Integrated Defense Systems

Paper 057

Model Interoperation for Effects Based Planning

Lee W. Wagenhals
GMU
lwagenha@gmu.edu

Raymond A. Janssen
Rite Solutions
raymondjanssen@aol.com

Edward A. DeGregorio
Raytheon
Edward_A_DeGregorio@raytheon.com

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Objective

- Improve the understanding of how tactical actions affect the *infrastructure* and the *civil environments* in an area of operation
- Broaden the capabilities of models used to conduct effects based planning and operations
- Investigate the feasibility of three different types of interoperation between two different modeling techniques
  - Timed Influence Nets (TIN)
  - A civil environment modeling (CEM) tool based on the W. Leontief input-output economics model
- Increase the value of evaluation through interaction between the two models

Challenge

- Actions taken by all (coalition forces, the adversary, and the civilian population) interact to affect the outcome of the coalition's course of action.
- The quality of the commodity services provided by the infrastructure is one of the main factors affecting the socio-cultural attitudes, especially the actions of the local population.
- A lower-level tool (CEM) provides quantification of commodity availability, but the higher-level tool (TIN) needs belief quantification as its metric.
- Lacking, today, is a method on how to interface these two.

Premise

- The TIN approach generally used at the operational and strategic level of warfare
- The CEM tool is more focused on the immediate effects of tactical actions on the infrastructure.
- The basic proposition: Effects based course of action evaluation can be improved by using these two models together ***exchanging information or data between them.***
- The question of how data or information could be passed between the models was unknown.
- A Discovery Experiment was used to explore the potential interoperation between these two modeling techniques to determine if:
  1) interoperation is possible, and
  2) use of such interoperation would improve the overall analysis over that provided by the models independently.
- A case study approach was taken using the situation in Iraq.

Two EBO Modeling Approaches

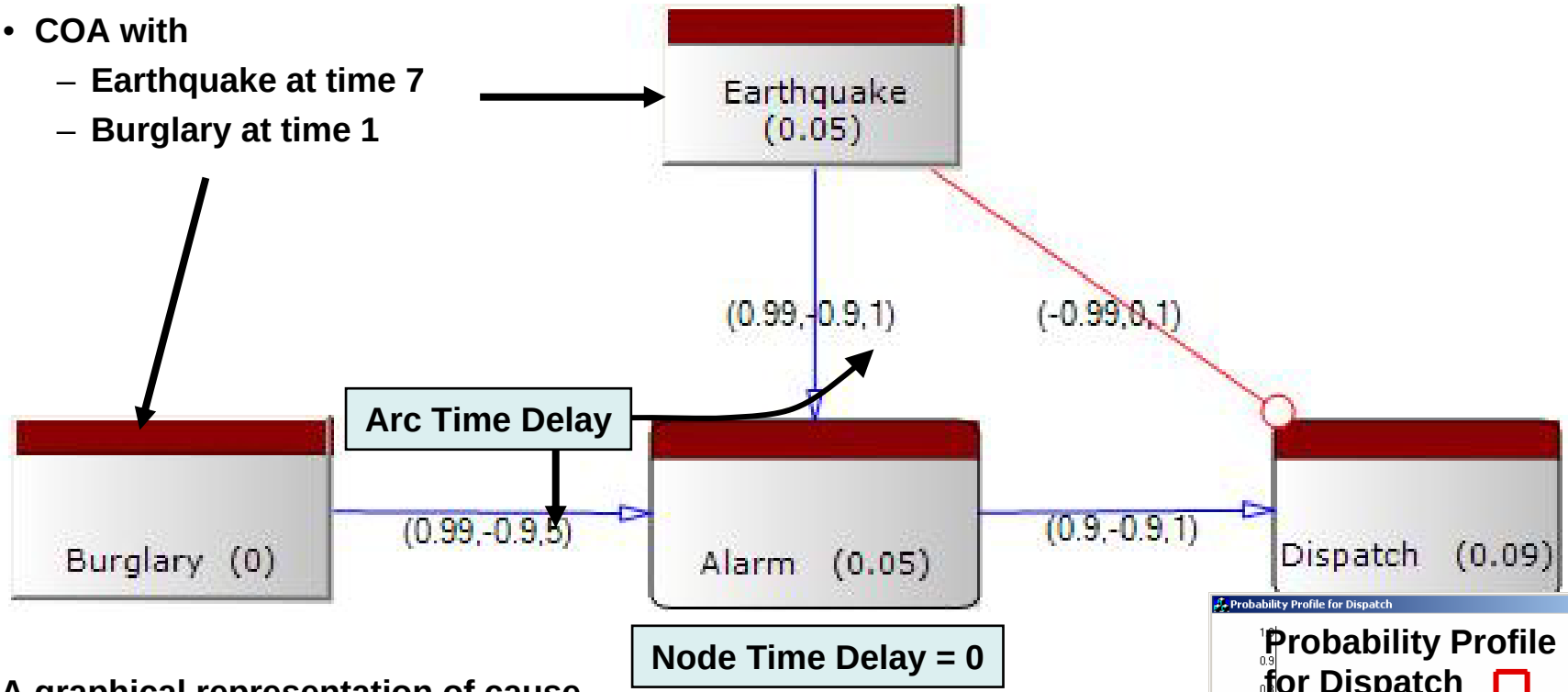
- Effects based plans (EBP) relate actions to effects through a series of causal linkages.
  - Links timed tactical tasks to the desired higher level effects.
- System of System (SOS) models represent the components of and links between systems in the area of operation.
  - Political, military, economic, social, infrastructure, and information (PMESII).
- The EBP should map to the SOS models to show how effects on a component of a system can cause the nature or state of that system and perhaps other systems that are related to it to change.
  - SOS models can provide the explanation for causal linkages in the EBP
- Major differences in the levels of abstraction
- Differences in modeling the physical systems in the PMESII construct, (engineering or physics based models) and models of the cognitive belief and reasoning processes of humans (individuals and groups)

The Cultural Landscape

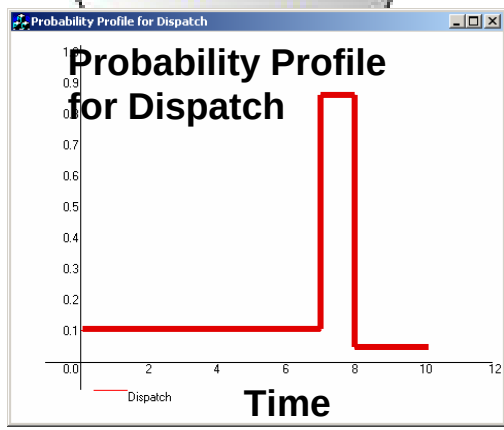
- The purpose of affecting the physical systems is to convince the leadership of an adversary to change its behavior, that is, to make decisions that it would not otherwise make.
- If an adversary is imbedded within a culture and depends upon elements of that culture for support, the effects of physical actions may influence not only the adversary but also the individuals and organizations within the culture that can choose to support, be neutral, or oppose the adversary.
- Thus, the effects on the physical systems influence the beliefs and the decision making of the adversary and the cultural environment in which the adversary operates.

Timed Influence Nets

- COA with
  - Earthquake at time 7
  - Burglary at time 1



- A graphical representation of cause (or influencing) relationships between actions and effects or between different effects
- Incorporates temporal information
- Is executable to provide probability profiles



Pythia 1.5

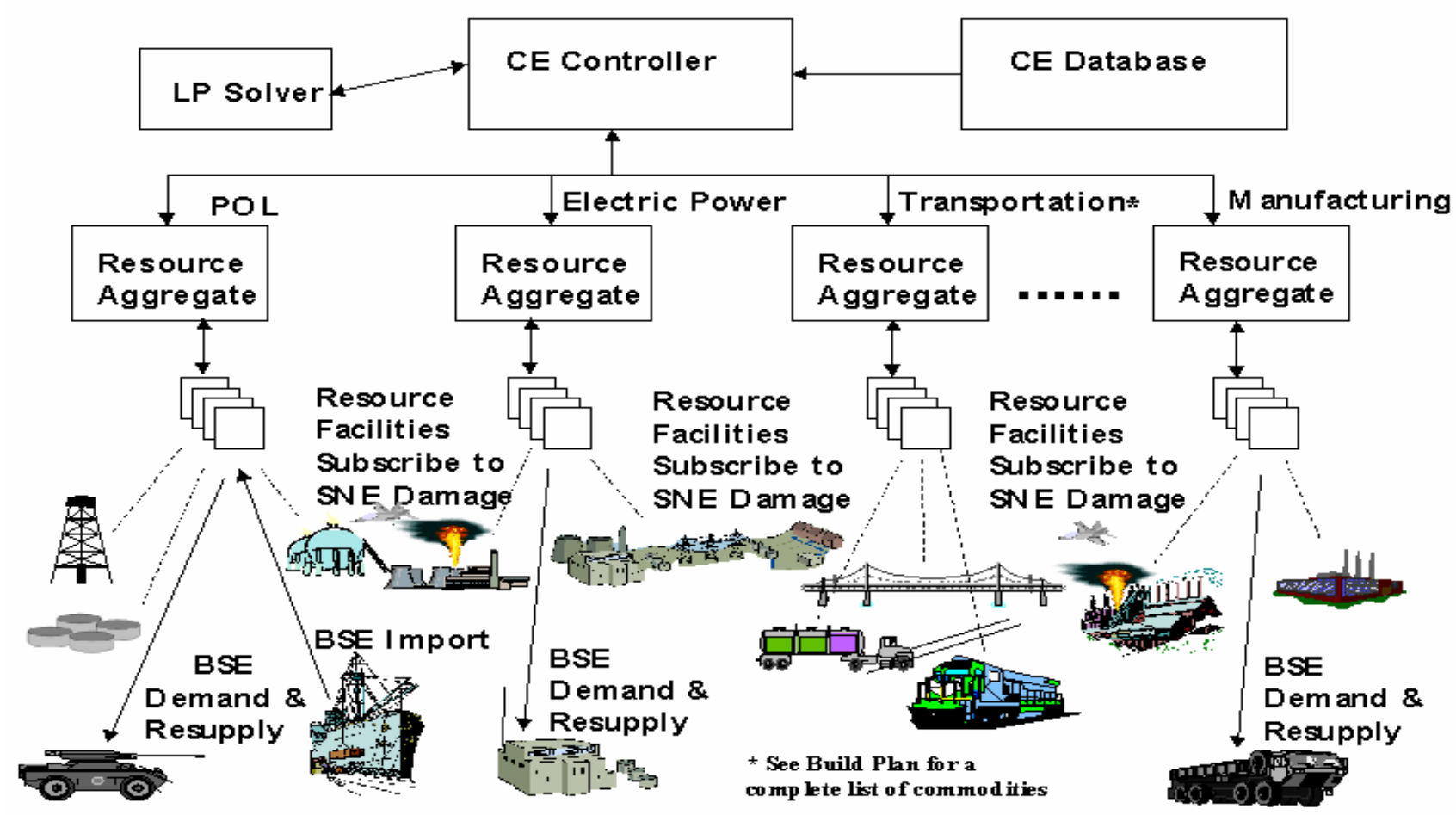
- **Timed Influence Net Modeling and Analysis tool**
- **Developed with support from ONR, AFOSR, and AFRL (and initially with support from AFIWC)**
- **Enables analysts to create executable (probabilistic) models that link potential actions (elements of a COA) to effects based on *knowledge* about the environment**
- **Captures the rationale for COAs that explain how actions can achieve effects**
  - **Given a set of actionable events, determine the Courses of Action that maximize the achievement of desired effects as a function of time**
- **Pythia 1.5 has been created in both a stand-alone and a server based versions**

- **Visual Studio .NET platform**
- **C# as the programming language.**
- **The front end of the tool is designed with the help of AddFlow™, a Commercial-Off-The-Shelf (COTS) API.**

The Civil Environment Model

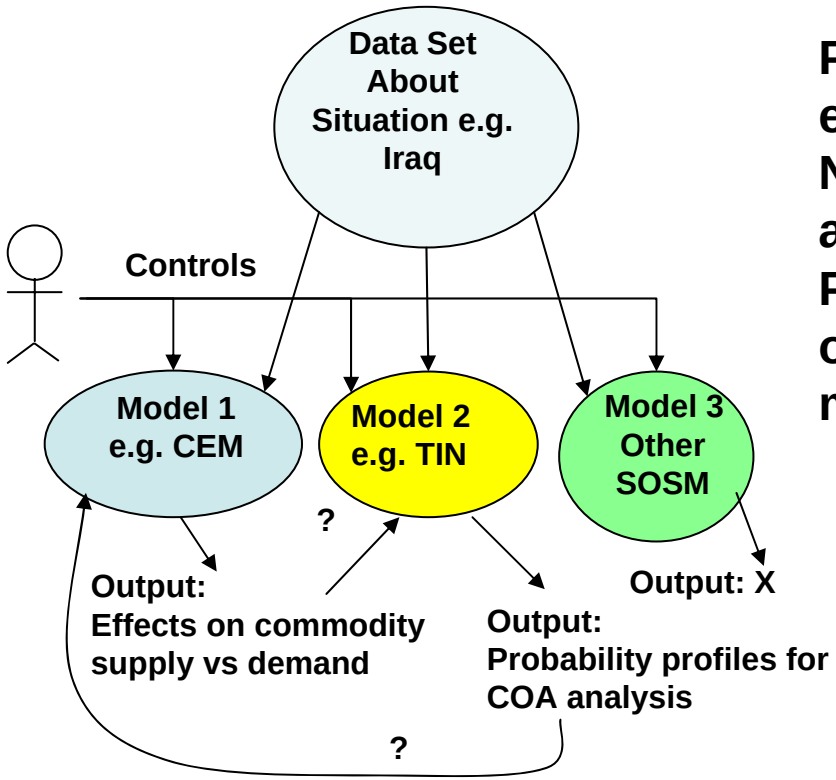
- Developed by Raytheon with support from the Air Force Electronic System Center
- An effects-based operations logistics commodities model that reflects a nation's ability to wage war based on damage effects to its civil infrastructure.
- Based on W. Leontief I/O Economic Model, a set of linear equations whose optimal solution expresses a balance between competing demands on an infrastructure.
  - Relates physical damage effects and repair capabilities
  - Models cascading effects
  - Monitors production, storage and transportation capabilities
  - Projects the long-term effects of damage and repair on a national level.
- CEM employs a ***large database*** that contains descriptions of the various commodity systems that make up the infrastructure in the area of operation. Its output is usually a large data set that shows the amount of ***production, storage, transport, and consumption*** for each commodity at each location as a function of time.

CEM Structure



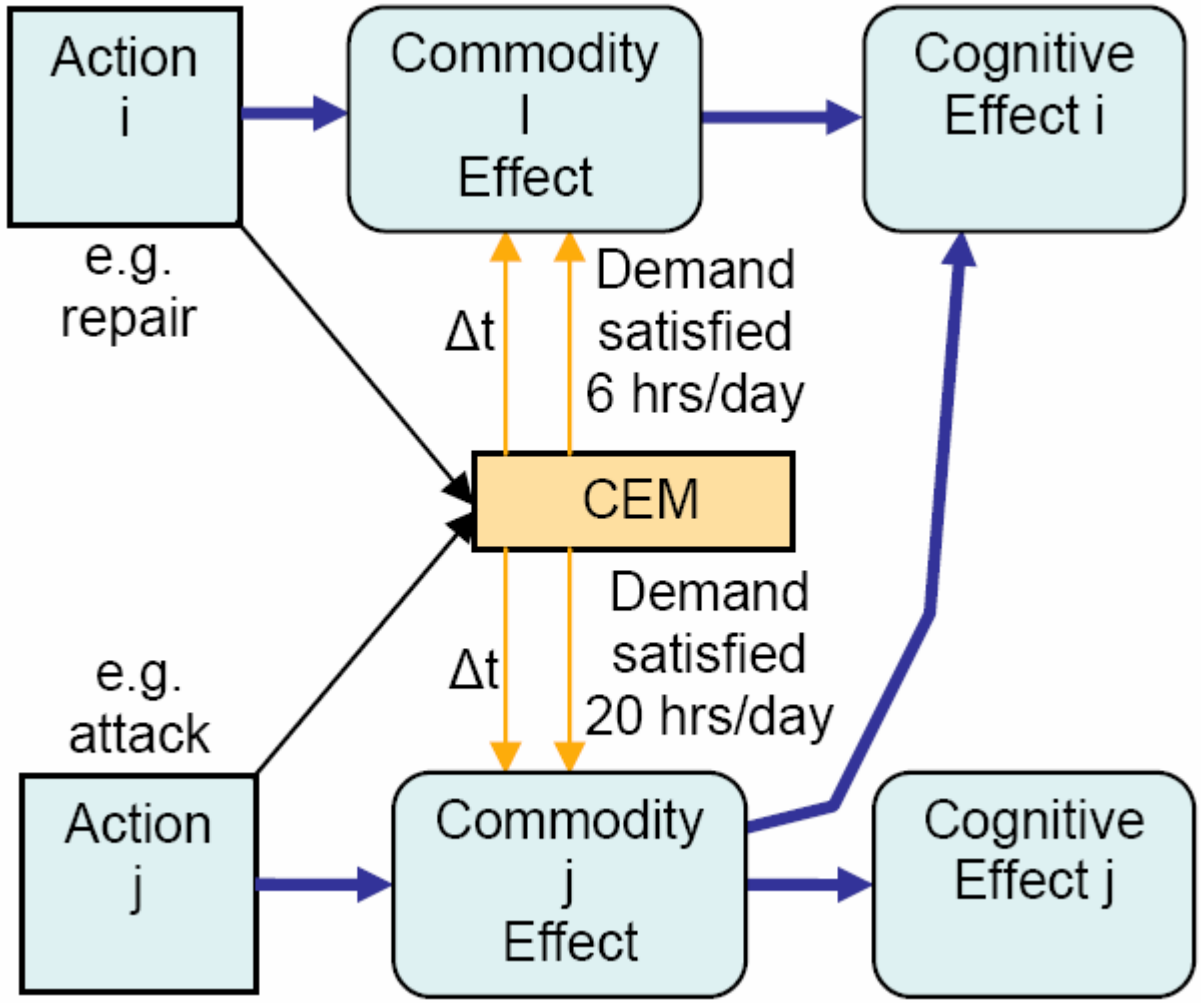
Experimental Design

- **The general problem being addressed is: Given a data set about a region or area of operation, how can a common data set be used in different types of models to synergistically analyze the situation and enable effects- based planning and assessment?**



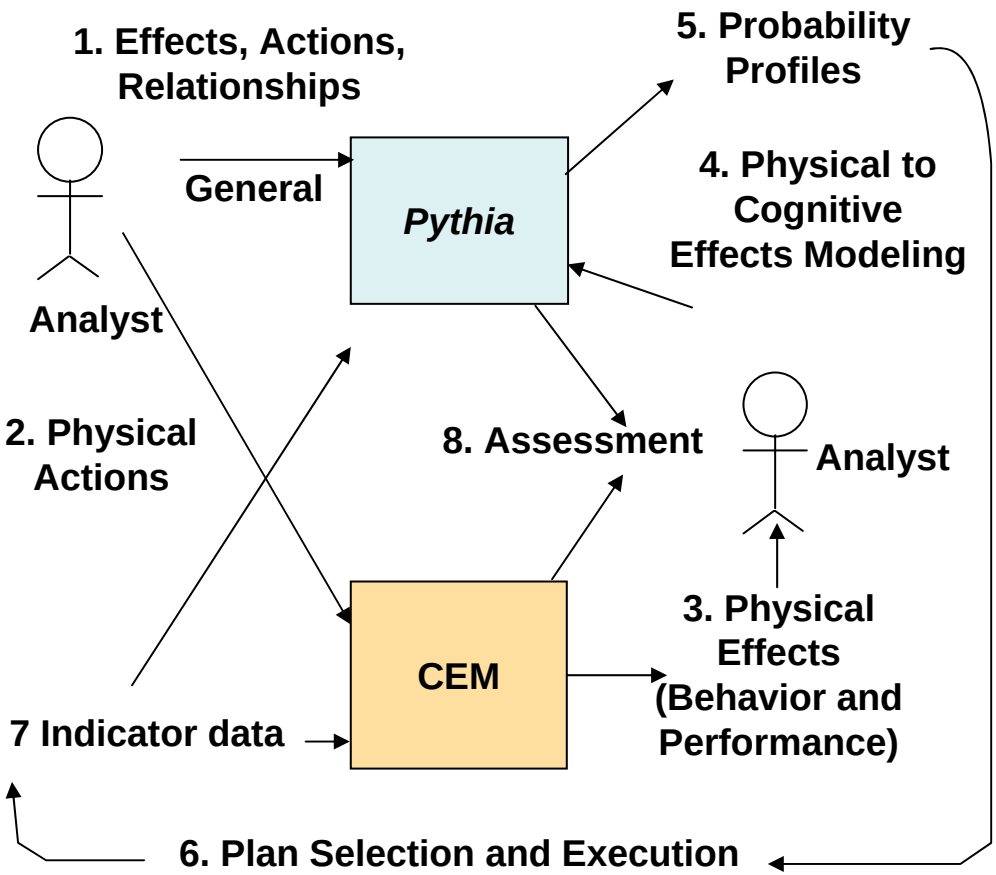
Proposition 1: It is possible to use elements of the *Pythia*/Time Influence Net (TIN) model in the set up and analysis of the CEM models
Proposition 2: It is possible to use outputs from a CEM model to refine TIN models

Postulated Relationships



- **Actions in TIN are incorporated in CEM**
- **CEM provides details of effects on commodities including temporal information**
- **Commodity effects are refined in TIN**

Experiment (Interoperation) Process



1. Analyst ***sketches out the TIN*** with effects, actions, relationships and potential observable indicators that effects have or have not occurred. Some actions and effects can be mapped to the CEM.
2. ***CEM analysis*** shows detailed physical effects on commodities from various actions.
3. The analyst "translates" physical effects from CEM to ***refine the TIN*** including adding time delays and possibly adjusting action to commodity influence strength values.
4. CEM analysis provides detailed ***description of physical effects*** on the infrastructure.
5. Analyst uses TIN to produce probability profiles, ***comparing COAs for selection.***

Step 1 Sketch on TIN

Coalition Actions

- Promote the Rule of Law and promote civil rights
- Establish national and local government structure with supporting police and judicial infrastructure to provide for personal security and a fair system of law and order to promote civil obedience and provide individual freedom of choice
- Existence of a supporting infrastructure of food, utilities (electricity, water and sanitation), housing and health services that promotes individual well being
- Development of an internal Iraqi economy that provides for generation of national revenue, functioning in-country industries and employment for its citizens

Iraqi Response

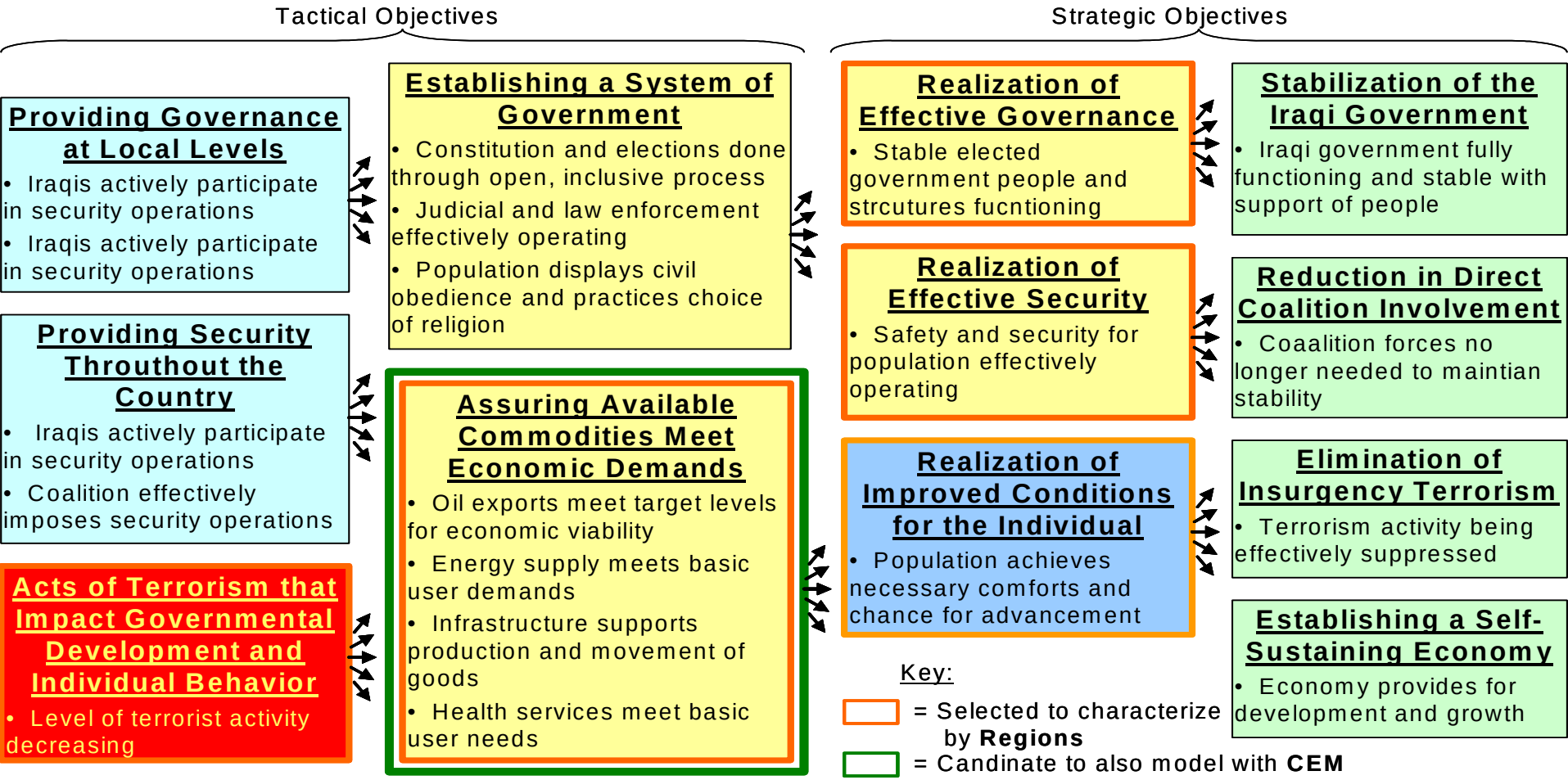
- Promote strategic communication promoting public understanding of coalition efforts and public isolation of the insurgents
- Transition to security self-reliance by the Iraqi government isolation of the insurgents
- Provide essential services to the Iraqi people

End-State Objectives

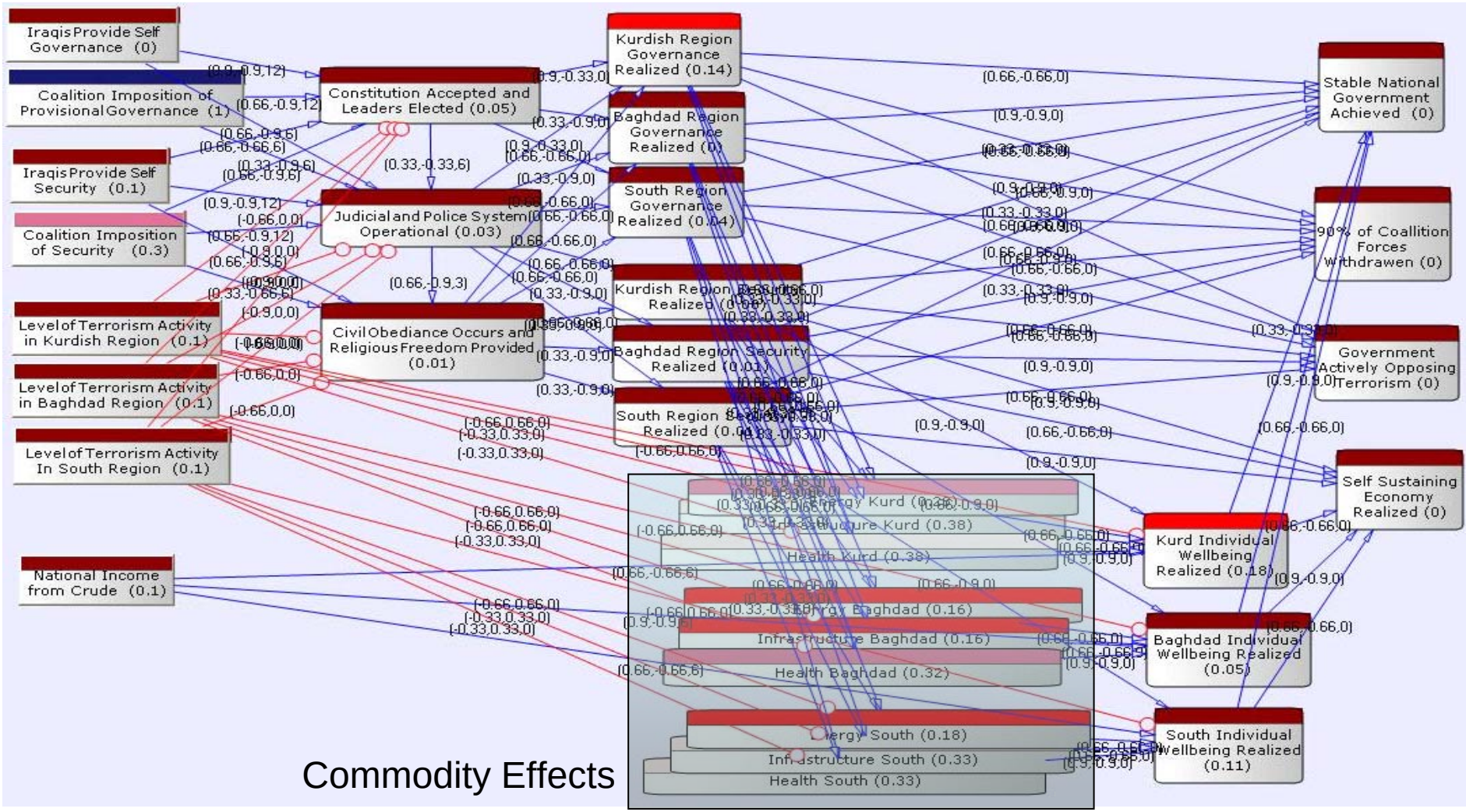
- Support the establishment of a free and democratic Iraq
- Maintain international engagement and increase support for a democratic Iraq
- Defeat the terrorists and neutralize the insurgents
- Establish the foundation for a strong economy

- **We started by capturing the behavioral aspects of the key pillars for mission completion and insurgency activities that can impact realization of these pillars**
- **These all fall into areas of action that the coalition (in support of Iraqi efforts) might take that, with the support of the Iraqi people, can realize desired endstate objectives.**

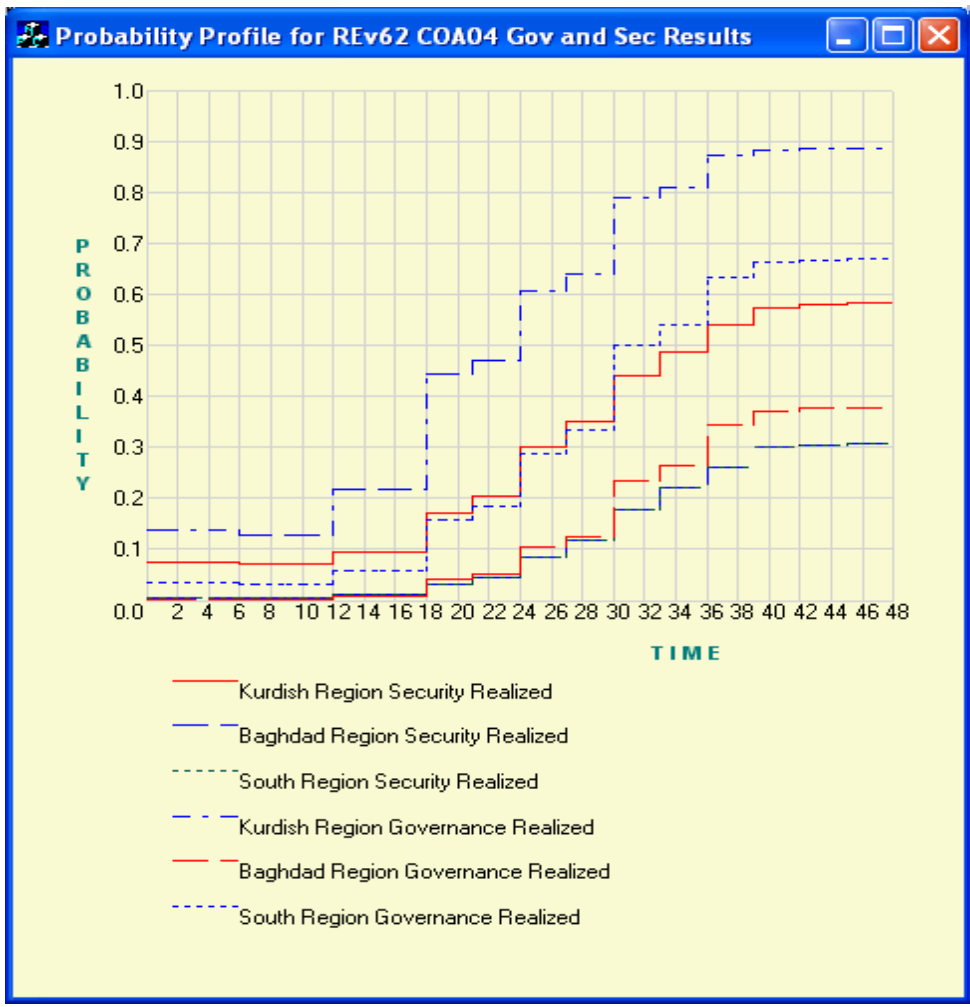
TIN Architecture

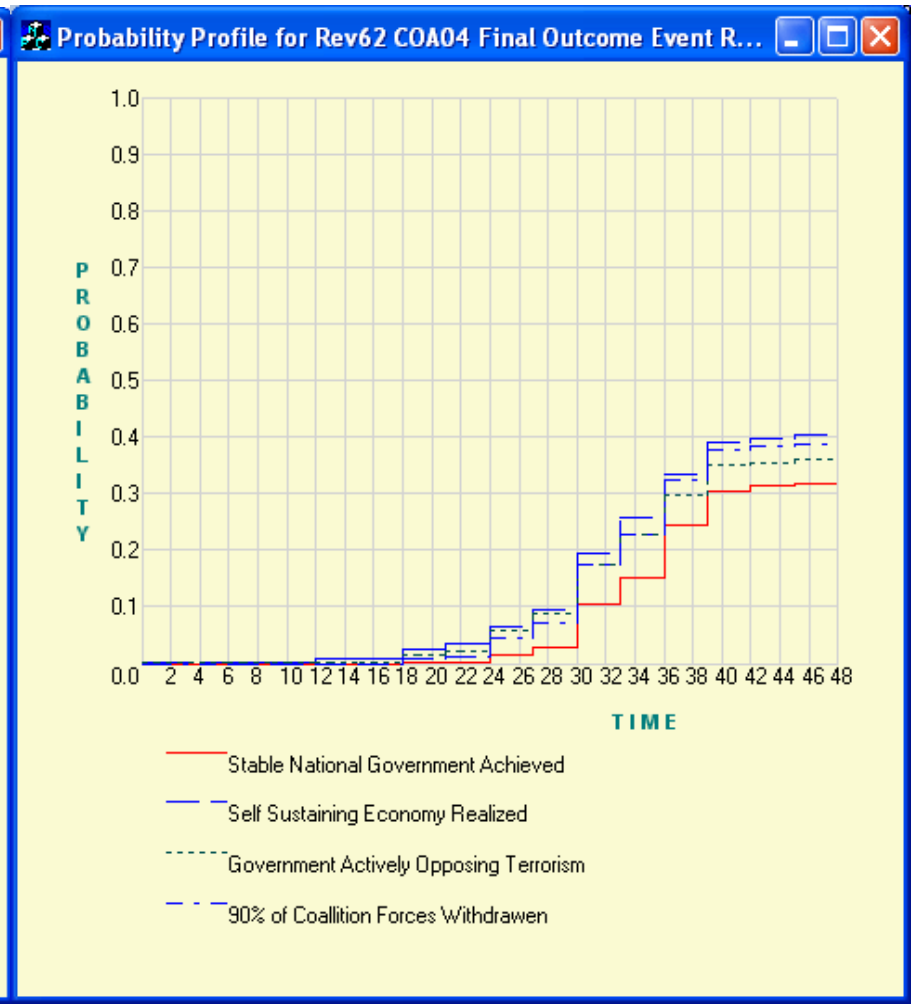


CASE STUDY TIN MODEL



Pythia Results





Security **End State**

CEM Model

- Same data set as was used to create the TIN model (open sources)
- CEM was tailored to produce the type of commodities that would have a direct influence on the attitude of the Iraqi individuals (also reflected in the TIN).
- The database for this study was configured to produce estimates of the 14 commodities

Commodity Name (14)

– CLT-Clothing	CMB-Comm_Broad	CMT-Comm_Tele
– CON-Construction Materials	CRD-Crude_Oil	ELE-Electric
– FOD-Food	MAN-Manufacturing	MCH-Machinery
– MED-Medical	PER-Personal	
– POL-Petroleum, Oil & Lubrications	RPT-Repair_Parts	WAT-Water

CEM computes the value of key parameter values at a function of time:

P: the amount of a commodity that entered a district from production

p: the amount of a commodity leaving a district to be used in production.

Z: the amount of a commodity remaining in stock after re-distribution.

C: the amount of consumption of a commodity in a district.

Interoperations

- **Tailoring CEM outputs to TIN was done by grouping Commodities into four consolidated categories**
- **The data was aggregated under those four categories by three regions, south, north, and Bagdad**

CEM Commodity	Consolidated Categories			
	Health	Energy	Infra-structure	National Income
CLT	x			
CMB			x	
CMT			x	
COM			x	
CRD				x
ELE		x		
FOD	x			
MAN			x	
MCH			x	
MED	x			
PER	x			
POL		x		
RPT			x	
WAT	x			

CEM Computed
Percent of Time Demand is Met

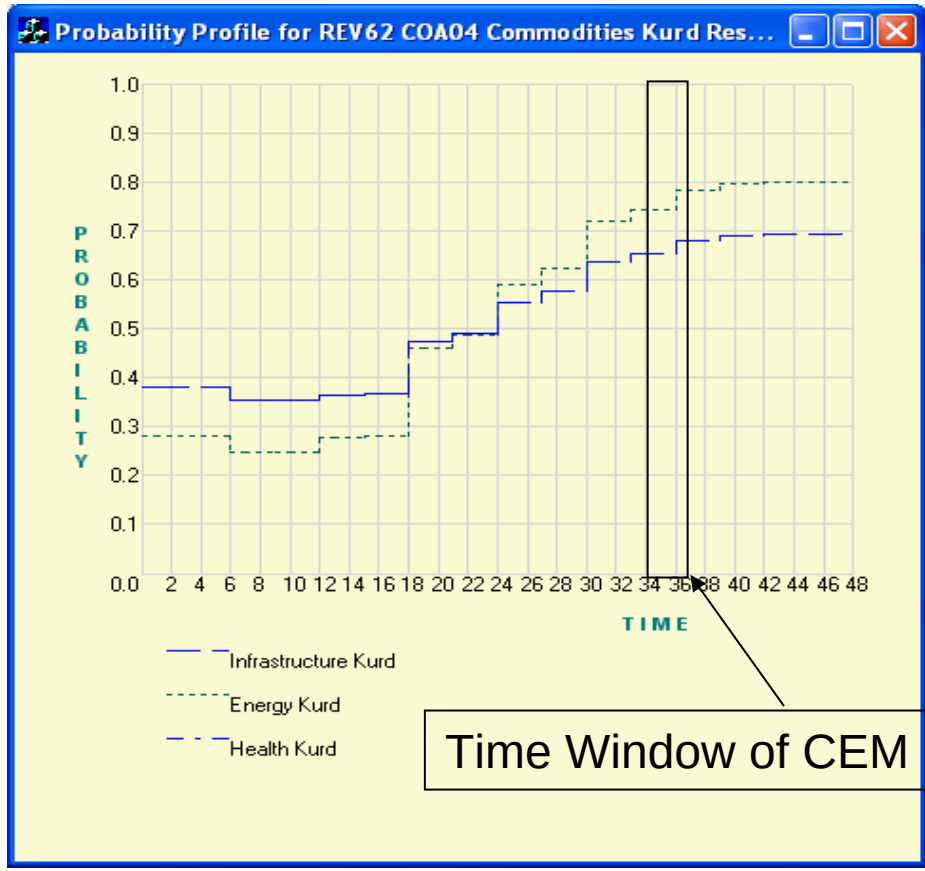
	South	Bagdad	Kurd (North)
Health	83	84	77
Energy	83	25	56
Infrastructure	75	71	70
Income	89	100	100

Interoperations

CEM Computed
Percent of Time Demand is Met

	South	Bagdad	Kurd (North)
Health	83	84	77
Energy	83	25	56
Infrastructure	75	71	70
Income	89	100	100

- **CEM was run for one 3 week period**
- **The CEM output had to be synchronized with the TIN input**



Comparison CEM and TIN Outputs

	South-CEM	South-*Pythia*	Bagdad-CEM	Bagdad-*Pythia*	Kurd (North) - CEM	Kurd (North) - *Pythia*
Health	83	0.5	84	0.4	77	0.7
Energy	83	0.6	25	0.3	56	0.8
Infrastructure	75	0.5	71	0.4	70	0.7
Income	89	0.7	100	0.7	100	0.7

- **The CEM, reflecting a more detailed analysis of the commodities, shows considerable differences with the results calculated by the original Pythia (TIN) model**
- **Pythia model needs to have the influencing parameters adjusted so that the Pythia model results more closely match those of the CEM**
- **More ambitiously it indicates that *it is possible to substitute the output of the CEM directly into the TIN* replacing the TIN commodity nodes with nodes that reflect the CEM output**

Summary of Experimental Results

		Human to Human	Data to Data	Model to Model
CEM to *Pythia*	Verified	Yes	Yes	Yes
	Comments	Structural Modifications and improvements to *Pythia* (grouping of commodities)	Verification of Probability Values Postulated Adjustments to g, h, and t values	Postulated CEM outputs directly feeding inputs to *Pythia*
Pythia to CEM	Verified	Yes	No	No
	Comments	Structural Modifications to CEM (Commodity Types, Repair or Damage Types)	Postulated Damage or Repair Levels (Probabilities) for multiple time periods	Significant interface issues yet to be explored.

- **Three types of interoperation were considered Human to Human, Data (from model A) to Data (for model B), and Model to Model (direct interconnection)**
- **The interactions are in two directions**
- **Human to Human was verified in both directions**
- **The CEM to Pythia direction was verified across all three types**
- **The TIN to CEM interface for Data to Data and Model to Model was not verified**

Conclusion

- Some promising insights were found into the possibility of obtaining better effects based analysis by employing various levels of interoperation between very different modeling techniques.
- The question of the feasibility of integrating the use of Effects Based Plans, represented as probabilistic models and including socio-cultural factors, and System of System models, which provide a physical quantification, has been explored in some detail through the conduct of a discovery experiment.
- Each of three levels of potential interoperation provided some perceived improvement to the collective analysis of the individual models.
- The increased value of creating interoperation between TIN and CEM models has been confirmed with increased confidence in the strategic TIN model (due to verification of probability values and timing) and improved focus for the CEM based on the strategic look of the TIN
- Following the process for interoperation, each model can better answer specific sets of questions of concern to the decision makers.
- Overall, this effort points to a more robust approach for conducting effects based operations in the 21st Century and illustrates the use of experimentation to explore and discover new approaches.