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Developing 2D and 3D Applications for Real-Time Visualization and Analysis

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Outline

- Introduction
  - ESRI Technologies for Real-time Data
  - Real-time Data Sources & Applications
- Implementing Real-time Application
- Publishing Real-time Data
  - Tracking Server & DataLink
- Visualizing Real-time Data
  - ArcGIS 9.3 Tracking Analyst
- Custom Solution
- Summary
- Demos
- Discussions

Introduction

- Real-time data
  - Frequent changes in location or attributes
  - Various transmission techniques and protocols
- Challenges
  - Efficient representation and rendering
  - In-memory database handling
  - Real-time search, query, analysis
  - Prediction models, dead reckoning algorithms
  - Maintaining historical data
  - Communication protocols
  - etc

ESRI Technologies for Real-time Data

- Input and Data Distribution
  - Tracking Server
- Data representation & Analysis
  - Tracking Analyst
- Dynamic Representation
  - Dynamic Map Display
  - Globe Display

ArcGIS Extensions

- Tracking Analyst
  - Display and analysis
  - 1D as graph
  - 2D Map, Dynamic Map
  - 3D Globe
- GIS-to-SIM
  - Developed by MAK Technologies
  - Distributed real-time simulation on GIS data
  - Real-time data communicated using DIS, HLA, TENA
  - 2D Map, Dynamic Map
  - 3D Globe

Real-time Data Sources

- Web Services
  - Already collected from many devices
  - Already decoded from raw signals
  - Less real-time
  - Pull mode
- Direct from Devices
  - Need to deal with multiple devices
  - May need to be parsed/decoded
  - More real-time
  - Pushed mode
- Results from Simulation
  - Computer generated forces

Real-time Data Sources (Examples 1)

- FAA ASDI (Aircraft Situation Display to Industry)
  - Web streaming
  - Up to 10,000 aircraft tracked
- ADS-B (Automatic Dependent Surveillance - Broadcast) – for aircrafts
  - FM radio wide-band transmission @1090 MHz
  - No encryption
- AIS (Automatic Identification System) – for vessels
  - IEC 62320-1 world-wide standard (since 2007)
  - > 40,000 ships international
  - VHF maritime channels 87B (161.975 MHz) and 88B (162.025 MHz)
  - 6-bit ASCII encoded

Real-time Data Sources (Examples 2)

- APRS (Automatic Position/Packet Reporting System)
  - Amateur radio based system for digital communication
  - For position of person, object, weather
- AVL (Automatic Vehicle Location System)
  - King County, Seattle
  - Bus tracking
  - On board radio & computer
  - Distributed signpost location transmission
  - Data published via SOAP service

Real-time Data Sources (Examples 3)

- Direct from the devices
  - GPS receiver
    - NMEA sentence

      (National Marine Electronics Association)
    - USB or Bluetooth connection
  - AirNav RadarBox (AirNav Systems)
    - For ADS-B
    - Output XML format
    - Network of devices to share data
    - Range of 250 Miles
    - USB connection
  - NASA AIS Engine

Transponders

Comar Systems Ltd CSB200

SevenStar Electronics Ltd SeaTracer™

Specification of Comar CSB200

Electrical

Power supply : 12 Volts DC
Power consumption : 0.5A continuous
Power consumption : 6W average

Physical

Dimensions: L:165mm, W:120mm, H:50mm
Weight: 600g
Mounting: Trunnion bracket

Connectors

Output/Input port: 9 pin D socket
Power: 2 pole plug
VHF Antenna connector: BNC
GPS Antenna connector: TNC

Receiver

Frequency: 156.025-162.025 MHz
Channel Steps: 25KHz
Receivers: 2, one shared AIS/DSC
Sensitivity: -107dBM
Message Error Rate: 20%
Adjacent Channel: 70dB
IMD: 65dB
Blocking: 84dB
Demodulation: GMSK/FSK
Data Rate: 9600
Antenna Impedance: 50 ohms

Transmitter

Output power: 1W - 4W
Modulation: GMSK

I/O Interface

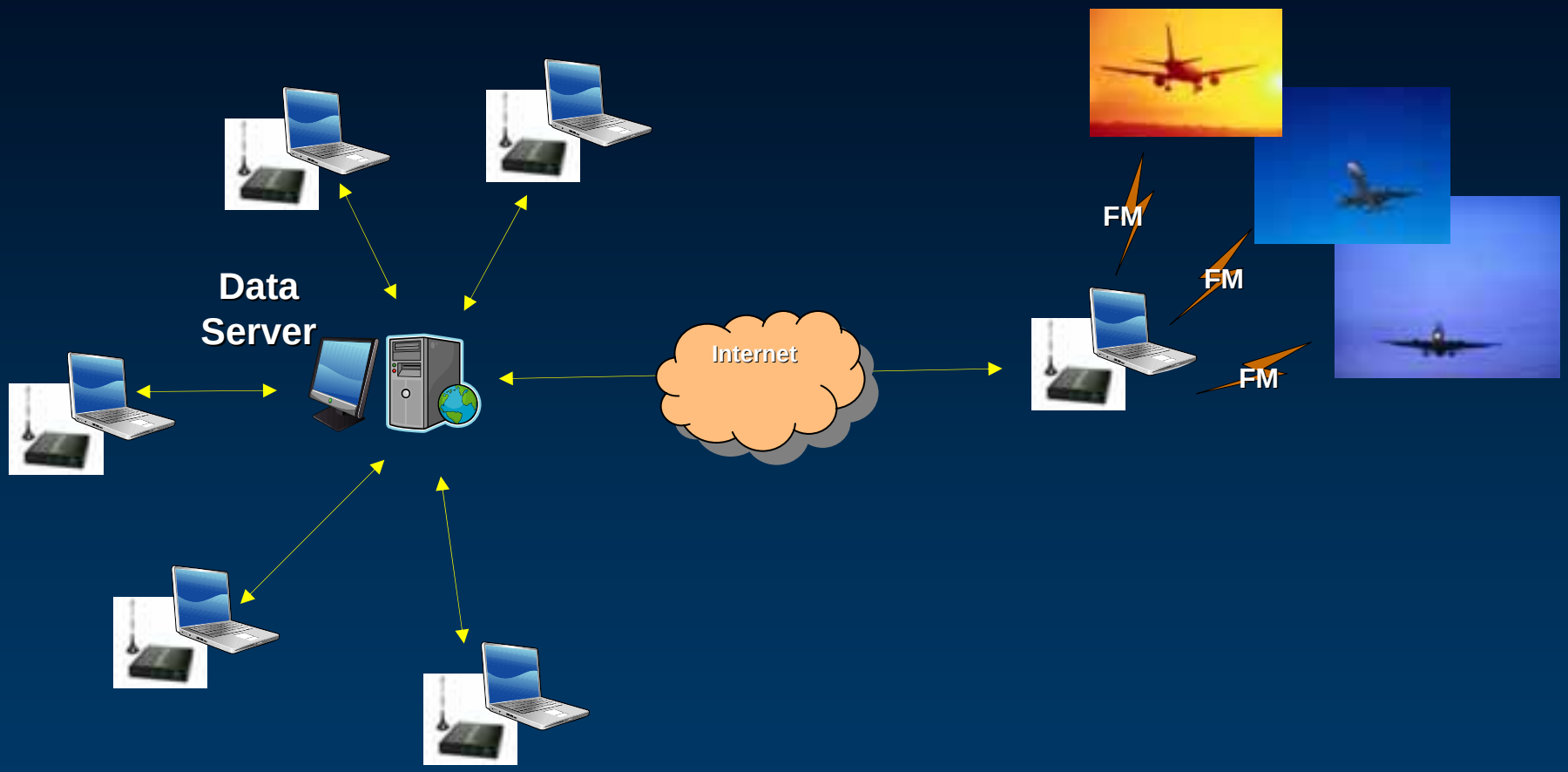
RS232: 115.2K/38.4K
RS422/NMEA Bi-directional

Compliant with

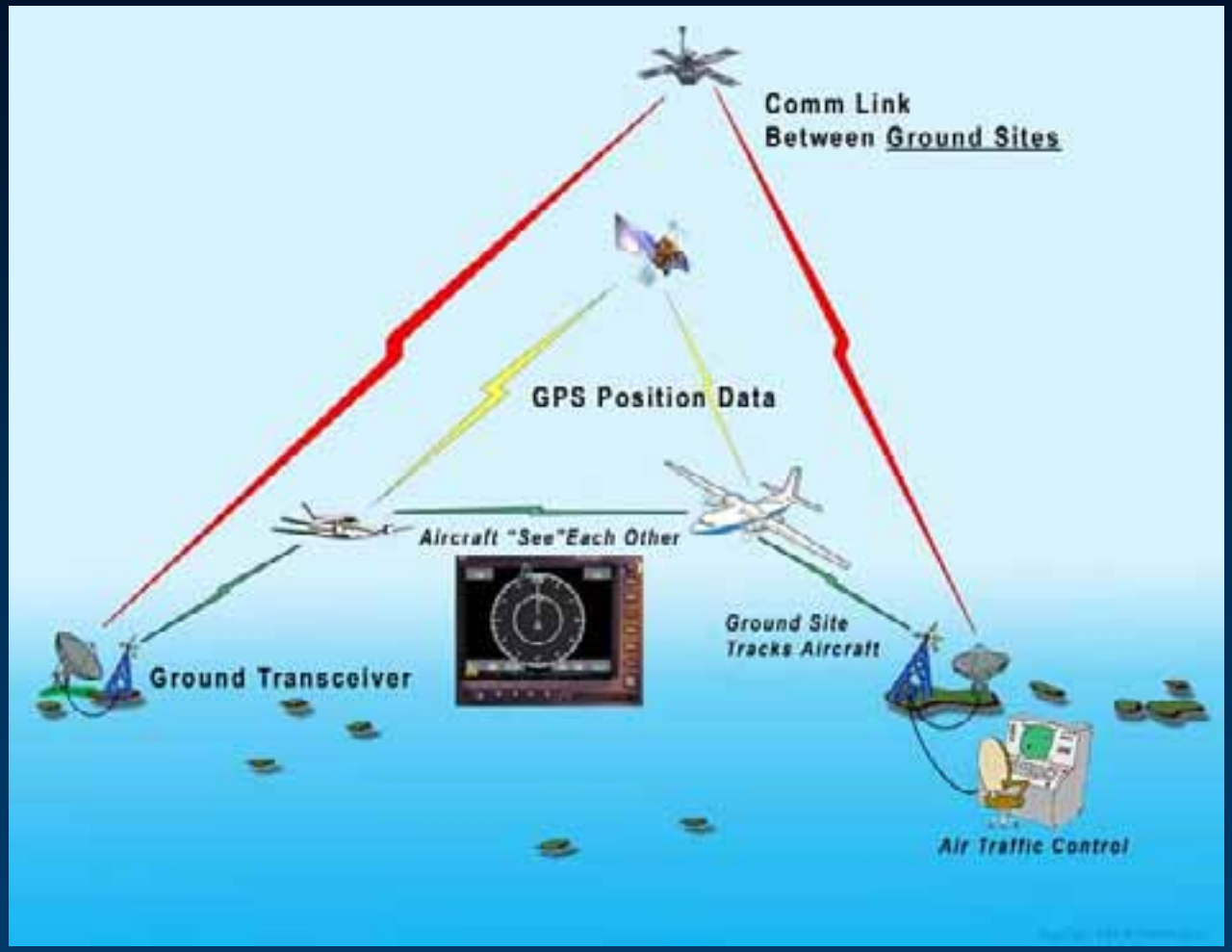
IEC62287 draft Class B
ITU-RM.1371-1
IEC61162-100
EN-60945

Sources: Dr Andy Norris 2006

Sensor Network

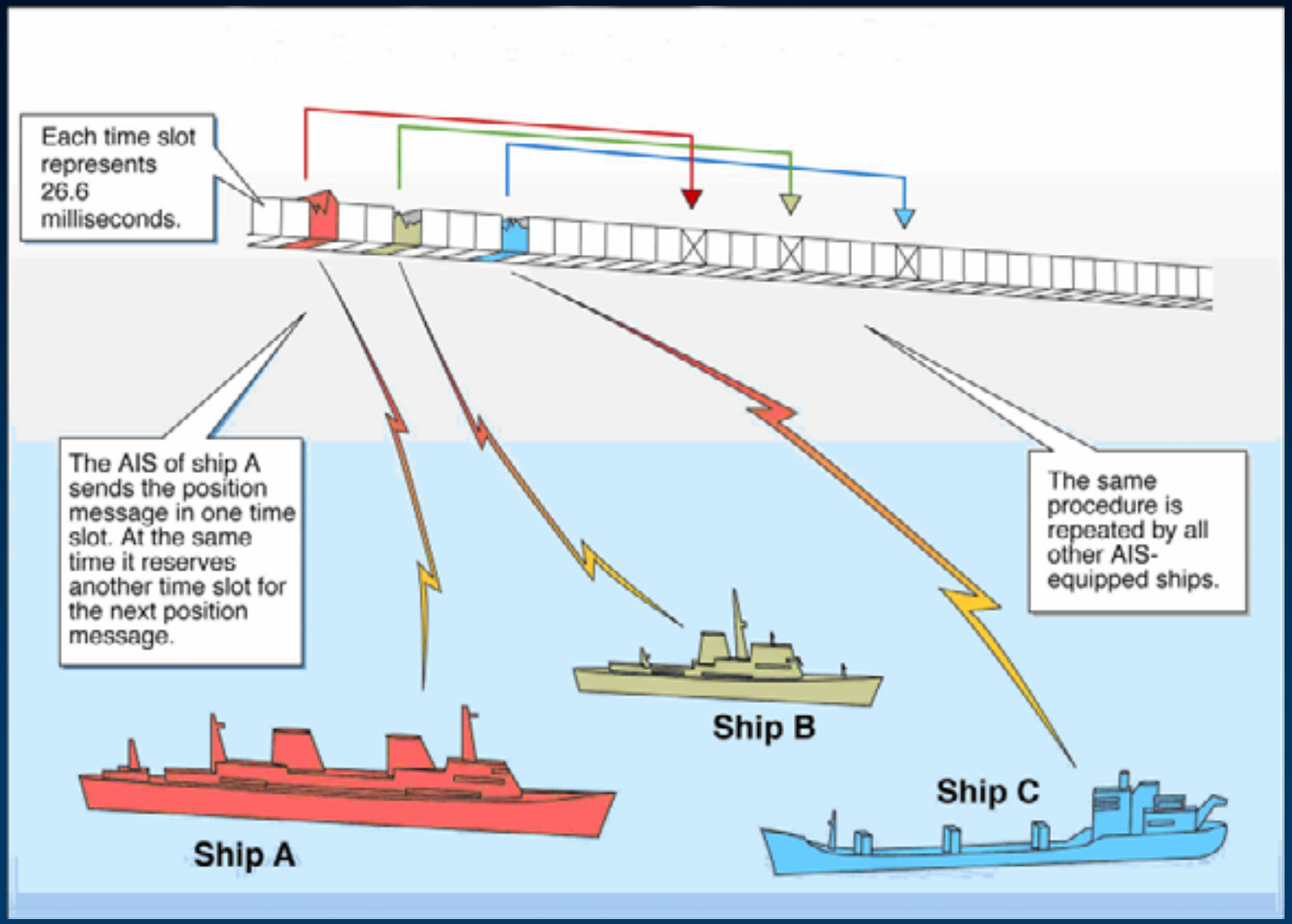


ADS-B



Source: http://www.ads-b.com

AIS


Each time slot represents 26.6 milliseconds.
The AIS of ship A sends the position message in one time slot. At the same time it reserves another time slot for the next position message.
The same procedure is repeated by all other AIS-equipped ships.
Ship A
Ship B
Ship C

Sample Data (1)

- GPS-NMEA sentences

```
$GPGGA,130441.89,5239.3154,N,00907.7011,E,1,08,1.25,16.76,M,46.79,M,,*6D
$GPGLL,5239.3154,N,00907.7011,E,130441.89,A,A*6C
$GPGGA,130451.79,5239.3342,N,00907.5049,E,1,08,1.25,27.07,M,46.79,M,,*6D
$GPGLL,5239.3342,N,00907.5049,E,130451.79,A,A*68
$GPGGA,130501.79,5239.3529,N,00907.3115,E,1,07,1.25,33.09,M,46.79,M,,*68
$GPGLL,5239.3529,N,00907.3115,E,130501.79,A,A*69
$GPGGA,130511.79,5239.3743,N,00907.0929,E,1,08,1.25,38.92,M,46.79,M,,*65
$GPGLL,5239.3744,N,00907.0653,E,130512.79,A,A*64
```

Sample Data (2)

- **AIS Data**

Raw:

!AIVDM,1,1,,A,13u?etPv2;0n:dDPwUM1U1Cb069D,0*24

Decoded:

MMSI : 265547250 (ship Identification)

Latitude : 57.660353°

Longitude : 11.832977°

Speed : 13.9 knots

Heading : 41°

Course over ground : 40°

Rate of turn : -2° /min

Navigational status: 0

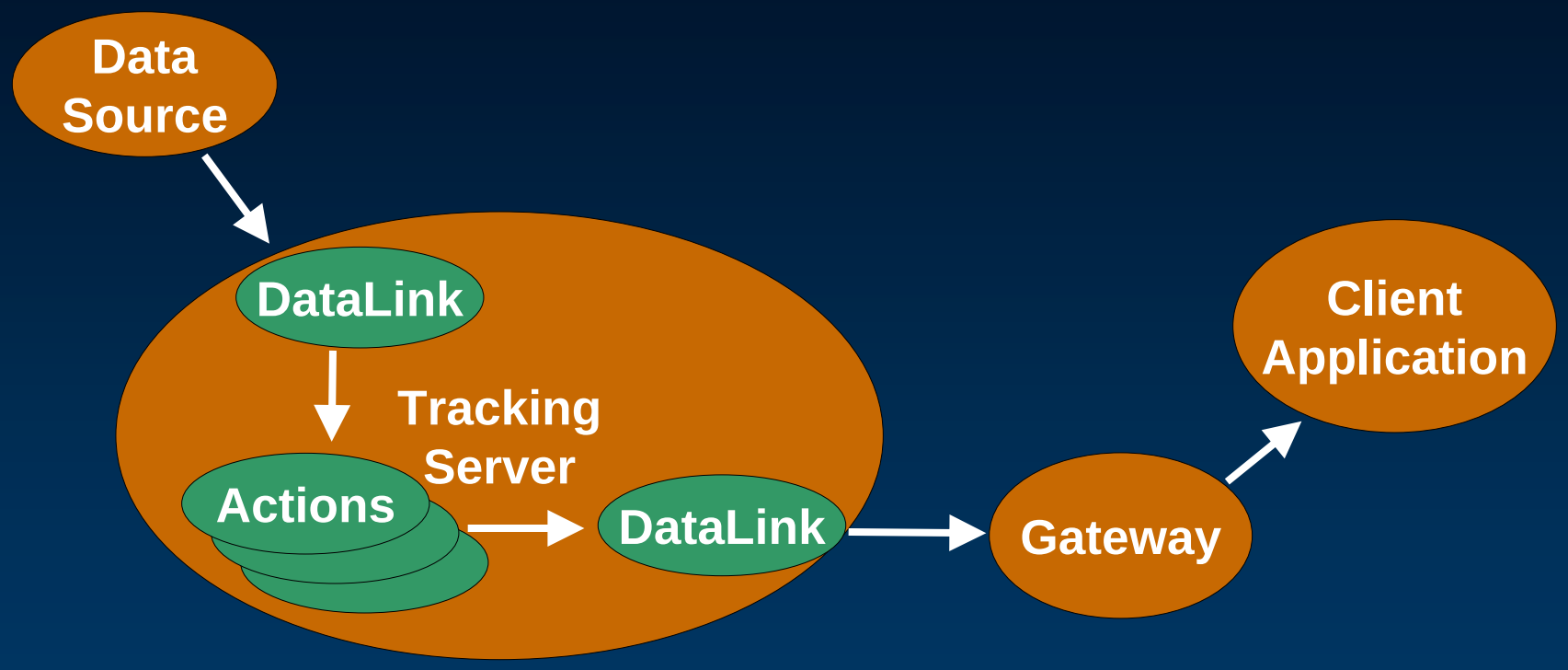
Applications of Real-time Data

- Collision avoidance
- Traffic services
- Aids to navigation
- Search and rescue
- Surveillance
- Stolen vehicle recovery
- Fleet management
- Passenger information
- Asset tracking
- Passage management

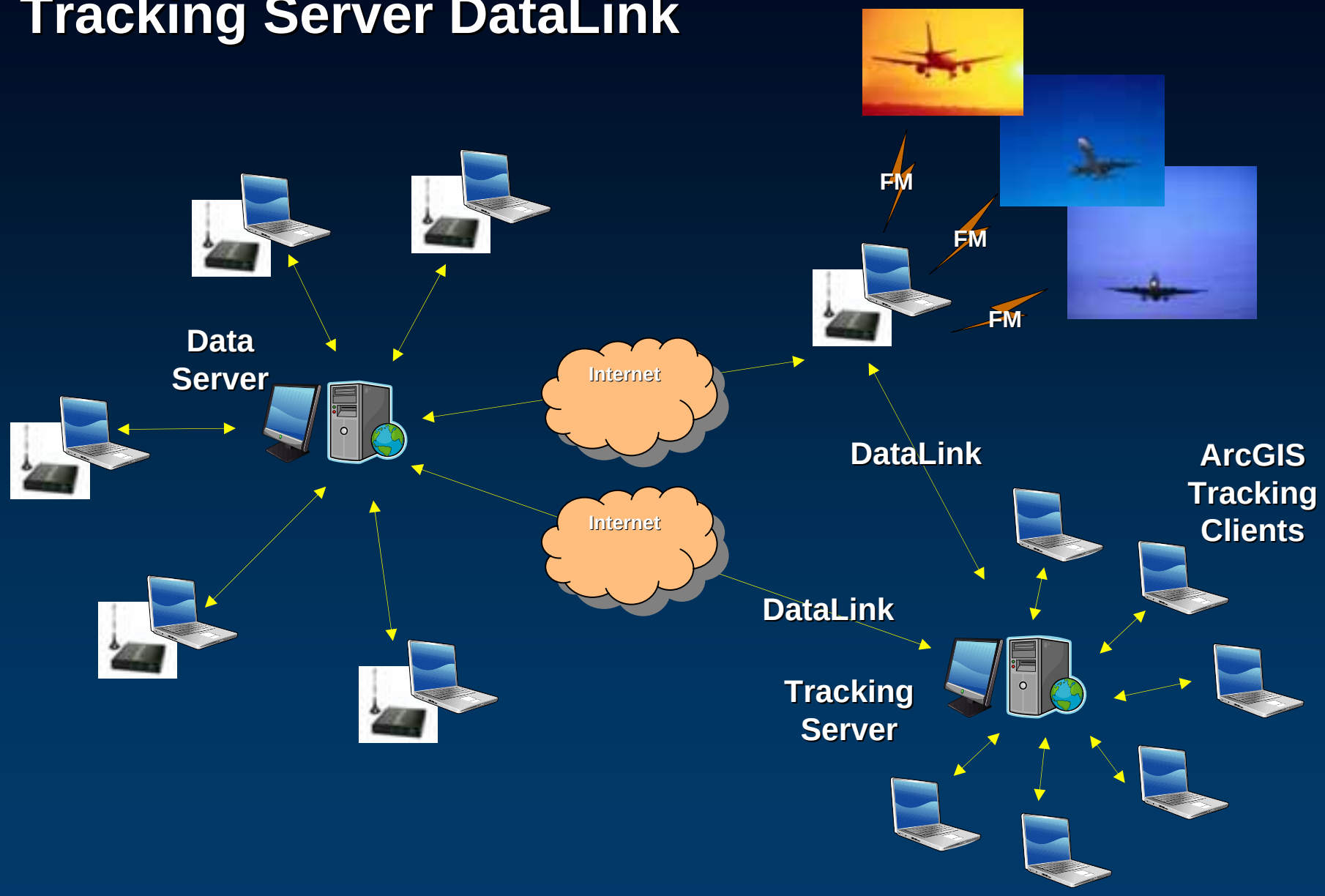
Implementing Real-time Application

- Setting up a real-time service to collect the data
- Distribute the data (including real-time processing in the server)
- Visualizing the data in a client application
  - Searching & query
  - Prediction/dead reckoning
  - Rendering analysis results

Tracking Server



Tracking Server DataLink

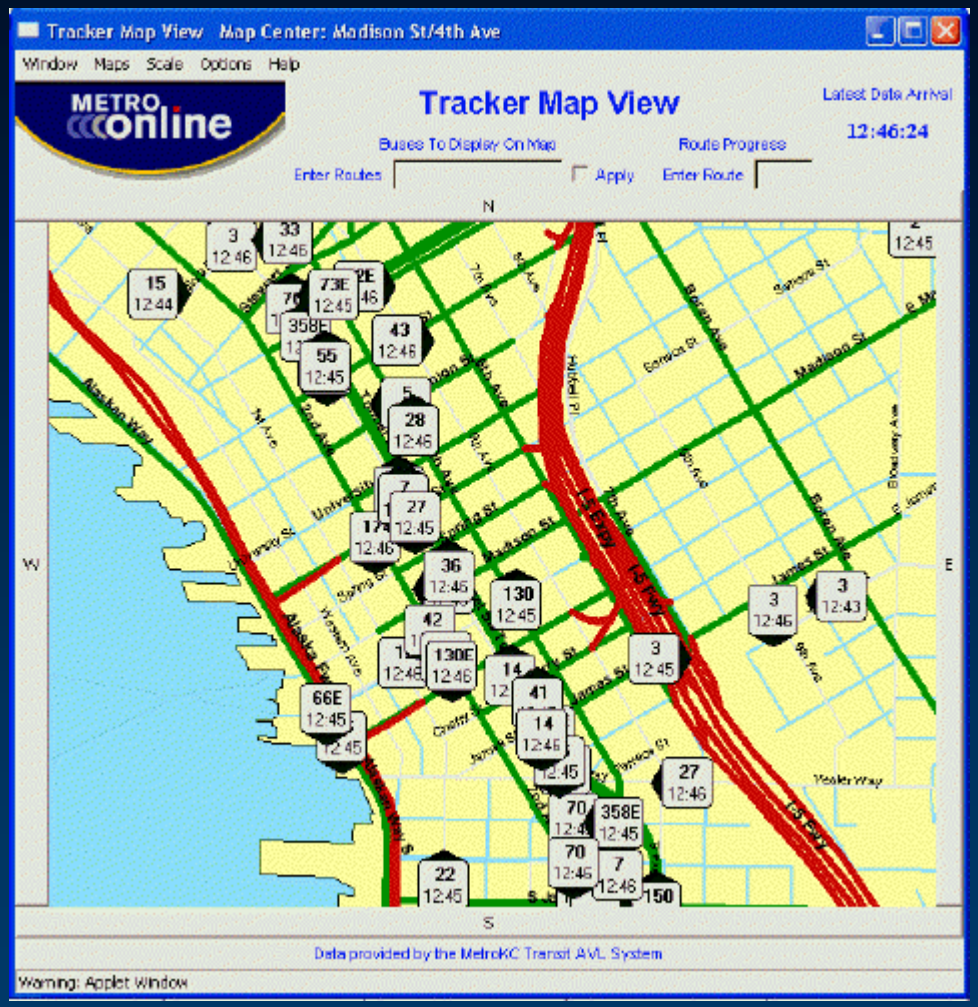


Implementing DataLink

- Generic XML Datalink
- C++ ATL Template
- Experimental .NET Template (Unsupported at this time)

DataLink Case Study (Seattle Bus Tracking)

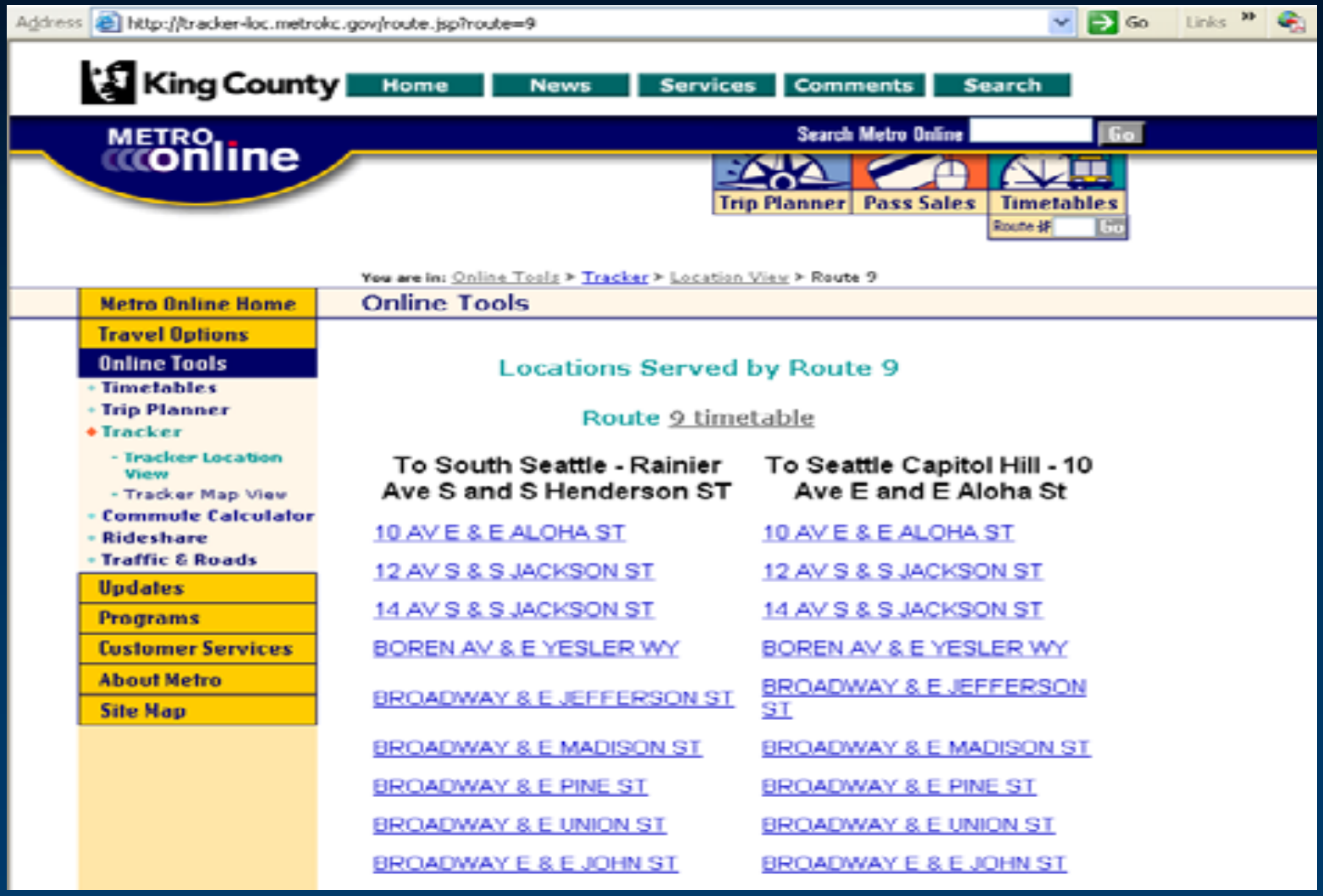
- Hundreds of routes
- Many buses per route



http://tracker-map.metrokc.gov/tracker-map-sysreq.html

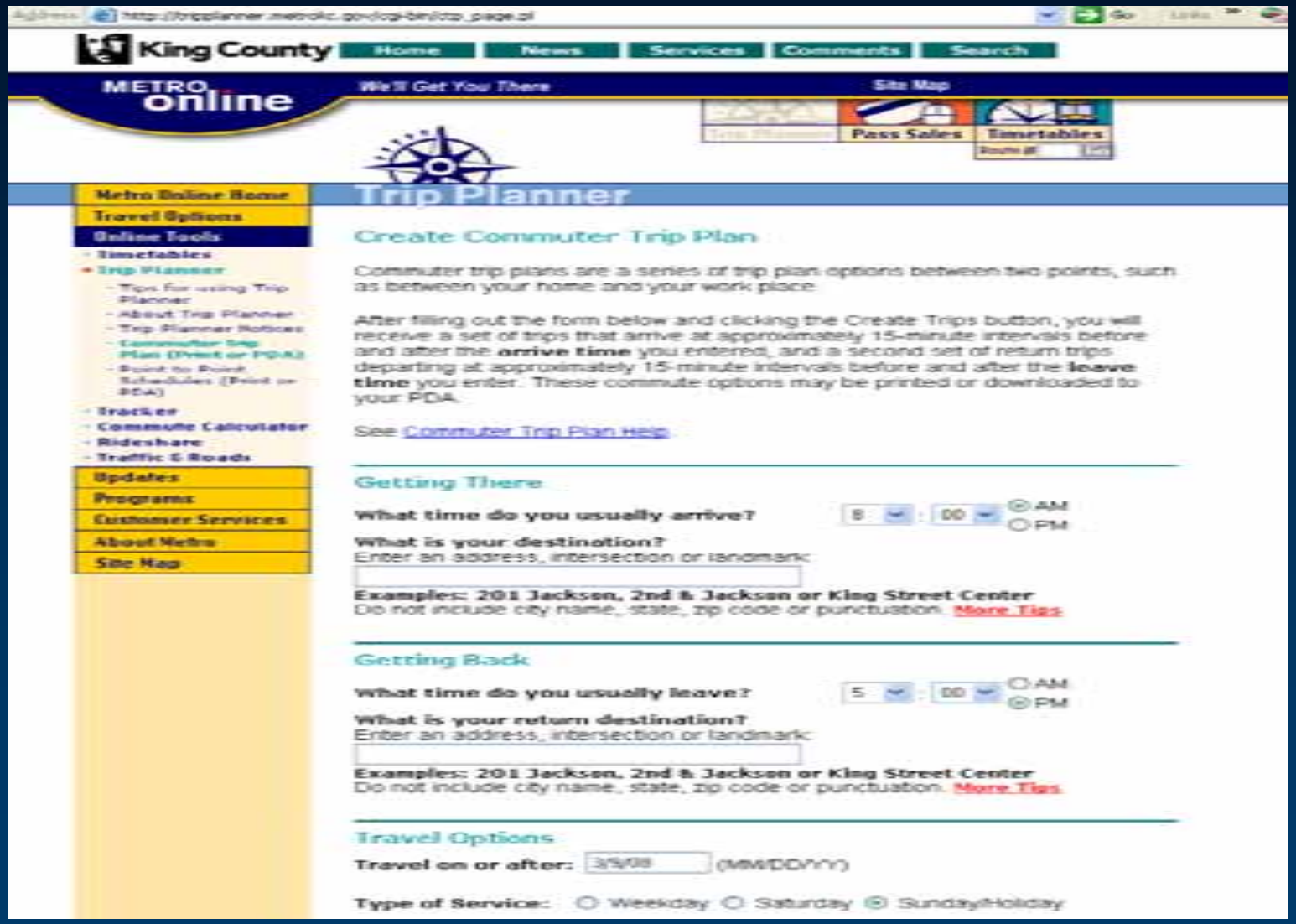
Route Query

http://tracker-loc.metrokc.gov/route.jsp?route=9



Trip Planner

http://tripplanner.metrokc.gov/cgi-bin/ctp_page.pl



Bus Tracking DataLink

- Web Service Definition Language (WSDL)

http://ws.its.washington.edu:9090/transit/avl/services/AvlService?WSDL

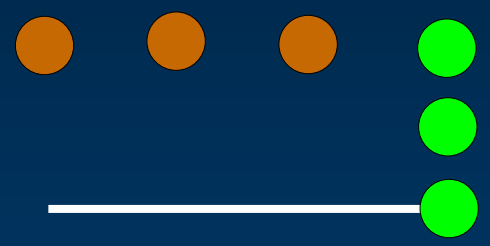
- Uses as Web Reference in .NET programming
- Becomes simple function calls via SOAP (Simple Object Access Protocol)

Visualizing Real-time Data

- 2D Map
- 2D Dynamic Map
- 3D Globe
  - ArcGlobe
  - ArcGIS Explorer

ArcGIS 9.3 Tracking Analyst

- Layer
  - Real-time data stored in-memory for speed
  - Limited historical
  - Purge rule to conserve memory
- Renderer
  - All occurrences
  - Most recent occurrences
  - Track lines
  - Time Graph (1D + Time)



- Analysis
  - Temporal offset
  - Overlay
  - Table join

Custom Solution

- Reasons:
  - Performing simulation, prediction, dead reckoning
  - Performing real-time analysis
    - Proximity test
    - Containment test

Implementing Custom Solution

- Connecting to Tracking Service
  - ArcObjects-based
  - Connector Toolkit (non-ArcObjects)
    - Connector Toolkit in ArcGIS Explorer
- Implementing custom layer
- Motion simulation/dead reckoning
- Rendering text and heads up display
- Using animation for smooth navigation
- Providing object list for quick search
- Implementing real-time analysis

SDK Samples

- Many SDK samples and articles
- SDK Samples
  - DynamicObjectTracking
  - DynamicDisplayHUD
  - DynamicDisplayCompass
  - GlobeDynamicObjectTracking
  - RSSWeatherLayer3D
  - GlobeDigitizing
  - ArcGIS Explorer OpenGL sample
- Articles
  - Implementing Custom Globe Layers with Dynamic Feed
  - ms-help://ESRI.EDNv9.2/NET_Engine/b0e91ce8-c180-47dc-8323-06cac5d77064.htm

Connecting to Tracking Service (1)

- ArcGIS Engine
- Required licenses:
  - ArcGIS Engine SDK
  - Tracking Analyst Extension
  - ArcGIS Engine Run-time for deployment
- Assemblies needed
  - ESRI.ArcGIS.TrackingAnalyst;

Connecting to Tracking Service (2)

- Using IInternetServerConnection to connect to Tracking Service
- Requesting for a specific service
  - Gets TrackingServiceDef
  - Gets DatasetDef
  - Enables DatasetDef

Tracking Server Connector Toolkit

- Distributed with TS installation
- Only two jar files (tsconnector.jar, tscore.jar)
- Doesn’t need license on the client-side
- Can be brought into .NET assemblies via IKVM Java Interop
  - tsconnector.dll, tscore.dll
  - Needs IKVM.Runtime.dll, IKVM.GNU.Classpath.dll
- Use IKVM for .NET-Java interop
  - Open Source (http://www.ikvm.net)
  - Calling Java API from .NET code

Connector Toolkit .NET Assemblies

- Tested IKVM version 0.34.0.2
- Command line for generating .NET Assemblies:
  - IKVMC.EXE –target:library tsconnector.jar
  - IKVMC.EXE –target:library tscore.jar
- .NET C# usage:
  - Add reference tsconnector, tscore
  - using com.esri.tracking;
  - using com.esri.tracking.msg;

Using Connector Toolkit in ArcGIS Explorer

- Connecting to real-time feed from Tracking Server
- No dependency on ArcGIS Engine
- No license needed
- Custom rendering using OpenGL
  - View3D.DrawOpenGLBegin()
  - View3D.DrawOpenGLFinish()

Implementing Custom Layer

- Dynamic Layer – IDynamicLayer (3 methods)
  - DrawDynamicLayer()
- Custom Globe Layer – ICustomGlobeLayer (9 – methods)
  - DrawImmediate()
  - DrawType() – esriGlobeCustomDrawOpenGL
  - UseCache() – false
  - Hit() – to support identify, zoom to
- ESRI.ArcGIS.ADF.BaseClasses provides:
  - BaseCustomGlobeLayer – 3D
  - BaseDynamicLayer – 2D
  - Override just a few methods (mostly DrawXXXXX())

Rendering Strategies

- Rendering at 30 frames per second (fps) is challenging
- Use simple symbol where possible
  - Use bitmap, textured billboard
  - Avoid symbol with complex geometry (low polygon count)
  - Replace detailed geometry by image texture where possible
- Use multiple representations (Level of Details):
  - Use simplified symbol for object far away from the viewer
- Set up separate timers and threads for:
  - Updating in-memory database
  - Scene/Map rendering

Motion Simulation/Dead Reckoning

- Using existing data to predict:
  - Position
  - Direction
  - Orientation
  - Velocity
  - Other states

Motion Simulation Models

- Specific to object type:
  - Aircraft (commercial aircraft, fighter jet, helicopter)
  - Vessel (tanker, frigate, submarine)
  - Satellite (orbital parameters)
  - Car (in traffic, not in traffic)
  - Bus (frequent stop and go)
- Motion constrains:
  - Ground-based – attached to terrain
  - Airborne - floating above ground
  - Spaceborne – follows orbit
  - Surface-based – floating above water surface
  - Undersurface – moving between sea bed and sea surface
- Other factors (wind speed, soil type, water current)

Motion Simulation Strategy

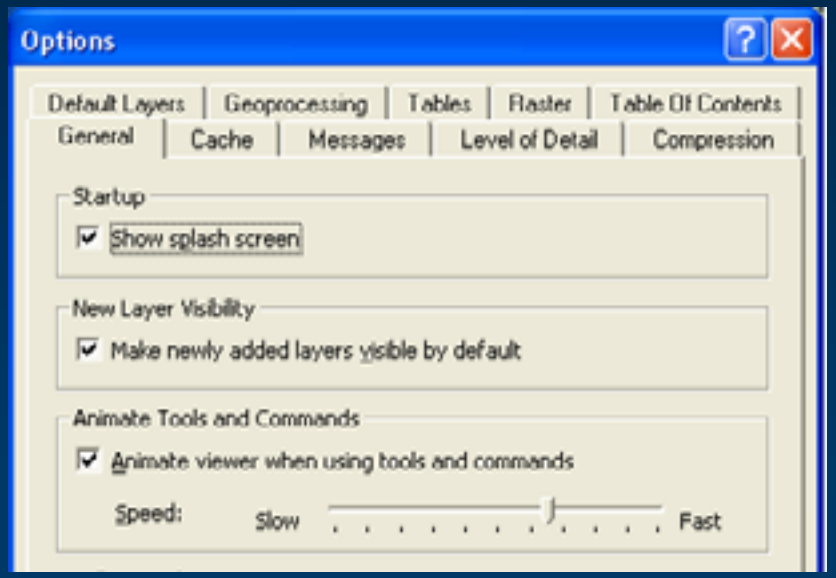
- Implement linear prediction where applicable
- Avoid accessing terrain database in real-time
- Use cache when possible
  - Globe terrain cache
- Use integrated data type, e.g. TIN
  - Optimized for fast search, data traversing, containment test
  - Allows embedding additional information (e.g. building footprints, soil-types, ground covers)

Rendering Text and Heads up Display

- Shows textual information with real-time update
- Labels object
- Choices of Outline, Bitmap, or Textured fonts
  - Outline fonts offers 3D effects, rotate, scale
  - Bitmap fonts for quick implementation, 2D, no rotation/scaling
  - Textured fonts for 2D, rotate, scale
- Can be pure OpenGL

Using Animation for Smooth Navigation

- Smooth transition from one location to another location
- More user-friendly
- Needs ArcGIS Engine
- Uses IGlobeCamera.SetToZoomToExtents() for quick implementation
  - Must turn on the Animation



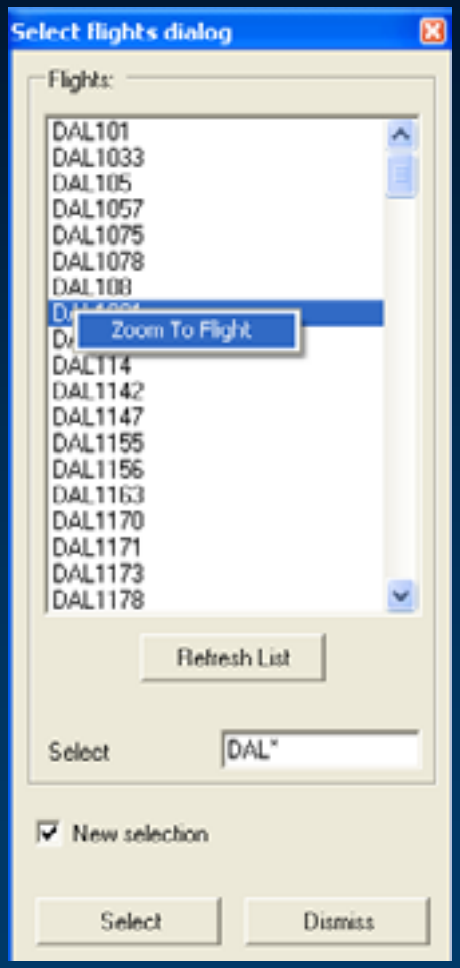
Generating and Using KeyFrames

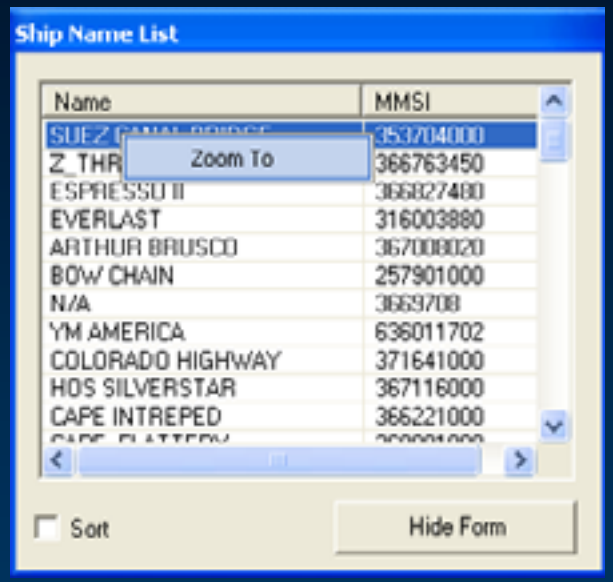
- Plan the camera position for each keyframe
- Generating keyframes
  - IAnimationTrack.InsertKeyFrame()
  - IKeyFrame.set_PropertyValueX()
- Playback animation
  - Attached camera to animation track
    - animationTrack.AttachObject(sceneViewer.Camera as IGlobeCamera)
  - Looping for the desired duration and call IAnimationTrack.InterpolateObjectProperties()

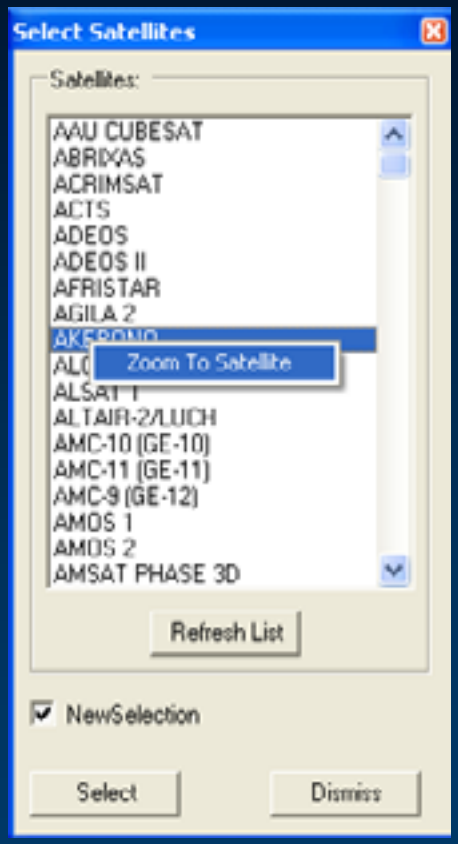
Providing Object List for Quick Search

- Facilitates text-based search and query
- List should be populated/updated when the record arrived
- List may be updated using event-based handlers
  - Fire_Object_Added
  - Fire_Object_Updated
  - Fire_Object_Removed
- Avoid interrupting the rendering cycle
- Using multithread to improve performance

Object List Examples





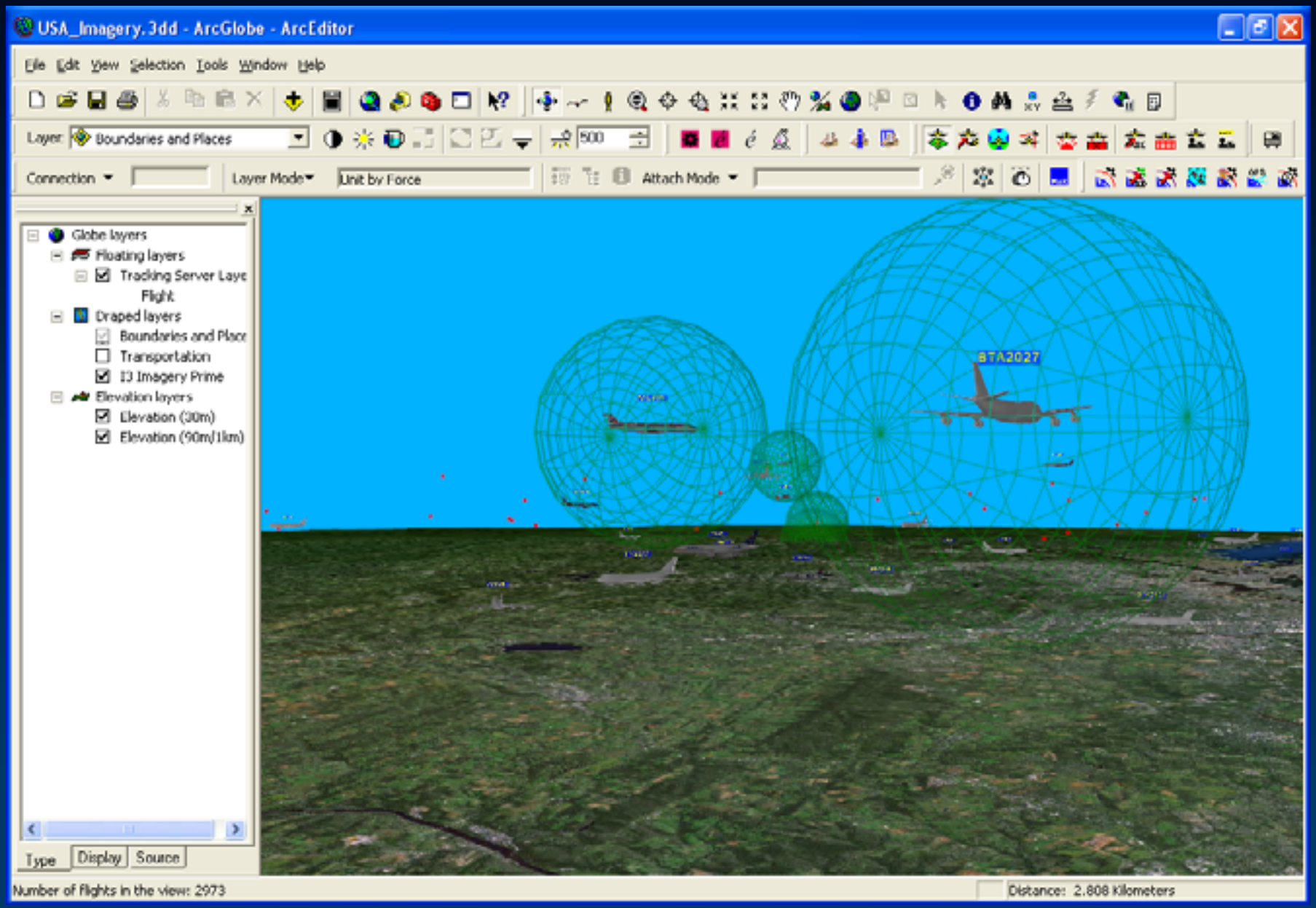


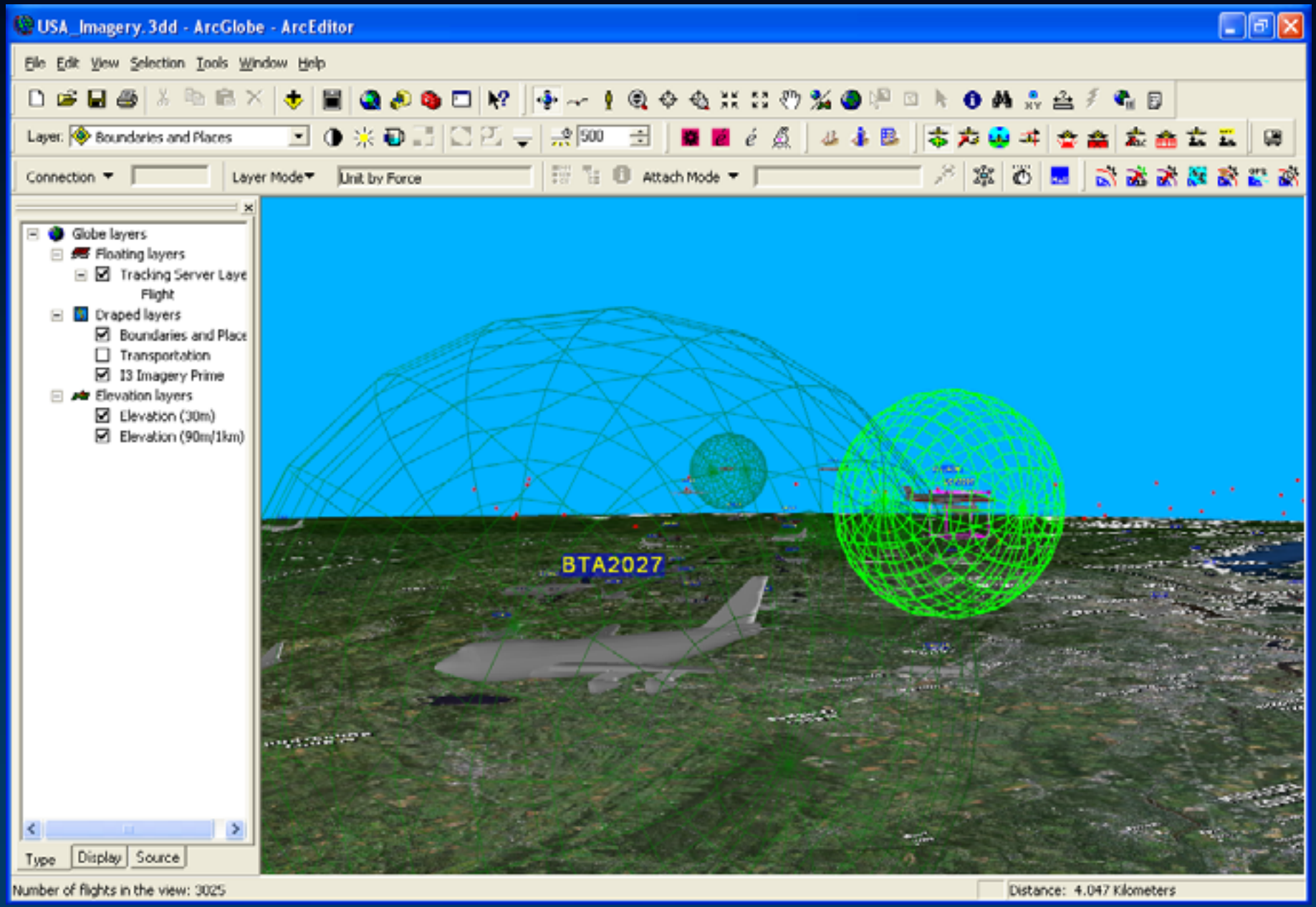
Implementing Real-time Analysis

- Analyzing while moving
- Needs efficient data structure and algorithm to traverse real-time object collection
- Proximity test
- Containment test

Proximity Test

- Distance between object and a specified location
- Distance between objects
- Can be used for collision detection


USA_Imagery.3dd - ArcGlobe - ArcEditor
File Edit View Selection Tools Window Help
Layer: Boundaries and Places
500
Connection
Layer Mode
Unit by Force
Attach Mode
Globe layers
Floating layers
Tracking Server Laye
Flight
Draped layers
Boundaries and Place
Transportation
II Imagery Prime
Elevation layers
Elevation (30m)
Elevation (90m/1km)
BTA2027
Type
Display
Source
Number of flights in the view: 2973
Distance: 2.808 Kilometers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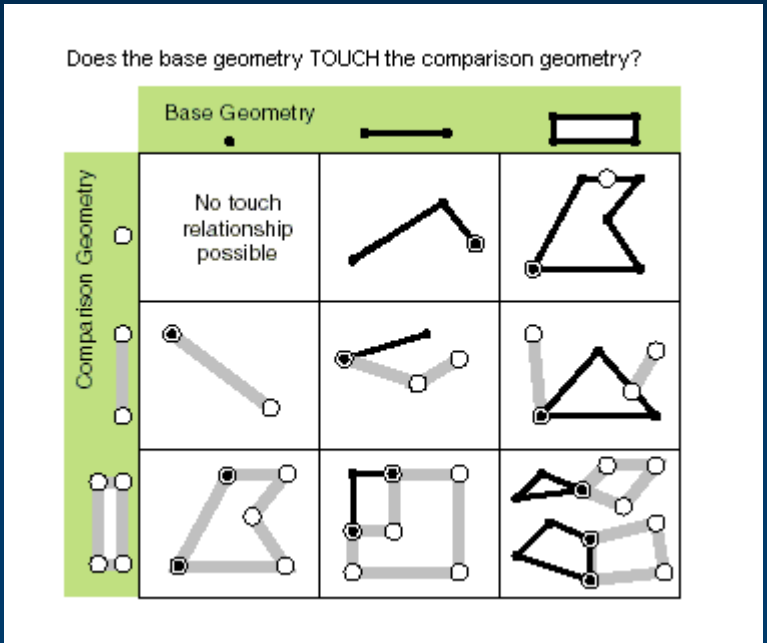
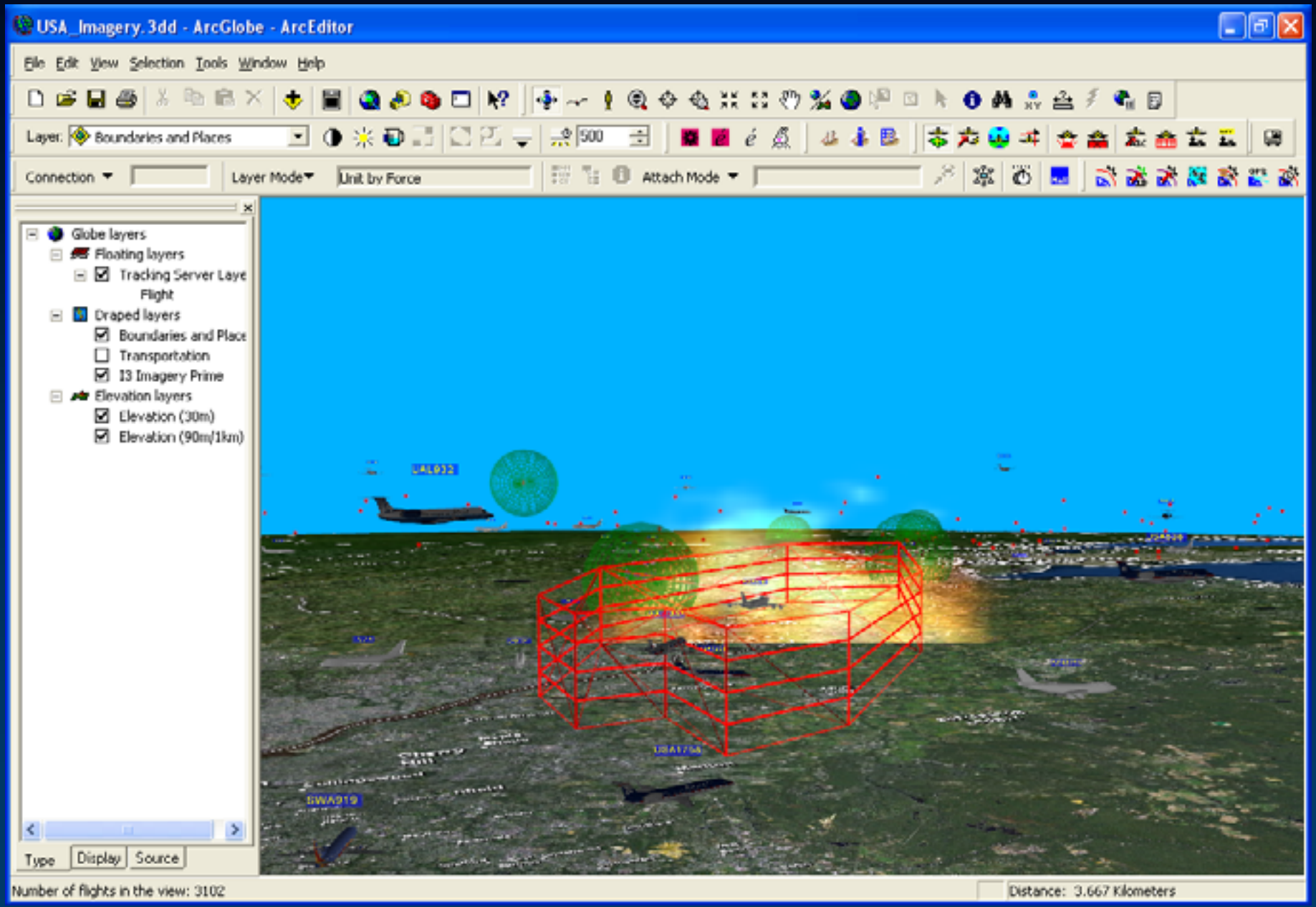
Flight
Draped layers
Boundaries and Place
Transportation
I3 Imagery Prime
Elevation layers
Elevation (30m)
Elevation (90m/1km)
BTA2027
Type
Display
Source
Number of flights in the view: 3025
Distance: 4.047 Kilometers

Containment Test

- Is object inside a bounded area or volume?
- Full 3D test can be expensive
- Coarse to fine approach
  - Bounding box test
  - Test 2D bounded area (IRelationalOperator)
  - Test elevation range

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File Edit View Selection Tools Window Help
Layer: Boundaries and Places
500
Connection
Layer Mode
Unit by Force
Attach Mode
Globe layers
Floating layers
Tracking Server Laye
Flight
Draped layers
Boundaries and Place
Transportation
I3 Imagery Prime
Elevation layers
Elevation (30m)
Elevation (90m/1km)
Type
Display
Source
Number of flights in the view: 3102
Distance: 3.667 Kilometers

Summary

- Publishing real-time feed through Tracking Server
- Connecting to real-time Tracking Services
- 2D and 3D Visualization of real-time data
  - ArcGIS Tracking Analyst Extension
  - Custom solutions
- Searching & querying objects from real-time feed
- Real-time analyses

Demos

- Ship Tracking
- Flight Tracking
- Satellite Tracking

Discussions