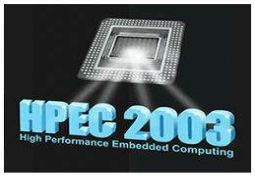

LOCKHEED MARTIN

Embedded Distributed Real- Time Resource Management

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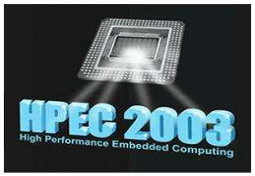
September 25, 2003

HPEC 2003



Challenge: Embedded Real- Time Management of Distributed Resources

- General reoccurring problem. Resources may be heterogeneous
- NP Hard – Many possible solutions; Most not sufficient.

Example Applications:

- Mission scheduling, planning, logistics, multi- sortie control of autonomous units, teams of UAV's, UGV's, UWV's, ...
- Multi- computer task scheduling, load leveling.
- Plant management, power & operations scheduling, vehicle signature control.
- Network load balancing, routing, wireless spectrum allocation.
- Carrier deck operations scheduling.
- Traffic flow management, optimization, intelligent highways.

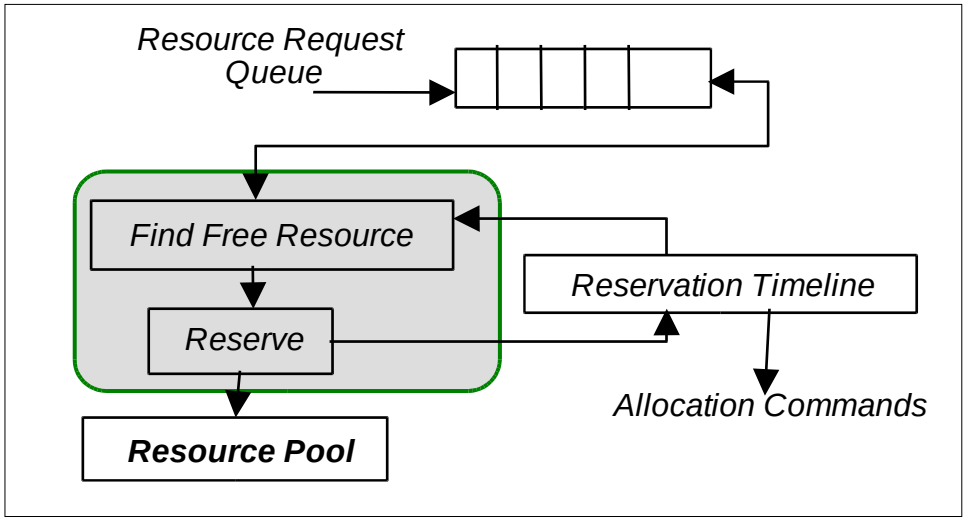
- Management ==> Continuous re- planning.

Existing Solutions:

- Bin Packing (Coffman 1998, et. al.)
- First- Fit (J. Ullman, 1973)
- Cookie- Cutter (Hoffman 1998)
- HARMONICM (JL Yowell, 1999)
- Multidimensional Bin Packing Algorithms (Kou/Markowsky '77)

Tendency: One shot, centralized, static, pre- schedule off- line. Not intended for continuous real- time operations.

Traditional First Fit Scheduling Algorithm



Improved Methods

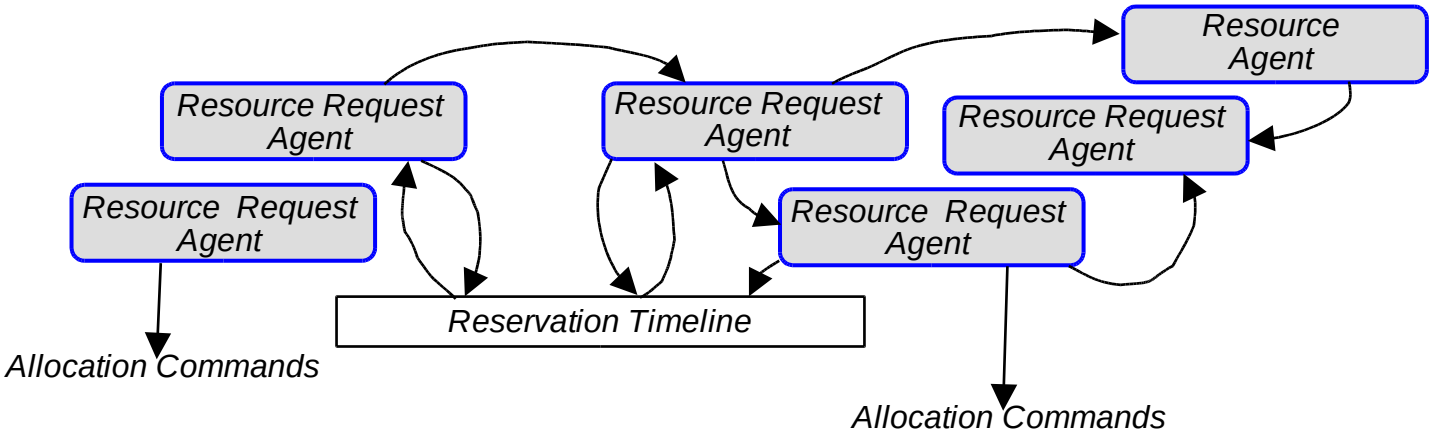
Approach:

- Leverage previous methods by distributing and extending them.
  1. Select distribution framework: *Intelligent Agents*
  2. Extend allocation algorithms within agent paradigm.

Intelligent Agent:

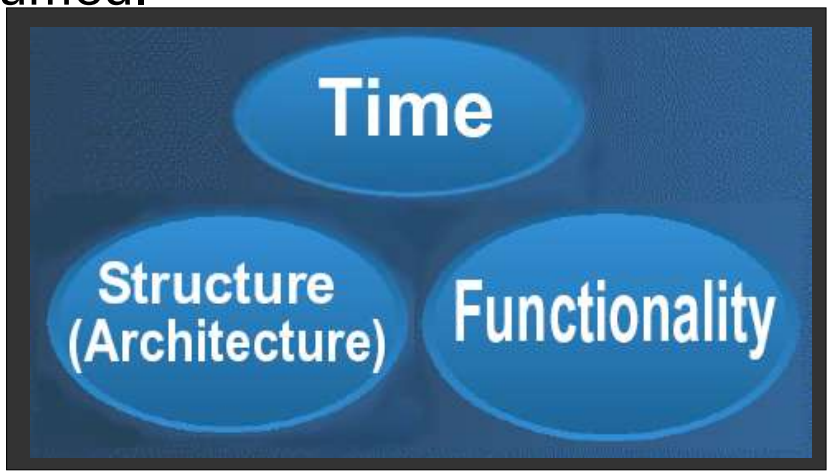
- Independent software process w/Persistence, Continual operation.
- Has perception, goals and logic to achieve goals. *Intent oriented* method.
- Serves as proxy for an application stake- holder.
- Collectively finds global solution by cooperative negotiations w/other agents.
- Light weight, embeddable, mobile.

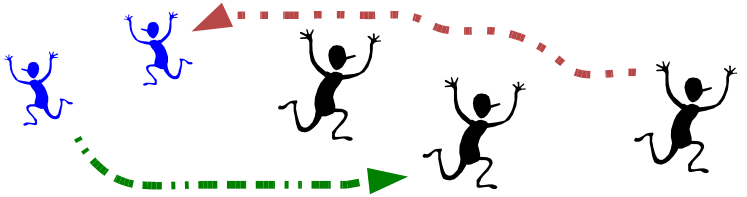
Agent Method



Agent & Resource Simulation Environment

- **Complex systems - - Difficult to understand.**
- Exploit modeling & simulation for rapid efficient exploration & development.
- Must investigate **Temporal, Spacial, and Functional** aspects:
  - Temporal = When resource needed or used.
  - Spatial = Where requested / consumed.
  - Functional = Express complex agent allocation rules.
- Used ATL CSIM
  - www.atl.lmco.com/proj/csim
  - Good agent simulator.
  - Multi- domains/levels with common simulator.
  - Provides mission- level context for engineering models to assess mission success impacts.



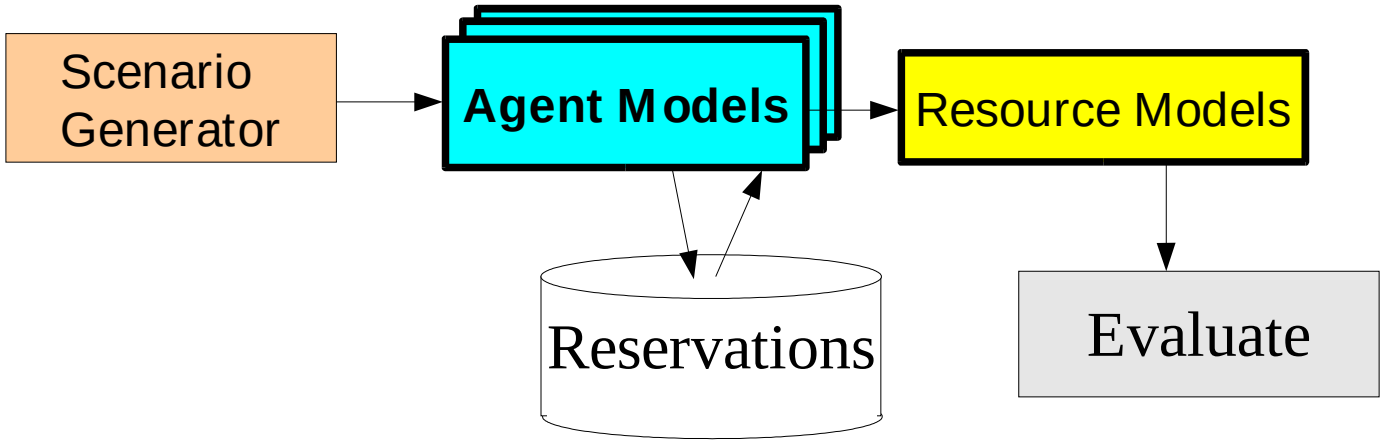


Experiments:

Metrics:

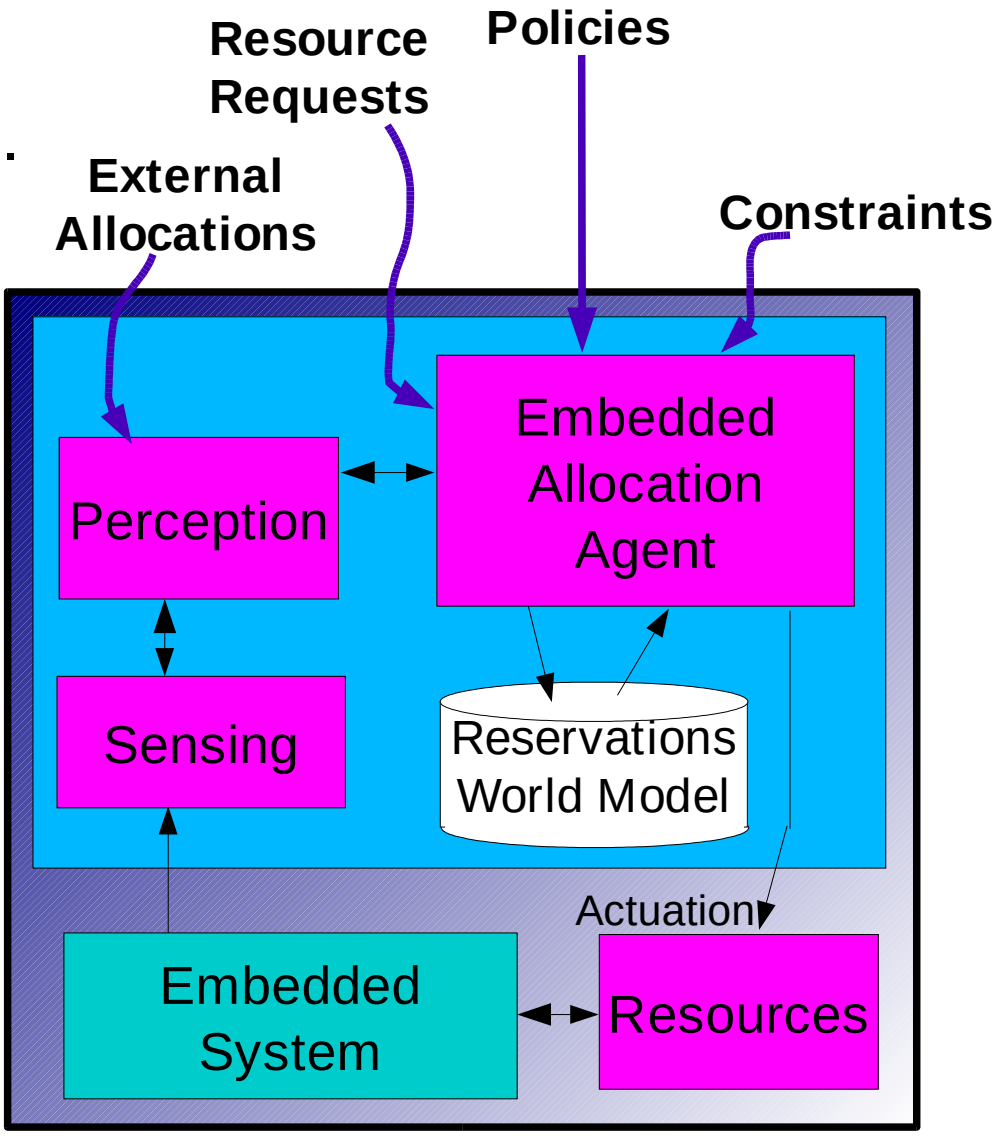
- Response Time (min, mean, max, variance)
- Overhead, agent communications (bytes/sec)
- Scalability (growth as function of complexity)

Simulation Approach:



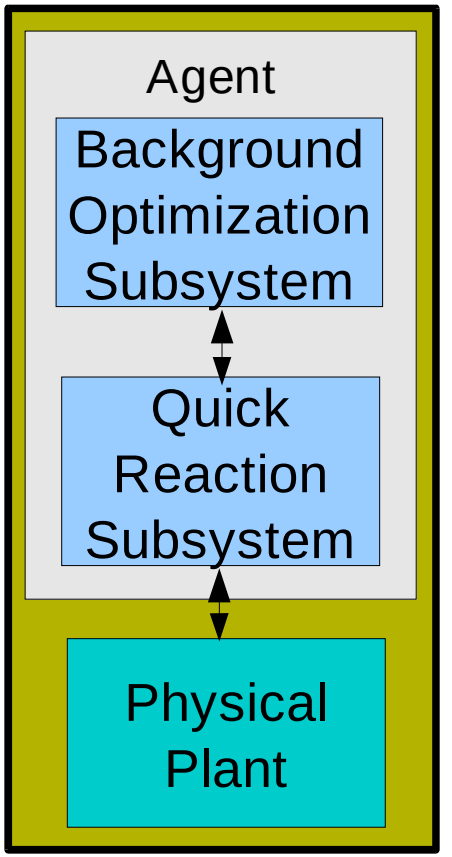
Agent Design

- Tried several approaches.
- Key discovery - - > Agents with their own internal *world models* reduce inter- agent negotiations.
- World models enable agents to test tentative future actions a priori.
- Enables continuous predictive re- planning, - - > Anticipatory optimal sequencing.



- **Dual mode operation:**
  1. Quick reaction subsystem,
  2. Background optimization subsystem.

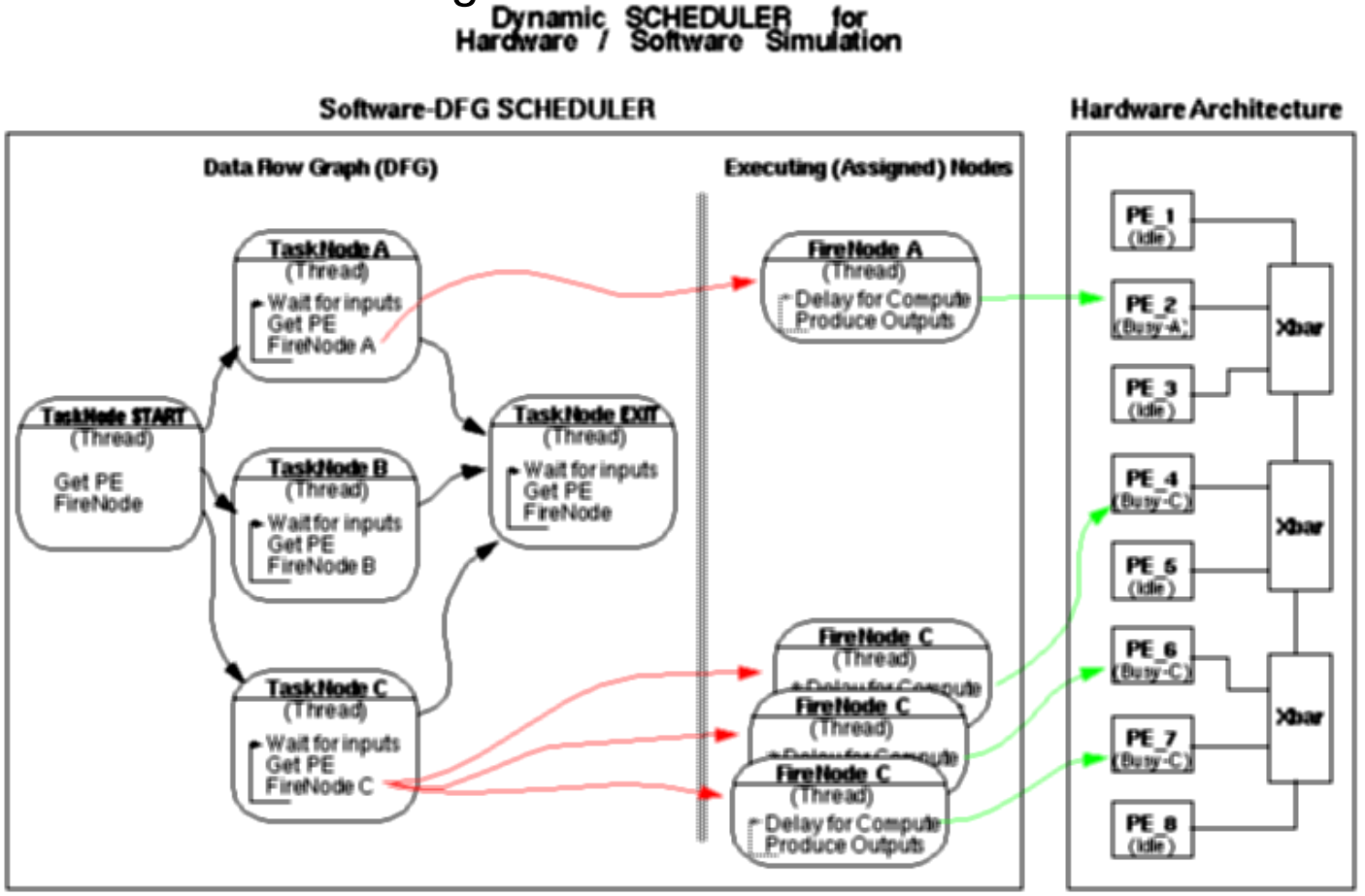
- Agents maintain own world models through observation of environment/past experience.
- Agent considers decision alternatives by simulating outcome on internal model.
- Requires lightweight, portable, embeddable simulator such as CSIM.
- During simulations in CSIM, agents launch their own *mini- simulations* within virtual world.



Application Example 1

Agents Applied to Real- Time Software Task Scheduler

Agent based controller



Task Management Agents

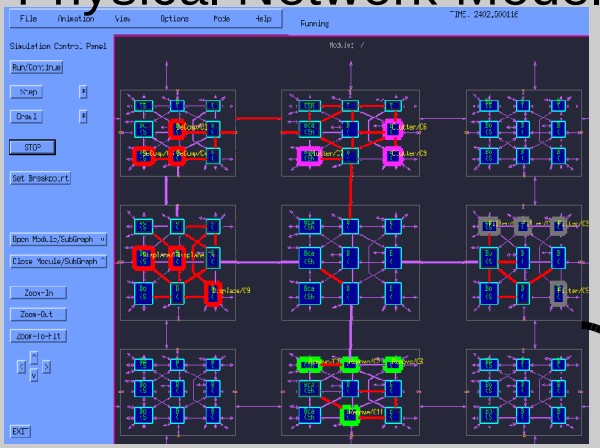
Execution Management Agents

Physical Hardware System

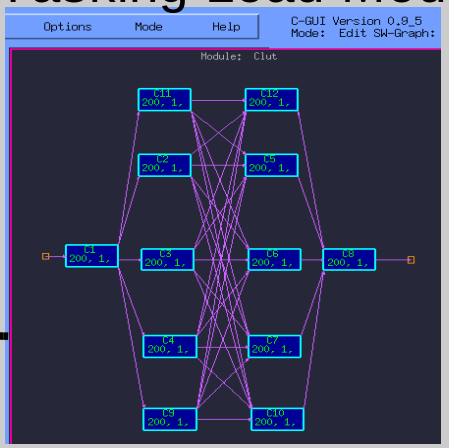
Application Example 1

Simulation Process

Physical Network Model

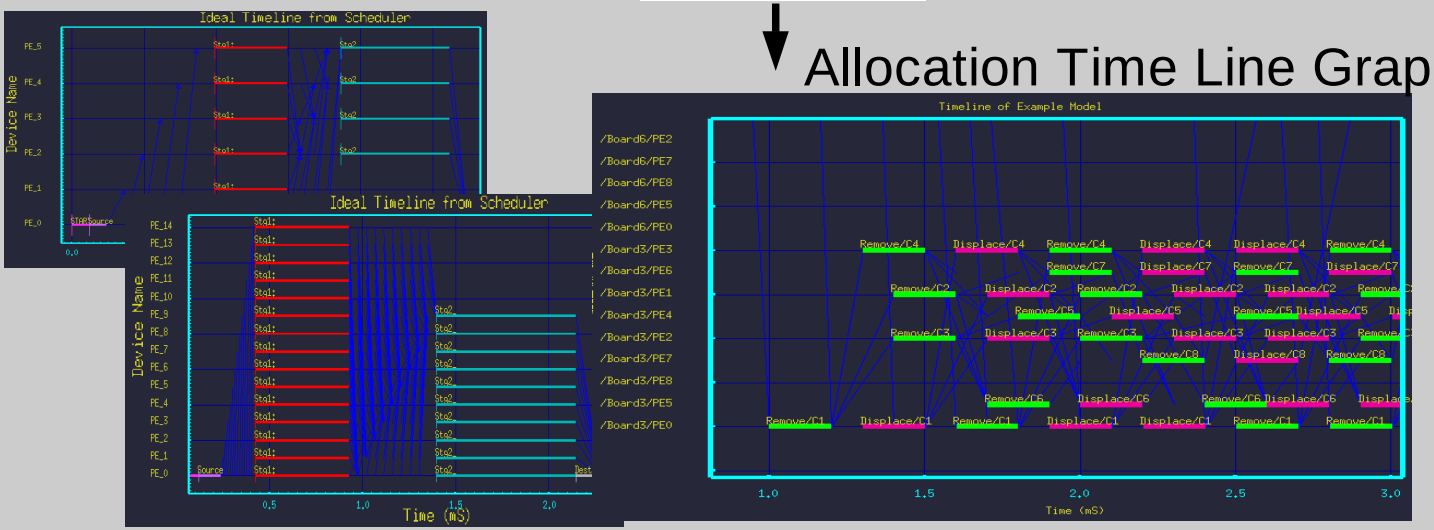


Tasking Load Model



CSIM

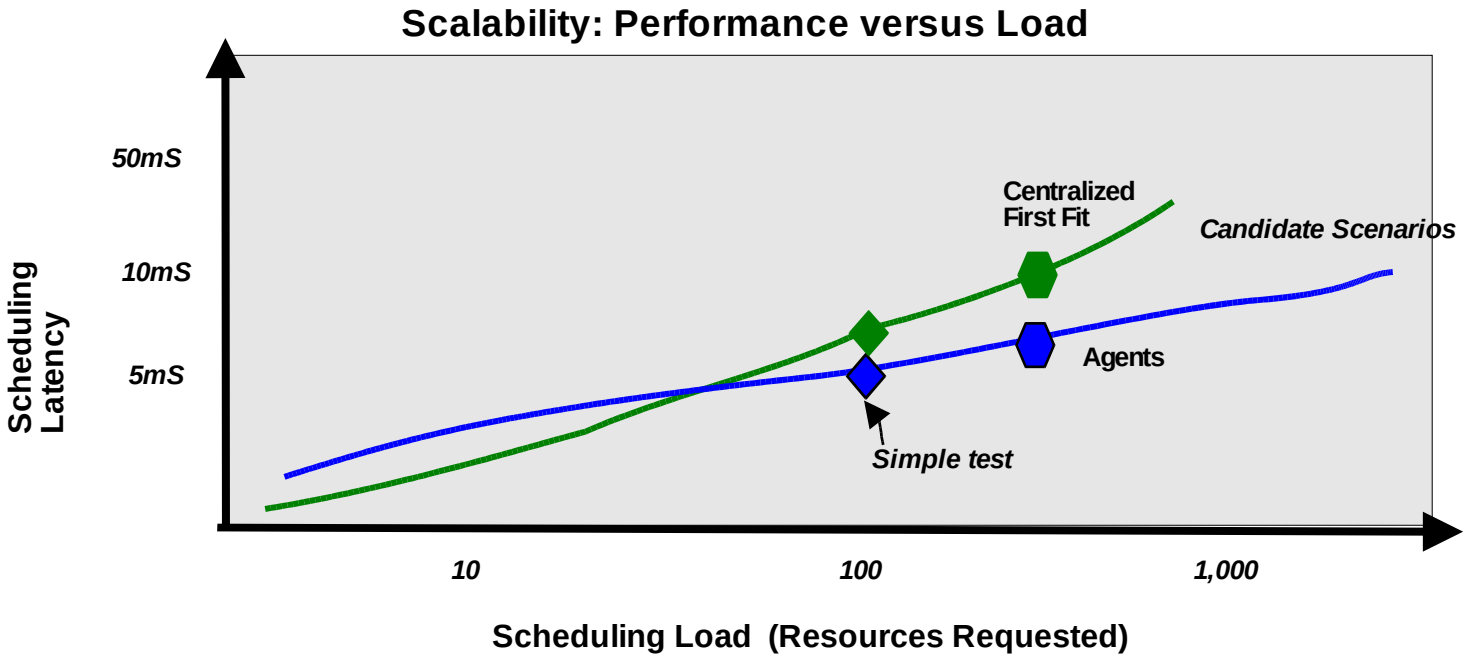
Allocation Time Line Graphs



Application Example 1

Application Results:

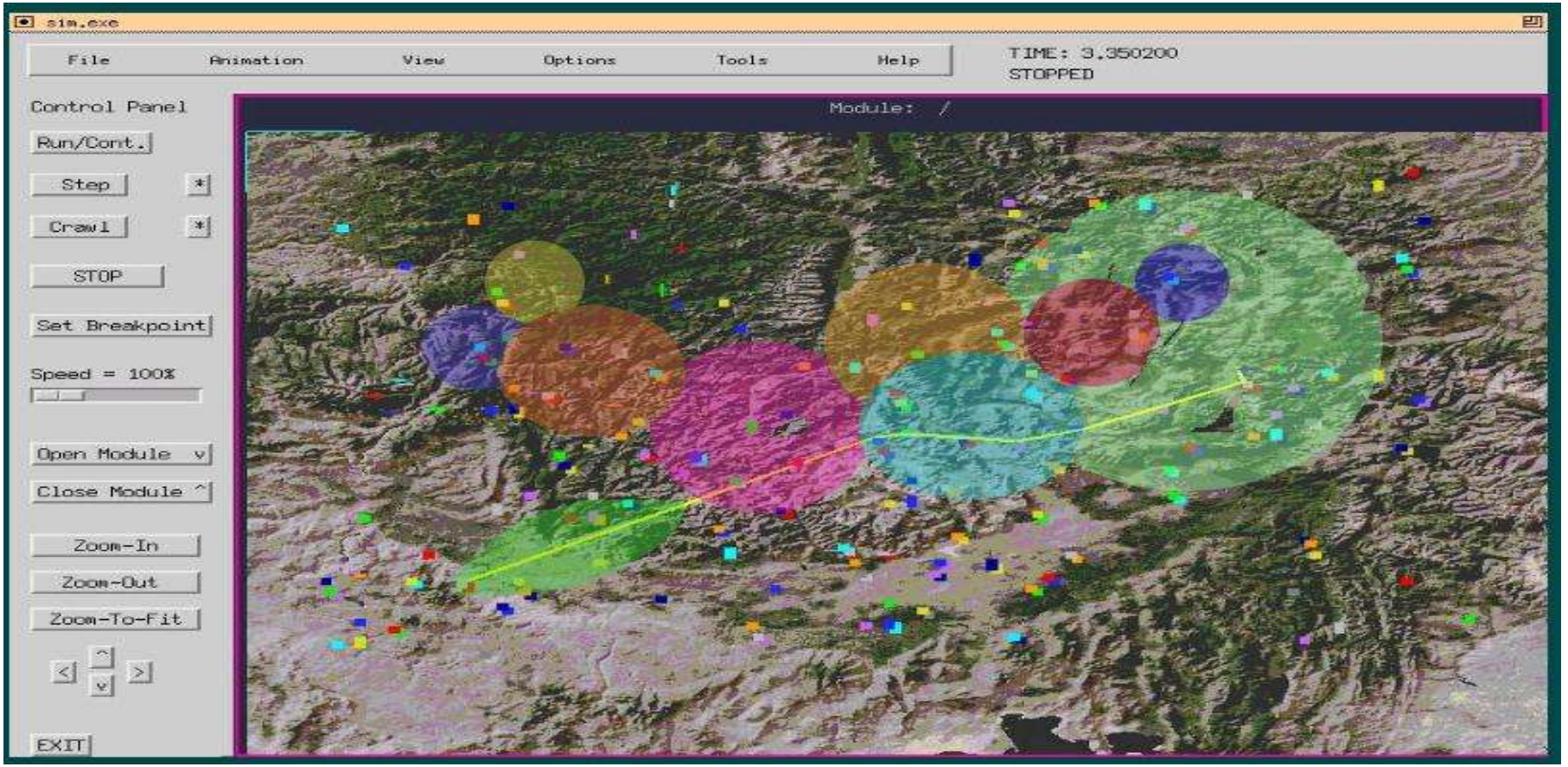
- Combination of advanced algorithms found to enable efficient distributed operation.
- Neither agent paradigm by itself, nor advanced algorithms alone could account for improvement individually, but only in combination.
- Greater scalability indicated for new approach on applied scenarios.



Application Example 2

Next Generation Communications - (XG Comms)

- DARPA program to demonstrate 10x > usable wireless spectrum.
- Spectrum is presently allocated statically, centrally, but not efficiently.
- All spectrum is allocated. Little occupied at any one time or place.
- Is multi- dimensional (Time, Freq, Area, Modul) dynamic allocation app.



Application Example 2

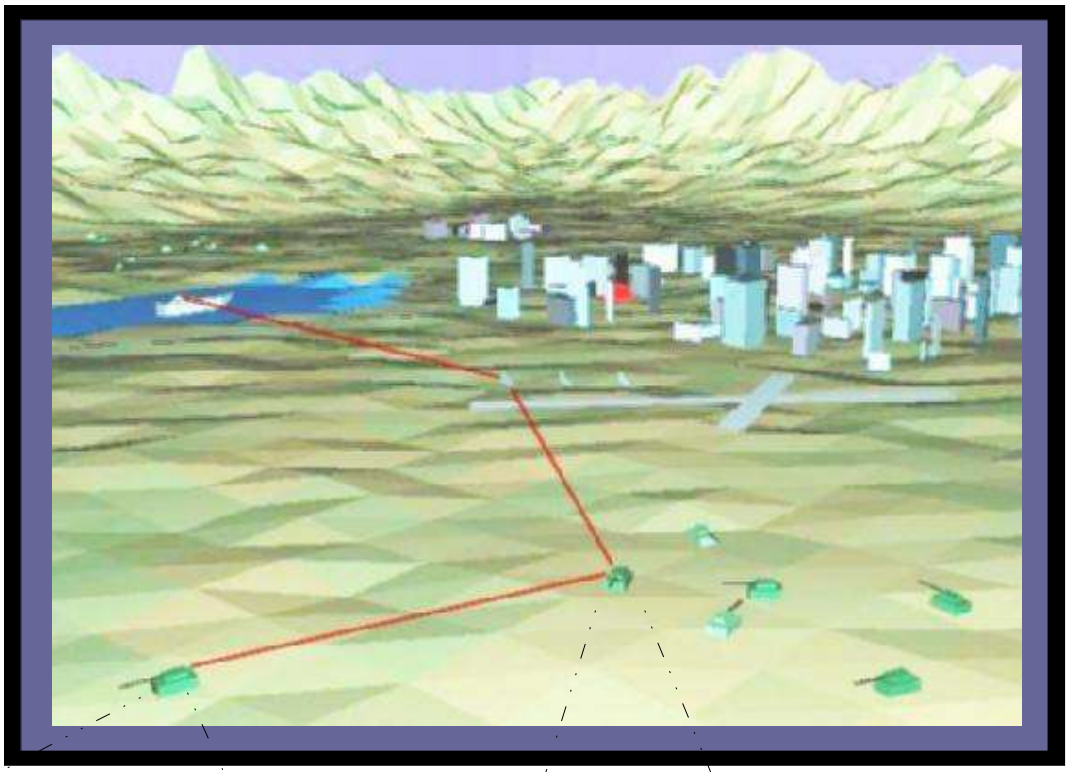
Spectrum Management

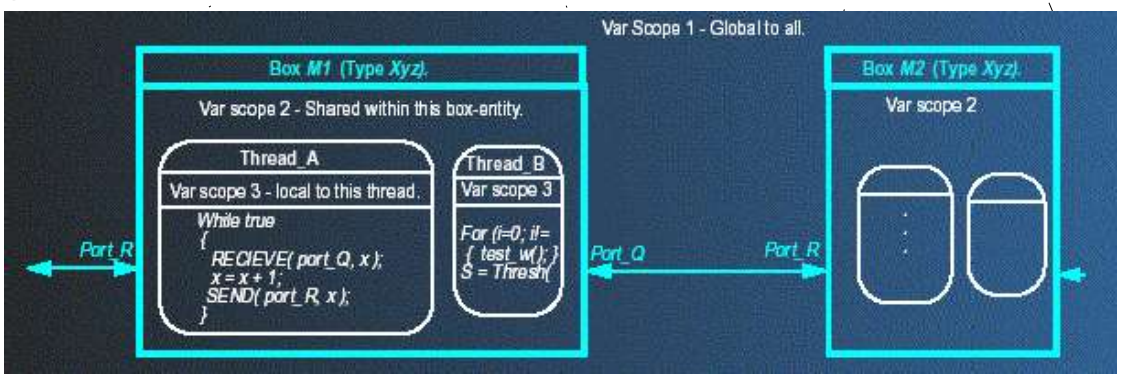
- CSIM Simulations at multiple simultaneous levels.

- Enable agent interaction in realistic mission scenarios.

- Multi- view visualizations aid understanding.

- Agent models under each vehicle model, contain agent submodels.

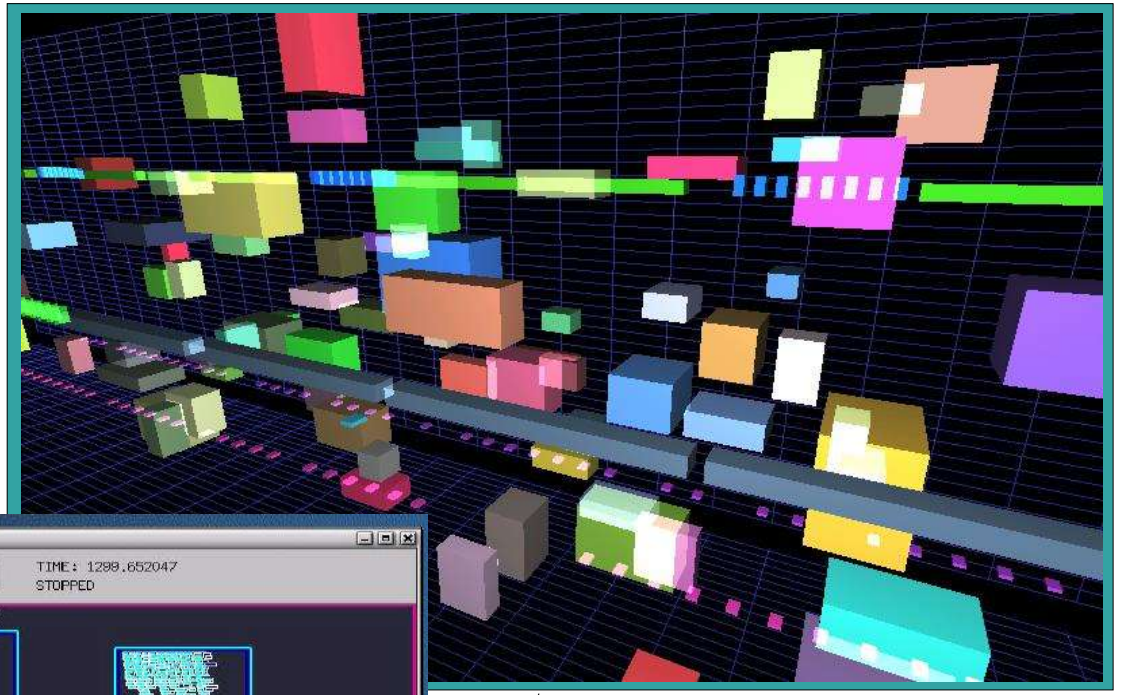


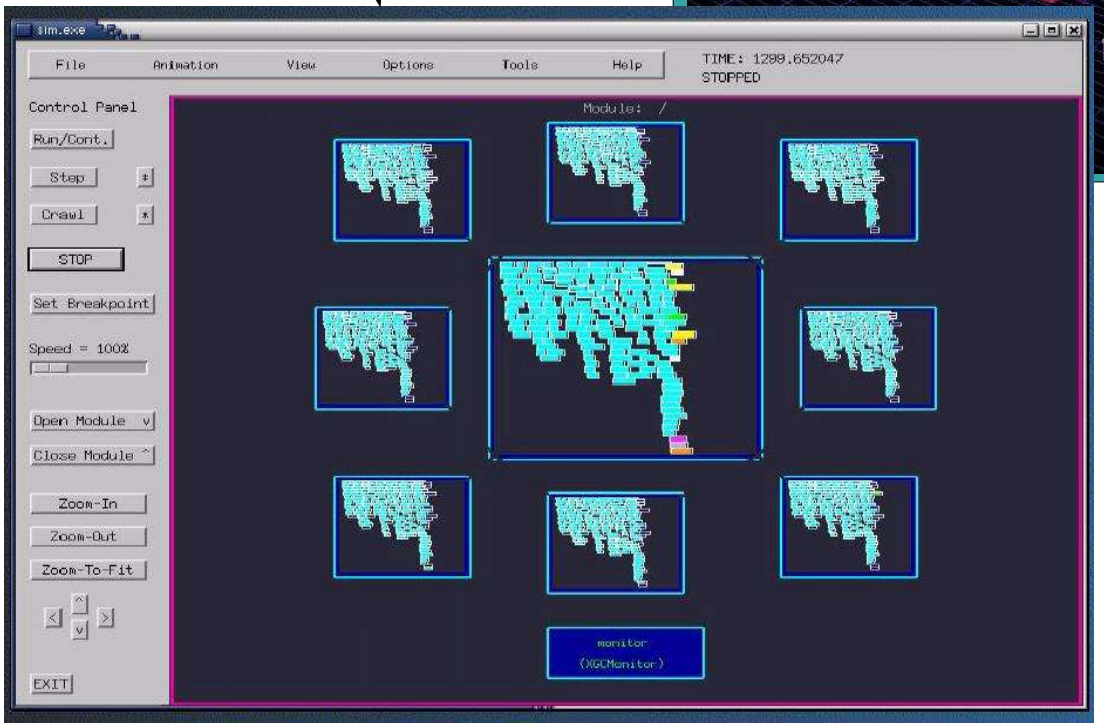


Application Example 2

Spectrum Management

- World models of agents within each radio view show allocations vs. time (horiz.) and vs. freq. (vert.)





- Multi- dimensional view shows allocations in time duration (right- left) vs. location (depth) vs frequency (vertical) and vs priority (color/owner).

Conclusions

General purpose distributed real- time control method.

Advantages:

- Decentralized, continuous operations, real- time.
- Embeddable, lightweight.
- Minimizes central- dispatch communications .
- Improves efficiency, reduces disruptions & response delays.
- Greater scalability than centralized solutions.

Risks:

- New inter- agent communication overhead.
- Convergence, solution quality, stability, limit cycles, chaos.
- Predictability, ability to set bounds.
- The unknown.

Lessons learned:

- Modeling & simulation essential for agent deployment.