Synthetic Environment for Analysis and Simulation

Towards theory-based Synthetic Environment for Computational Experimentation

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I am believer!!

Most models are right!!

Data is not the problem!!

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AlJazeera.com, October 25, 2005

Baghdad hotel attack kills at least 17

Three bombers have staged a coordinated attack on a Baghdad hotel complex used by foreign journalists, killing at least 17 people and ending a lull in violence in front of the world's media. ... it exploded beside a US Bradley armoured vehicle on guard duty,....The explosions were captured in television footage by cameras trained on the area after the first blast and perfectly placed for subsequent detonations. … Two Sunni Arab provinces have returned resounding no votes on the charter

CNN.com October 24, 2005

Explosions rock central Baghdad, Police say 10 killed, 22 wounded in three blasts at sunset

BAGHDAD, Iraq (CNN) -- Three explosions near two hotels housing international journalists and contractors rocked Iraq's capital at sunset Monday, killing 10 people and wounding 22, Baghdad emergency police said.

Police said the three blasts were caused by suicide bombers using two car bombs and a cement truck, but journalists in one of the hotels said the first two explosions were rockets, followed by a car bomb. A statement from the coalition press office said the explosions were a combination of rockets and car bombs and that no coalition forces were injured.

FOXNews October 24, 2005

Journalists' Hotel Attacked in Iraq

BAGHDAD, Iraq — Three massive vehicle bombs exploded Monday near the Palestine Hotel (search), home to many Western journalists, killing at least 20 people. Dramatic TV pictures showed one of the bombers driving a cement truck through the concrete blast walls that guard the hotel, then blowing up his vehicle.

Iraq's national security adviser, Mouwafak al-Rubaie, said the attack — which appeared well-planned — was a "very clear" effort to take over the hotel and seize journalists as hostages.

…All three were believed to be suicide attacks.

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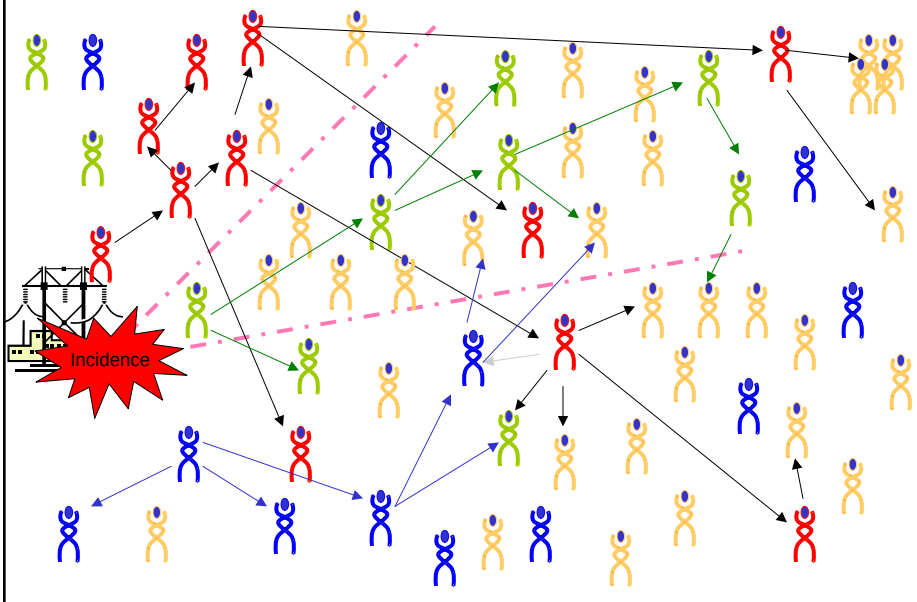

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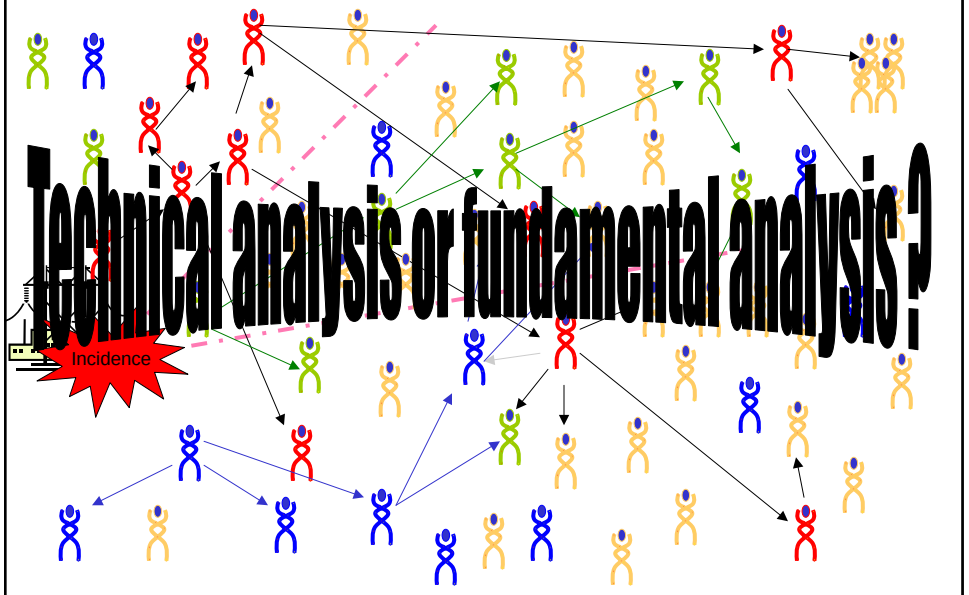

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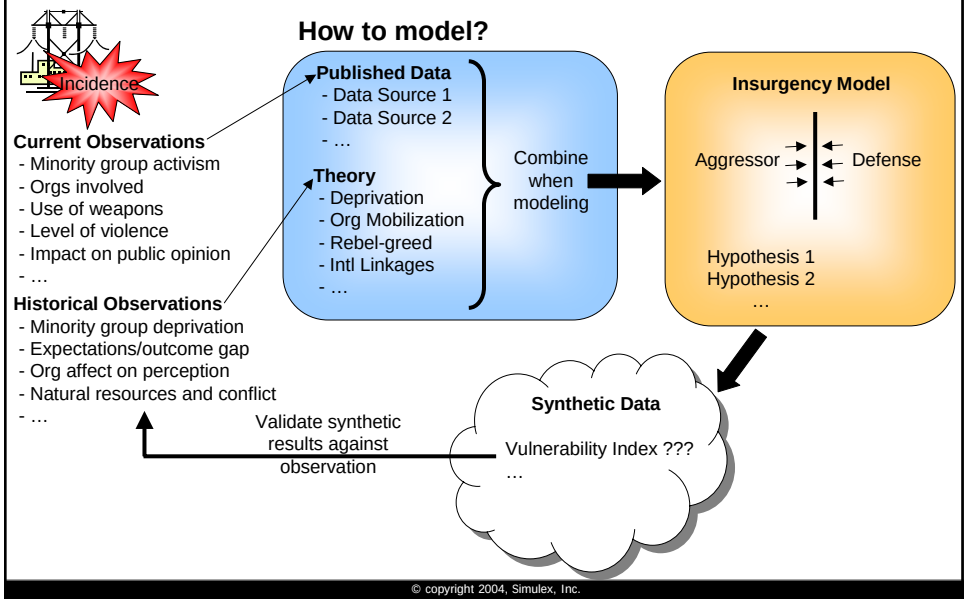
Modeling Approach (Insurgency Example)



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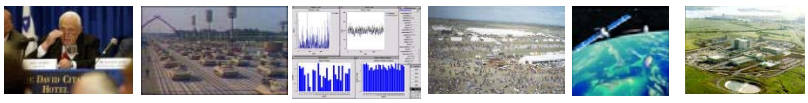
Macro to Micro Challenge

Reality

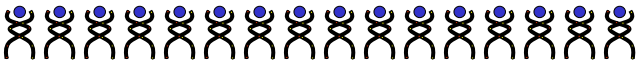


Diversity Gap

Using Macro Level Theories to simulate Micro Level behavior leads to a lack of richness in diversity

Experiment

System Level Observations



Micro Behaviors

Macro Theories

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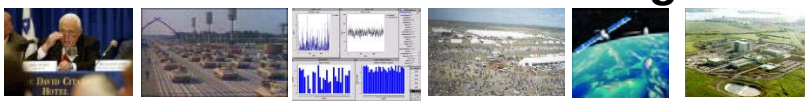
Micro to Macro Challenge

Experiment



Validation Gap

Using Micro Level Theories to make Macro Level observations leads to a gap in reality

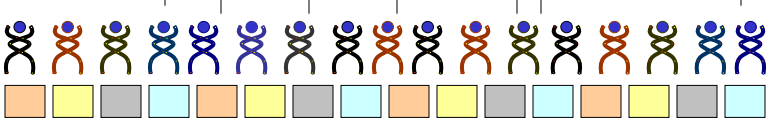
Reality

Macro Observation

Macro Observation

Macro Observation

Macro Observation



Micro Level Theories

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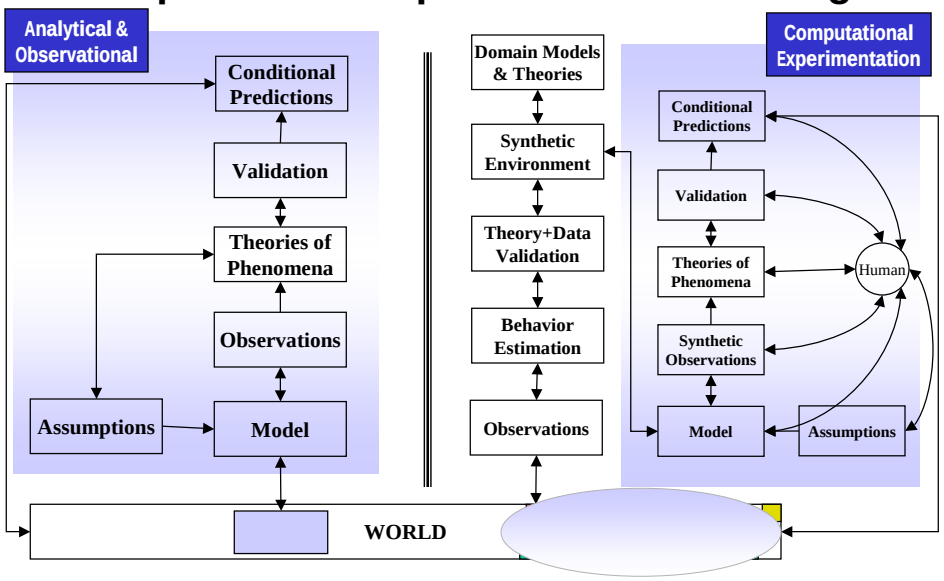
Computational Experimentation Paradigm



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Issues in Computational Experimentation..

- High fidelity computational experimentation requires deep understanding of:

  The underlying Science -- physical, social, computational, life sciences, humanities

  The computational models
  - Mathematical equations
  - Equation free
  - Differential equations vs Difference equations
  - Baseball or basketball

  Representation paradigms -- Common (?) Uniform (?) Diverse (?)

  Presentations -- digital art (?) semantics (?) ontology (?) storytelling (?) entertaining (appeals to emotions)

  Platform HPC (?) Peer-2-Peer (Xbox, PS 2/3, PDA)

  Business models (?)

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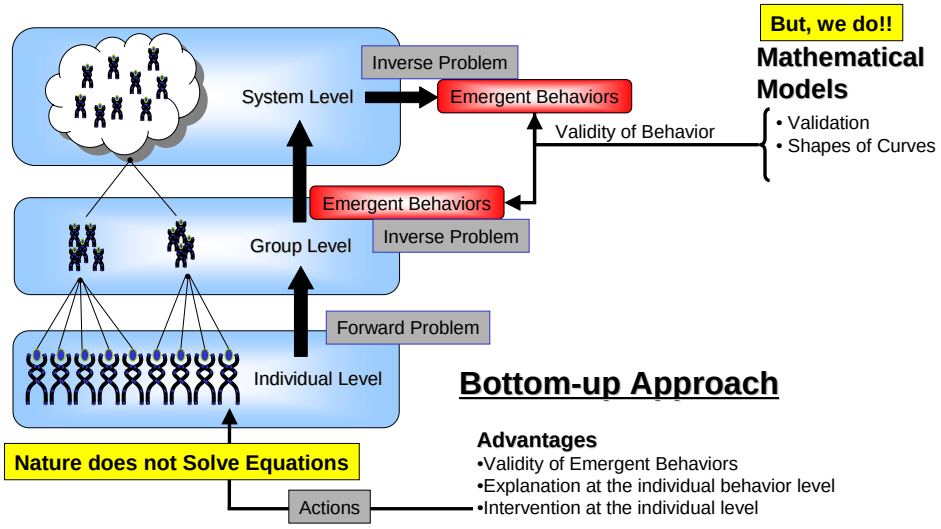
SEAS Modeling Approach



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It all starts with an Agent

- An agent is defined by its:

  Traits (demographics, nationalism, religion, etc.)
  - Social psychology

  Sensors -- through media, social groups
  - Communications

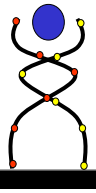
  Expectation and predisposition -- security, education, financial well-being, etc.
  - Hedonic psychology, economics

  Perception -- to evaluate sensed information
  - Psychology, economics

  Behaviors -- normal or transgressive
  - Sociology

  Feeling and emotions -- normal or aroused
  - Psychology

  Memory -- short term and long term
  - Computational neuroscience



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Well-being

- WB is the cognitive process of evaluation of an individuals life or with the experience of emotions
- Understanding the individual within her/his socio-environmental context
- It is an integrative theory of human functioning

Diener, Suh, Lucas, & Smith, 1999; Kahneman, Diener, & Schwarz, 1999

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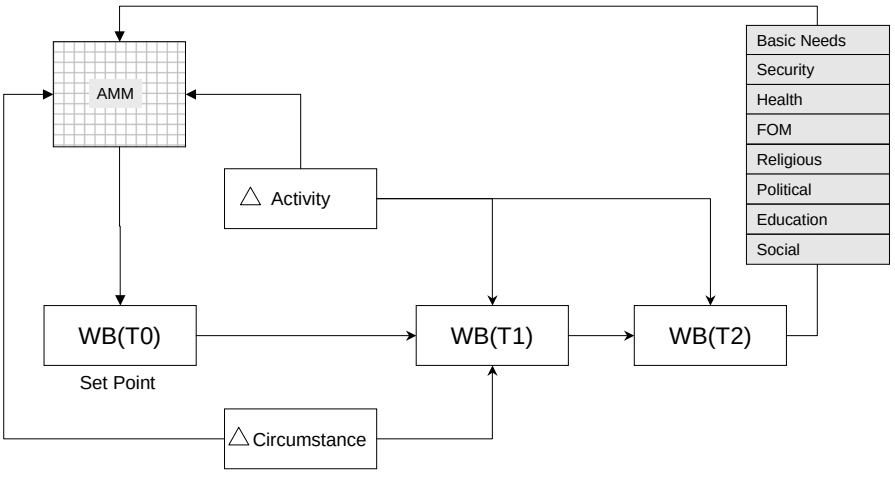
Maintained Changes in Well being



Sheldon and Lyubomirsky, in Positive Psychology in Practice, 2004

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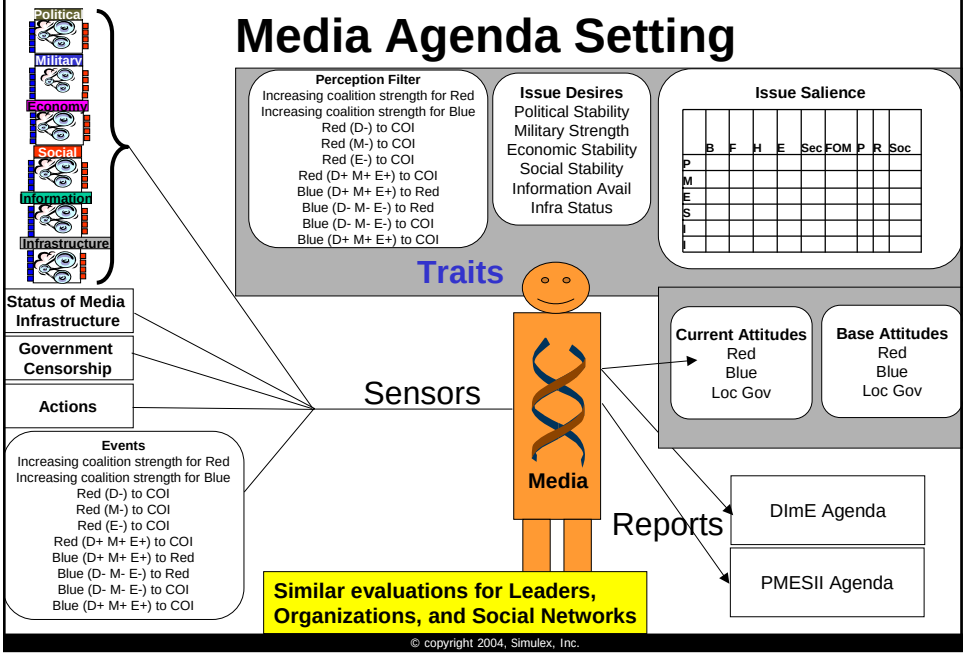
Media Agenda Setting



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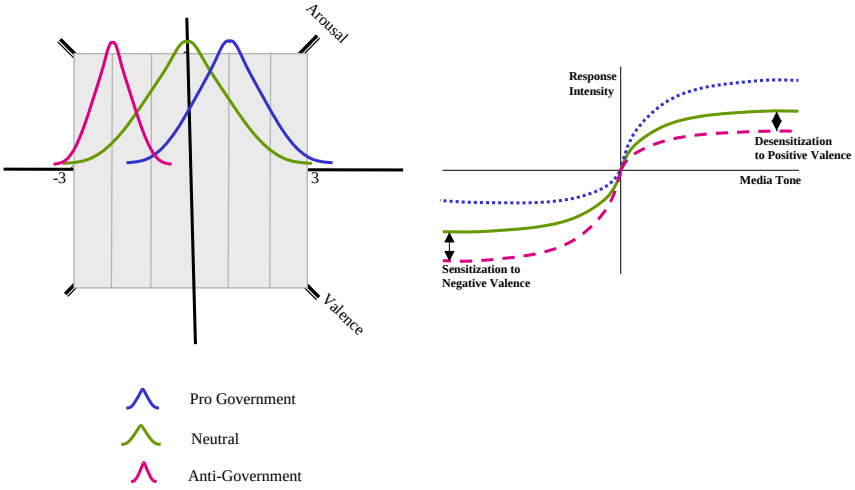
Media Effect on Emotions



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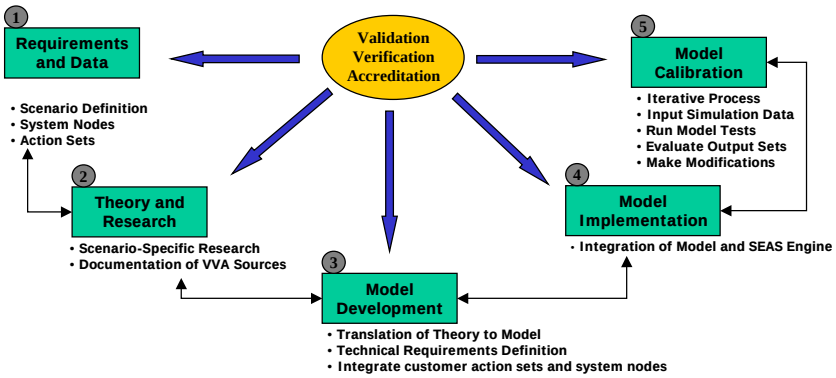
Model Development Process



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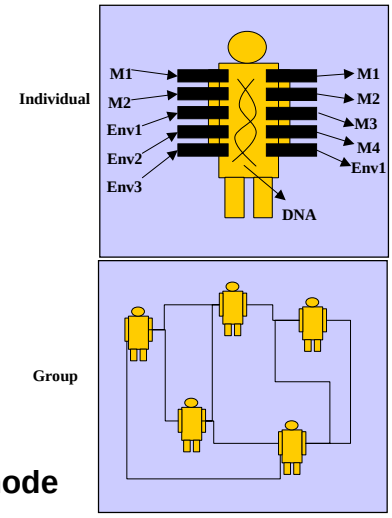
V&V Toolset – Model Bull Pen

- Place a model within a "canned" environment and test behavior
  - Test correctness of implementation (verification)
  - Ability to fix random seed
- Semantics are very important
  - Initial Conditions
  - Range of inputs
- Tools Required
  - Bull Pen configuration loader
  - Bull Pen driver
  - Data Collector
  - Data Visualizer
  - Statistical Analyzer



Analysis mode vs Wargame mode

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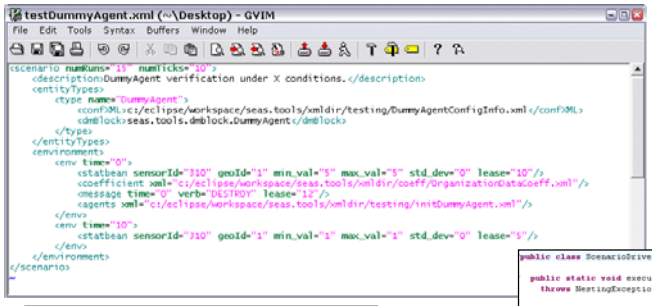
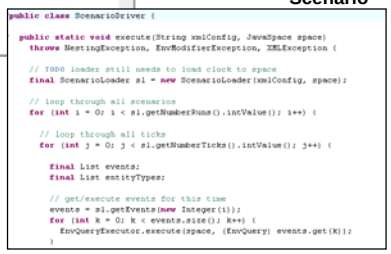
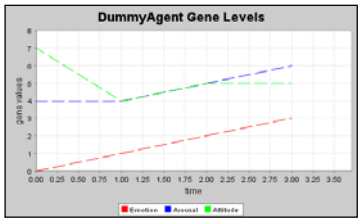
V&V Toolset – Model Bull Pen



Custom scenario parsed from XML and constructed in run-time

Driver runs Scenario





Visualize scenario outputs

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SEAS
VIS, NRT, and SimBridge

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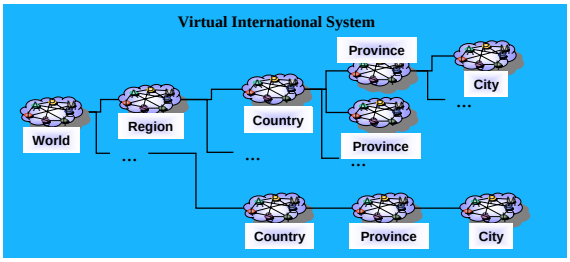
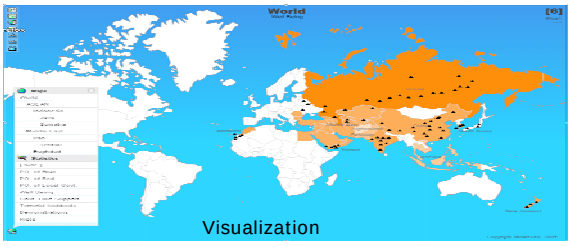
SEAS Virtual International System

Synthetic Environments for Analysis and Simulation (SEAS) is a Computational Experimentation Environment that is:

- Theoretically validated, behaviorally accurate, light weight virtual agents for detailed oriented behaviors
- Allows human in the loop experimentation for strategic interaction
- Detailed environment modeling for accurate interaction and situational context
- Emergent agent-environment interaction





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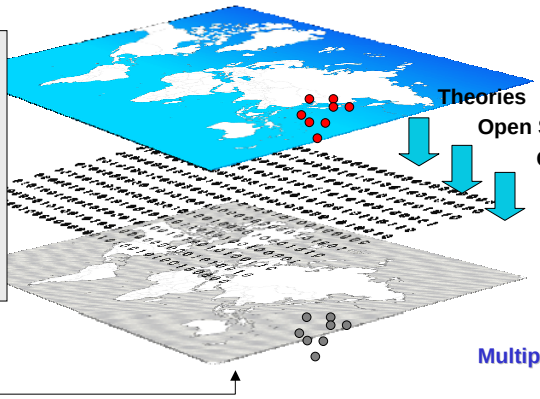
.. By creating a synthetic environment consisting of nodes* from the Real World ..

Nodes

- Citizen
- Organizations
- Institutions
- Infrastructure
- Media
- Governments



Theories

Open Source

Client's Databases:

- Historical
- Live
- Synthetic

Multiple Perspectives

***Any object of interest -- contains traits, behavior..**

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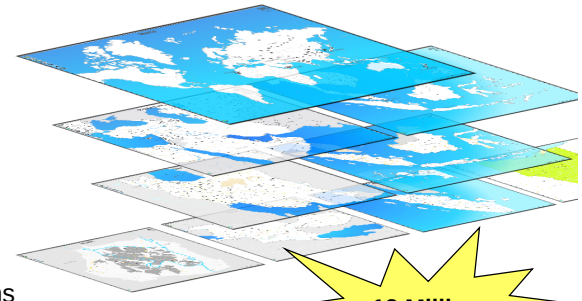
SEAS-VIS 2006 Capabilities

Multi-layer, Multi-Granularity, Effects Based

SEAS VIS is a representation of 40 countries with "validated" models (well accepted, published in peer-reviewed journals)

Represents
- Political Nodes
- Military Nodes
- Economic Nodes
- Social Nodes
- Information
- Infrastructure



- 100+ Named Organizations
- 150+ Named Leaders
- 1200+ Named Infrastructure Nodes
- 500+ Named media nodes

12 Million Active Agents

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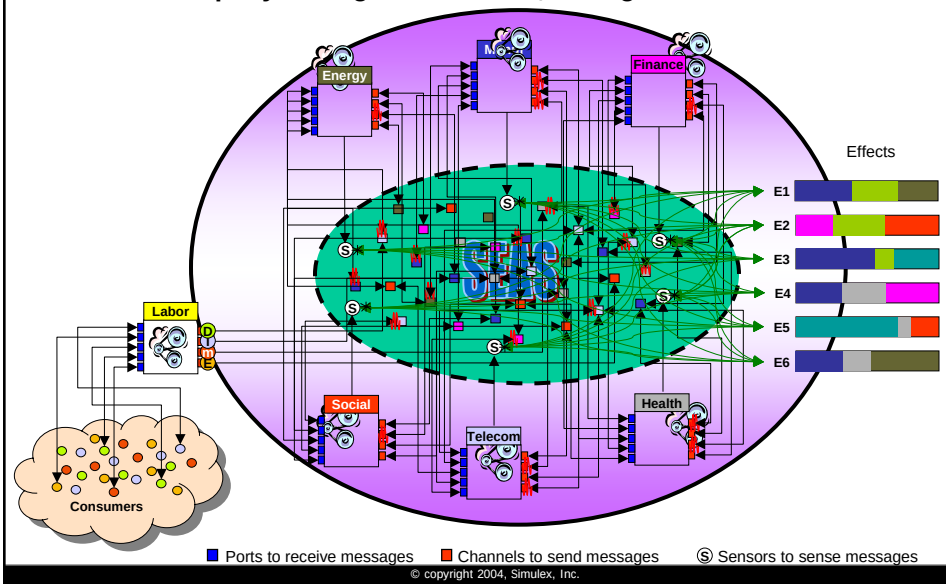
Rapidly Configurable Nodes, Emergent Network



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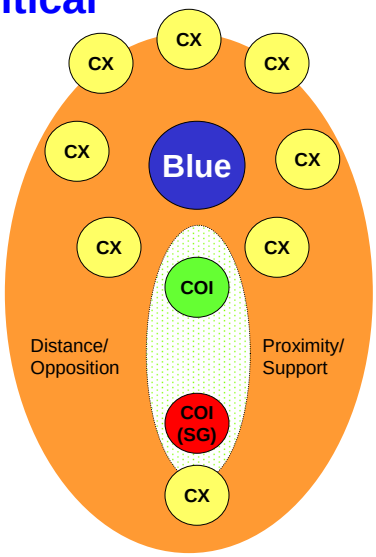
PMESII: Political

Highlights
- Individual objectives of entities
- Objectives are dynamic
- Objectives might converge or diverge as the scenario unfolds
- Emergence of various alliances based on objectives

Some Indicators
- Institutionalization
  - Regime durability
  - Fractionalization
  - Legitimacy
  - Bureaucratic quality
  - Regime's responsiveness
- Democratization
  - Political and civil liberties
  - Freedom of the press



SG: Secessionist Group

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PMESII: Political

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Some Indicators
- Dependence
- Border disputes
- Resource disputes
- Terrorism
- Trade restrictions

N-sided pre-conflict shaping
- Blue's Strategic Objective
  - Regional
    - Prevent destabilization of countries
  - Country of Interest
    - Prevent state failure
    - Prosecute GWOT
    - Prevent spread of WMD
- Green's Strategic Objectives
  - Maintain territorial Integrity
  - Restore order
  - Restore Effective Governance
- Red's Strategic Objectives
  - Gain popular support
  - Gain international recognition
- CX and Organization Objectives
- Individual Objectives

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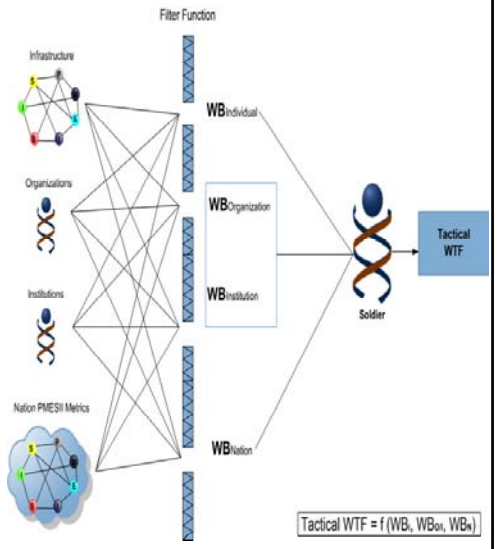
PMESII: Military

Highlights

- Military Institutions, Leaders and Infrastructure as distinct entities
- Soldiers and other combatants as extension to citizens
- Strategic Will to Fight modeled at Institution Level
- Operation Will to Fight modeled at Organization Level
- Tactical Will to Fight modeled at Soldier Level

Some Indicators

- Degree of political control over military organizations
- Nature of populations support for the military factions
- Scope of violence against the civilian population



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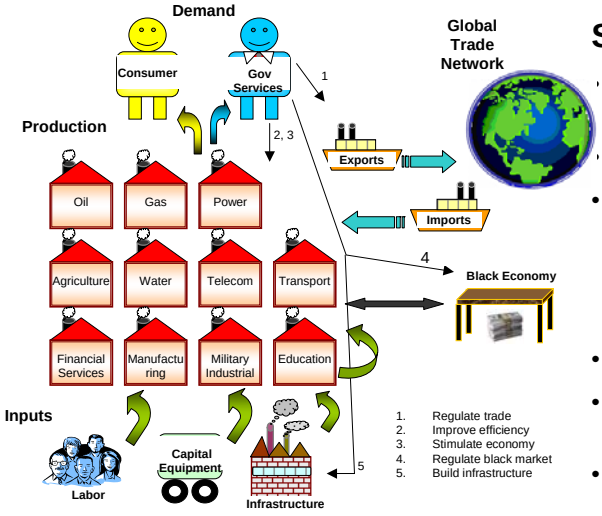
PMESII: Economy/Infrastructure



The new SEAS-VIS synthetic economy

Salient Features:

- Conformity with economic theory
- Demand driven
- Bilateral trade
  - Close/open economy
  - Greater international dependence
- Black market effects
- Greater government influence
- Realistic monetary values for all components
- Adaptive and emergent

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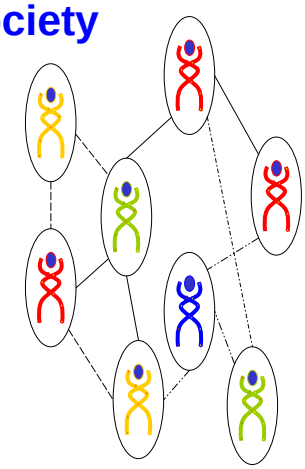
PMESII: Society

Highlights
- Emergent social networks
  - Religious, Ethnic and other
  - Strength of each network changes
  - Networks are information sources
- Social and Religious Organizations
- Ethnic and Religious Unrest
- Terrorism Propagation

Some Indicators
- Wealth distribution
- Ethnic Identity
- Extremism
- Xenophobia
- Nationalism
- Terrorism



Multiple Emergent Social Networks

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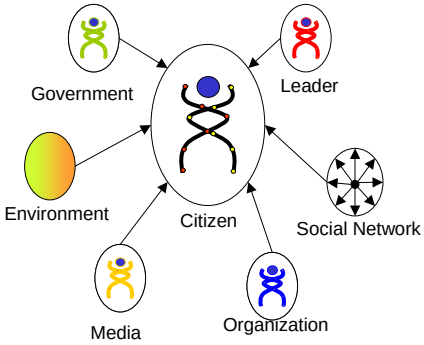
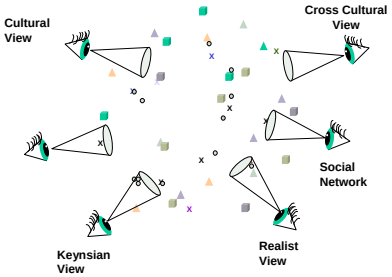
PMESII: Information

Multiple Sources of Information
- Organizations
- Media
- Social Network
- Leaders
- Direct sensing





Perception and Agenda Setting
- Entities perceives information based on certain preconceptions
- Entities report information in the agenda setting model based on individual objectives

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Courses of Action Analysis

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Effects Based Operation

E Observe the achievement level of each Effect over the past 10 days

N Select node to act upon to increase the achievement of an effect

A Select one or more actions to impose on the node to achieve this effect

R Set the amount of resources to utilize for this action over 10 day period

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Effects Based Plan

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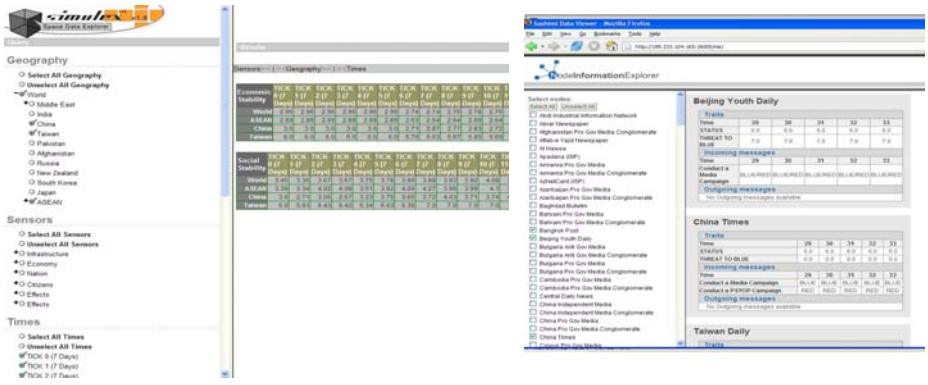
Online Analysis Tools



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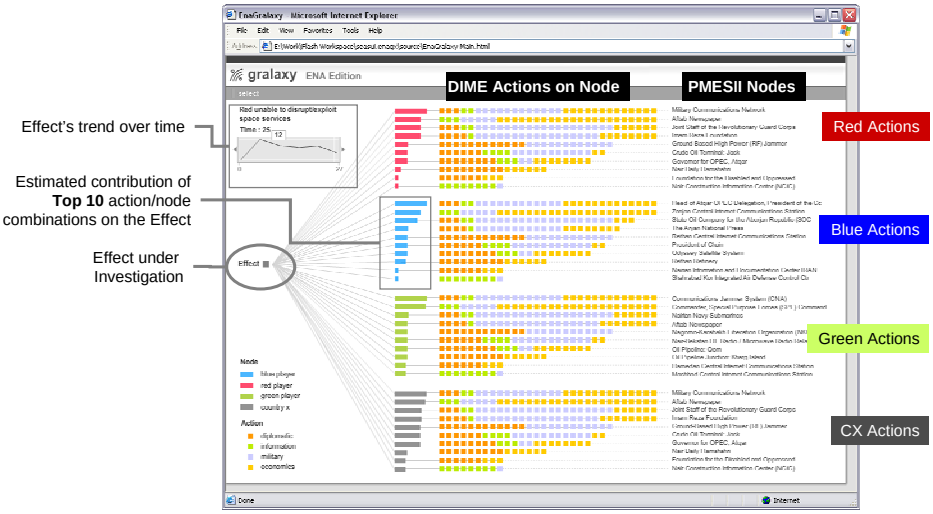
Dynamic Ontology Development - N-sided view



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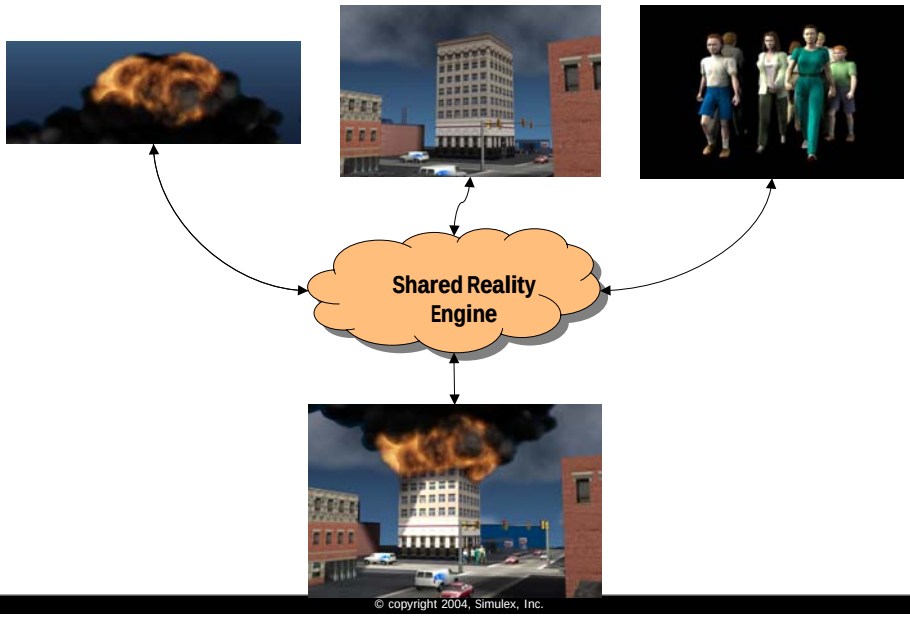
Shared Reality Model



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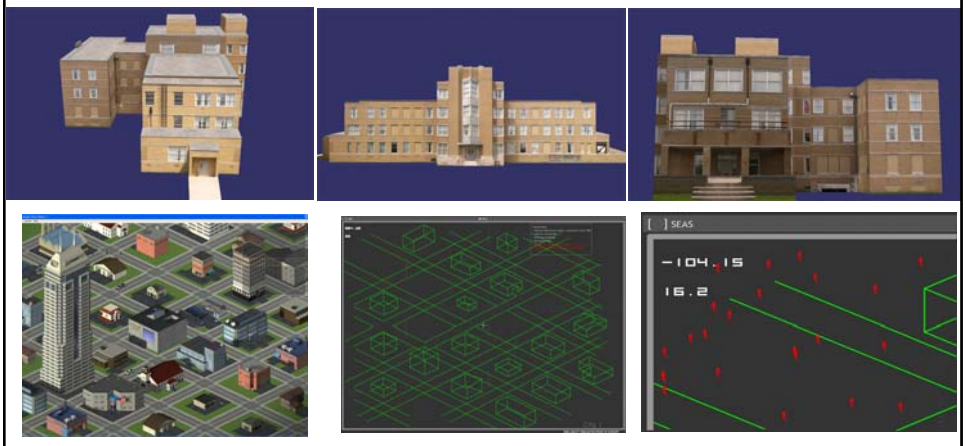
3-D models for buildings and City blocks



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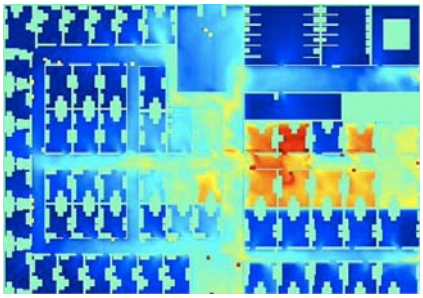
Developing algorithms for agents to navigate through building and city blocks

A* Algorithm



Artificial Physics Algorithm

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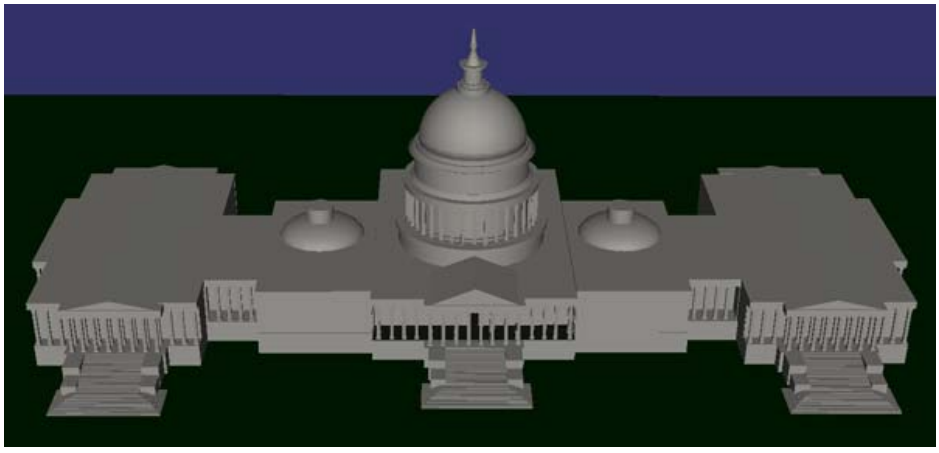
Capitol Building Evacuation



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Capitol Building Evacuation

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Mixed Reality
for Concept
Development,
Testing,Training --
Real Muscatatuck
Building virtual placed
On Purdue Campus

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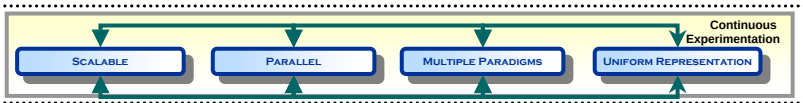
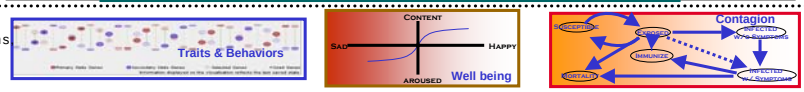
SEAS-VIS Architecture

Web-based Collaborative Modeling Tools

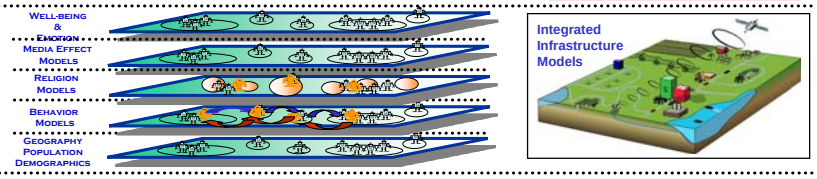
Gaming, Simulation, & Experimentation Framework



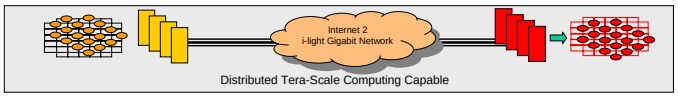
Agents' Traits, Emotions & Contagion Models



Population & Infrastructure Models



Computational Models -- Palm top to Teraflop



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Geography

Indonesia: 10 regions

Citizens:	473500
Named Leaders:	9
Named Orgs:	9
Named Media:	9
Specific Sectors:	140
Specific Infrastructure:	406
Total Agents:	**474073**

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Theories: Can we observe them?

- Deprivation Theory: examines the range of discriminations and disparities that is experienced by minority groups as contributing factors of rebellion inequity (Gurr 1970, 2000; Schmid 1983; Harmon 2000; Krueger and Maleckova 2002; Duckitt et al. 2002; Post, Sprinzak and Denny 2003; Besancon 2005)
- Rebel-Resource Theory: states that depended extensively on natural resources for capital generations were more prone to civil violence (Collier and Hoeffler 2004; Fearon 2004; Weinstein 2005; Regan and Norton 2005; Humphreys 2005; Lujala et al. 2005)
- Organizational Mobilization Theory: action and activism is a result of the mobilizational capacity of groups and organizations. (Tilly 1978; Tarrow 1994; Lichbach 1998).

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Data Source (examples)

- **Groups and Conflict**
  - http://www.tkb.org/Category.jsp?catID=1
  - http://garnet.acns.fsu.edu/~whmoore/M@R.HTM
  - http://edition.cnn.com/2001/WORLD/asiapcf/southeast/12/04/indonesia.unrest/index.html?related
  - http://edition.cnn.com/2002/WORLD/asiapcf/southeast/01/15/indonesia.irianjaya/index.html?related
  - http://news.bbc.co.uk/2/hi/asia-pacific/3391689.stm
  - http://news.bbc.co.uk/1/hi/world/asia-pacific/1937049.stm
  - http://news.bbc.co.uk/1/hi/world/asia-pacific/1847071.stm
  - http://news.bbc.co.uk/1/hi/world/asia-pacific/1820462.stm
  - http://news.bbc.co.uk/2/hi/asia-pacific/3815909.stm
  - http://www.internationalviewpoint.org/article.php3?id_article=327
- **Political Systems/ Regime Type**
  - Polity IV data set
    http://garnet.acns.fsu.edu/~phensel/itlpoli.html#regime
- **Political and Civil Liberties**
  - Freedom of the Press 2005: Draft Country Reports
  - www.freedomhouse.org
- **Ethinc, Linguistic, and Religious Minorities**
  - http://garnet.acns.fsu.edu/~phensel/data.html
  - Minorities at Risk
  - http://garnet.acns.fsu.edu/~whmoore/M@R.HTM
  - http://www.joshuaproject.net/peopctry.php

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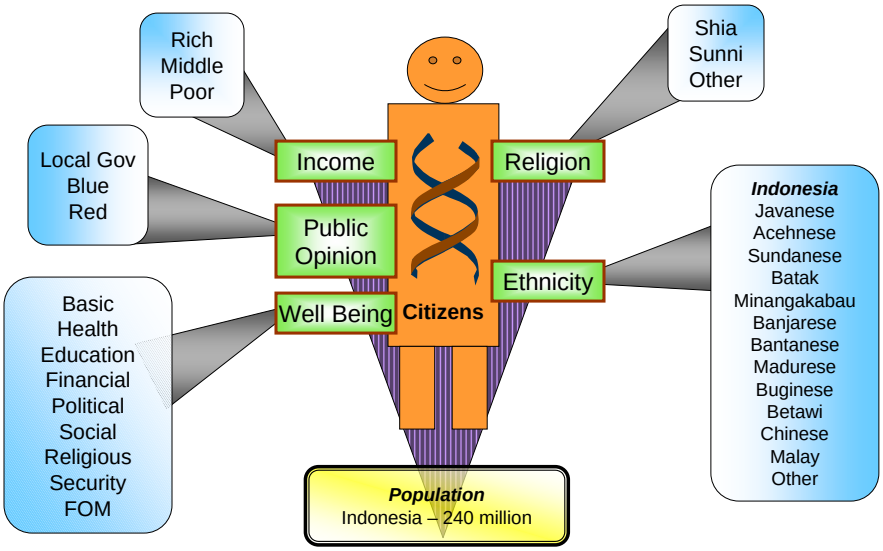
Demographics



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"Named" Leaders/Organizations

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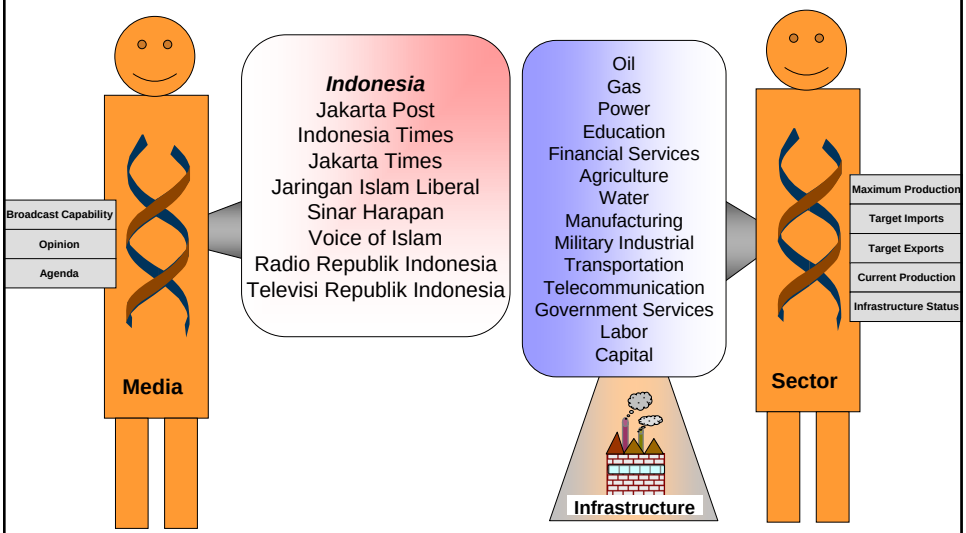
Media/Economic Sectors



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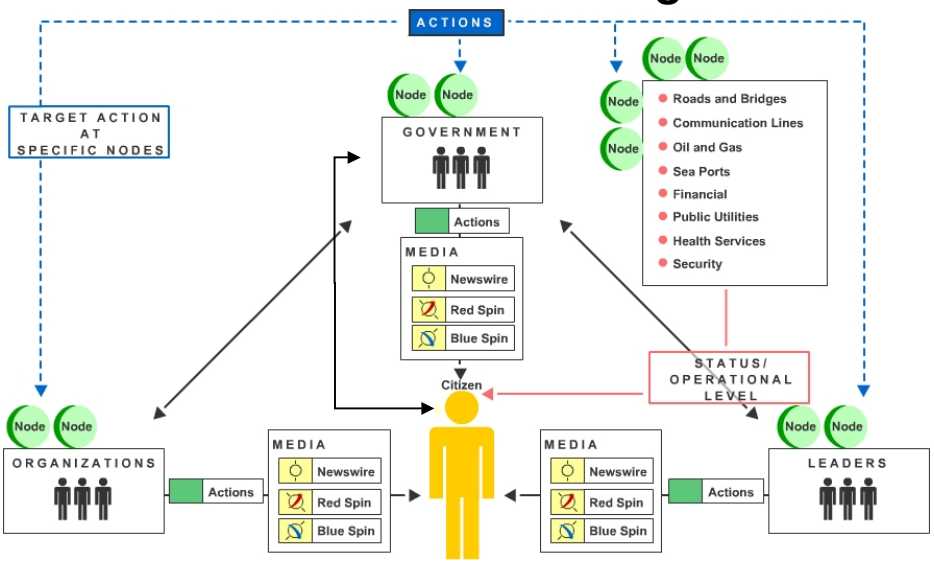
Schematic of a VIS Configuration



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Insurgency Indicator

- Insurgency Indicator, **S** = total number of **mobilized** citizens/total population
- Intention to Rebel, **I** = f {grievance, risk propensity}
- Grievance, **G** = f {subjective well-being; legitimacy}
- Subjective Well-being, **W** = f {basic needs, political needs, financial needs, security needs, religious needs, educational needs, health needs, and freedom of movement needs}
- Legitimacy, **L** = f {Government actions; media, organization & leader attitudes}
- Risk Propensity, **R** = f {media, organization & leader actions}

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Scenario

A. Pre-Tsunami: Calibrate experimental scenario for Aceh, Indonesia
   - pre-existing active secessionist movement led by GAM and its leader Hasan Di Tiro

B. Immediate aftermath of Tsunami: Insert our best approximation of response to the calamity by the local government and the international community

C. Post-Tsunami Recovery: Local Government and International Aid

D. Intermediate aftermath of Tsunami: Indonesian Government actions

E. Local Government permits greater freedom to citizen and media while interdicting organizations

F. Prediction of the outcome of government policies on insurgency indicator.

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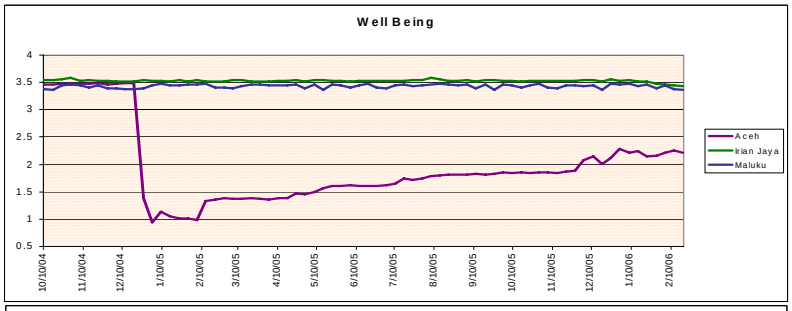

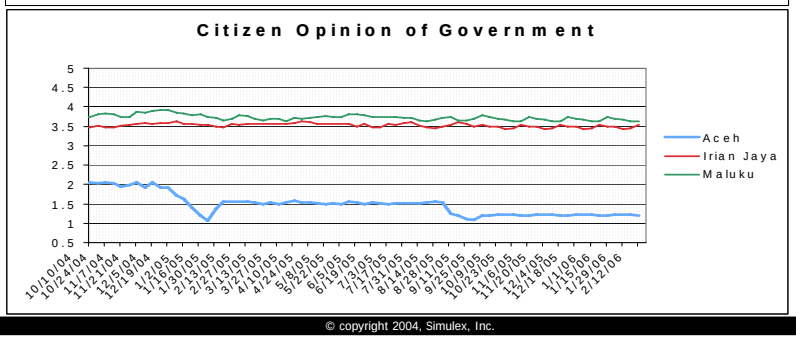

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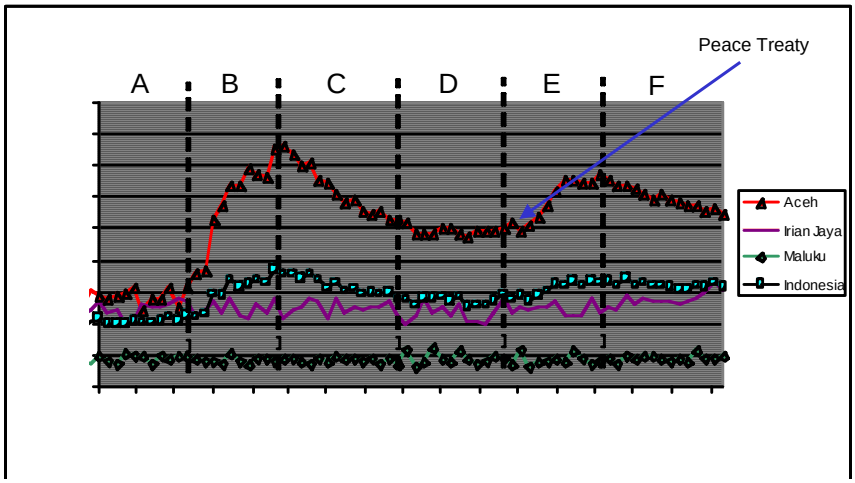
Insurgency Indicator



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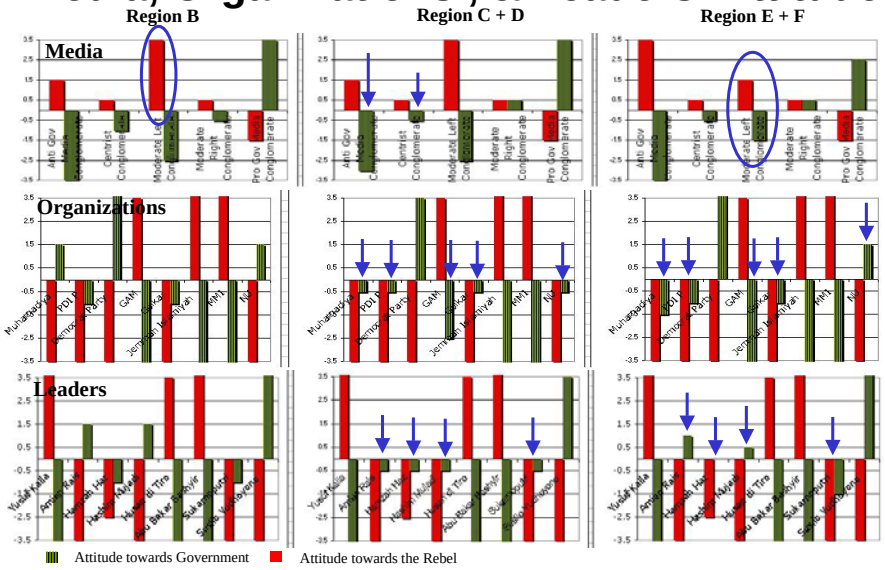
Media, Organizations', & Leaders' Attitude



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SEAS Summary

- Robust, scalable, extensible engine to support a variety of experimentation domains
- Persistent experimentation environment
- Repository of organizational memories through play books
- Plurality of thoughts
- An approach to bridge micro-macro divide
- Complete transparency of data, algorithms, and assumptions
- User configurable and extensible
- Multiple courses of action analysis with time travel capability

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