Effective Scenario Composition for the Revelation of Blind Spots in Critical Infrastructure Protection Planning

1st Annual IFIP Working Group 11.10 International Conference on Critical Infrastructure Protection

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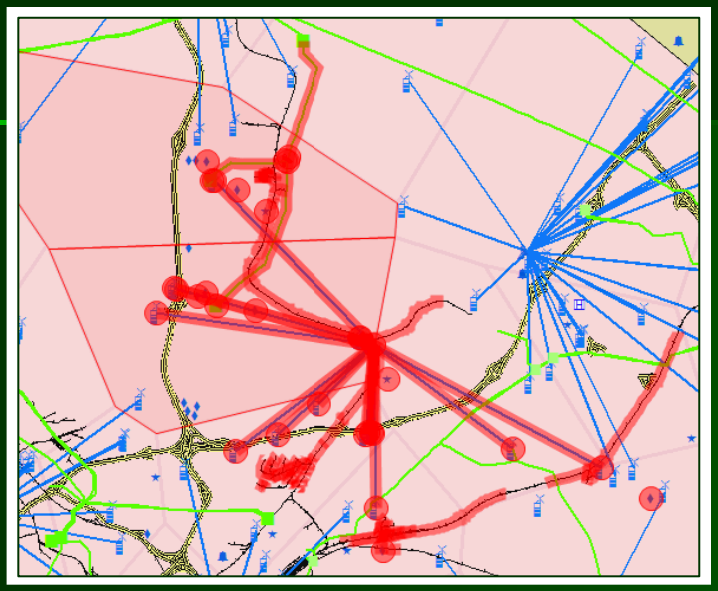
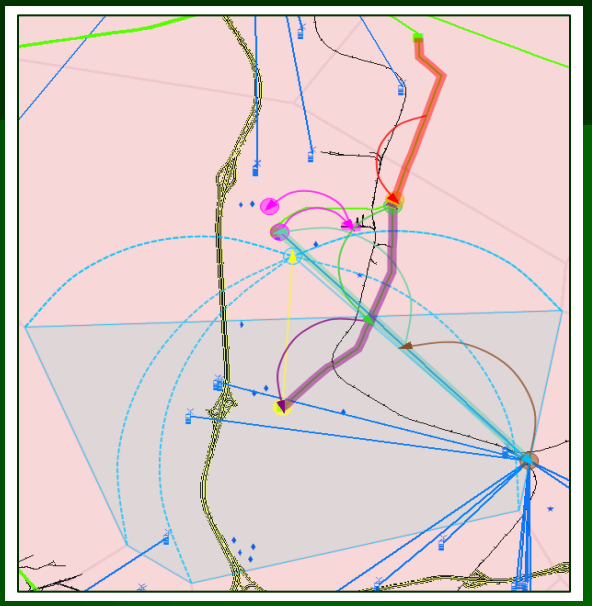
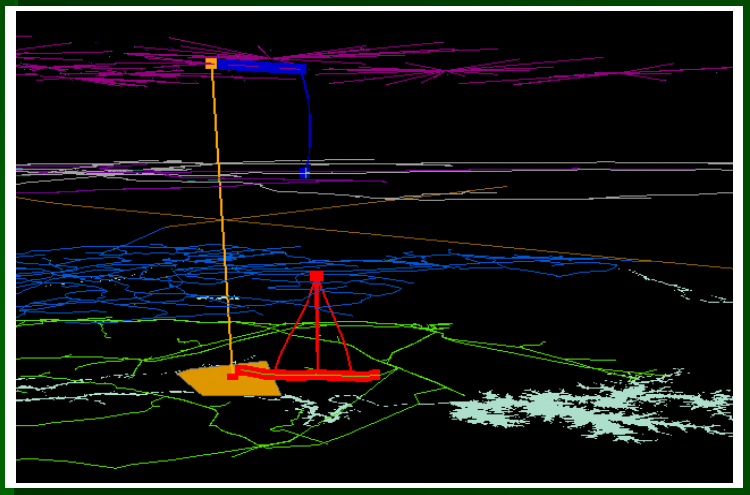
Project Overview

- Critical Infrastructure Integration Modeling and Simulation Project
  - System of systems analysis project supported by the U.S. Government 2003 – present
  - Currently completing 7th award
- Our objective is to enable integrated analysis of multiple critical infrastructures
  - Initial focus: physical infrastructures (EP, C4I, Transportation…)
  - Approach has been extended to demonstrate combined analyses of physical, organizational, and population behavior models
  - The integration of economic models is planned
- Our approach combines support for ontological, geospatial, and temporal analysis under a common framework
  - The support for ontological and geospatial analyses enables multi-infrastructure analyses
  - Individual infrastructure models, however, may leverage other modeling approaches or model representations

Illustration







Video Clip

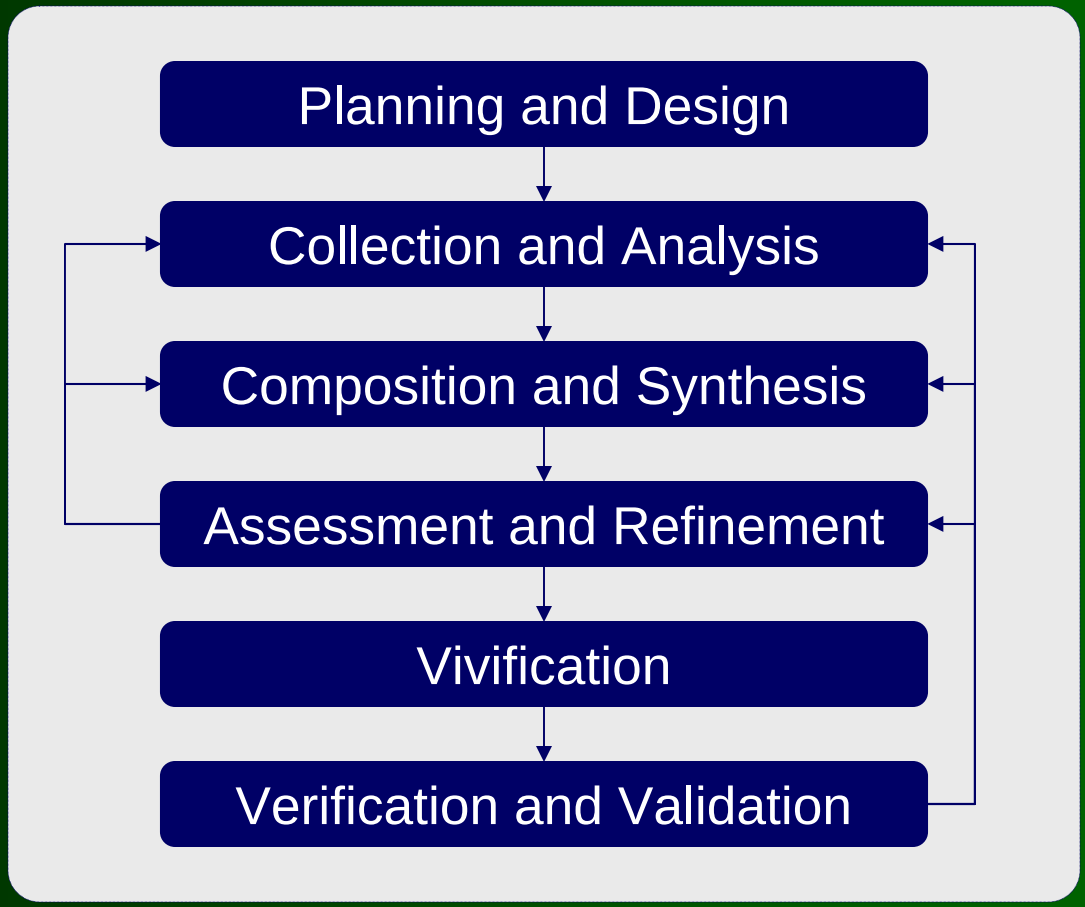
Introduction: The Role of Scenarios in CIP Planning

- Definition: A scenario set bounds the range of vulnerabilities by connecting an initiating event(s), or initial conditions, to desired and undesired end states (different levels of damage) with a sequence of events linking the two
- Functionally, a scenario set is both:
  - A *bridge that connects* the process of analysis with that of planning
  - A *cognitive apparatus that stretches* people's thinking to broaden their perspectives of what is possible
- Scenarios are a favored instrument for CIP Planning

Introduction: Blind Spots in CIP Planning

- Motivation
  - Unfortunately, scenarios are commonly composed using a non-systematic "back-of-envelope" approach that relies *solely* on ease-based heuristics
- Problem
  - Strategies employed with ease-based heuristics, while simple, easy, and useful, are also narrow, shallow, and often biased
- Result
  - "Blind spots" in CIP planning
    - *Blind spots* are hidden or poorly understood relationships within a single or among multiple critical infrastructures that may lead to surprises and/or multiply infrastructure disruptions in negative ways
- Challenge
  - The revelation of blind spots to minimize their negative impact on the CIP planning process

A Methodology for Scenario Set Composition



A Methodology for Scenario Set Composition

- Planning and Design
  - Identifying the goals, phenomena, scope, and objectives
- Collection and Analysis
  - Collect and analyze information that is related to the scope of a scenario set to formulate a *picture of the known*
    - The range of potential events; the known immediate and cumulative consequences of each event; the causal bonds between consequences and events; timing information; geospatial properties; the cumulative consequences of each event
  - Identify, document, and relate factors that contain substantial variability and/or uncertainty
- Composition and Synthesis
  - Composition involves the arrangement of selected infrastructure information into a format that reflects a new future to be considered
  - It is a synthesis of spatial and functional representations and relationships to create narratives of plausible futures
  - Predictive analysis v. plausible futures

A Methodology for Scenario Set Composition: Composition and Synthesis - Disruption Event Taxonomy

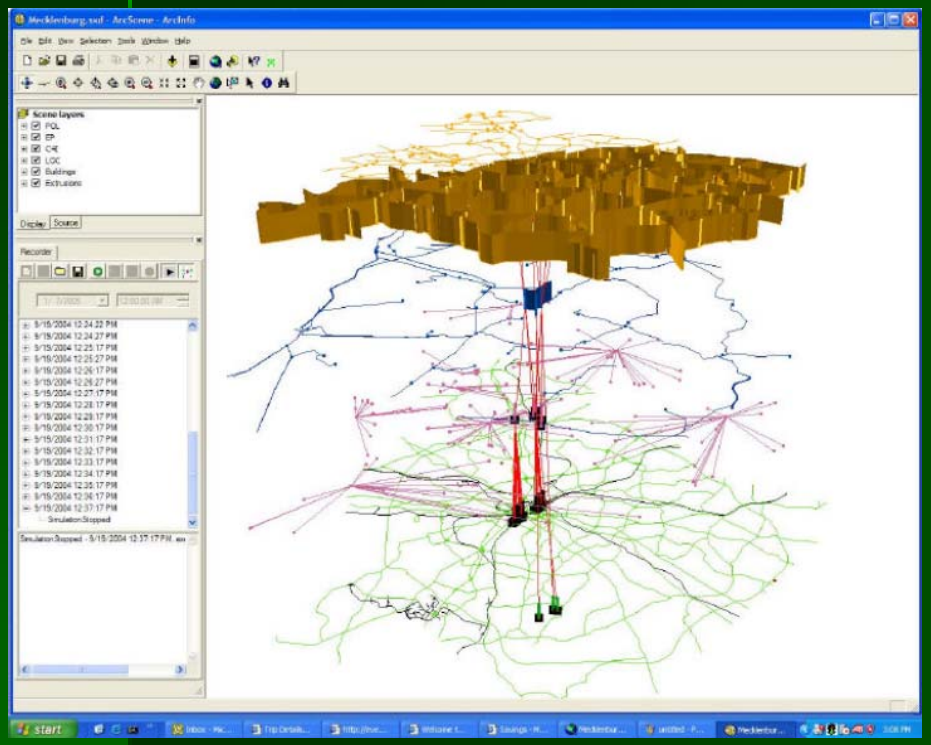
DISRUPTION TYPE	DESCRIPTION
Type 1	One disruption event at one location disabling one feature
Type 2	One disruption event at one location disabling multiple features
Type 3	Multiple, simultaneous disruption events of type 1 and type 2
Type 4	Multiple, temporally distributed disruption events of type 1, type 2, and type 3

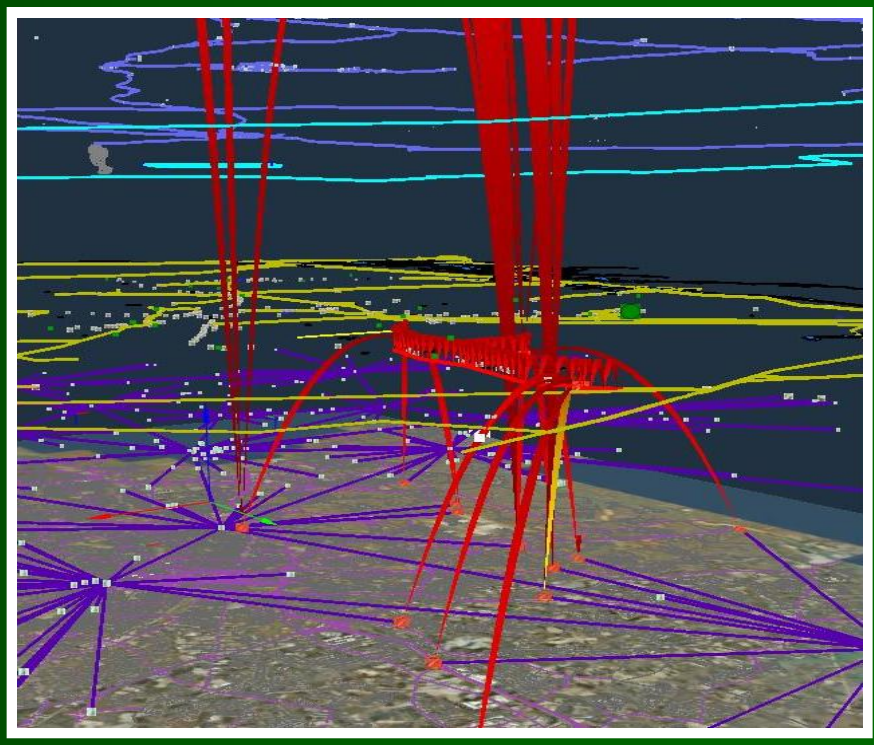
A Methodology for Scenario Set Composition

- Assessment and Refinement
  - Examine each of the possible scenarios for coherence or internal consistency
- Vivification
  - Vivid information is more accessible and more likely to attract and maintain attention while exciting the imagination
  - Scenario set vivification requires planners to pay close attention to their intended audience as some members may be more or less technical than others
- Verification and Validation
  - *Scenario set verification* is the process of determining whether the resulting scenarios are an accurate representation of the planner's conceptual *picture of the known*
  - *Scenario set validation* is the process of determining whether the resulting scenarios are consistent with the "real world" given the intended use or goals of the scenario set

A Methodology for Scenario Set Composition: Vivification

A Methodology for Scenario Set Composition: Vivification





A Functional & Spatial Framework for Scenario Set Composition

SPATIAL PROXIMITY		FUNCTIONAL INTERDEPENDENCIES: Direct	FUNCTIONAL INTERDEPENDENCIES: Indirect
	High	**Examples** Substations and regulators Tandem offices and toll centers Regulators and pipelines ***Quadrant A***	**Examples** Gas pipelines and high power lines MTSOs and toll centers Roads and substations ***Quadrant B***
	Low	**Examples** Central office and Central office Towers and MTSOs Power plant and substations ***Quadrant D***	**Examples** Power plants and central offices Power plants and regulators Roads and high power lines ***Quadrant C***

A Functional & Spatial Framework for Scenario Set Composition

- Critical Infrastructure Scenario Advisory Panel
  - Representatives from Electric Power, Natural Gas, Telecommunications, and Transportation
  - Multiple contacts over ~15-18 month period
- Methodology
  - Delphi™ Approach
    - Co-located, synchronous assessment sessions
    - Distributed, asynchronous assessment sessions
  - Case Study Designed Approach (Lee and Rine, 2004)
    - "Mimicked" real events
- Findings
  - Quadrant A – high spatial proximity / direct functional dependency
    - Interdependencies in this quadrant are the central focus of most CIP planning
  - Quadrant B – high spatial proximity / indirect functional dependency
    - Interdependencies in this quadrant usually receive insufficient attention during CIP planning
  - Quadrant C – low spatial proximity / indirect functional dependency
    - Interdependencies in this quadrant are usually overlooked in the practice of CIP Planning
  - Quadrant D – low spatial proximity / direct functional dependency
    - Often "intra-" infrastructure dependencies

Conclusions

- The more obvious
  - Tools are not enough
    - The study of methodology and practice are essential
    - Proper tools and methodologies can counter the natural tendencies of ease-based heuristics
  - The validation of CIP models is essential, but can be challenging
- The less obvious
  - The validation challenge is compounded when attempting to share analyses
    - Transparency of analysis
  - *Context is key* to critical infrastructure analyses
    - Context gives proper meaning to actions and events
    - Tools and methodologies must properly situate analyses geospatially, temporally, ontologically, etc.
- Situational Awareness v. *Shared Situational Understanding*

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