model Upload

```
User uploads IFC model → Parser extracts ITS equipment →
Stores in infrastructure_elements table with:
- ifc_guid (unique ID)
- element_type (IFCSENSOR, IFCACTUATOR, etc.)
- geometry (3D position)
- properties (manufacturer, model, etc.)
```

2. ARC-ITS Device Registration

```
For each IFC element:
  IF device_id property exists:
    Link to existing ARC-ITS asset record
  ELSE:
    Prompt user to map to ARC-ITS device
    OR auto-discover via spatial proximity matching
```

3. Real-Time Data Integration

```
For each registered device:
  Poll ARC-ITS data feed (NTCIP/API/SNMP)
```

Update operational status in database
Trigger alerts if status changes
Display live data overlaid on 3D model

4. Bidirectional Updates

IFC Model Changes → Update ARC-ITS asset database
ARC-ITS Deployments → Update IFC model with new equipment
Field Installations → Synchronize both systems

ARC-ITS Standards Support

NTCIP (National Transportation Communications for ITS Protocol)

NTCIP 1203 - Dynamic Message Signs

- Message content and scheduling
- Display configuration
- Font and character support

NTCIP 1204 - Environmental Sensor Stations

- Weather data (temp, precip, visibility)
- Surface conditions (wet, icy, snow)
- Atmospheric conditions (wind, pressure)

NTCIP 1209 - CCTV Camera Control

- PTZ (pan/tilt/zoom) positioning
- Preset positions
- Video stream management

NTCIP 1211 - Signal Control & Prioritization

- Phase timing data
- Signal preemption/priority
- Coordination patterns

SAE Standards

SAE J2735 - Dedicated Short Range Communications (DSRC) Message Set

- SPaT (Signal Phase and Timing)
- MAP (Intersection geometry)
- TIM (Traveler Information Messages)
- BSM (Basic Safety Messages)

SAE J3216 - V2X Cooperative Perception

- Sensor sharing
- Object detection
- Infrastructure sensor data

IEEE Standards

IEEE 1512 - Traffic Incident Management

- Incident detection
- Response coordination
- Lane closure reporting

IEEE 1609 - WAVE (Wireless Access in Vehicular Environments)

- RSU communication protocols
- Security credentials management (SCMS)
- V2I messaging

Example: Traffic Signal Integration

IFC Model Data

```
#12345 = IFCSIGNAL('2v8K...')

Properties:
  - signal_controller_id: "INT-001-MAIN-001"
  - intersection_name: "I-80 & US-6"
  - station: "125+45.2"
  - offset: "-12.5 ft"
  - signal_type: "vehicular"
  - num_phases: 8
  - coordination_enabled: true
```

ARC-ITS Operational Data (NTCIP 1211)

```
GET /api/signals/INT-001-MAIN-001

{
  "controller_id": "INT-001-MAIN-001",
  "current_phase": 2,
  "time_to_change": 15,
  "coordination_pattern": "PM_PEAK",
  "preemption_active": false,
  "detector_faults": [],
  "last_update": "2025-01-15T14:32:15Z",
  "spat_broadcast_enabled": true
}
```

Integrated View

Digital Infrastructure Dashboard displays:

- 3D model showing signal location from IFC
- Live phase & timing from ARC-ITS NTCIP feed
- SPaT data availability for CV applications
- Detector status and health alerts
- Station/offset for maintenance crew dispatch

Benefits of Integration

For Traffic Operations Centers

- **Visual Asset Inventory** - 3D visualization of all ITS equipment
- **Spatial Queries** - "Show all cameras within 1 mile of incident"
- **Maintenance Planning** - Equipment age, condition, replacement schedules
- **Incident Response** - Quick identification of nearby devices

For Field Maintenance

- **Device Location** - Precise coordinates and station/offset
- **Installation Details** - Mounting specs, power requirements
- **Spare Parts** - Manufacturer, model, compatibility
- **Work History** - Maintenance logs, calibration records

For Connected Vehicles (V2X)

- **RSU Coverage Maps** - DSRC/C-V2X communication zones
- **SPaT-Enabled Intersections** - Signal timing data availability
- **Infrastructure Sensor Data** - Weather, traffic, hazards
- **Digital Twin** - Real-time infrastructure state for AV planning

For Digital Twin Applications

- **Real-Time State** - Live operational status overlaid on 3D model
- **Predictive Maintenance** - ML models using operational + physical data
- **What-If Scenarios** - Simulate equipment failures, upgrades
- **Historical Playback** - Replay traffic incidents with infrastructure context

Implementation in DOT Corridor Communicator

Database Schema Enhancement

```
-- Add ARC-ITS integration fields to infrastructure_elements table
ALTER TABLE infrastructure_elements ADD COLUMN device_id TEXT;
ALTER TABLE infrastructure_elements ADD COLUMN communication_protocol TEXT;
ALTER TABLE infrastructure_elements ADD COLUMN data_feed_url TEXT;
ALTER TABLE infrastructure_elements ADD COLUMN ip_address TEXT;
ALTER TABLE infrastructure_elements ADD COLUMN current_status TEXT;
ALTER TABLE infrastructure_elements ADD COLUMN last_communication TIMESTAMP;
```

IFC Parser Enhancements

The parser should extract these properties from IFC property sets:

- Pset_DeviceIdentification → device_id, manufacturer, model
- Pset_NetworkConnection → ip_address, protocol, data_feed_url
- Pset_OperationalStatus → current_status, uptime
- Pset_MaintenanceSchedule → next_service_date, calibration_due

API Endpoints

```
GET /api/infrastructure/devices
  - List all ITS equipment from IFC models
  - Include live operational status from ARC-ITS
```

```
GET /api/infrastructure/device/:guid/status
  - Real-time status for specific device
  - Poll ARC-ITS data feed on-demand

GET /api/infrastructure/spatial-query?corridor=I-80&station=125+00&radius=1mi
  - Find devices near specific location
  - Return IFC geometry + ARC-ITS operational data

POST /api/infrastructure/device/:guid/link-arc-its
  - Associate IFC element with ARC-ITS device ID
  - Enable bidirectional data sync
```

Standards Compliance Checklist

IFC Model Requirements

- Include IfcSite with geolocation (lat/long or map conversion)
- Use IfcAlignment for linear infrastructure positioning
- Include device_id property for each ITS element
- Specify communication_protocol property (NTCIP, SNMP, etc.)
- Include data_feed_url for real-time data access
- Provide manufacturer and model_number for asset management

ARC-ITS Integration Requirements

- Device IDs match between IFC and ARC-ITS systems
- NTCIP Object Identifiers correctly mapped
- Network addressing (IP/MAC) documented
- Communication protocols specified
- Data feed endpoints accessible
- Security credentials configured (SNMP communities, API keys)

Operational Requirements

- Real-time status polling configured
- Alert thresholds defined for device failures
- Maintenance schedules synchronized
- Spatial queries enabled (station/offset, radius searches)
- Historical data retention policy established
- Performance metrics tracked (uptime, data quality)

Future Enhancements

Machine Learning Integration

- Predict device failures based on operational patterns
- Optimize maintenance schedules using IFC lifecycle data + ARC-ITS performance
- Anomaly detection for unusual device behavior

Advanced Visualization

- Real-time 3D dashboard with live ARC-ITS data overlays
- Heatmaps showing device health across corridors
- Time-series playback of historical incidents

Automated Workflows

- Auto-generate work orders when devices go offline
- Synchronize IFC model updates with ARC-ITS deployments
- Alert nearby maintenance crews using geofencing

Document Version: 1.0 **Last Updated:** 2025-01-15 **Related Documentation:**

- `/docs/data-quality.md` - Event data quality standards
- IFC Parser: `/utils/ifc-parser.js`
- Database Schema: `infrastructure_elements` table

Standards References:

- NTCIP Library: <https://www.ntcip.org/library/>
- SAE Mobility: https://www.sae.org/standards/content/j2735_202309/
- buildingSMART IFC4x3: https://standards.buildingsmart.org/IFC/RELEASE/IFC4_3/