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The Use of Agent-Based Modeling and Data Farming for Planning System of Systems Tests in Joint Environments

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**76th MORSS
June 2008**

SEED Center Mission: Advance the collaborative development and use of simulation experiments and efficient designs to provide decision makers with timely insights on complex systems and operations

Report Documentation Page

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Agenda

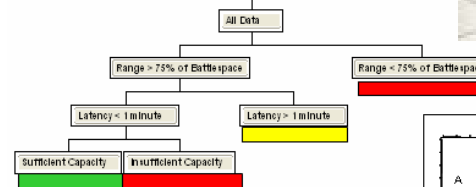
- SEED Center and Philosophy
- Data Farming
- Support to Joint Test and Evaluation Methodology (JTEM)
- Agent Based Modeling
- “TheTester” ABM

SEED Center in a nutshell...

Enable rapid and efficient computational experimentation and analysis to be readily available to those informing decision makers

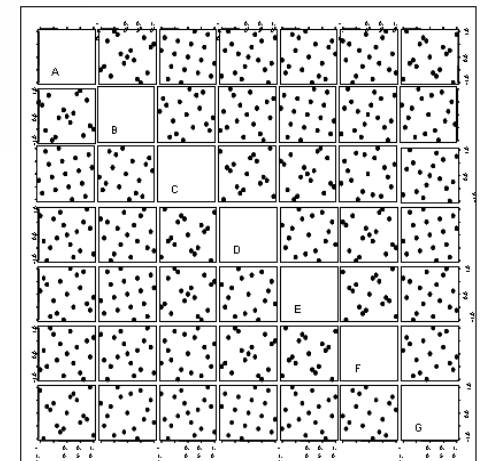
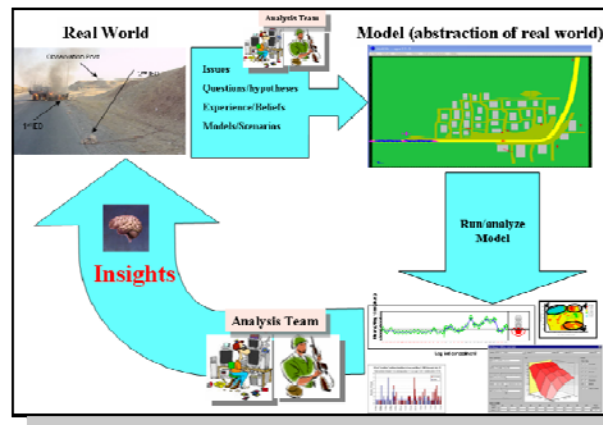
• Harnessing Enabling Technologies

- High-performance computation
- New Design of Experiments (DOE)
- (Emerging) models
- Data mining and visualization



• Revolution in analysis capabilities

- Quick turnaround...
- Address uncertainties
- Robust solutions

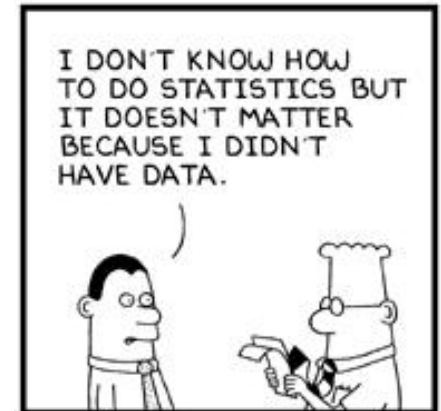


Resources: SEED Center for Data Farming

<http://harvest.nps.edu>

Check here for:

- lists of student theses (available online)
- spreadsheets & software
- pdf files for several of our publications, publication info for the rest
- links to other resources
- updates



All models are wrong, but some are useful—George Box



Data Farming: Iterative Loop of Loops

- **Data Farming Loop**

- **Scenario/Model Building Loop**

- Iterate model/simulation for experiment definition and analysis to support definition of hypothesis, and areas of interest

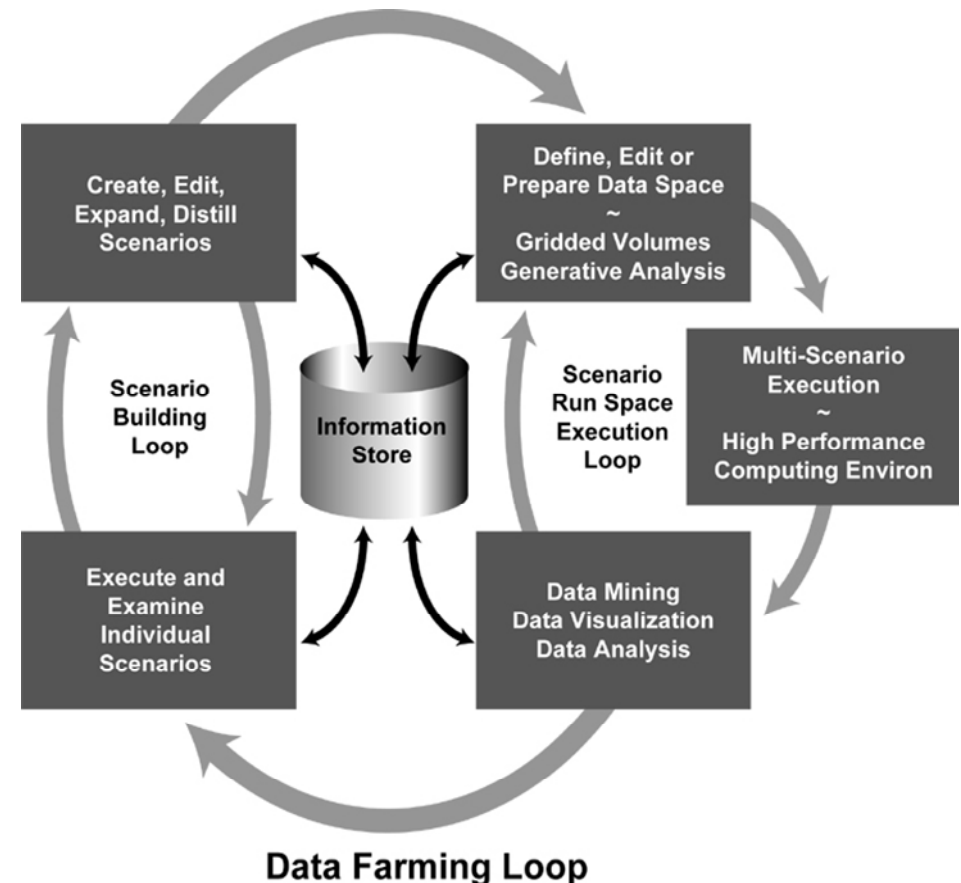
- **Possibility Space Development Loop**

- Iterate model/simulation using high-performance computing to refine analysis, study parameter sensitivity, drill-down into areas of interest, and confirmation or refutation of hypothesis
 - Data exploration, mining

and then

- **Adjust-Synthesize (another loop)**

- Adjust model/simulation with knowledge/concepts/intuition from data farming...
Repeat

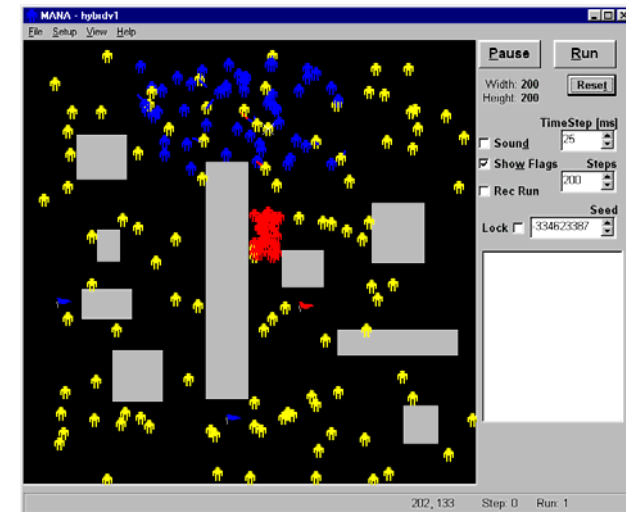
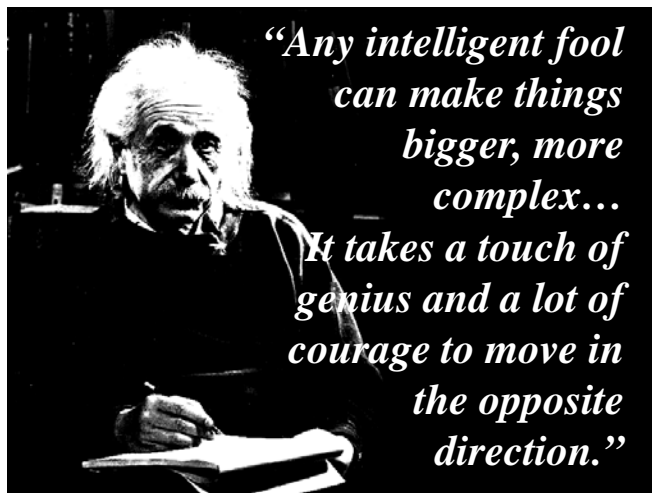


Support to Joint Test & Evaluation Methodology

- **Overall Objective:** Determine if analytical techniques employing agent-based models and data farming can be applied to the following areas
 - Helping to select a limited number of test vignettes for accomplishment in an actual L/V/C joint mission environment
 - Determining overall joint mission effectiveness
 - Establishing the relationship between system or system-of-system performance and joint mission effectiveness
- **Previous Effort:**
 - Tested other agent-based models for applicability
 - Ran computational experiments within the SEED Center's Data Farming environment
 - Developed custom-made agent-based modeling environment ("TheTester")

Agent Based Modeling (ABM)

- **What is an ABM?**
 - Composed of (usually) relatively simple discrete autonomous entities making decisions based on interactions with other agents and their local environment
 - Are characteristically intuitive, transparent, transportable, repeatable, and farmable
 - Have been useful in studying complex adaptive systems in a number of domains
- Several have been developed specifically for military domain (ISAAC, MANA, Pythagoras, SEAS)
- **Scenarios (usually) can be produced in a matter of hours/days vs weeks/months**



“TheTester” ABM

- **Motivation:** To address some of the limitations encountered using more traditional agent-based models based on reactive agents, while retaining their strengths in farmability, ease of use, and fast run times
- **Primary Design Goal:** Focus on Systems of Systems testing, initially modeling one aspect (Joint Fires) of the C2 Joint Capability Area (JCA)

“TheTester”: Model structure

- Is written in JAVA, and uses the MASON multi-agent simulation toolkit for its underlying simulation infrastructure
www.cs.gmu.edu/~eclab/projects/mason/
- Time-stepped
- Continuous 3D space, flat terrain
- Uses XML for input - working on an Automated Scenario Generator
- Selectable MOEs (CSV output)
- 3D visualization with probes

“TheTester”: Other Design Goals

- Composable

allows users to build up or construct agents using software components specific to the domain

- Extensible

allows users to develop their own software components to extend functionality provided by the basic framework

- Farmable

enhances computational experiments with the model by allowing users to easily vary input parameters associated with the agents

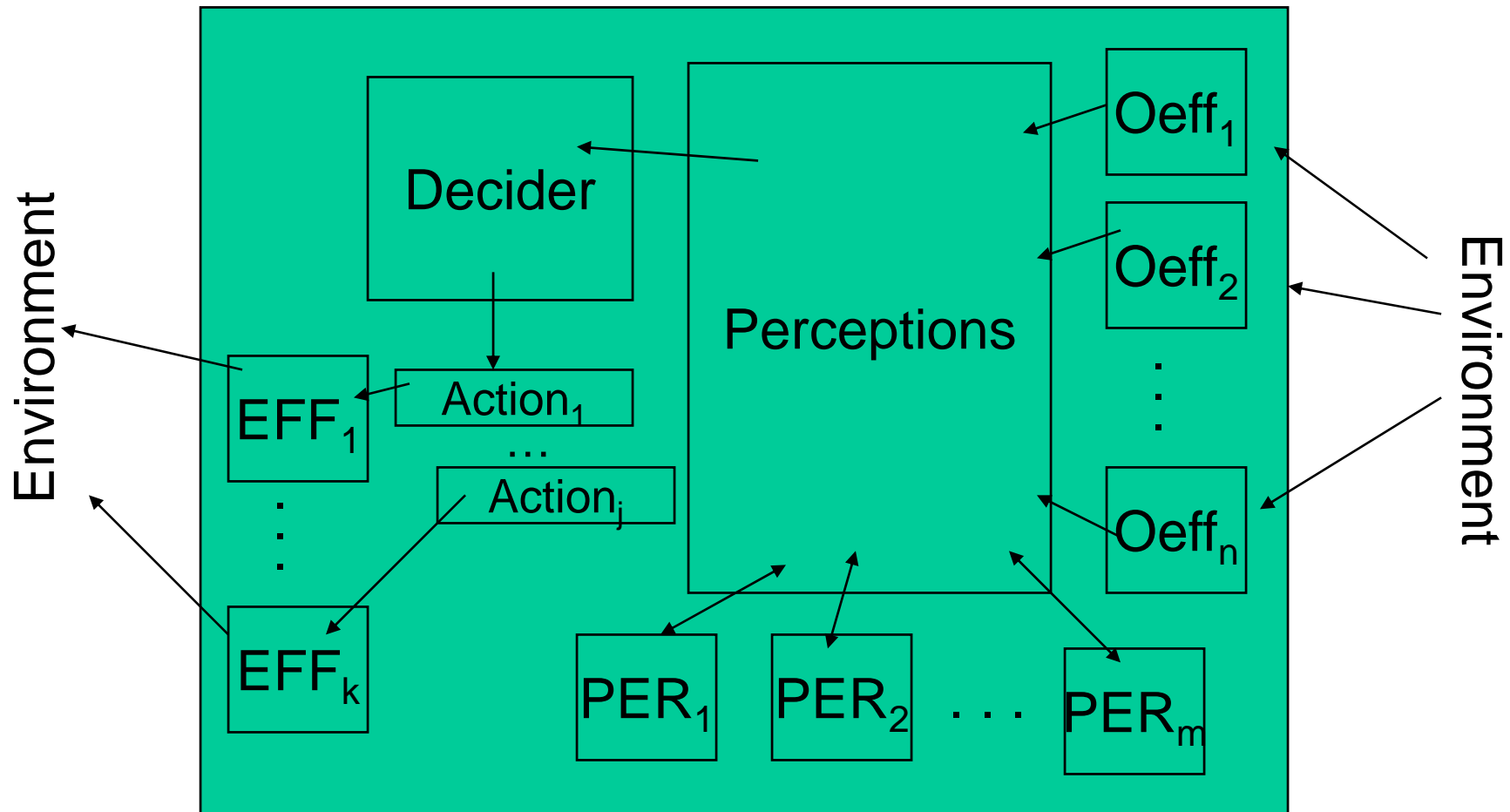
- Fast-running

analyses could be completed within a reasonably short period of time, commensurate with our experience with other agent-based models used for similar purposes

Agent Decision Making

- Each Agent has OODA loop
- “Observe” - depends on whether Agent has Effector for sensing
- Orient
 - Process Comm messages
 - Update Perceptions from other Perceivers
- Decide
 - Agent Decision Making is based on Deciders: these are composable object structures that base decisions on Perceptions - SimpleRuleBaseDecider currently implemented. Different agents can have different Deciders. SimpleRuleBaseDecider has a set of Rules that are a conjunction of Clauses (Perception Condition Value), with Actions as consequents
 - E.g., If NewEnemyDetected then SendMessageASR
- Act
 - Each Agent has a set of Actions that it can accomplish (based on what Effectors can do)

“TheTester”: Agent structure



Examples (Implemented So Far)

- Observe-type Effectors
 - CookieCutterSensor
- Perceivers
 - SimpleThreatPerceiver
 - BasicMessageProcessor
 - MessageSentTracker
 - MemoryContactFilter
- Other Effector types
 - MoveAlongWaypoints
 - AgentCarrier / AgentCarried
 - BasicMessageSender
 - SingleMissionEffector
 - MultipleMissionEffector
 - FiresMissionTasker
 - BasicIndirectWeapon

Examples (cont.)

- Perceptions (concepts an agent “knows about”)
 - AgentPercept
 - LocationPercept
 - MessagePercept
 - Observation
 - RestrictedOperatingZone
 - SimplePercept
 - TargetPercept
- Deciders (used to choose an action, based on the current state of perceptions)
 - SimpleMoveDecider
 - RuleBaseDecider

Comm modeling

- CommLinks
 - Explicit communication links specified in input file
 - Reliability for the link
 - Range for the link
- MessageData – for each message class
 - messageClass for each message
 - probUnderstood
 - inProcessTime, inProcessTimeOffset
 - outProcessTime, outProcessTimeOffset
 - probability distribution used for times
- MessageHandlers - for inserting and extracting content
- Implemented Message Handlers
 - CallForFireMessageHandler
 - FiresMissionMessageHandler
 - GoToRequestMessageHandler
 - ThreatLocationMessageHandler

FY07 Scenario Comm Matrix

	<i>RSTA</i>	<i>BNFSE</i>	<i>BDEFSE</i>	<i>CAOC/JAOC</i>	<i>ASOC</i>	<i>AWACS</i>	<i>FIRE BN</i>	<i>NLOS/FSPM</i>	<i>JSTARS</i>	<i>JTAC</i>	<i>CAS_AIRCRAFT</i>	<i>MEV</i>
<i>RSTA</i>		CFF										
<i>BNFSE</i>			RELAY-CFF									
<i>BDEFSE</i>				ACMREQ1; RFZ	ACMREQ1-COP ACMREQ2; RFZ		FIREMISSION					
<i>CAOC/JAOC</i>			RELAY-ACMF APPROVAL		ACMREQ1-APP COPY; ACMREQ APPROVAL	ACMREQ1- COORD			ACMREQ2 APPROVA			
<i>ASOC</i>			ACMREQ2- COORD			ASR- APPROVAL TASKING				ASR-APPRO TASKING		
<i>AWACS</i>				ACMREQ1- APPROVAL							CASMISSION	
<i>FIRE BN FSE</i>								RELAY- FIREMISS				
<i>NLOS/FSPM</i>	SHOT-CONFIRM	SHOT-CONFIRM	SHOT-CONFIRM				SHOT- CONFIRM					
<i>JSTARS</i>										THREATLOC		
<i>JTAC</i>			ASR								9LINE-ORDE	RETARGET- ORDER
<i>CAS_AIRCRAFT</i>										ONSTATION WPN-COOR TRANSFER		THREATLOC LAUNCHOR HANDOFF ORDER

Short Term Future Work on “TheTester” Will Include ...

- Expert System / Fuzzy Logic Decider (JESS, Fuzzy JESS)
- Move to a Discrete Event Framework
- GUI / Automated Scenario Generator

QUESTIONS?