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Planning and Assessing Effects Based Operations

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Overview

- Cascading Effects in the Real World
- Effects Based Operations Questions
- The NEMO Modeling Environment / Technical Approach
- Current Status and Achievements
- Summary

Cascading Effects

- **Today's critical infrastructures have become increasingly interconnected and interdependent**
- **These interdependencies between infrastructures are vulnerable to exploitation, and often lead to unintended consequences**
- **This increases the probability that a minor outage can cascade into a much larger disturbance/failure**
  - One local event can endanger the whole network
    - » 2001 Baltimore Train Crash
- **Much of today's vulnerability analysis of critical infrastructures is done manually**
- **A system for the automated identification of nodal interdependencies has become a necessity for adaptable infrastructures of large scale and complexity**

Train crash brings net to a halt

July 20 2001

by Tony Hallett

A CSX train similar to that derailed in Baltimore

Derailment brings chaos to the East Coast...

A major train crash in a tunnel in Baltimore has brought the internet to a crawl for some users in the US.

The CSX goods train involved is reported to have derailed and cut important fibre optic lines. It was carrying a mixture of wood, hydrochloric acid and at least five hazardous chemicals. The resulting blaze has been fought by over 100 fire fighters for over a day.

Late yesterday in the US, major East Coast-based ISPs Genuity and PSINet were experiencing peering problems with most other backbones. Peering locations in the eastern cities of New York, Philadelphia and Washington DC have been affected.

According to statistics from internet performance company Keynote Systems, there has been a dramatic slowdown for some websites starting at 03:00(EST) Wednesday.

In such circumstances, internet traffic is rerouted through other cities, and there have been reports of performance problems as far away as Atlanta, Los Angeles and Seattle.

silicon.com

Questions for EBO

NEMO provides a tool for observation/analysis of 2nd (and higher) order impacts of cascading effects.

Managing Unintended Consequences:

Cause ⟶ Effect

If X occurs what happens to Y?

Examples: If the allied forces destroy an Iraqi water line, will there be any effect on the transmission of electric power? How will taking out the road from Baghdad to Basra affect telephone communications between soldiers of the Iraqi army?

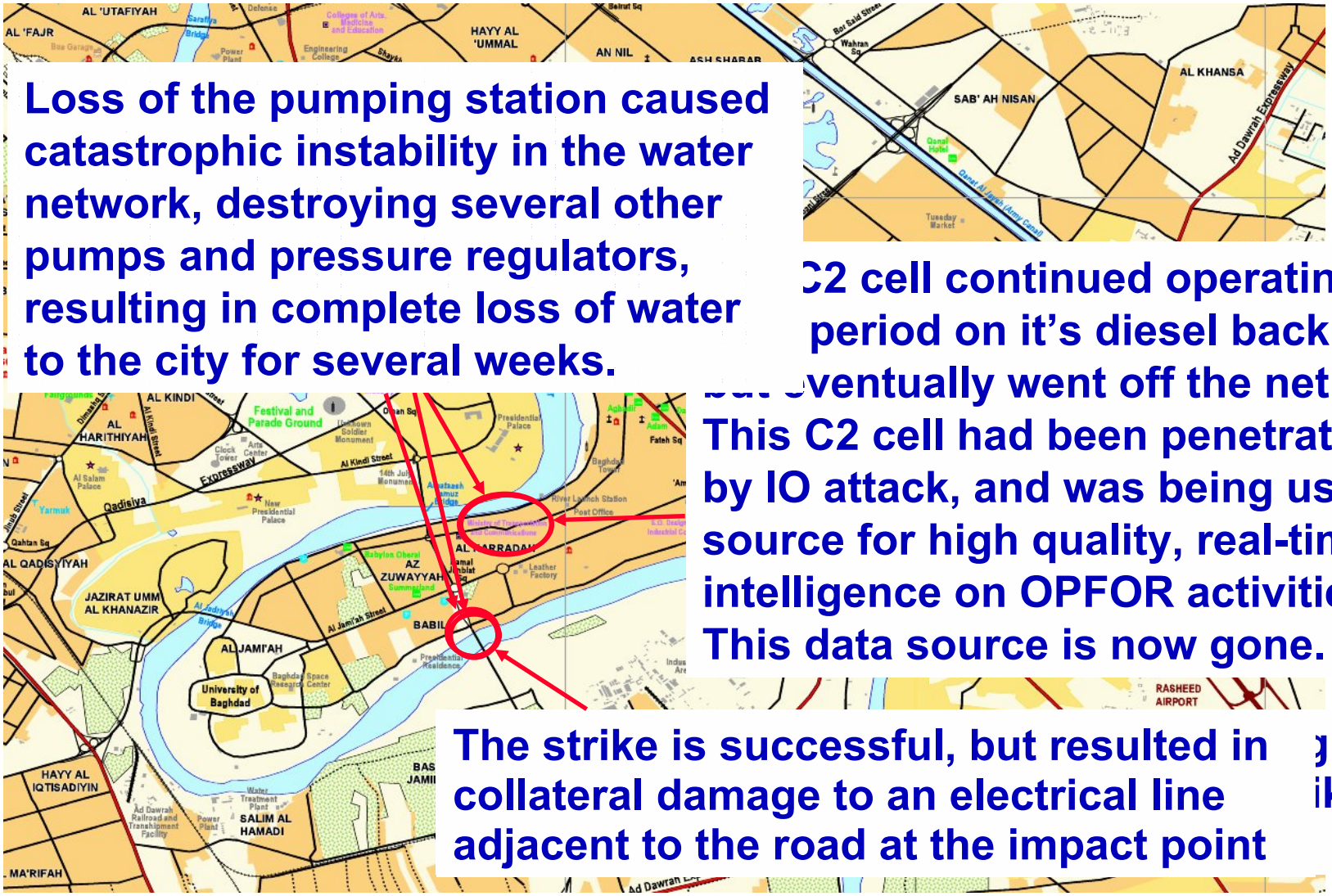
Effects Based Planning:

Effect ⟶ Cause

What is the best way for me to cause Y to happen?

Examples: Allied forces want to disrupt communications between Baghdad and Basra, of all the possible targets, which targets would achieve that goal for the least 'expense'. Can we prevent an opponent's use of WMD in a conflict through disruption of a portion of their power grid vice destroying R&D facilities known to be WMD? How can we inexpensively disable a foreign nation's military prowess without disabling various public institutions?

EBO Scenario



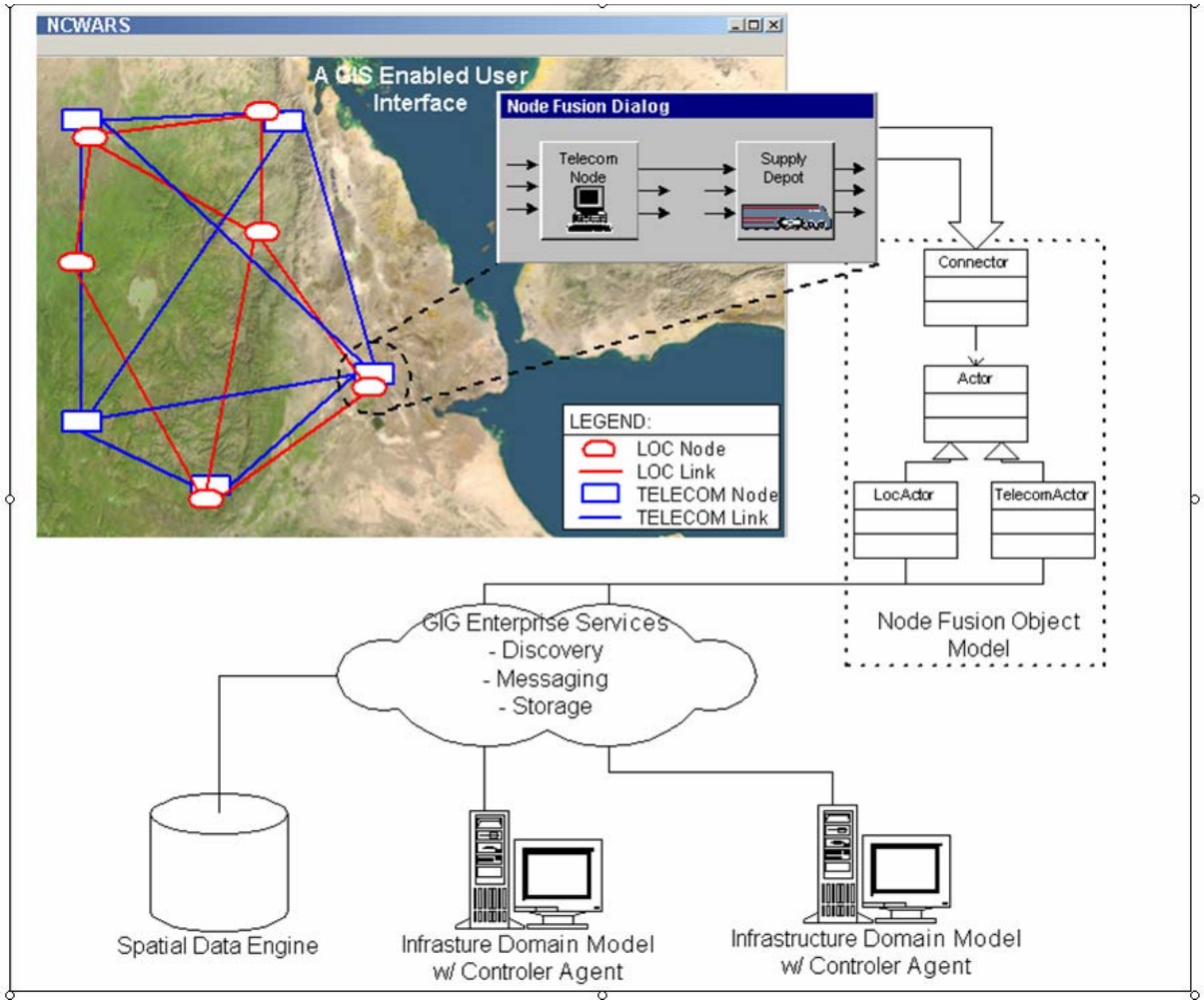
Loss of the pumping station caused catastrophic instability in the water network, destroying several other pumps and pressure regulators, resulting in complete loss of water to the city for several weeks.

C2 cell continued operating period on it's diesel backup, eventually went off the net. This C2 cell had been penetrated by IO attack, and was being used a source for high quality, real-time intelligence on OPFOR activities. This data source is now gone.

The strike is successful, but resulted in collateral damage to an electrical line adjacent to the road at the impact point

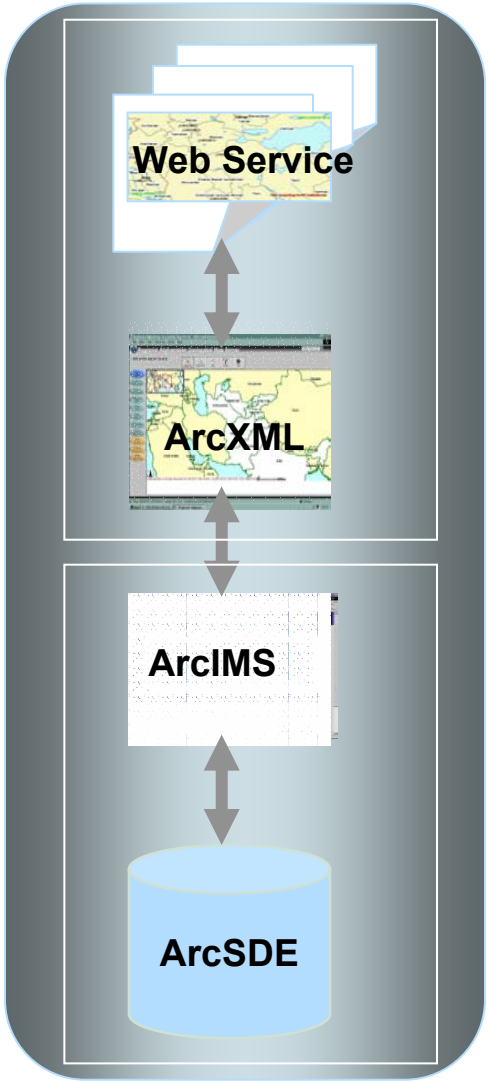
NEMO Technical Approach

- **Use Legacy Infrastructure Models**
  1. Lines of Communication (e.g., Cube Voyager)
  2. Electric Power (e.g., Synergee Electric)
  3. Telecommunications
  4. Petroleum, Oil, Lubricant
  5. Water
- **Provides means for defining relationships between networks, allowing events in one network to cause events in another network**
- **Phase I Objective was to Develop a "Proof of Principle" that Multiple Network Domains Can Be Integrated into an "Effects-Based Operations" Analytical Capability**

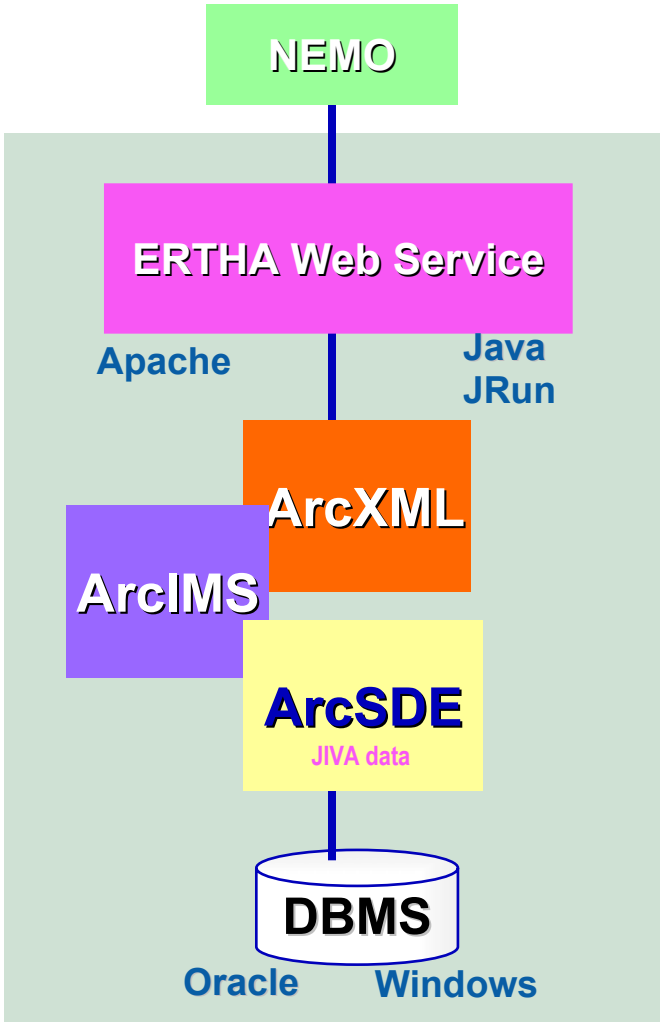


NEMO for Lines of Comm and Telecom Domains

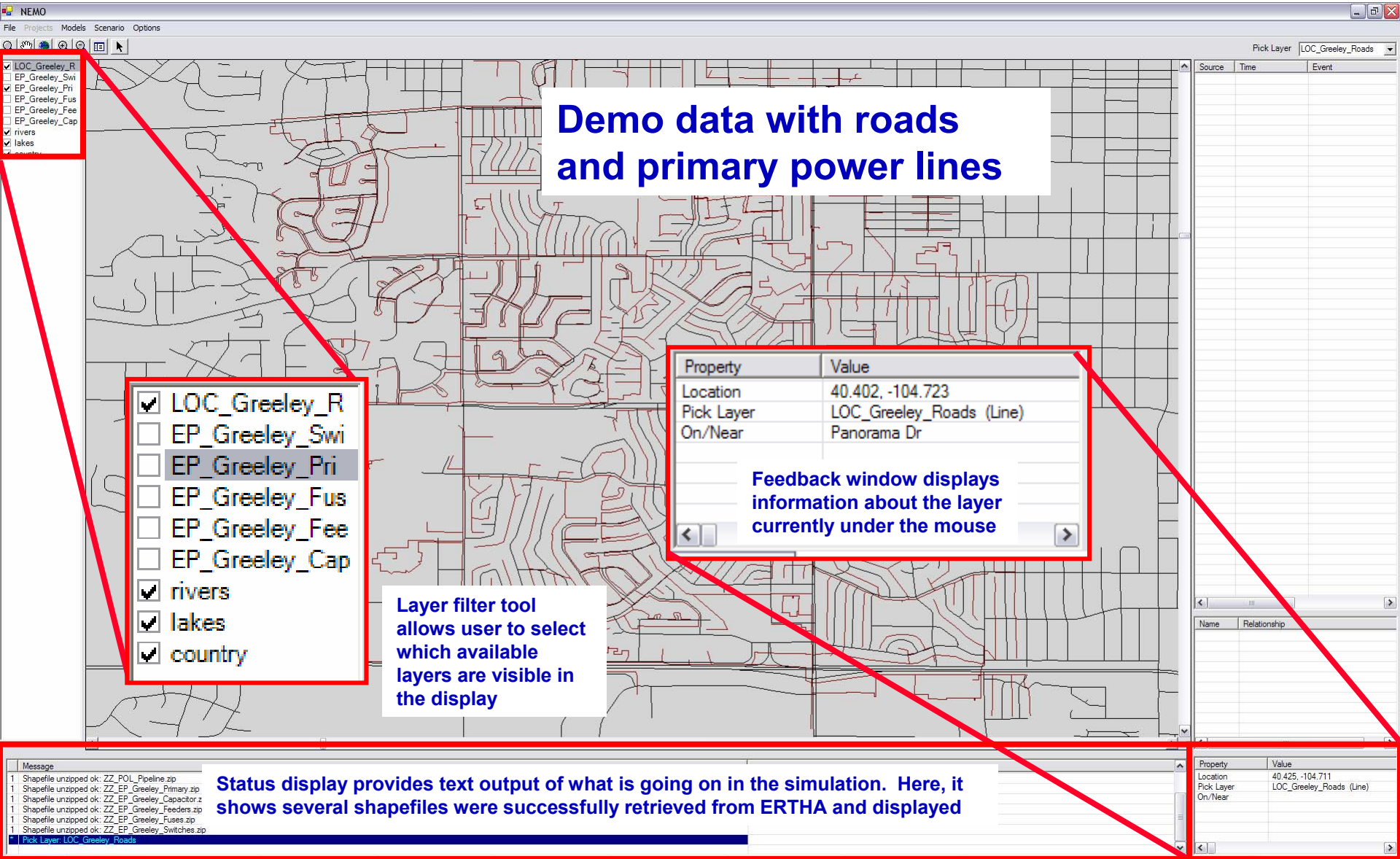
Earth Resource Terrain Hierarchical Archive (ERTHA)



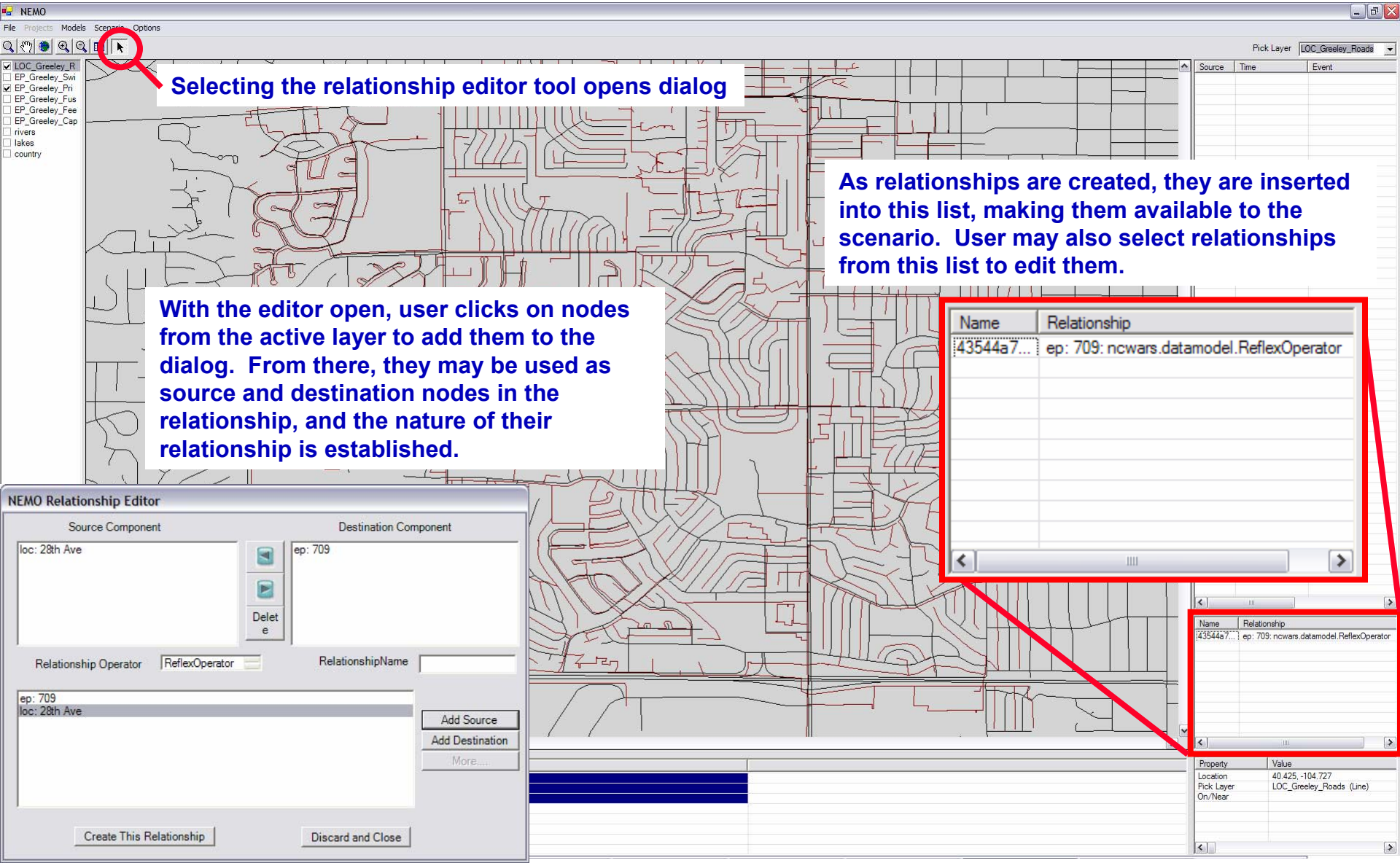
- **ERTHA Web Service**
  - Interface for all GIS Infrastructure Models
    - » "Get" shape files and associated attributes
- **ArcIMS and ArcXML**
  - ESRI's interface to ArcSDE and its Data
  - ArcIMS : Internet Map Server
  - ArcXML : Layer Definition and Query Language for ArcIMS
- **ArcSDE**
  - Spatial Database Engine
  - Centralized management of geographic information in a DBMS
    - » Vector, raster, table, annotation, relationships, CAD
  - Contains a subset of JIVA's data
- **DBMS**
  - Oracle database
  - Features as objects
    - » Geometry
    - » Attributes
    - » Behavior (rules, methods, relationships)
  - Uses ArcSDE for multi-user access and versioning



NEMO User Interface



Creating Relationships



Relationships Are Key!

- **Relationships are the key to EBO analysis, with or without the use of NEMO.**
  - Understanding how a particular element of one network relies on the elements of one or more other networks provides the basis for analyzing cascading effects.
- **NEMO provides a relationship editor to capture inter-dependencies between domains.**
  - Interdependencies may be quantified in any number of ways (on/off, time delayed on/off, one-to-many, many-to-one, etc.).
  - The NEMO architecture provides a straight-forward means for integrating new methods as they are identified and developed.
  - NEMO allows any number of relationships to be defined at various places across the infrastructure networks.
- **NEMO uses relationships to allow changes in one network to cause changes in another network.**
  - These changes may, in turn, cause other relationships to generate changes in yet other networks.
  - This change/evaluate/update process continues until no additional changes are detected.

More on Relationships

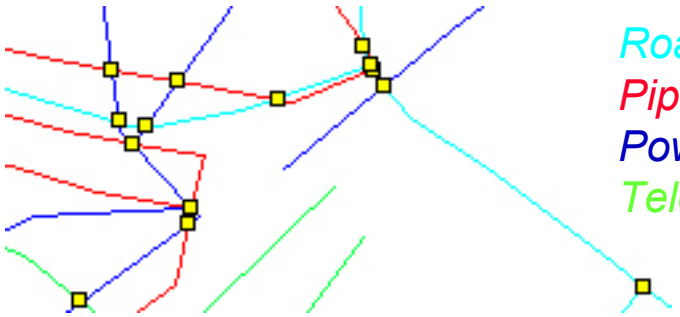
- **Relationships can be based on more than just proximity**
  - Functional, Logical, etc.
  - Geospatial search agent focuses on the proximity aspect
- **Relationships aren't necessarily static**
  - People adapt to adversity
    - » Attempt repairs
    - » Look for alternative sources
    - » Alter priorities
  - Allows mechanism for developing dynamic relationships in the future.
  - Provide a means of exploring emergent behaviors.
  - The architecture is present already; advanced behavior is not.
- **For NEMO, Relationships occur strictly across domains.**
  - The supporting domain simulations evaluate changes that occur within their models and notify NEMO of any changes that may occur, which are then displayed on the map.
- **NEMO has integrated an agent based approach to identify possible relationships**

The Nodal Interdependency Agent

- **The Agent uses ERTHA's Web Services to retrieve zipped ESRI® Shapefiles for each country**
- **The Agent iterates over all Shapefiles and identifies nodal interdependencies between any of the resources for which ERTHA has spatial data: Pipelines**
  - Powerlines
  - Telecommunications
  - Roads
  - Water
- **ESRI® Shapefiles of the interdependencies are produced**
  - Since interdependencies calculated from spatial data often yield mixed shape types and Shapefiles are restricted to contain only one type of shape, multiple Shapefiles are constructed for each interdependency "layer"

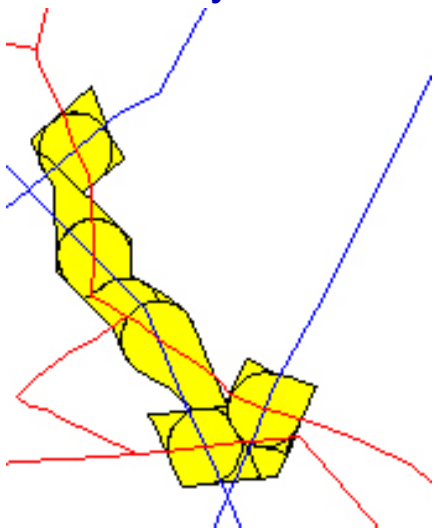
The Nodal Interdependency Agent (2 of 2)

- **The user specifies a threshold for the tolerance distance for the NI Agent to use when calculating nodal interdependencies**
  - A tolerance distance of zero results in intersections for nodal interdependencies



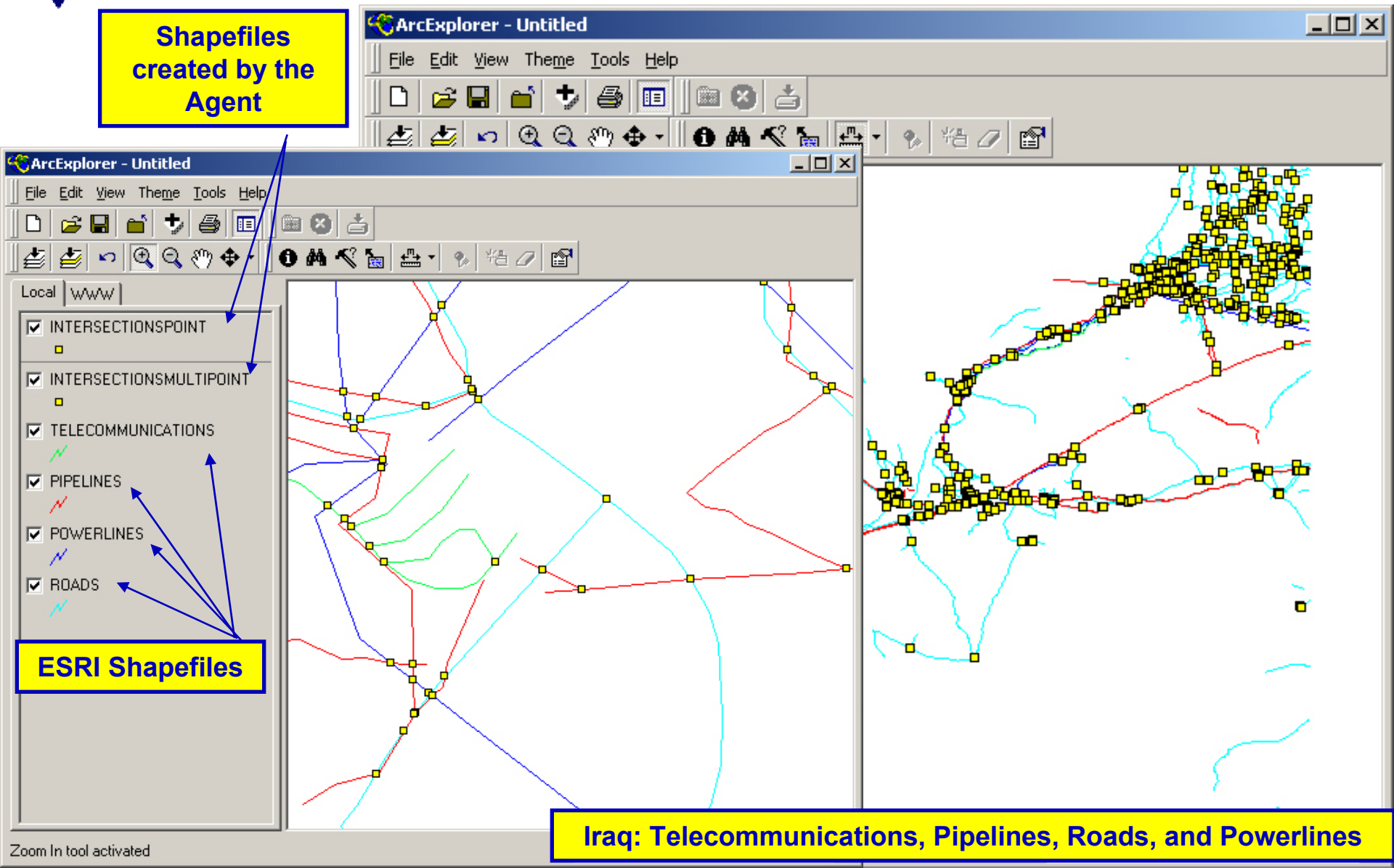
Roads
Pipelines
Powerlines
Telecommunications

  - A tolerance distance greater than zero results in a variety of shapes for nodal interdependencies
    - » e.g., area polygons for collateral effects



Example from ERTHA Crawl: Zero Tolerance Distance

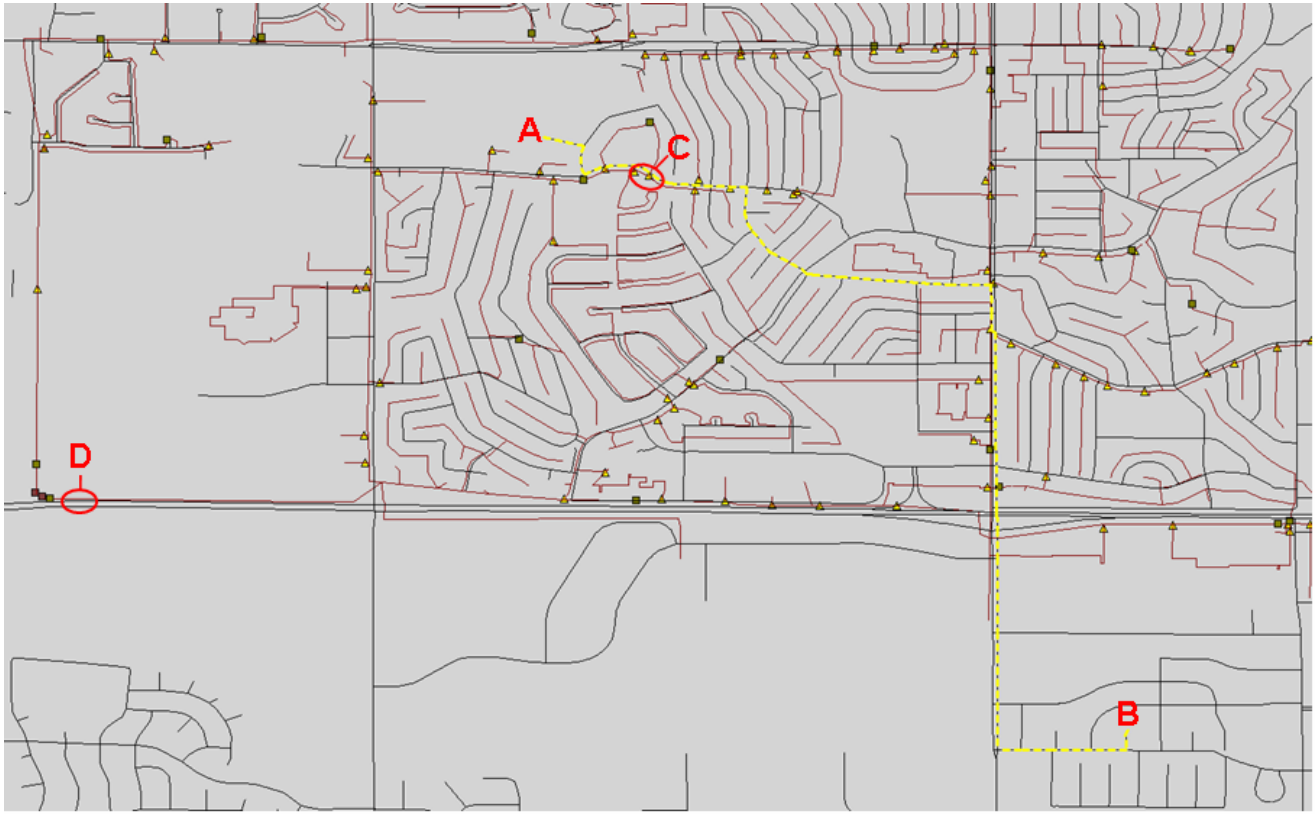
Shapefiles created by the Agent



Iraq: Telecommunications, Pipelines, Roads, and Powerlines

NEMO Demonstration

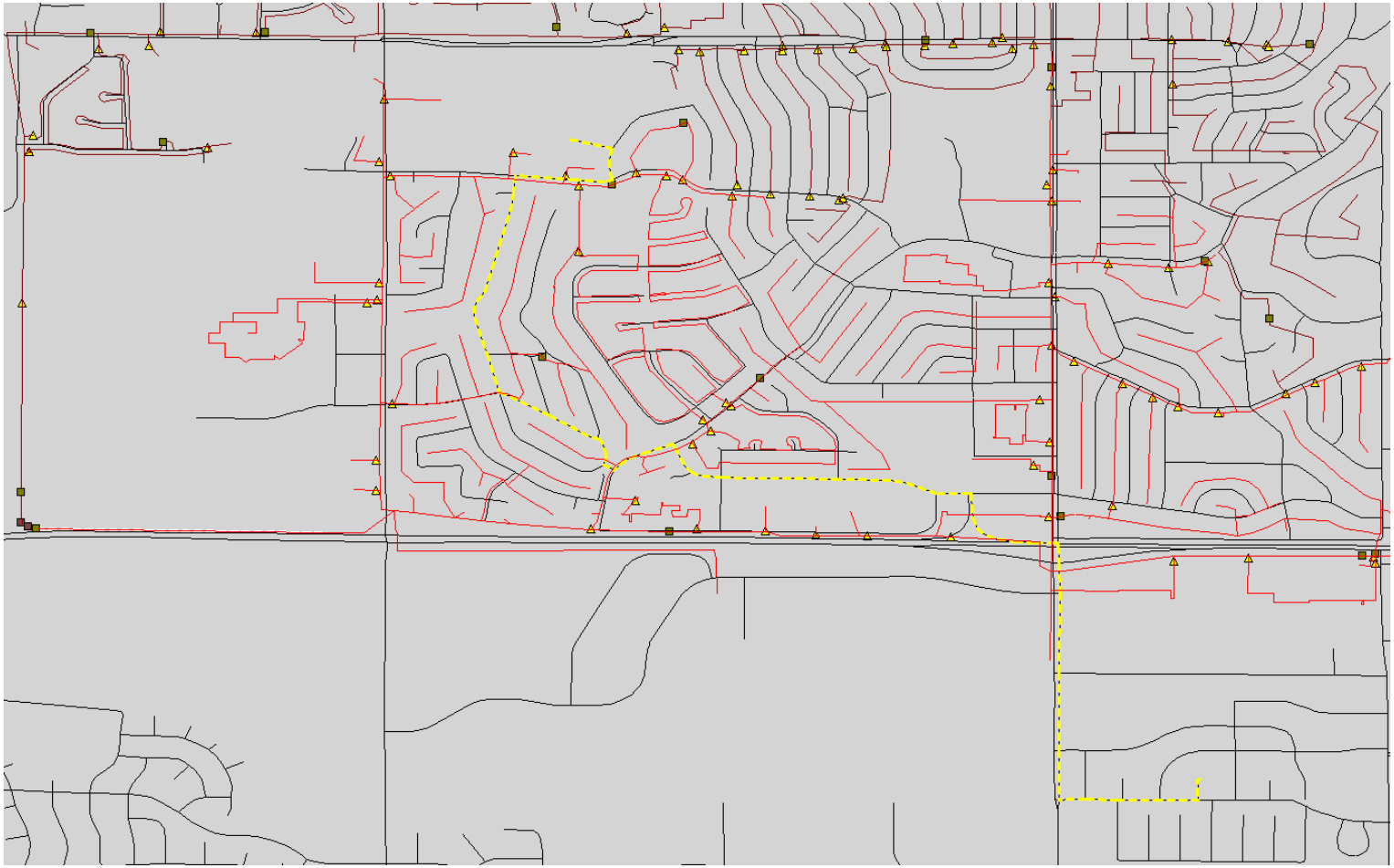
As a demonstration of NEMO's current capabilities, we will provide a notional example of how the cascading effects of strikes against a power network can be observed in an LOC network. Figure 2 shows the NEMO map, zoomed in to a region with electrical power (red lines) and LOC networks (black lines) available. We want to examine the impact on travel time between two points (A & B) after a strike against an electrical power target is made.



The current shortest path, reported by the LOC model is yellow. A nodal analysis reveals an electric draw bridge at point C, which reacts to power outages by automatically moving to the up position on emergency power to maintain navigational right-of-way on the river it spans, and remaining there until power returns.

Demonstration (Continued)

The strike resulted in a local power outage (bright red) that affected the draw bridge, which forced the LOC model to report a new shortest path to the destination.



NEMO Future Development

- **Modeling Counter Measures**
  - Party Who Loses Power Will Take Measures To Restore Power That Are Unaccounted For In The Model
- **Modeling Degradation Of Systems As Opposed To "On/Off"**
  - Loss Of Traffic Lights Slows Traffic But Does Not Completely Disable It.
- **Modeling Time Delays**
  - A Hospital Has Generators To Power Itself For A Period Of Time After Initial Power Failure
- **Modeling Social Behavior**
- **More Robust Infrastructures**
  - Transportation Lines
    - » Airways
    - » Shipping Lanes
  - Social Institutions
    - » Hospitals
    - » Schools
    - » Residential Areas
  - Food Supply
    - » Farms
    - » Warehouses
  - Financial Infrastructure
    - » Banks
    - » Stock Exchanges
    - » Credit Agencies

NEMO Summary

- **SPARTA has shown a 'Proof of Principle' Tool which uses Net-Centric Approaches (Web Services, Discovery, Software Agents, Java Messaging Service, ESRI Shape Files, etc) to Identify and model Critical Infrastructure Layer Interdependencies**
  - NEMO has both Effects Based Operations (EBO) applications to Offensive Military Operations and Homeland Defense/Homeland Security Applications