Agent-Based Computer Simulation for Operational Risk Analysis

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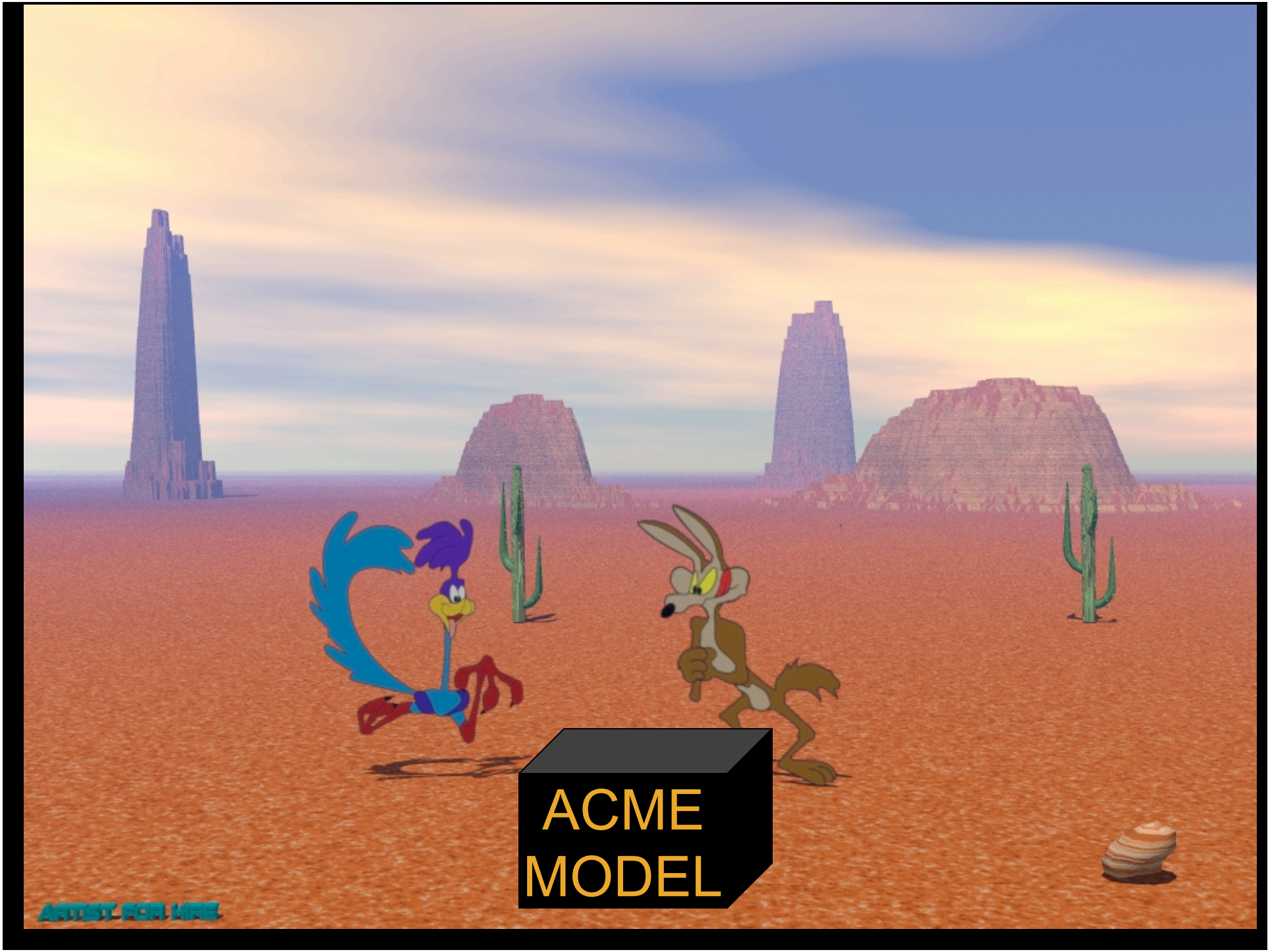
Outline

- Agent-Based Social Simulations
- Examples of these methods in real-world OpRisk modeling
- Pros and cons of Agent-Based Simulation
- New Directions… Eclipse Modeling Project, AMP-Agent Modeling Platform

Areas where I have applied Agent Simulation (last 12 years)

- Agent Based Modeling of OpRisk
  - National Banks, Energy Sector, Fortune 100 Corporations
- Intelligence Analysis and Policy Analysis
  - Simulate the dynamics of radicalized group formation
  - Simulation of Pashtun cultural norms mixing with Islamist extremists (Taliban and Pashtun)
  - Opium economic analysis in Afghanistan and Pakistan
- Challenging Neo-Classical Economic Theory with Agent Simulation
  - Implementing standard theory in agent simulation


ACME
MODEL
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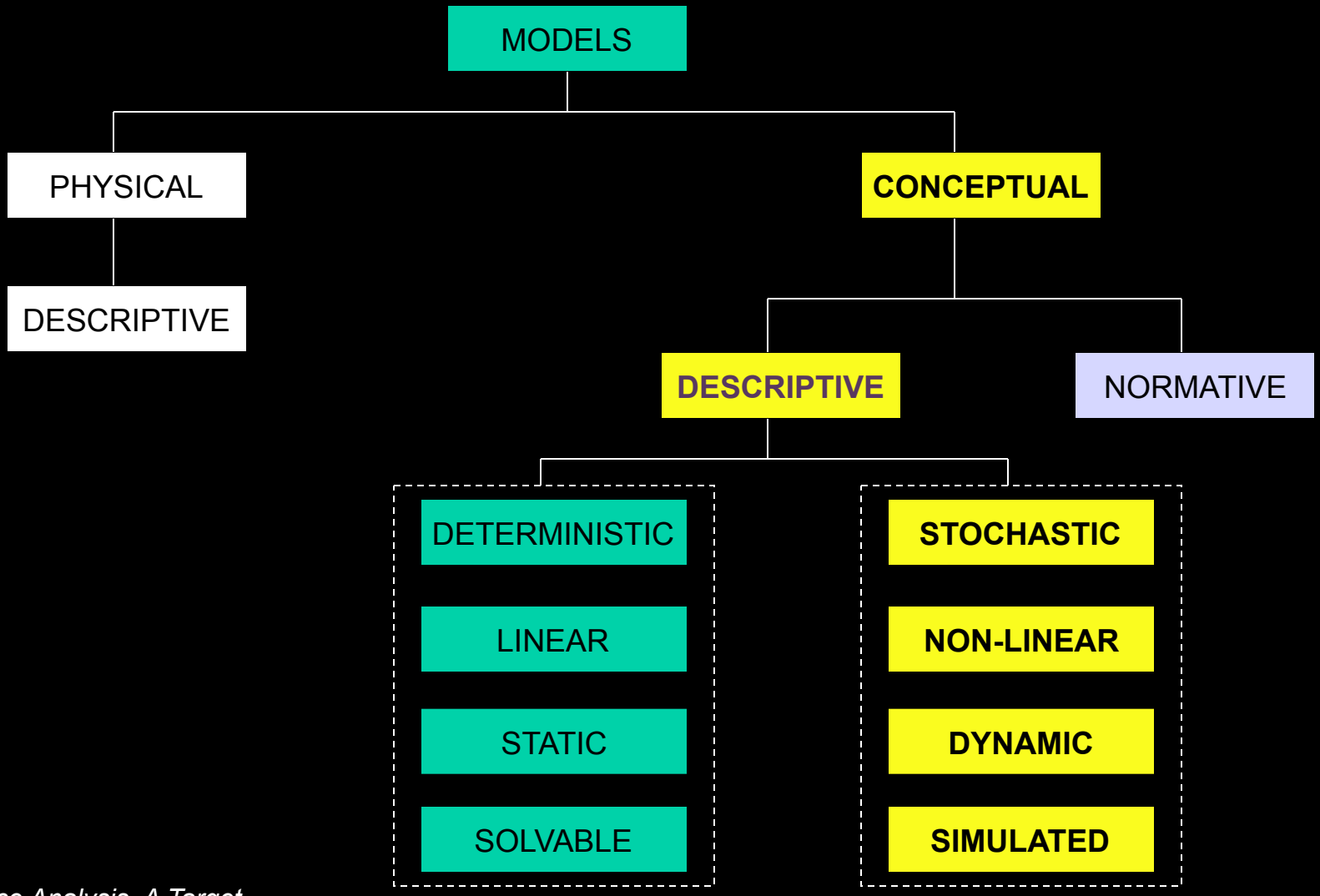
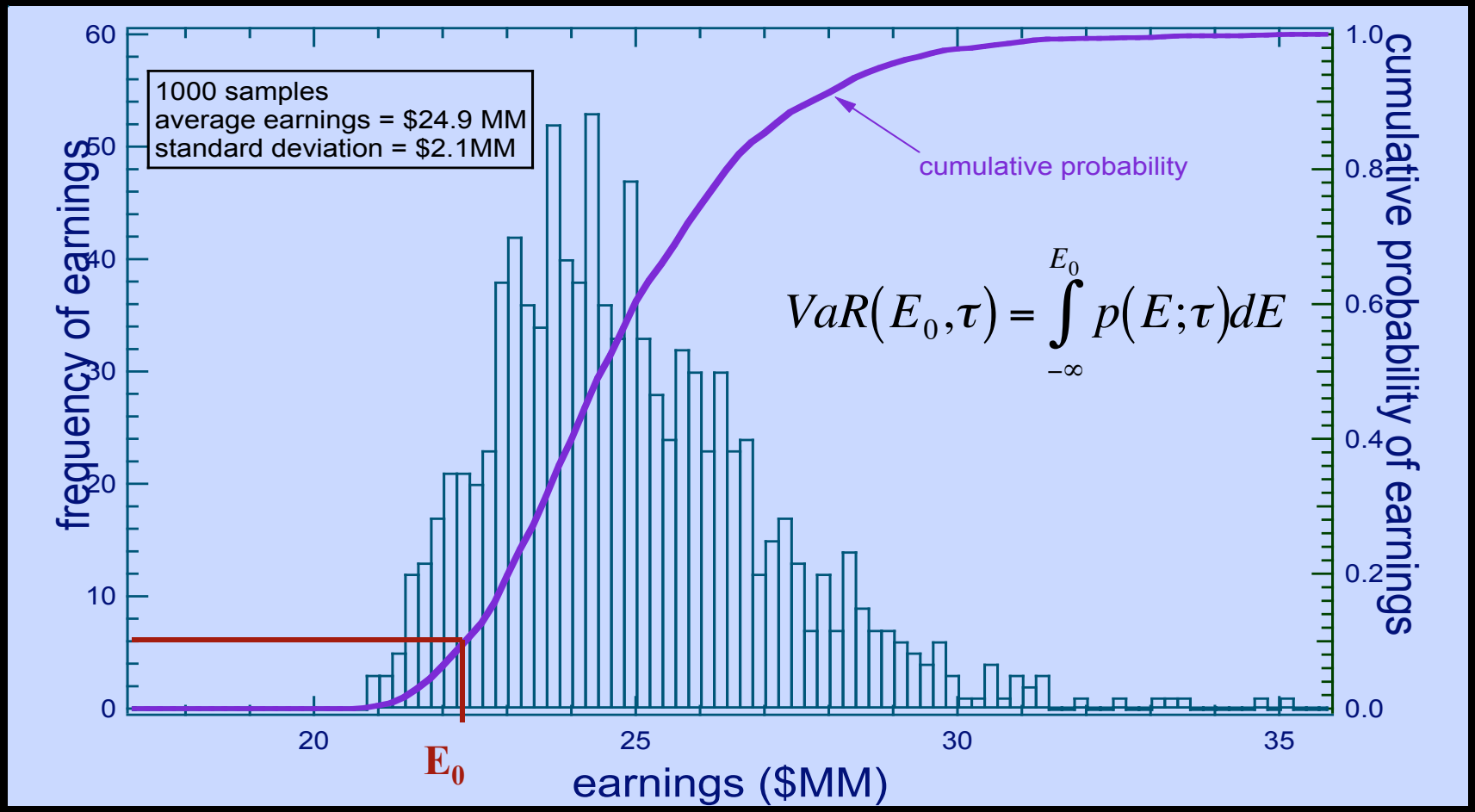
Models and Policy Analysis

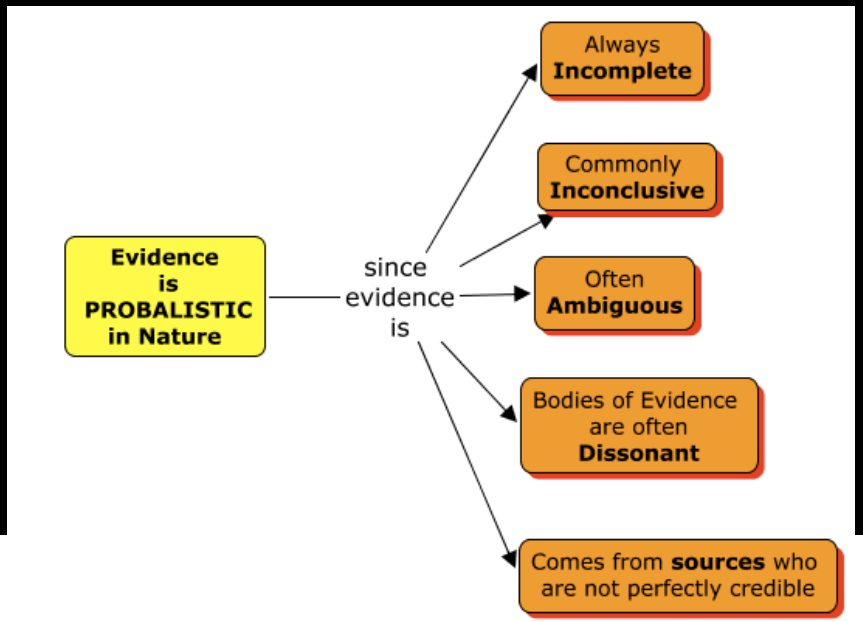


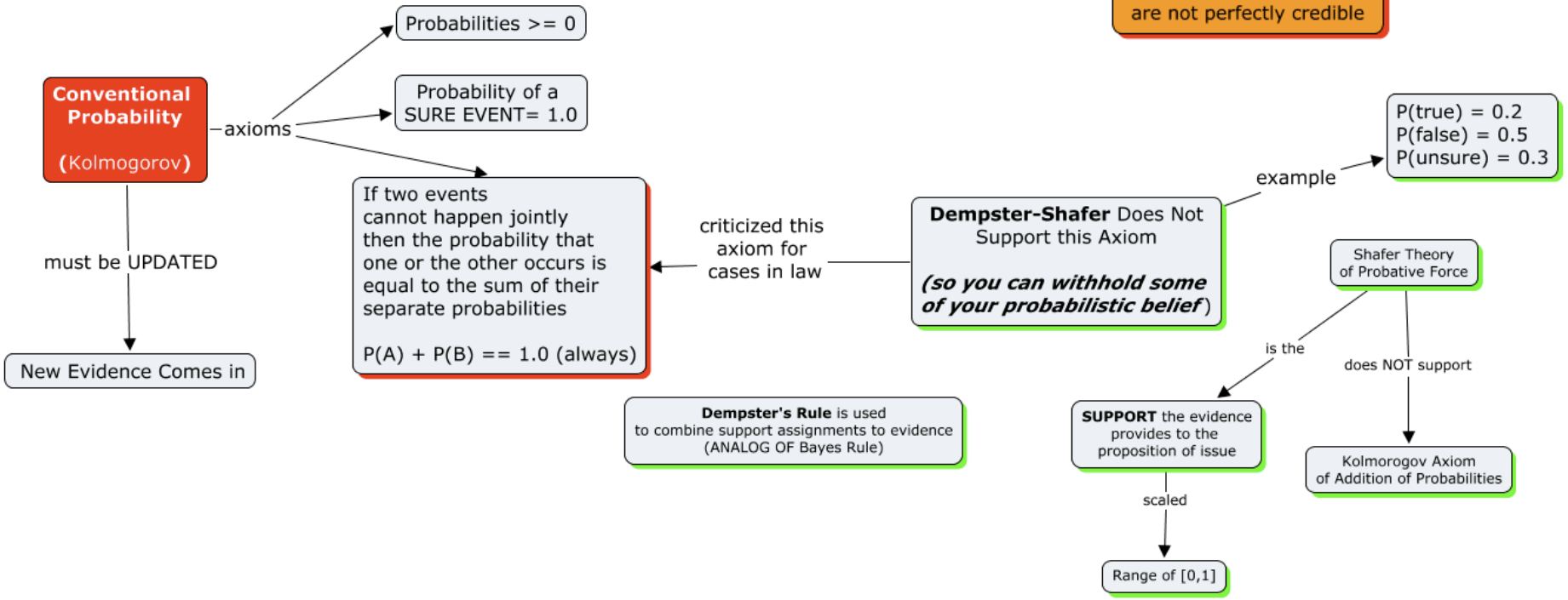
From "*Intelligence Analysis, A Target Centric Approach*", Robert M. Clark, 2004

The Cornerstone of Risk Management is the Distribution of Earnings

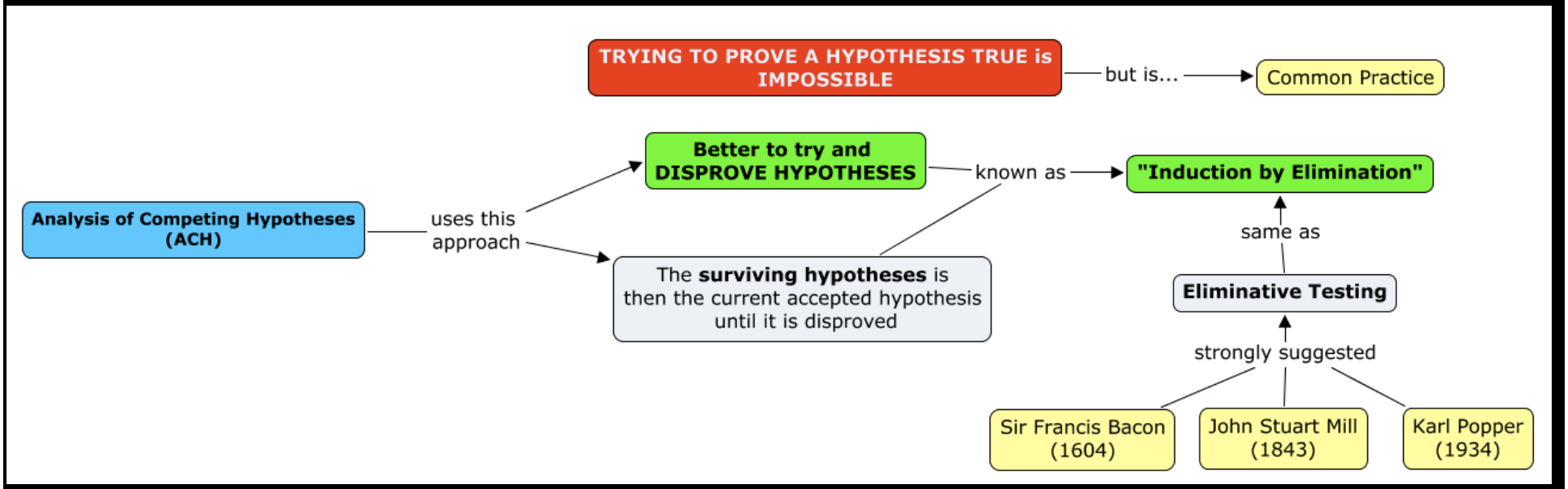


If we only knew the probability of ALL loss events... (we assume we do!)





Analysis of Competing Hypotheses



Agent-Based simulation can be used to falsify hypotheses and stress test policies and regulations

What are Agent-Based Computational Systems?

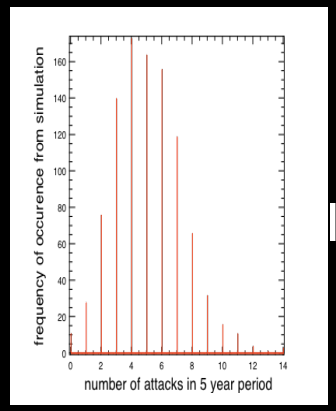
- Population of individual 'agents' **(10 - 10^7)**
- Each agent has **internal states** and **rules** of behavior; implementation as a **software object**
- Agents are **autonomous** or semi-autonomous
- Agents interact with one another and possibly with an environment (**local/social interactions**)
- Agents are **purposive** (self-interested, locally utility satisficing)
- Agents are now also being modeling using affective (**emotional**) behaviors
- Agents **learn**, **adapt** and **evolve** based on past interactions and imitation

➢ ***Aggregate dynamics emerge from the interactions of the agents***

The Application of **Scenario Generation** Via Agent-Based Simulation

Path Dependence Analysis

Generated Scenarios
"virtual histories"



Review by Experts

•Plausible, but nothing new learned

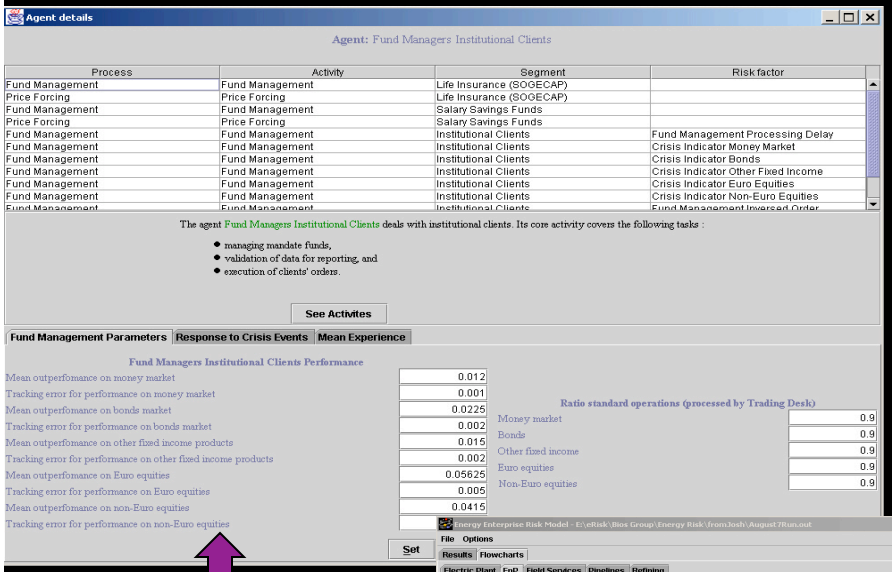
•Plausible, insight gained!

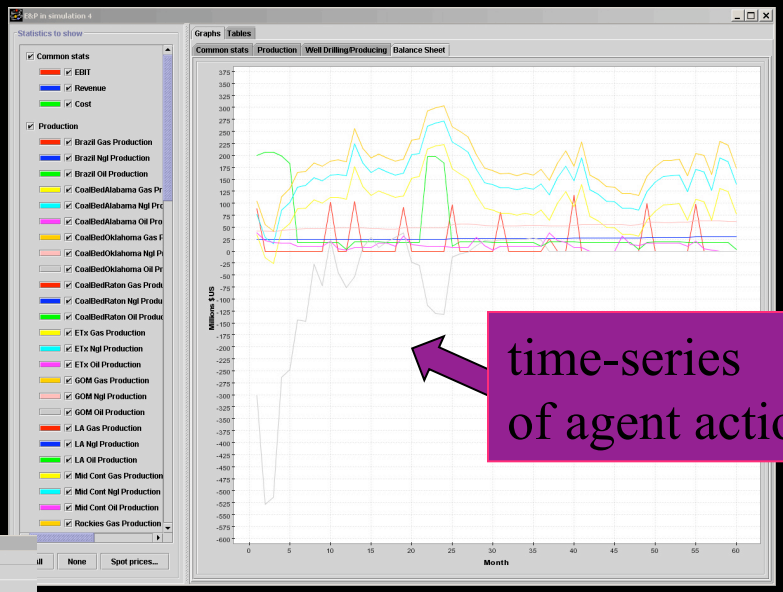
•Replay for path-dependent insights

•Implausible, … why?

•Model improvement

Example Ensemble of Scenarios for Path-Dependent Analyses

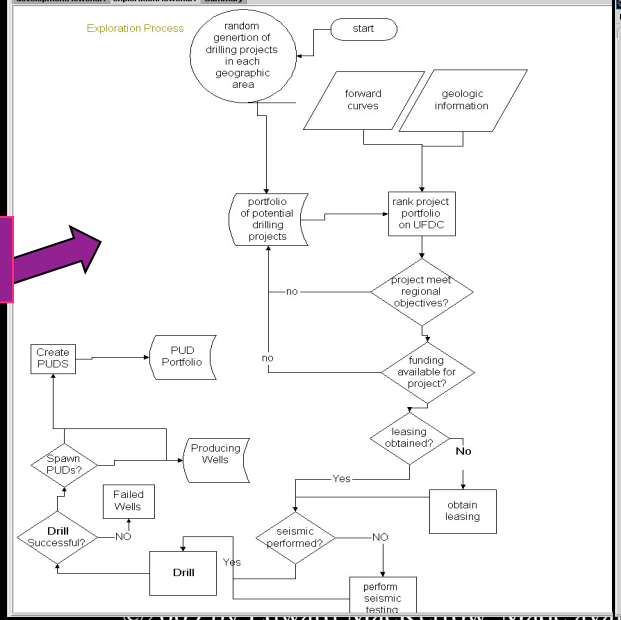


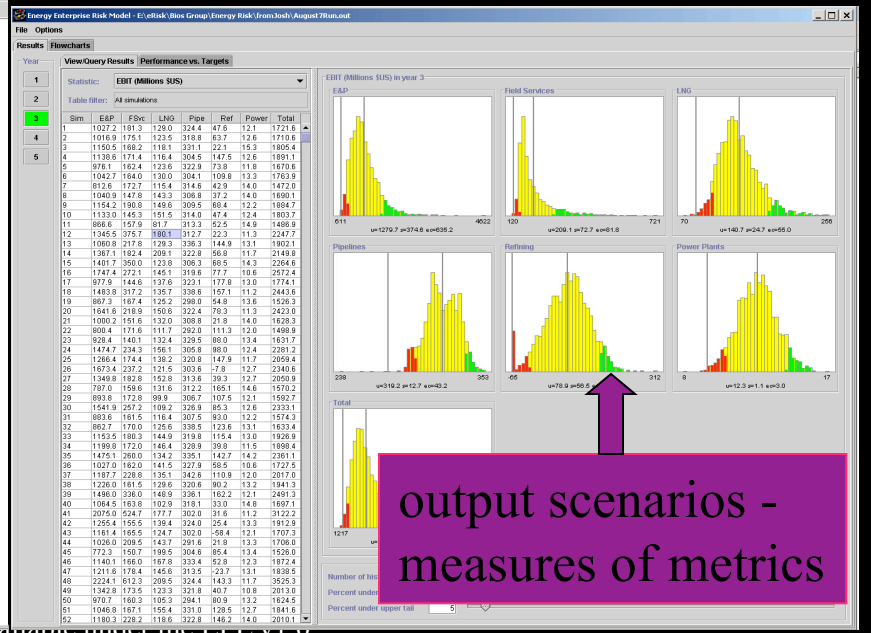


time-series
of agent actions

agent parameters
input by User

agent processes





output scenarios -
measures of metrics

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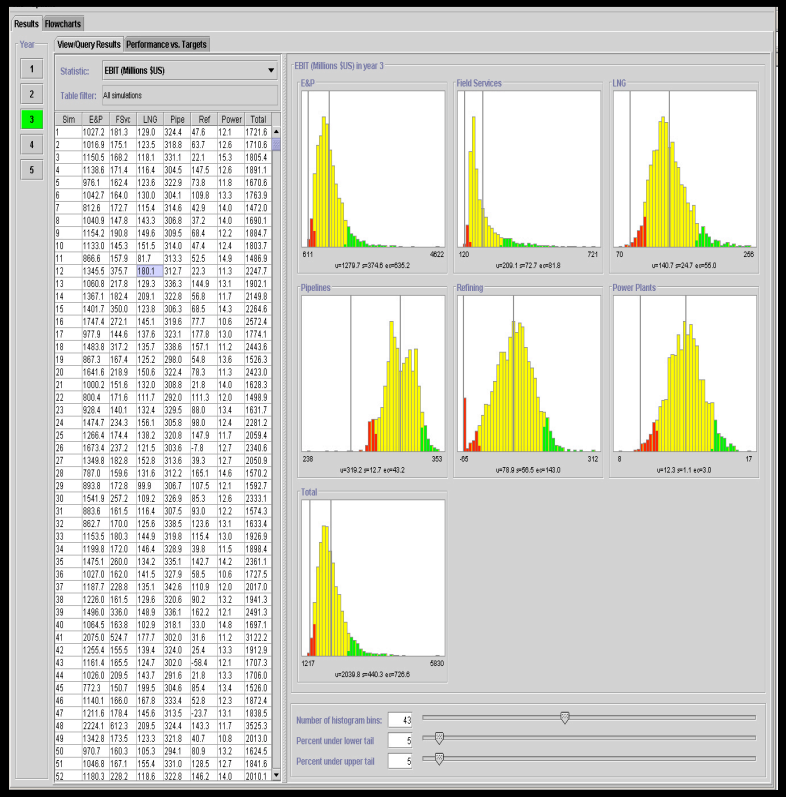
Simulation ➔Scenario Generation ➔ Scenario Evaluation

Output histograms (metrics of interest)

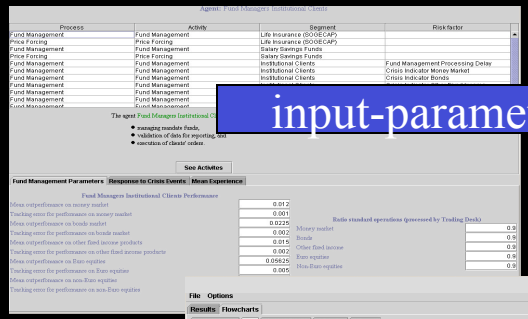


Simulation & Scenario Generation Steps

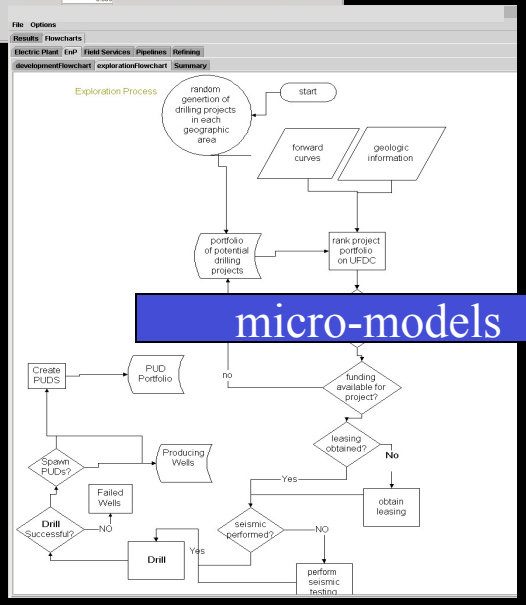
1. Multiple output metrics are recorded for each simulation run:
   {revenues, costs, departures, trends, etc…}
2. Select a simulation run(s) with interesting output metrics

Scenario evaluation of path dependencies

1. Are path dependent behaviors sensible?
2. Has this behavior been observed before?
3. Is the scenario plausible?
4. Sensitivity analysis of this scenario?

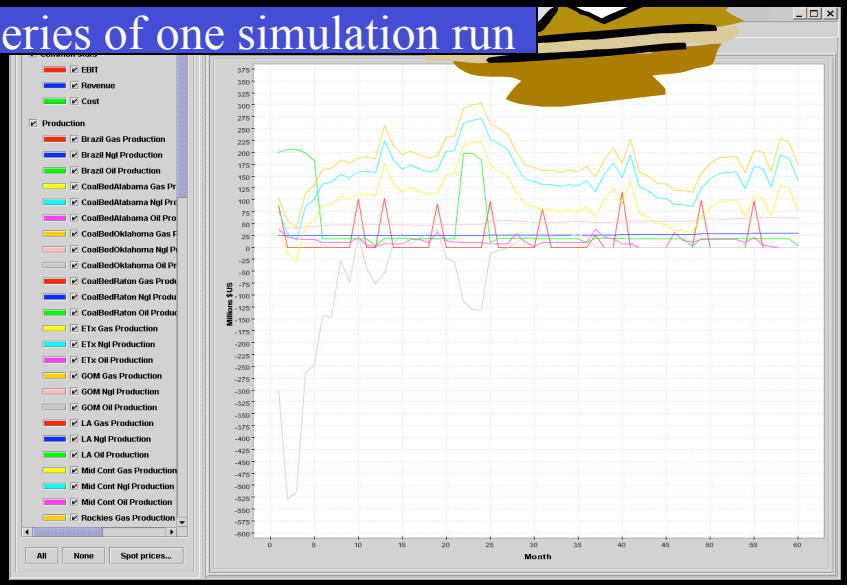


input-parameters

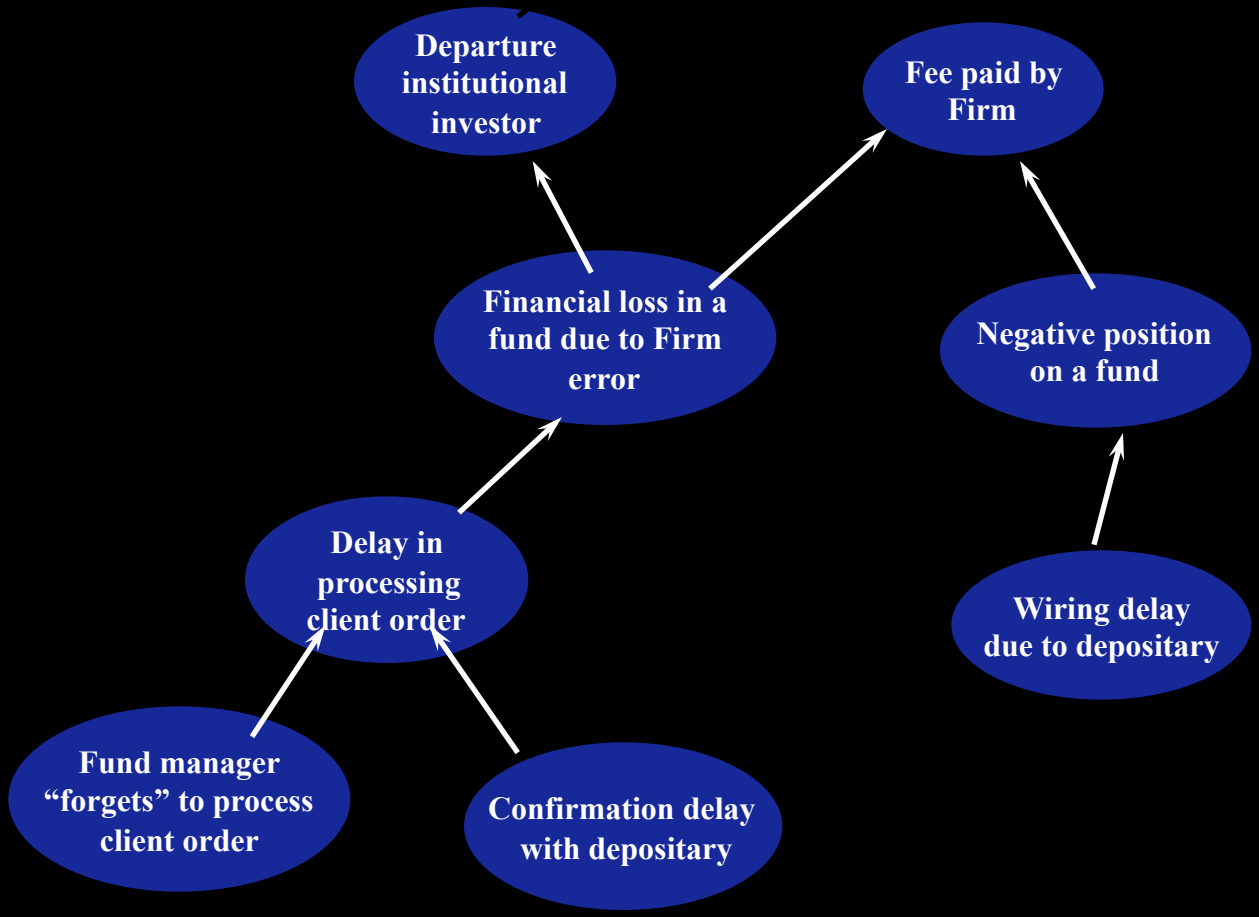


micro-models

Time series of one simulation run

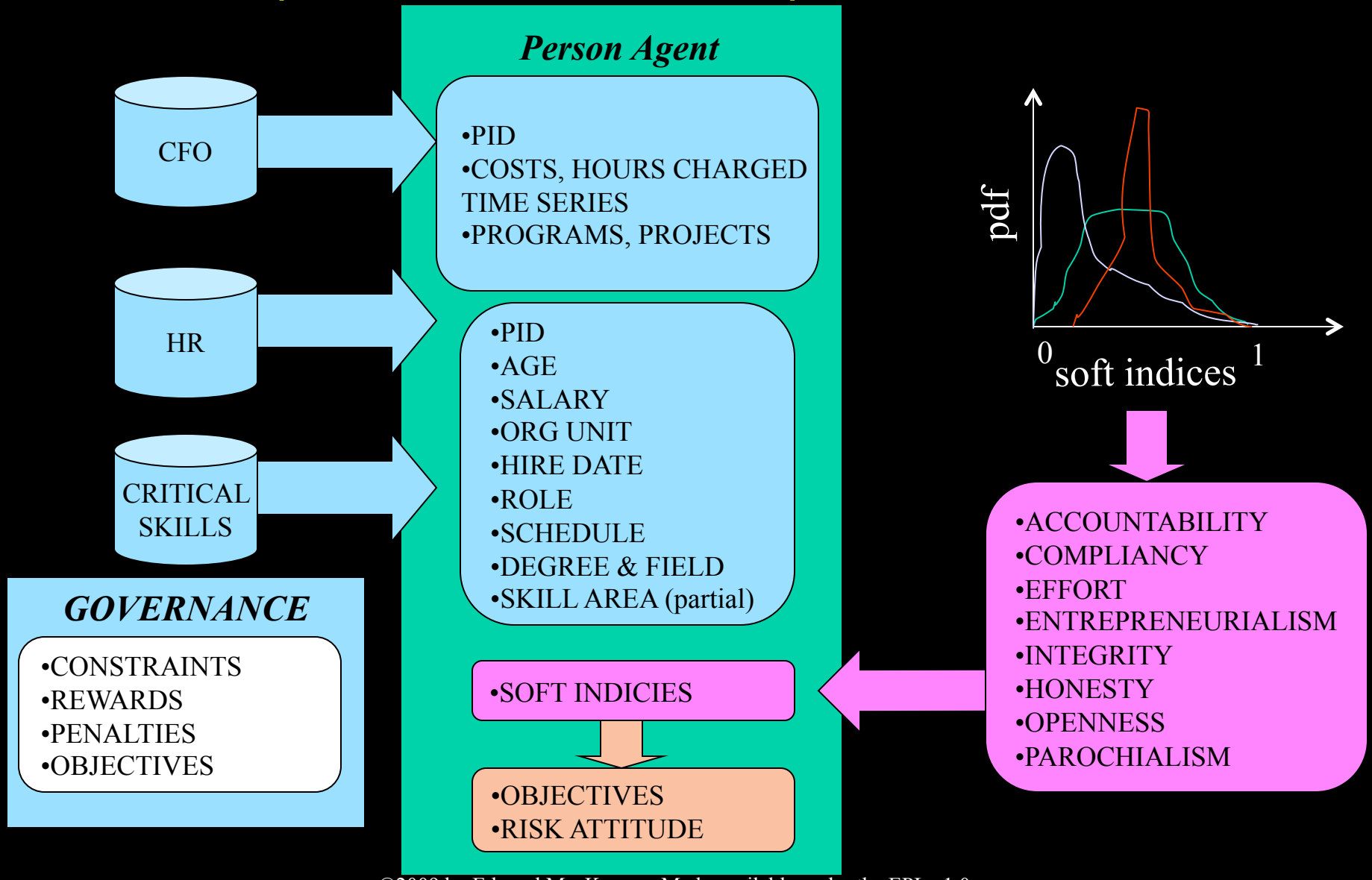


Complex Emergent System Behaviors Result from Many Different Path Dependent, Locally Simple, Events



Operational Risk Simulation of National Laboratory Funding Dynamics

Example: Data Rich OpRisk Simulation



Building Large Teams of Collaborating Scientists is Difficult

- " A Scientist would rather brush their teeth with another scientist's toothbrush than quote or use the other scientists ideas"

  – Murray Gell-Mann

Misalignment of Incentives at Management Levels

- Program Managers

1. Deliver to meet customer demand
2. Establish good relationships with customer--return work
3. Adapt to meet new customer demands

✓ Does not care WHO does the work, just that it gets done well and customer returns

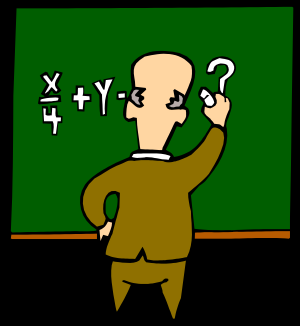
- Line Mangers

1. Obtain funds to cover salaries

✓ Will "promise" almost any work as long as they can secure funding

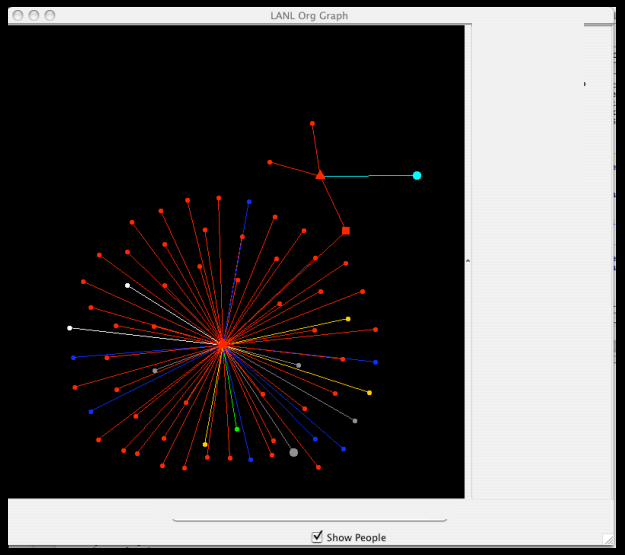
Incentives at the Individual Levels

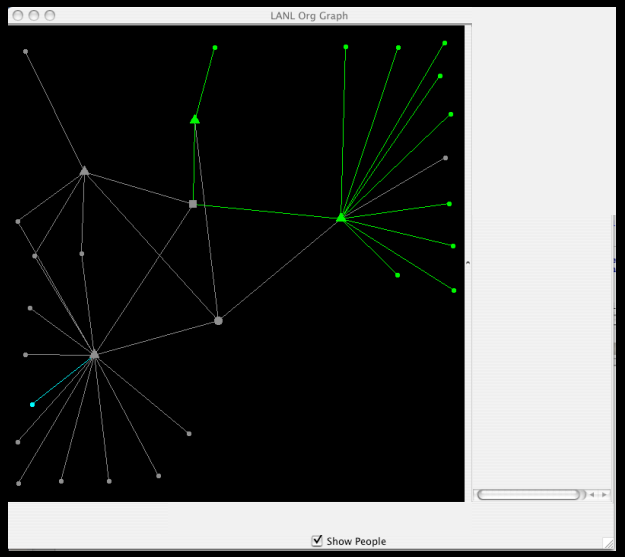
- Scientists
  - Work on their "own" research
  - Status, recognition of their "own" research
  - Not be told what to do
  - Increase their status relative to their peers

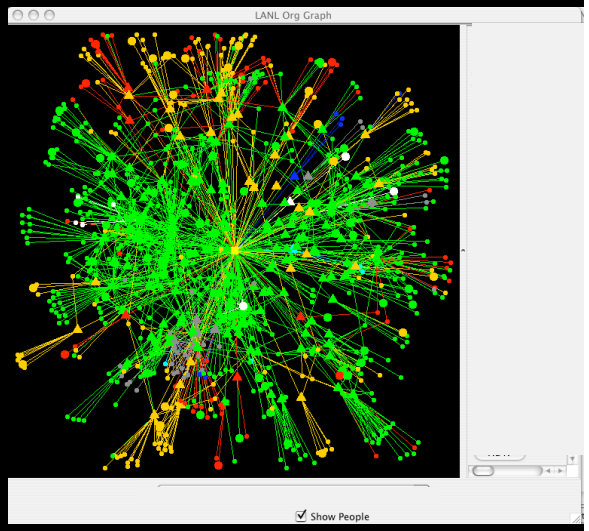


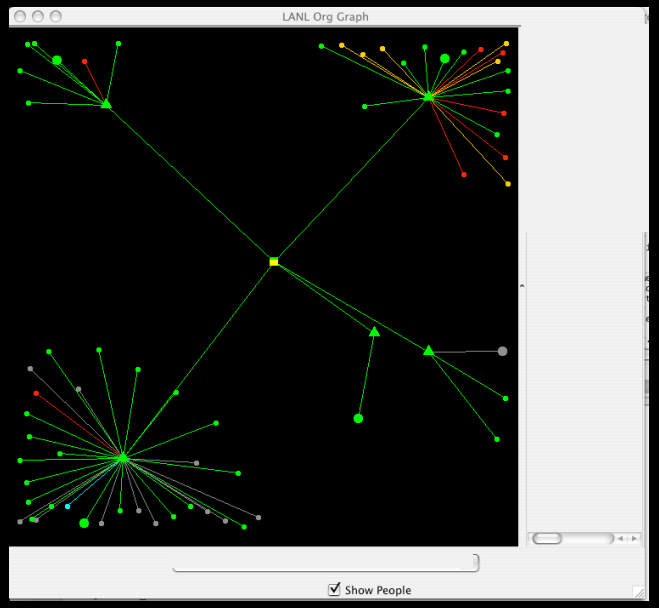
- Technicians
  - Get things done, stay focused, learn new skills
  - Recognition of their contributions
  - Contribute in meaningful ways to end deliverables

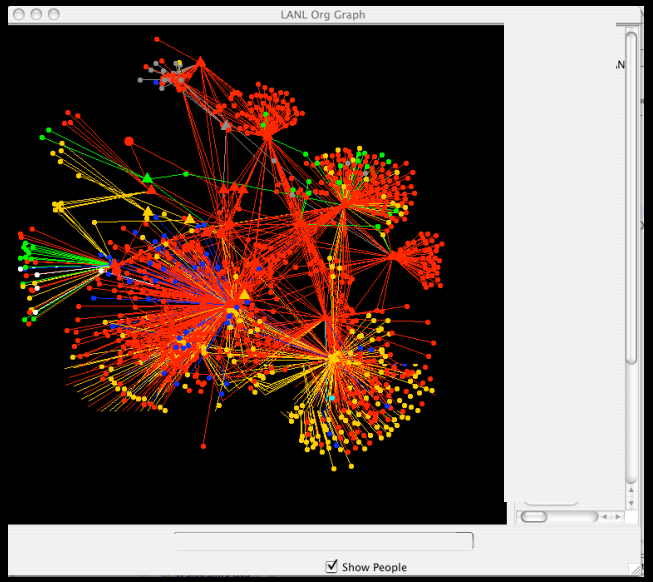
Observation of "Federation Effects" in Organizations – Stove Piping

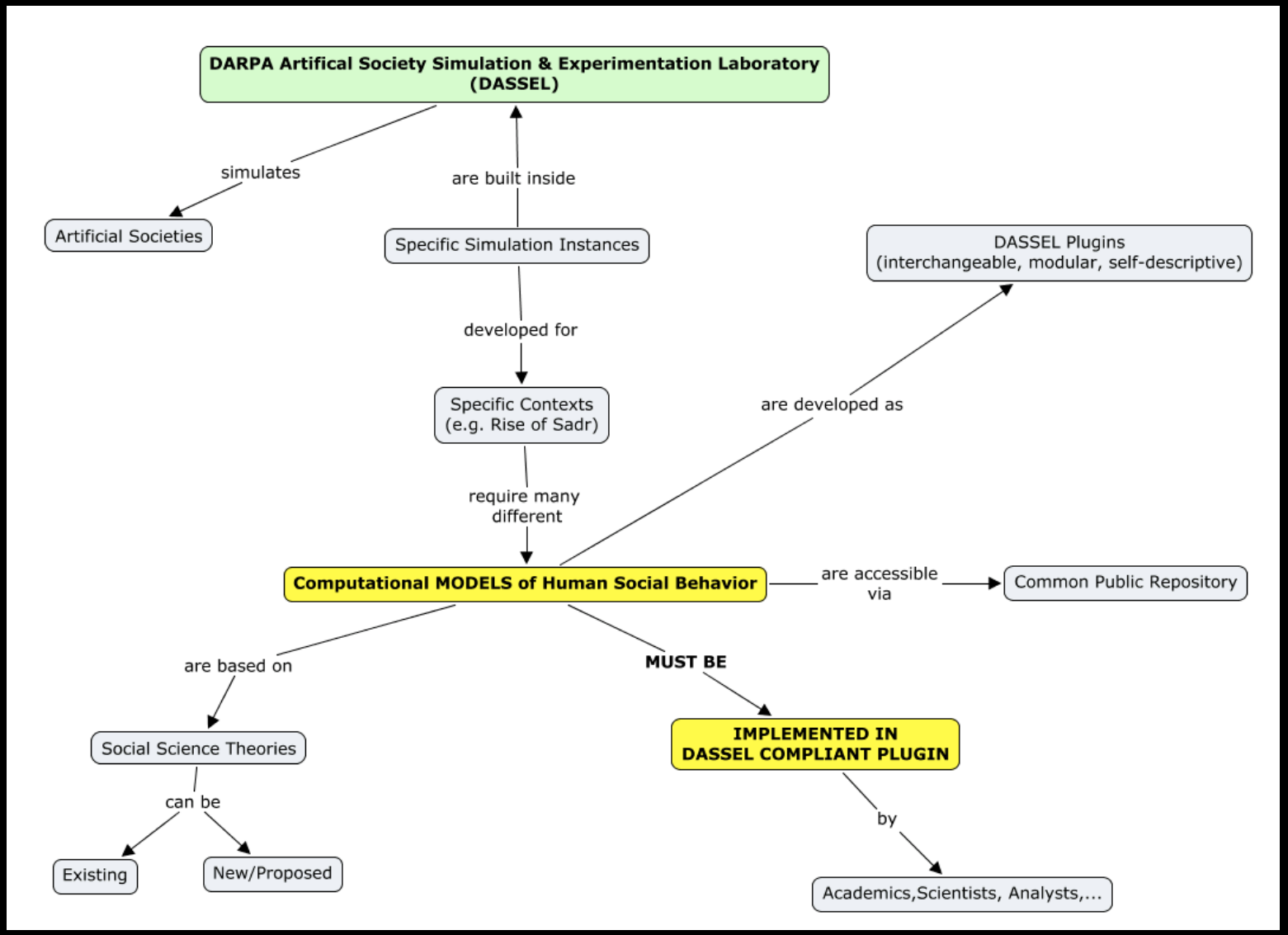


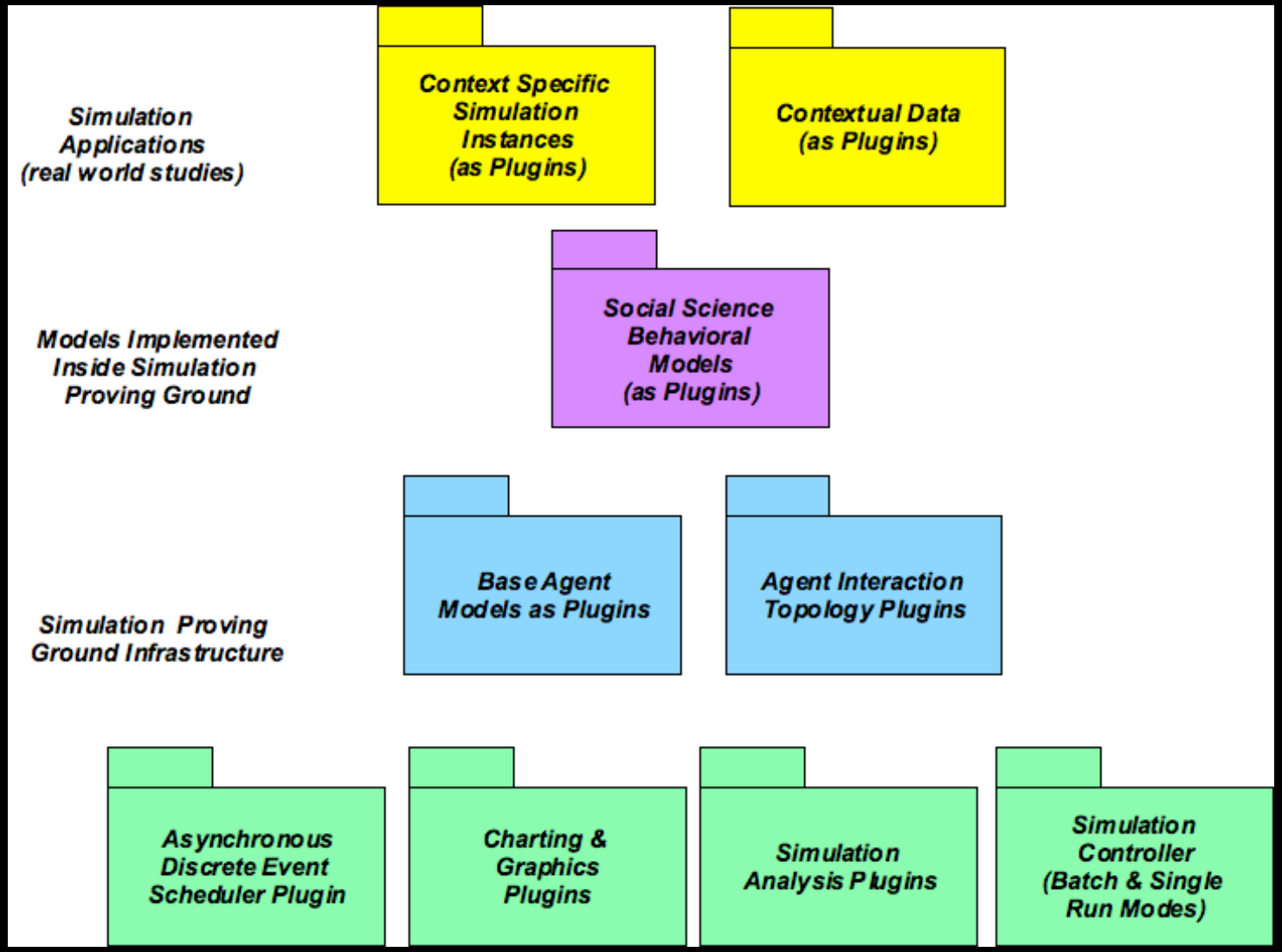












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Agent Modeling Platform

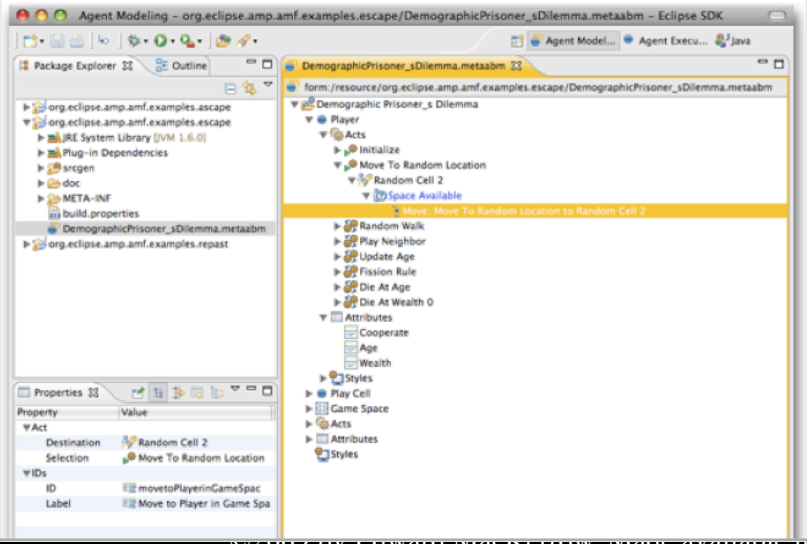
The AMP project provides extensible frameworks and exemplary tools for representing, editing, generating, executing and visualizing agent-based models (ABMs) and any other domain requiring spatial, behavioral and functional features. AMP has two main themes that complement but don't depend on one another:

Modeling

Agent Modeling Framework (AMF)

AMF provides an ABM meta-model representation, editor, generator and development environment. The AMF Acore meta-model is similar to EMF Ecore and defined in Ecore, but provides high-level support for complex agents.

AMF generates complete executable models for Escape, Ascape and Repast Simphony, as well as Java Skeletons and Interfaces, JUnit test cases and documentation and is easily extensible to support additional targets.



AMP is in the **Incubation Phase**.

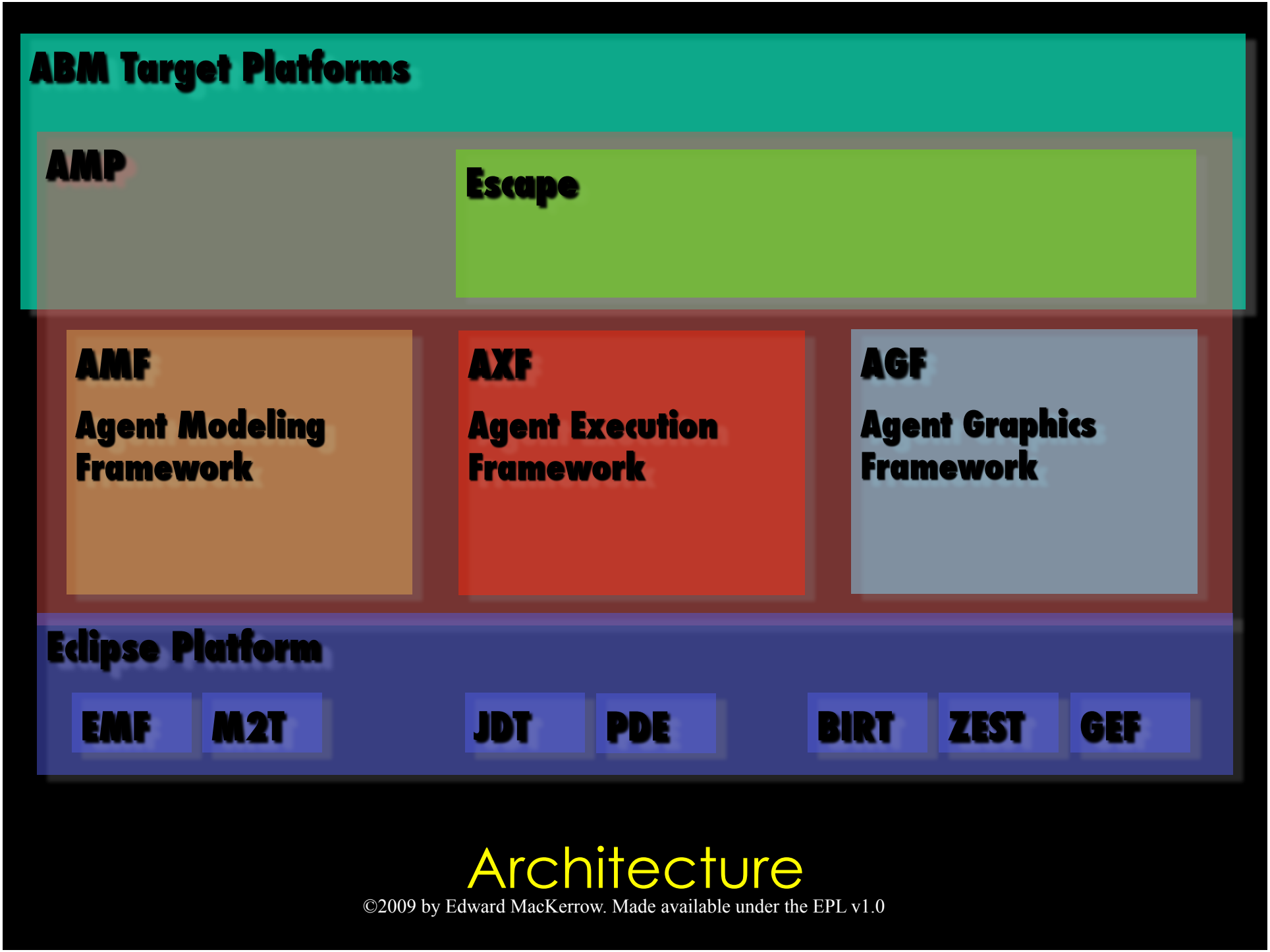
Current Status

The Update Site is up and the M1 release is forthcoming. And we now have some documentation to get you started! Please see our Project Plan for more details.

"What's an Agent-Based Model?"

The primary focus of AMP is "Agent-Based Modeling". ABMs share characteristics with object models, but are:

- Spatial: Models have explicit environment(s) in which agents interact. (An environment need not be a physical landscape; other examples of spatial relationships include social networks or positions within a logic system.)
- Temporal: Models change over discrete units of time.
- Autonomous: Agent behaviors are activated independently from other object requests.
- Heterogenous: Agents may share behavior definitions but have apparent and distinct states and behaviors.
- Collective: Models contain large communities of agents which exhibit collaborative and competitive behaviors.



Architecture

Verification and Validation

1. *Component model validation*. Validate the social micro-models that make up the agents and organizations in the simulation.
2. *Software verification and validation*. Does the computer code do what it is supposed to do?
3. *Input parameter uncertainty analysis*. Given the uncertainties in the inputs, what are the expected uncertainties in the outputs?
4. *Validation of the overall simulation*. Does the macro behavior compare to the real world?

Summary

- Agent-Based Simulation has been used for modeling operational risks in a handful of contexts
- Currently moving to a more standardized Eclipse Modeling framework
  - EMF based models for DOD sector
  - EMF based models for financial sector
  - EMF model suite of financial services business processes
  - Models are used in simulation studies to assess operational risks
  - Agent-based simulation used to generate ensembles of scenarios to anticipate unknown risk pathways