



## 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
IFCNETWORKSWITCH
```

## 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 = IFC SIGNAL('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

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**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/](https://www.sae.org/standards/content/j2735_202309/)
- buildingSMART IFC4x3: [https://standards.buildingsmart.org/IFC/RELEASE/IFC4\\_3/](https://standards.buildingsmart.org/IFC/RELEASE/IFC4_3/)