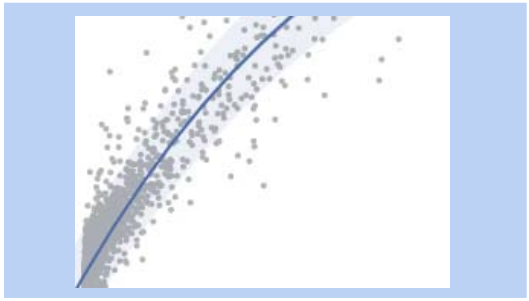
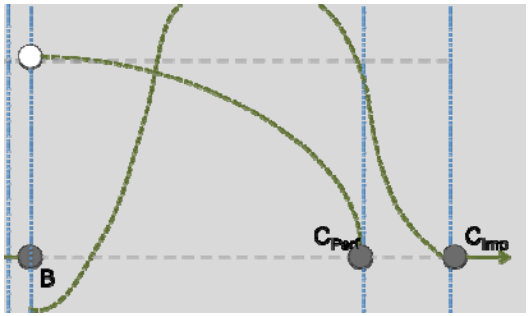





Sandia National Laboratories

*Exceptional service in the national interest*

# Event Response Resource Quantification and Prioritization

Kevin L. Stamber

Carl J. Unis

Donald N. Shirah

Jessica A. Gibson

U.S. DEPARTMENT OF ENERGY  NNSA

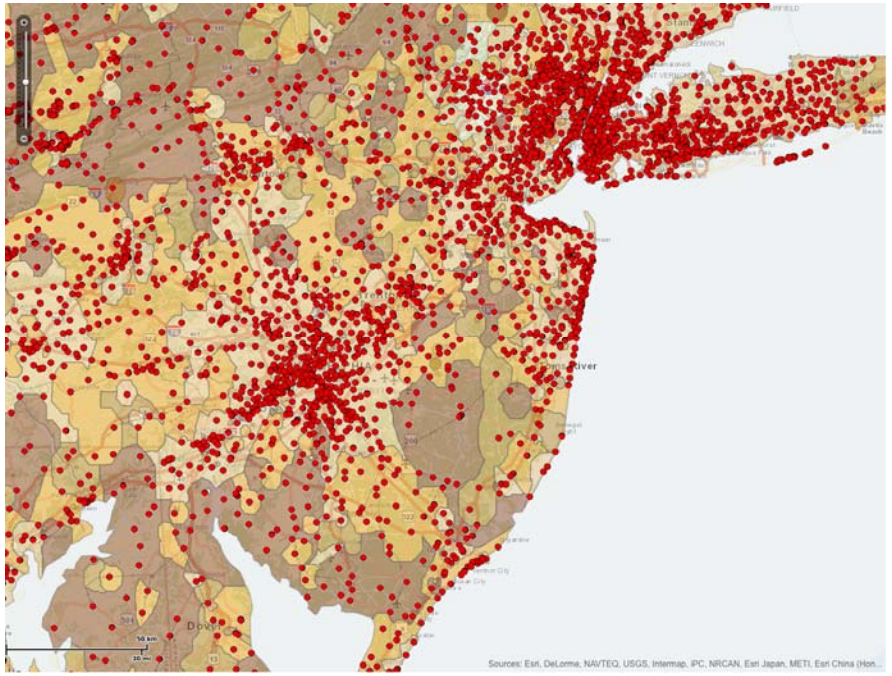
Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND 2014-16660 PE

# Motivation

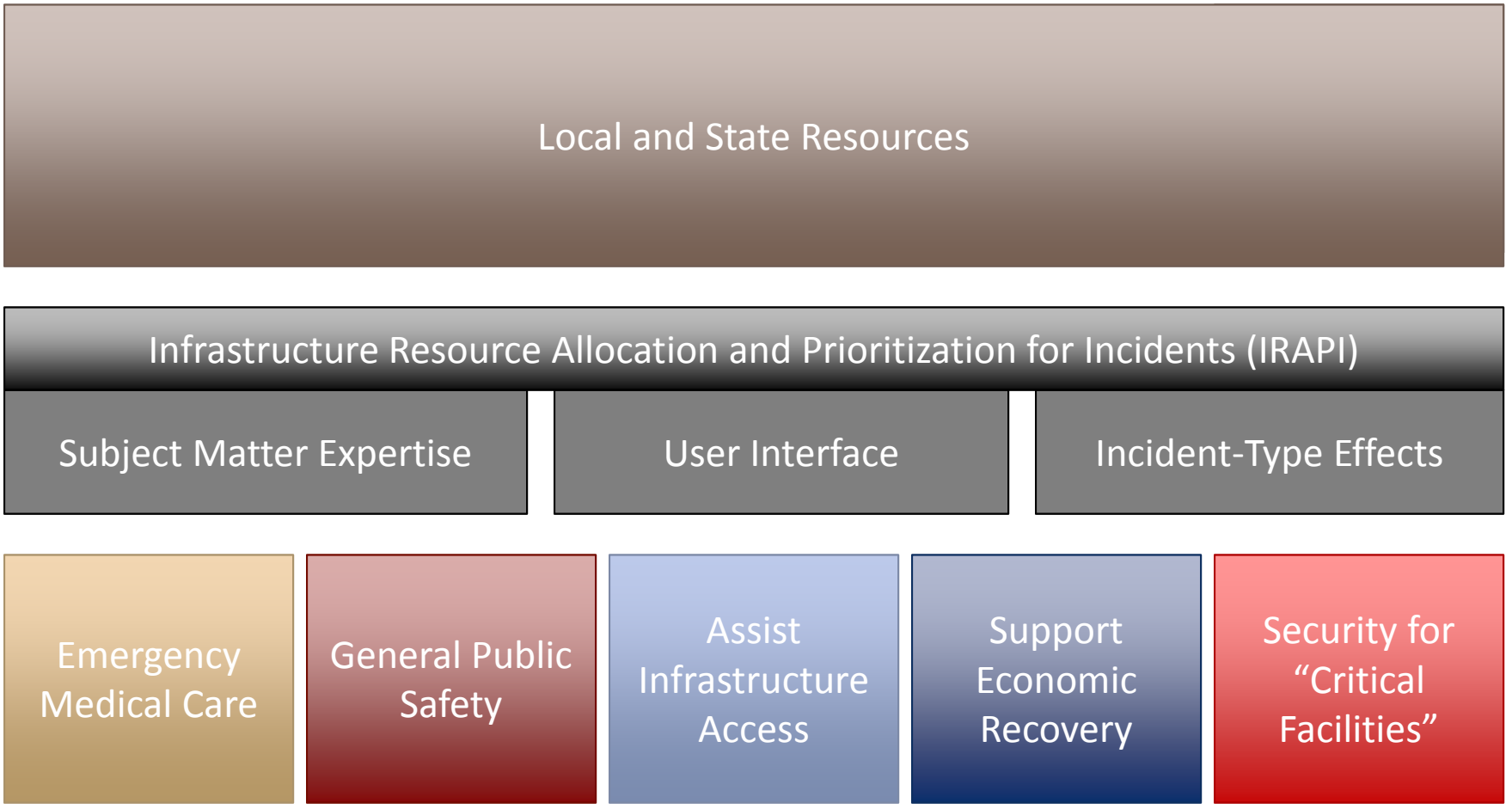
- Incident occurs
- Hundreds to thousands of impacted service providers across most critical infrastructure and key resource (CIKR) sectors
- Resources needed to
  - respond
  - recover
  - Restore

are beyond normal scope

  - possibly beyond planned scope



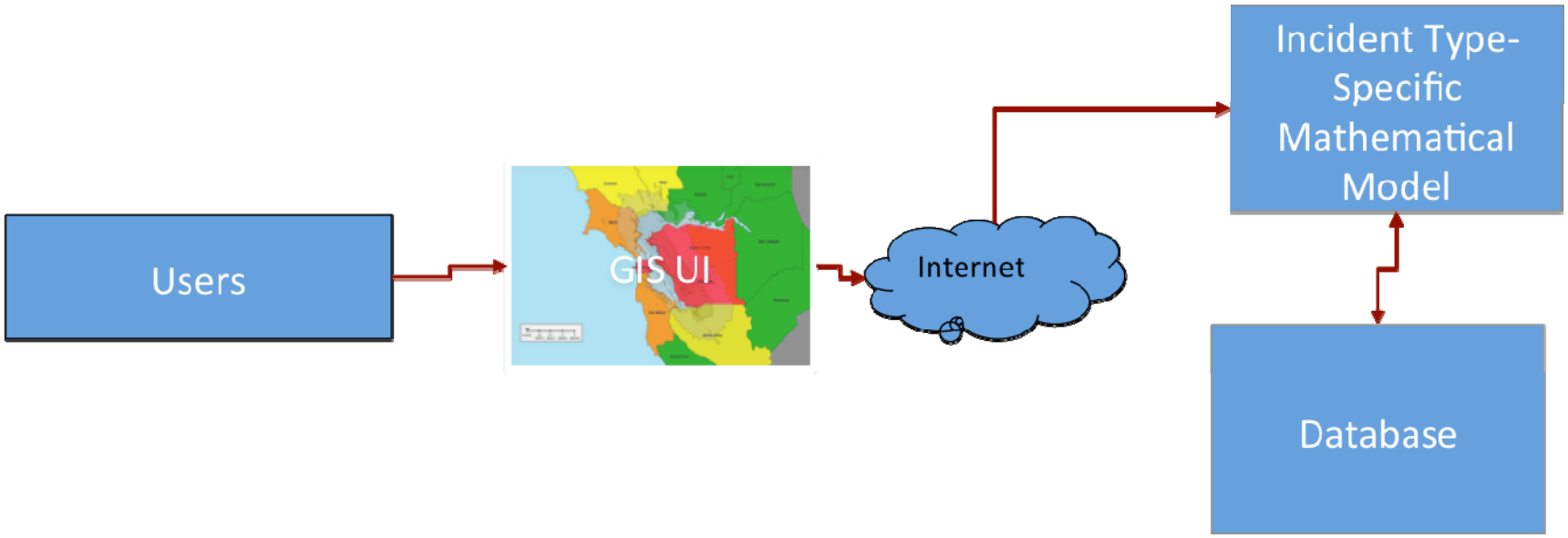
# Motivation


Local and State Resources
Infrastructure Resource Allocation and Prioritization for Incidents (IRAPI)
Subject Matter Expertise
User Interface
Incident-Type Effects
Emergency Medical Care
General Public Safety
Assist Infrastructure Access
Support Economic Recovery
Security for "Critical Facilities"

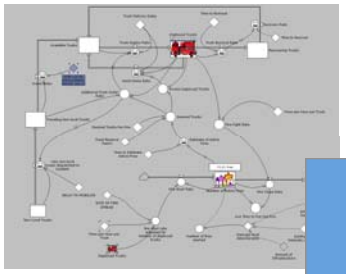
# IRAPI

- Infrastructure Resource Allocation and Prioritization for Incidents
- Previously Known As:
  - Dynamic Prioritization Methodology (DPM)
  - Prioritization of Resources for Infrastructure Systems Mitigation (PRISM)
- Earthquake Model (2012)
  - Focus on Emergency Response Resources
- Hurricane Model (2013-14)
  - Focus on Lifeline Infrastructures

# IRAPI Framework



# IRAPI Framework



Incident Type-Specific SD Model

Incident Type-Specific Mathematical Model

Incident Type-Specific Resource Priorities Survey

Users

**SECTION 1: PLANNING**

Questions in this section are designed to provide us with an understanding of the ways in which you plan for earthquakes, some of the assumptions you make in that planning, and the extent to which that planning is the product of interactions with other entities.

**Emergency Response Planning**

| | | | |
|---|---|---|---|
| 1. Do you have an emergency response plan for earthquakes? | | YES | NO |
| 2. If the answer to 1 was YES, | | | |
| | a. when was the latest revision? (Year) | | |
| | b. has this plan been exercised since its revision, as a tabletop exercise, a live exercise, or in response to a real-world event? | YES | NO |
| | c. if the answer to 2b was YES, | | |
| | i. when was the latest exercise for this plan? (Year) | | |
| | d. If the answer to 2b was NO, | | |
| | i. Was a previous revision exercised, as a tabletop exercise, a live exercise, or in response to a real-world event? | YES | NO |
| | ii. If so, when was it most recently exercised? (Year) | | |

**Timeframes Assumed in Planning**

$$v_o = \sum_t \sum_k w_{o\sigma}(k,t)\left[\frac{\sum_{z\neq b}\Xi_h(s,z,t)}{[P_h(s,b,t)-(\Delta_h(s,b,t)-\Lambda_h(s,b,t)]}\right.$$
$$\left. + \frac{\sum_{\varepsilon\neq b,Z} J_\varepsilon(h,t)}{[P_h(s,b,t)-(\Delta_h(s,b,t)-\Lambda_h(s,b,t)+\sum_{z\neq b}\Xi_h(s,z,t))]}\right].$$
$$\Xi_h(s,z,t) = 0, t < (\tau_I(h) + \tau_C(h,z,b) + \tau_T(h,z,b)).$$
$$J_\varepsilon(h,t) = 0, t < (\tau_I(h) + \tau_E + \tau_C(h,\varepsilon,b) + \tau_C(h,\varepsilon,j) + \tau_C(h,j,b) + [\tau_T(h,\varepsilon,b) \text{ or } [\tau_T(h,\varepsilon,j) + \tau_T(h,j,b]]])$$
$$\Xi_h(s,\varepsilon,t) = 0, t > (\tau_I(h) + \tau_C(h,\varepsilon,b) + \tau_T(h,\varepsilon,b)) + \tau_M(h,\varepsilon,b), \varepsilon \neq b,$$

Database

# IRAPI Framework

- Hurricane Model Parameters: resources needed for purpose p at time t in area of responsibility a are a function of
  - Emergency Response Posture
    - Do you have a plan?
    - Is it practiced?
    - Is it the top concern?
  - Population Density
  - Infrastructure Density
  - History
  - Parameters of the Event

# Population as a Proxy

The Effect of Population Density on Infrastructure:
The Case of Road Building*

Donald R. Glover
*University of Kansas*

Julian L. Simon
*University of Illinois, Urbana; and The Hebrew University*

**Introduction**

The ill effects of population density are well known: less farmland per farmer and consumer, and more congestion. The positive effects of population density have been discussed less and studied almost not at all. This paper takes up one of the ways in which increased population density can be of economic benefit: higher density causes more available infrastructure per worker. More specifically, this paper studies the effect of differences in population density upon the amount of road construction. The effect of per capita income upon road construction is also discussed, but primarily it enters the study as a factor that must be held constant so as to understand clearly the effect of population density. The main conclusion is that higher population density is a significant cause of higher road density.[1]

To our knowledge, this topic has not been previously studied. The closest facet of the literature seems to be Fishlow's demonstration that population density was an important determinant of railroad building in the counties of the American Midwest just prior to the Civil War.[2] But Fishlow's primary interest was somewhat different from ours.

As to the importance of the phenomenon studied here, students of economic development are unanimous on the crucial role of transportation and communication—both of which roads represent—in the development process. For example: "Road conditions in Uttar Pradesh [India] are an important factor in the lack of tubewells, shortages of fertilizer, backward agricultural techniques, and failure to produce more remunerative crops for

* The authors gratefully acknowledge helpful suggestions by Nathaniel Leff and Charles Kindleberger.

[1] A similar analysis indicates a similar relationship in land building in agriculture: higher population density causes farmers to irrigate more land (Julian L. Simon, "The Positive Effect of Population Growth on Agricultural Saving in Irrigation Systems," *Review of Economics and Statistics* [in press]).

[2] Albert Fishlow, *American Railroads and the Transformation of the Ante-Bellum Economy* (Cambridge, Mass.: Harvard University Press, 1965).



- Glover & Simon, 1975
  - Infrastructure Density = f(Population Density, GDP)
  - Used national data for 115 countries
    - Excluded island nations of Hong Kong, Singapore, Malta
  - Found strong correlations
    - $r^2$ of 0.83 for all roads
    - $r^2$ of 0.88 for paved roads

# Population as a Proxy

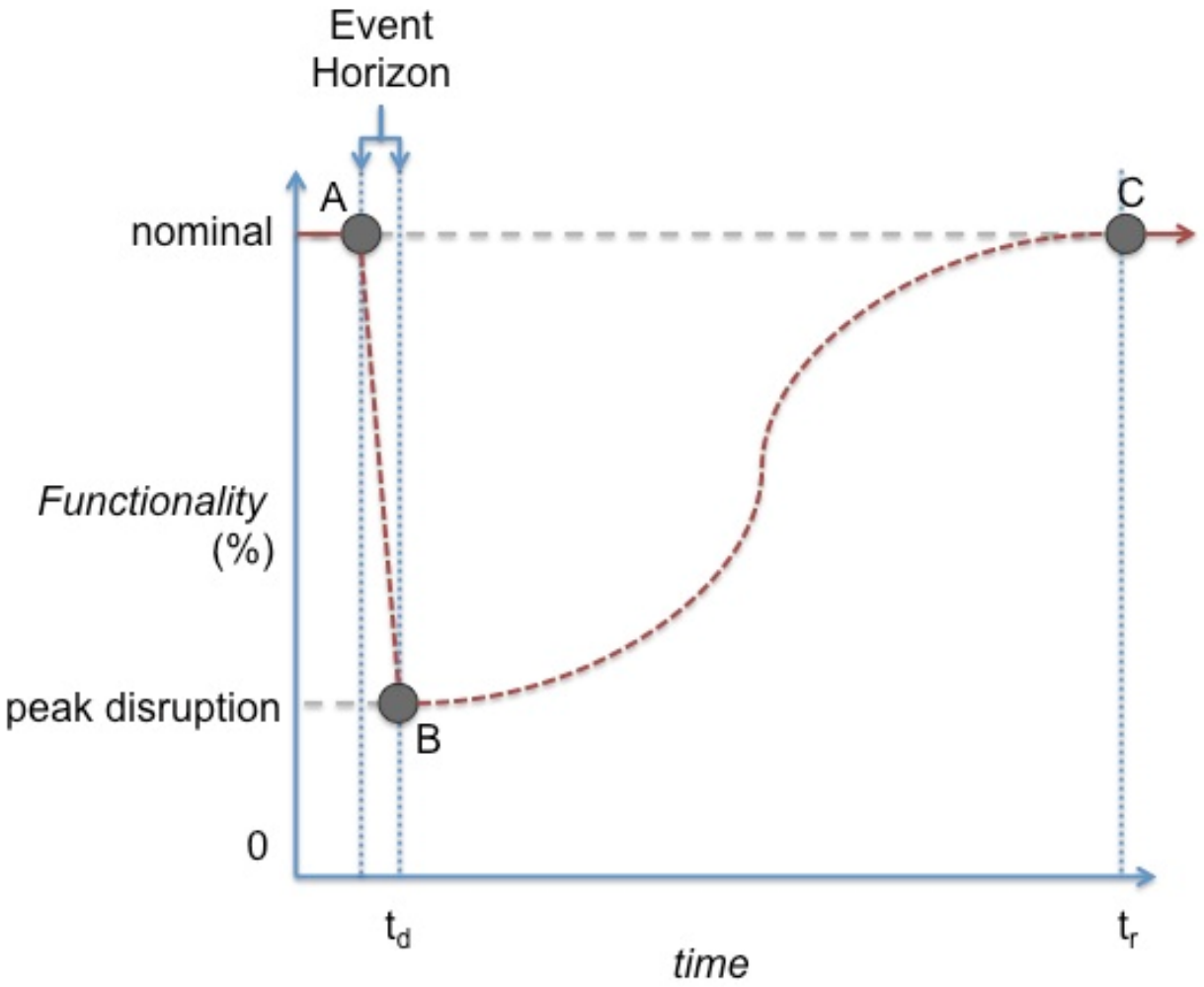
- Examined infrastructure data for lifeline infrastructures
  - Roads
  - Electric Power
  - Petroleum Fuels
  - Hospitals

  against population density at the county level within the US
- Question: Can we replicate the correlations shown by Glover and Simon
  - on smaller geographic scales?
  - for other infrastructures?

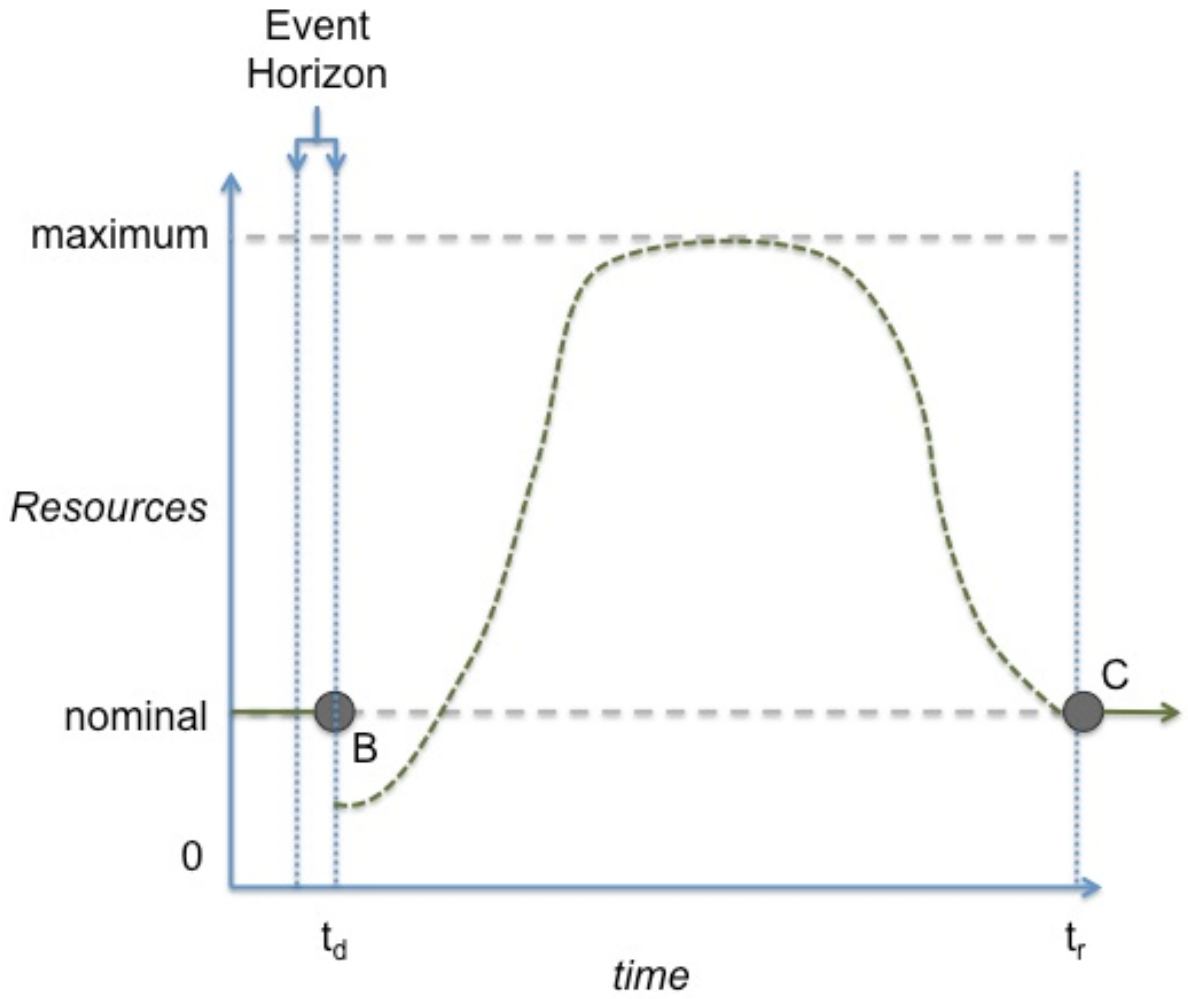
# Population as a Proxy

| Sector | Unit | Density Area | Population / sq mi | Exclusions/inclusions (other than nulls) |
|---|---|---|---|---|
| Electric Power | Transmission Line miles / sq mi | Service Area | 0.74 | IOUs only |
| | Generation Plant Operating Capacity / sq mi | Service Area | 0.78 | IOUs only |
| Healthcare | Hospital beds / sq mi | County | 0.81 | None |
| Petroleum Fuels | Terminals / sq mi | Modeled service area | 0.78 | None |
| Transportation | Road miles / sq mi | County | 0.87 | 16 counties with highest population density |

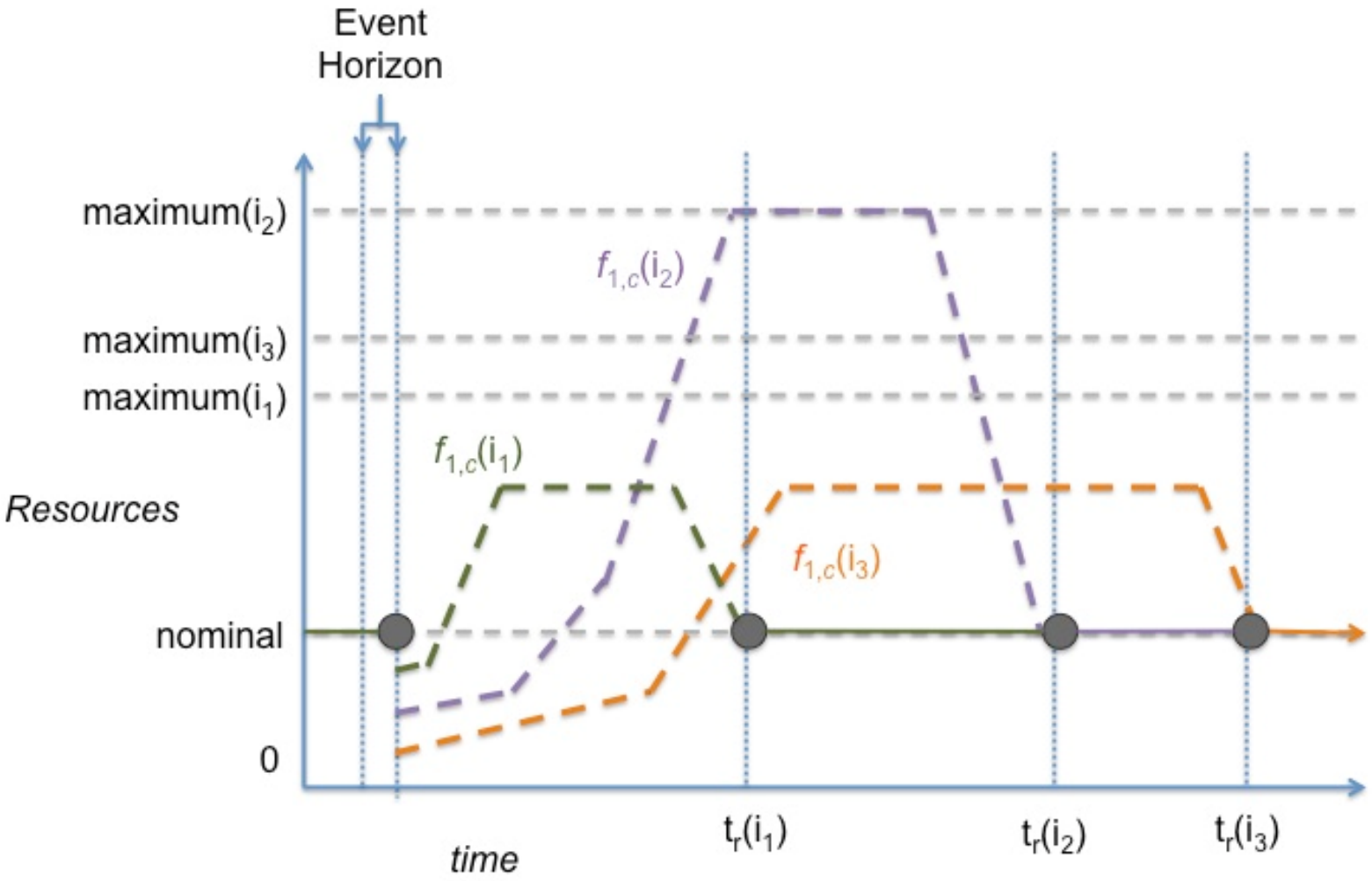
# Resource Allocation and Resilience



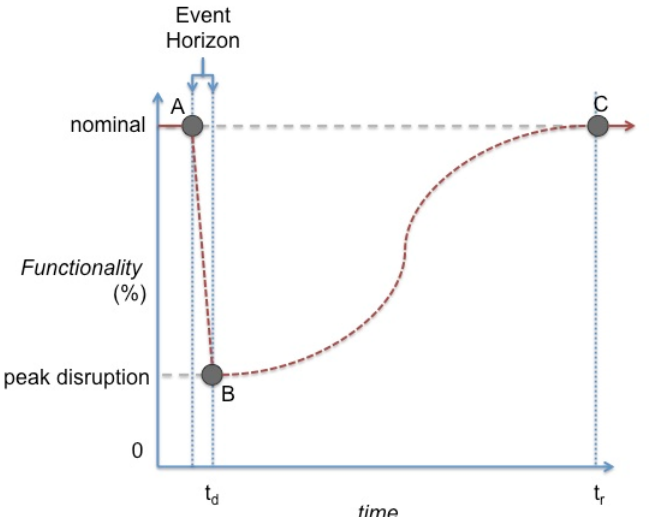
# Resource Allocation and Resilience

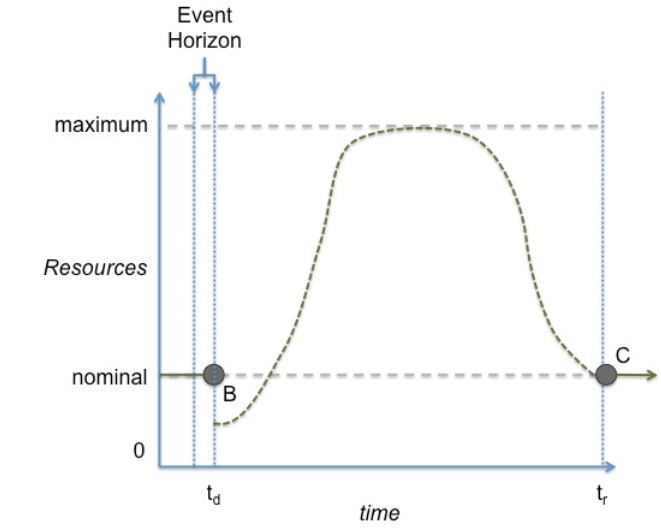


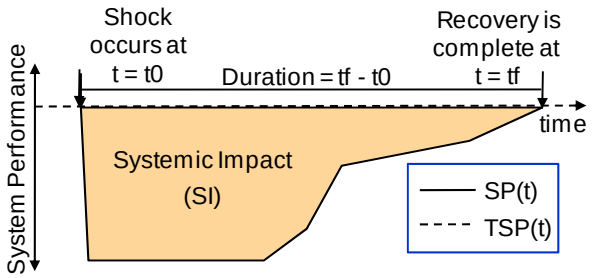
# Resource Allocation and Resilience



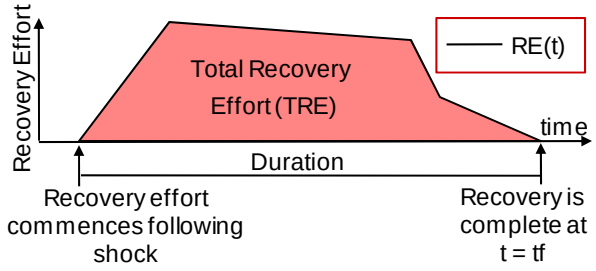
# Resource Allocation and Resilience




$$\frac{SI + \alpha \times TRE}{\int_{t0}^{tf} |TSP(t)|\, dt}$$



# pplication and Path Forward

Use in Real Time

- Superstorm Sandy

Refinement in the field

- Interaction with GA and SC for validation and metrics

Implementation at the laboratory

- Incorporation of model into NISAC analytic process for planning