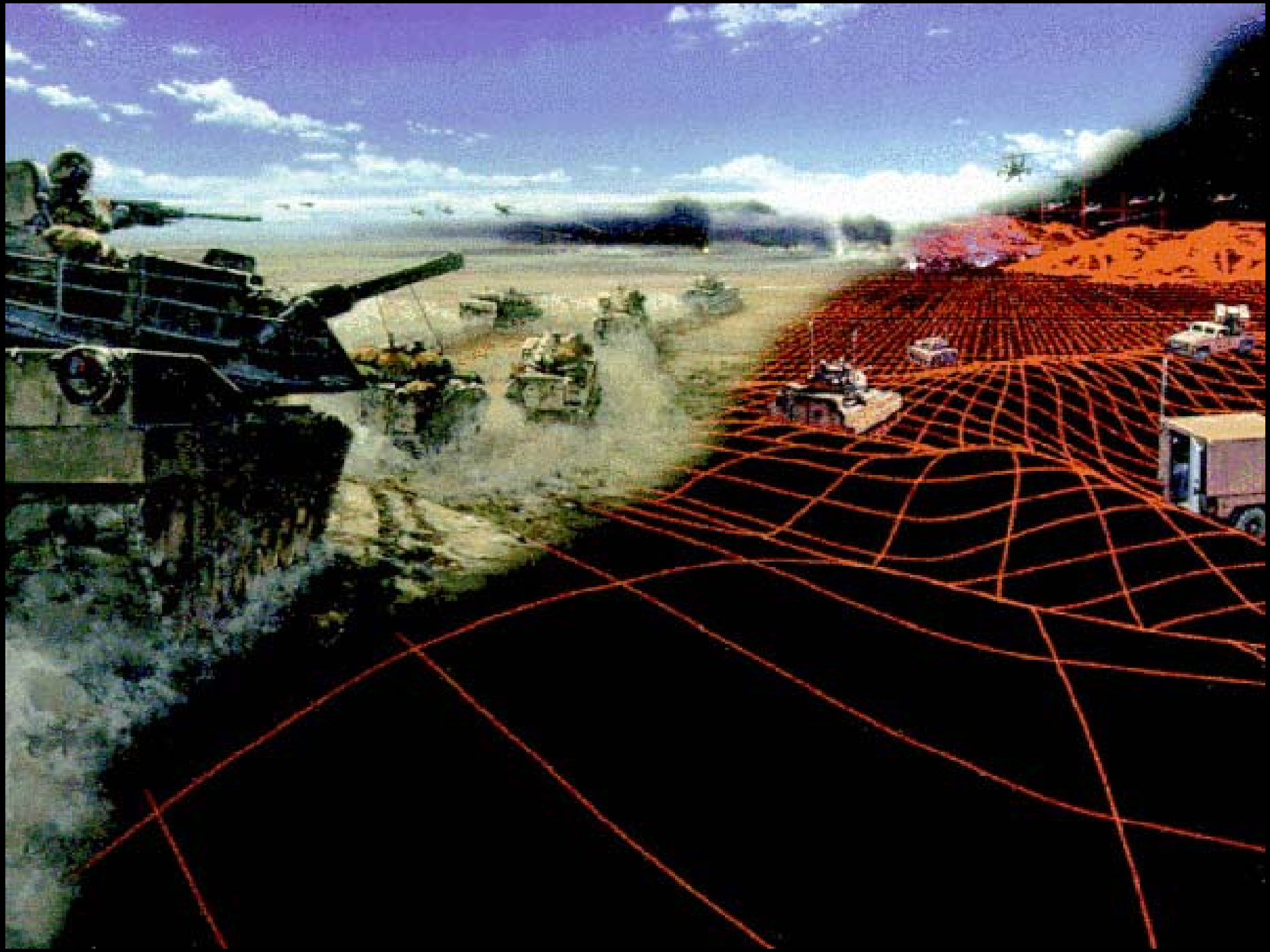
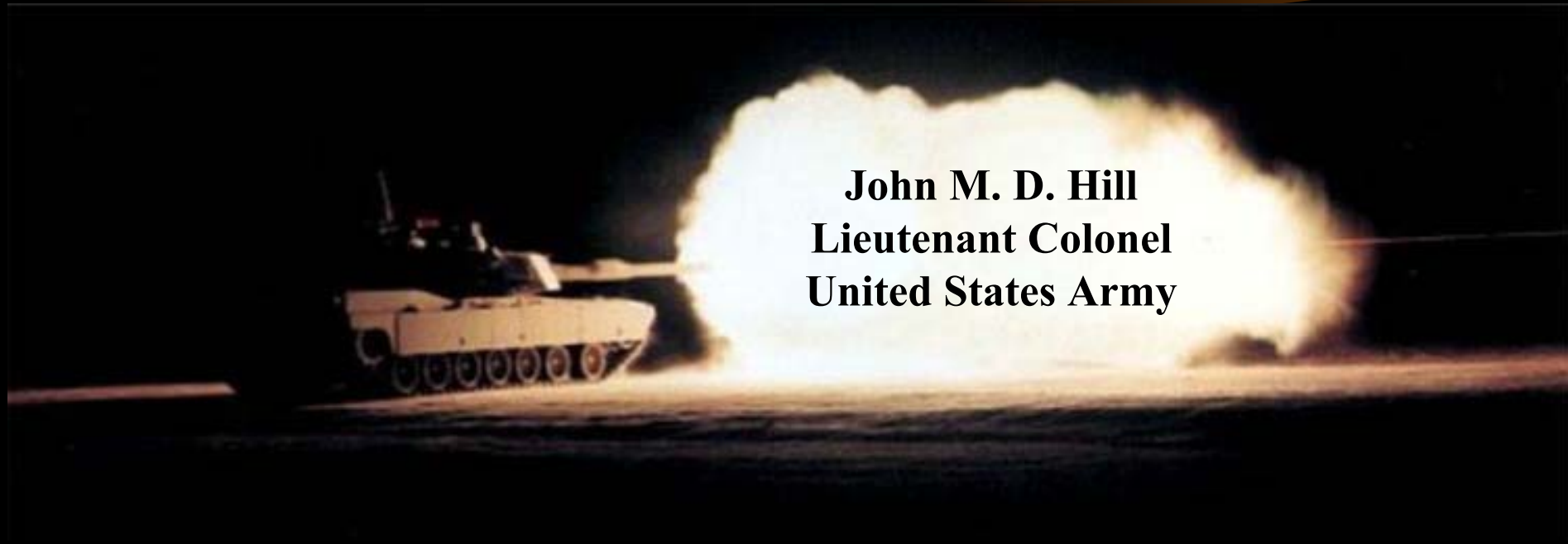


Anticipatory Planning Support Systems



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Agenda

- Background and Motivation
- Operationally-Focused Simulations
- Exploiting Artificial Intelligence Techniques
- Agent-Based Planning
- Conclusions

Planning Terminology

- Branch *
  - "a contingency plan or course of action (an option built into the basic plan or course of action) for changing the mission, disposition, orientation, or direction of movement of the force to aid success of the operation based on anticipated events, opportunities, or disruptions caused by enemy actions and reactions as determined during the war-gaming process."
- Sequel *
  - "Major operations that follow the current major operation. Plans for these are based on the possible outcomes (victory, stalemate, or defeat) associated with the current operation."

* US Army Field Manual 101-5-1 *Operational Terms and Graphics*

How We Plan

- The traditional military decision-making process (MDMP) focuses on developing friendly courses of action (COAs) against "most-likely / most-dangerous" enemy COAs.
- There is a well-known axiom in the military that "no plan survives the first shot."
- This is another way of saying that a branch has occurred during execution that was not included in the plan.
- When this happens, the commander and the staff immediately transition into reactive mode (if they weren't in that mode already).
- The military needs a new way to perform planning while executing the operation so that it retains option dominance.

Rethinking Planning

- The traditional MDMP is based on processes developed more than eighty years ago!
- Information technologies have been used to *automate those processes*.
- Only recently have we been taking a different approach; that is, *changing the processes* based on capabilities available from information technologies.
- Must monitor and predict the flow of battle
  - observe friendly execution of assignments
  - observe enemy actions and reactions
  - feed this information back into our understanding of the current situation
  - use this information to predict future situations

*Dominant BattleSpace Knowledge **

- Situational Awareness
  - The ability to see and understand what is happening on the battlefield.
- Information Dominance
  - Gaining and sustaining more / faster / better situational awareness.
- Option Dominance
  - Maintaining the offensive involves the ability to dictate the time and place of action.
  - A key to option dominance is being able to respond faster than one's adversary.
  - To do this, we must know what the available options are in time to choose between them.

* David Alberts, *Institute for National Strategic Studies*

Option Dominance

- Must recognize what needs to be done:
  - develop an understanding of the current situation and its implications
  - generate options to be considered, and analyze the options
  - obtain a command decision regarding which option will be taken
- Must accomplish all of the above faster than the enemy can act and react.
  - translate an option into understandable assignments
  - transmit the assignments to subordinates
  - have the subordinates understand and act upon the assignments
- "We need to be able to design a more streamlined process than we currently have to satisfy the time-critical nature of this task." *

* David Alberts, *Institute for National Strategic Studies*

Anticipatory Planning

- General (ret.) Wass de Czege has proposed a different approach to military planning and execution that he calls "anticipatory planning and adaptive execution."
- This anticipatory planning approach merges planning and execution into a single continuous process.
  - In planning, many reasonable branches are developed
  - As execution progresses the plan is continuously updated
  - Invalid branches are pruned and new branches are developed
- Anticipatory planning can be applied to many dynamic, uncertain, adversarial domains
  - military operations, fire fighting, business, information assurance

The Purpose of Anticipatory Planning

- To maintain as many viable options in the plan as possible
- To focus planning effort where it will do the most good
- To help the decision makers identify decisions that they { can | should | must } make NOW to ensure a desired option is available LATER

Supporting Technologies

- Information gathering systems
- Information fusion systems
- Planning systems that use the information to support the commander
  - Requires the integration of multiple domains
    - Military Planning and Execution
    - Computer Human Interaction
    - Simulation
    - Artificial Intelligence Techniques

Planning Techniques

- Contingency Planning
  - Develop and consider every possible branch
  - Not feasible for large planning spaces
- Probabilistic Planning
  - Assign probabilities to branches and consider the most likely
  - Still have to develop a lot of branches
  - Sensitive to changes in the probabilities
- Interleaved Execution and Planning
  - Observe the results of execution, then plan based on the new information
  - Not a good idea to wait to find out what happens to start planning
- Reactive Planning
  - Develop reaction rules for specific conditions
  - Difficult to build enough rules to cover all possible conditions
- Adaptive Planning
  - Situation Matching
  - Too many situations are possible

Applications of Technologies

- Fox-GA (Schlabach, Hayes, Fiebig)
  - Uses genetic algorithm to develop courses of action (COAs)
- Fuzzy-Genetic Decision Optimization (Kewley)
  - Uses fuzzy inference mechanism within a genetic algorithm to develop COAs
- Capture the Flag (Atkins, Cohen)
  - Heirarchical [Tactical Entity]Agent Control for user-guided COA development
- Multiple Trajectories (Gilmer, Sullivan)
  - Simulation entities instantiate their own simulations to determine their best COA
- Operationally-Focused Simulations (Surdu, Pooch)
- Anticipatory Planning Support System (Hill, Surdu)

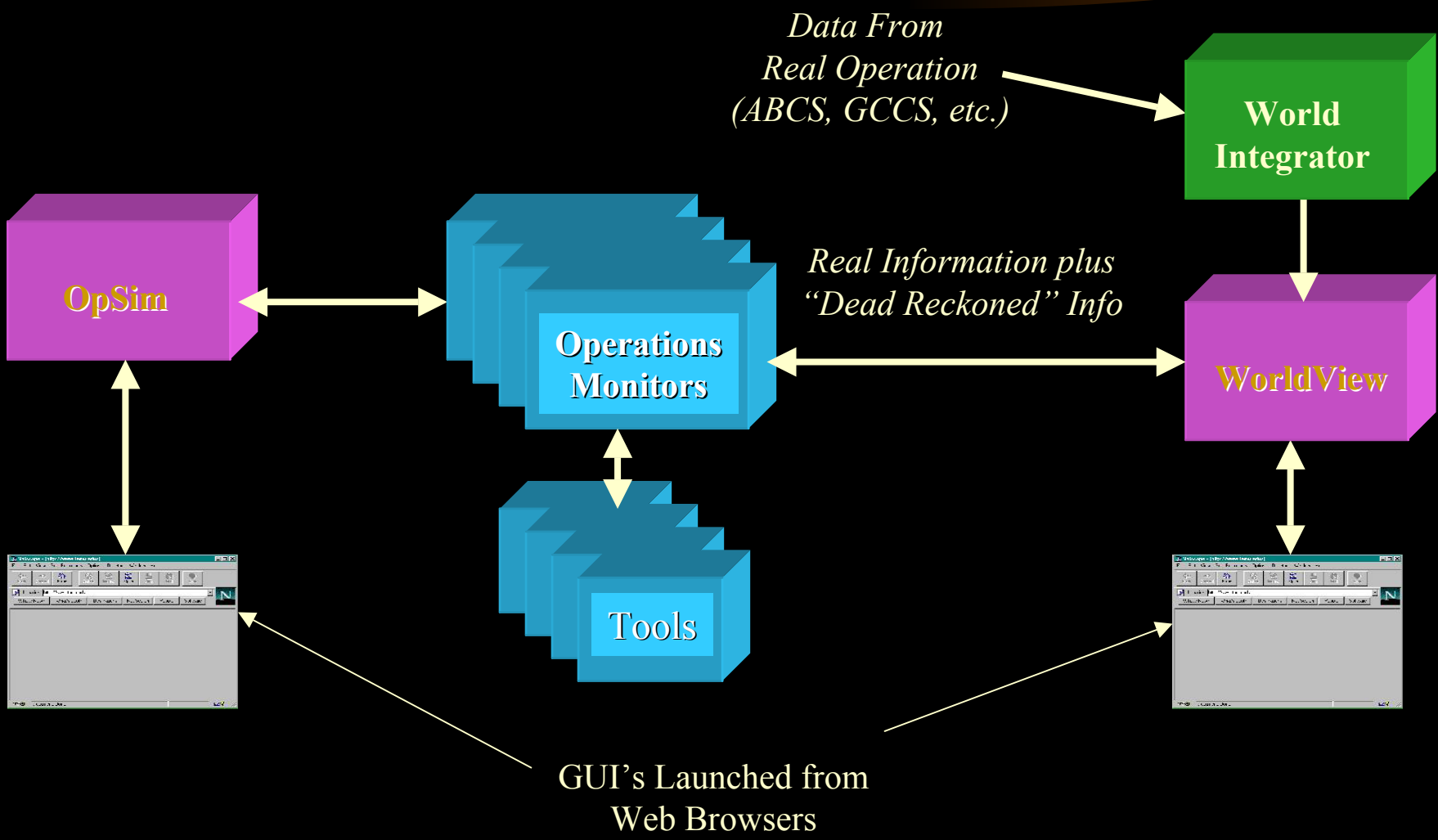
Operationally Focused Simulations

- Part of a planning support system
- The system watches for deviations from the plan
  - Operations Monitors (OMs) detect differences between the plan and the actual execution.
  - Different monitors for battlefield operating systems
    - Maneuver, fire support, etc.
- The system determining the significance of those differences
  - Instantiate an operationally-focused simulation
  - Supply it with the original plan and the current situation
  - Run the simulation and determine the impact the detected difference will have on the success of the plan.
- The system reports any significant differences to the commander

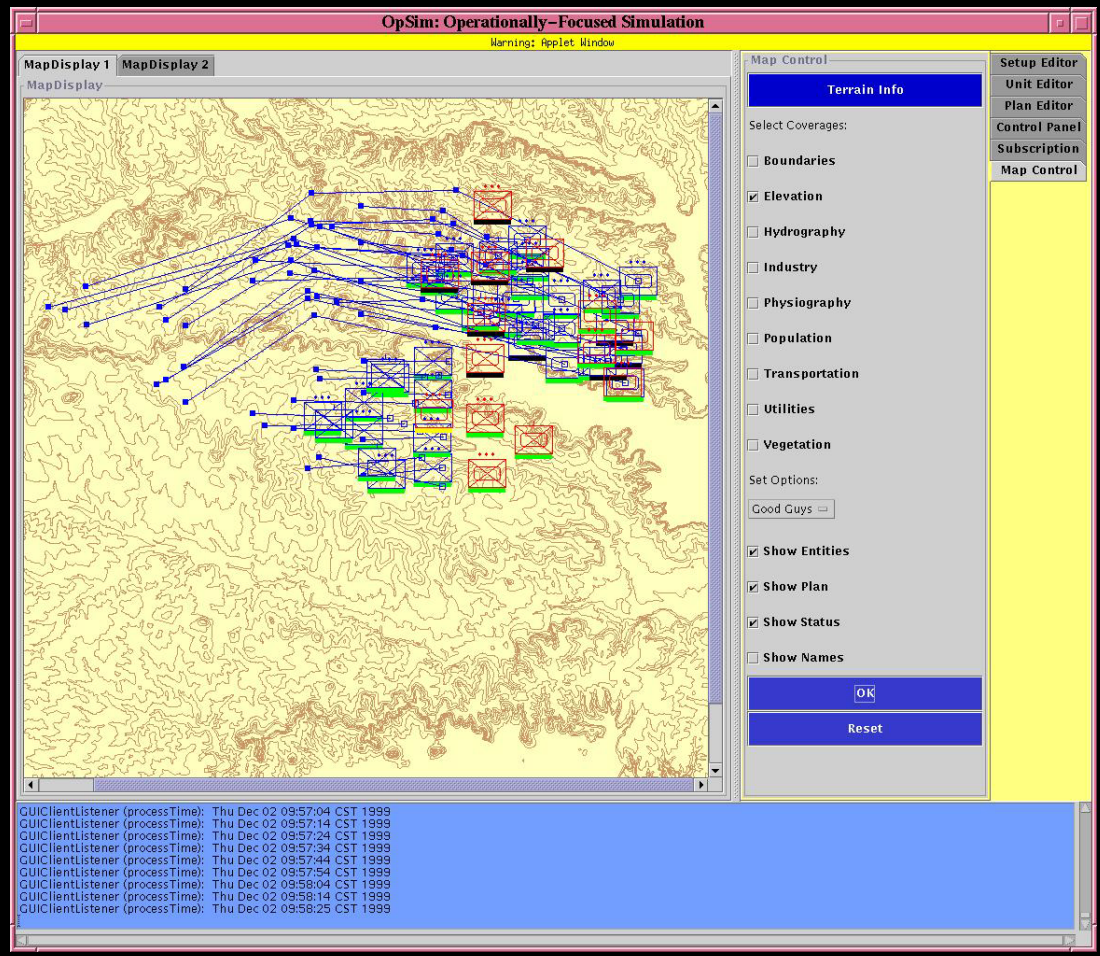
Desired Attributes

- An operationally-focused simulation should:
  - Run on a single workstation
  - Be low-cost, open systems, multi-platform
  - Be capable of hyper speed and real time
  - Answer external queries
  - Be able to operate at the aggregate level as well as entity level
  - Be able to perform rapid scenario and plan generation
  - Have pre-designed measures of effectiveness
  - Be able to interface with C4I equipment

OpSim Architecture



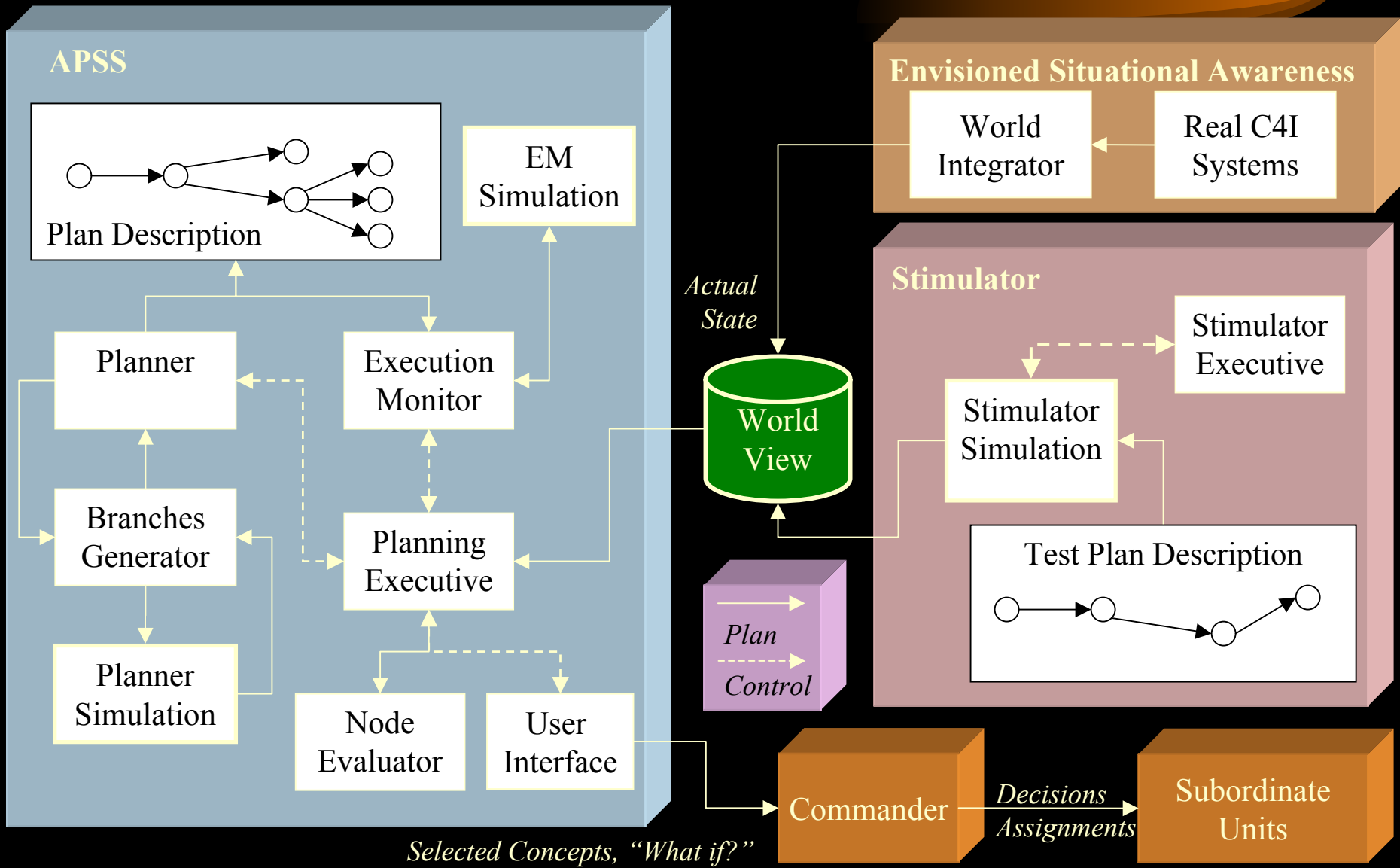
OpSim In Action



APSS Objectives

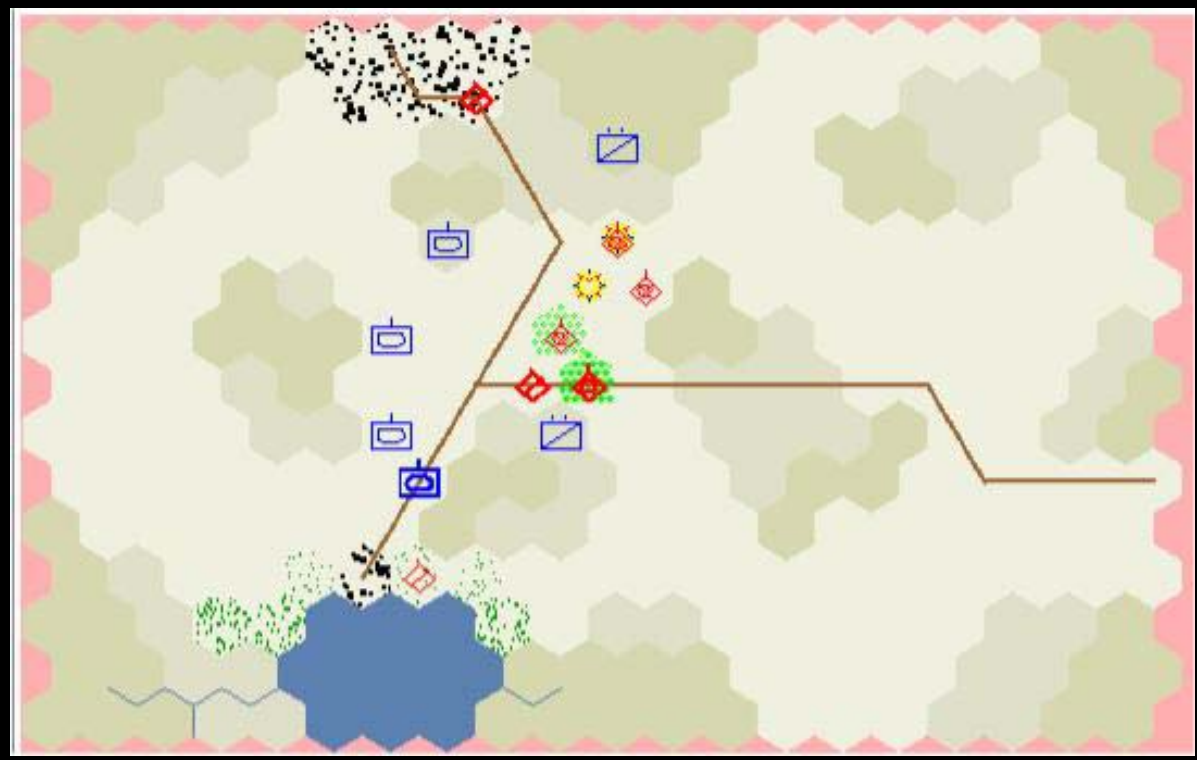
- Develop a methodology for the Anticipatory Planning Support System (APSS).
- Develop a common Plan Description that defines entities, attributes, and interactions in a complex, adversarial environment and facilitates rapid plan development, plan visualization, use of simulations, and use of artificial intelligence techniques.
- Develop agents to perform the Anticipatory Planning
  - An Execution Monitor that compares actual states to planned states and make recommendations used in pruning and re-planning
  - A Planning Executive that conducts concurrent execution and planning by instantiating, assigning, and terminating Execution Monitors and Planners
  - A Planner that performs local contingency planning and produces representative probabilistic outcomes
- Develop a prototype system that validates the Plan Description mechanism and the Planning Agents and demonstrates the feasibility of the APSS methodology.

APSS Architecture



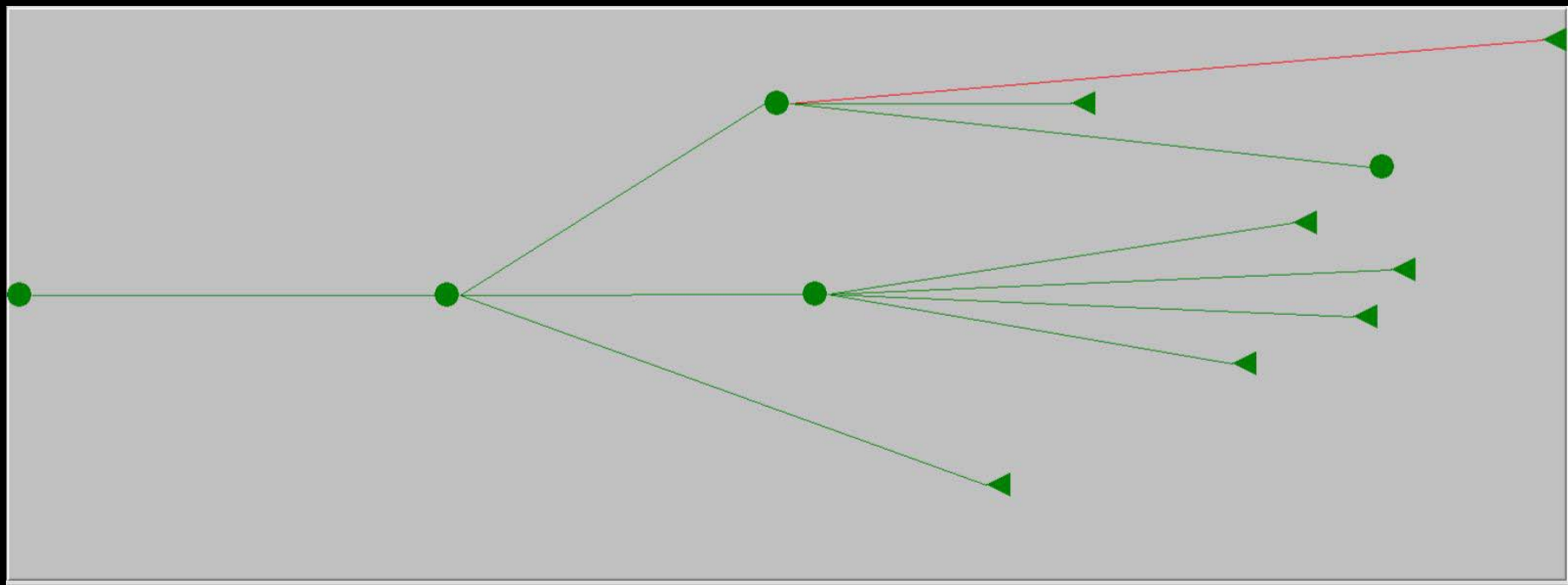
World View

- Tactical entities
  - TacEntity Builder Application
- Terrain
  - HexGrid Builder Application
- Actual State:
  - the status of tactical entities on the terrain at a particular time
- The World View
  - holds a sequence of Actual States and provides them to the planning system

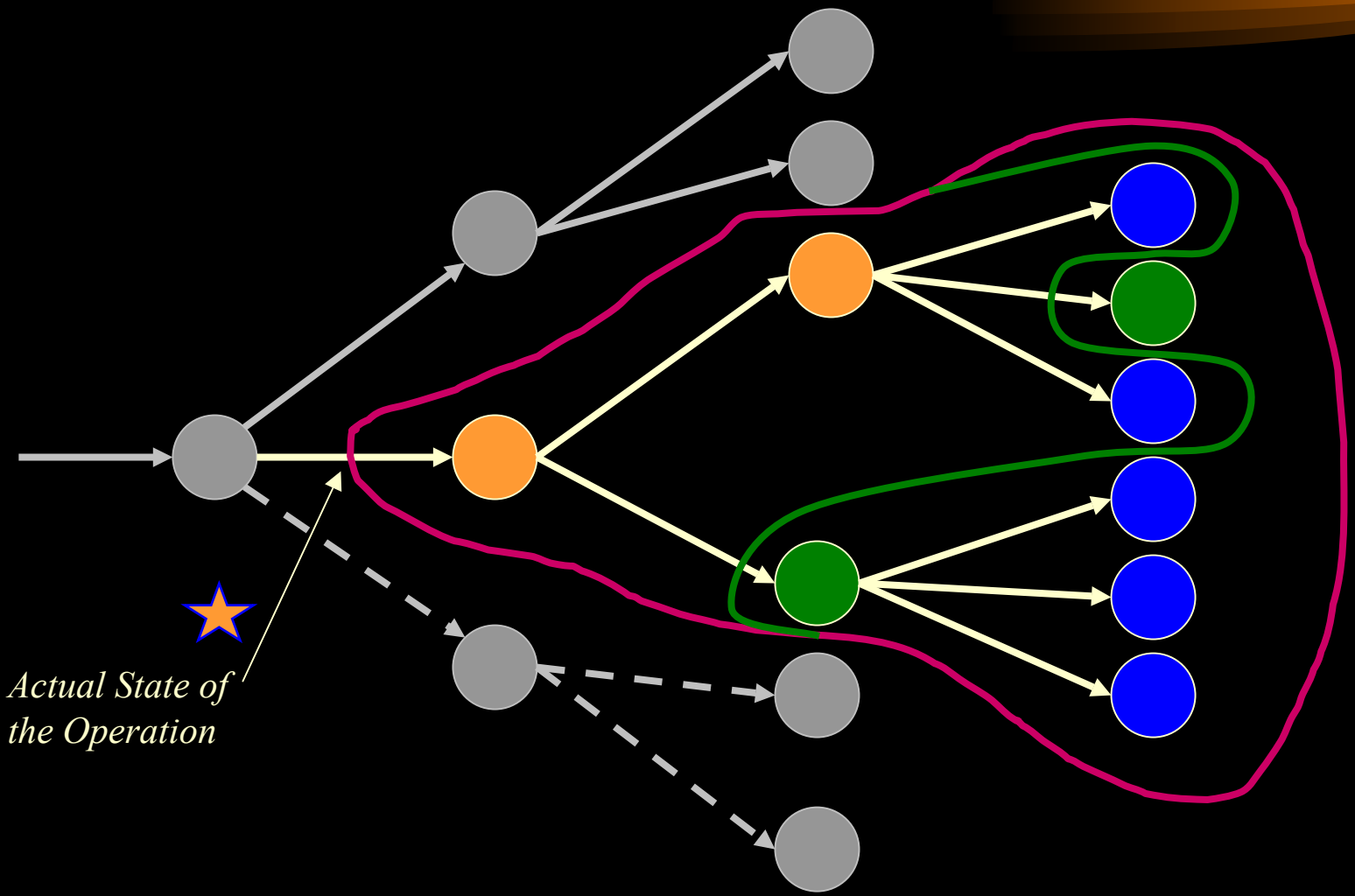


Common Plan Description

- Provides a means of visualizing different plan paths
- Enables rapid visual plan development through task assignment
- Feeds simulations for plan building, execution monitoring, re-planning, and system stimulation

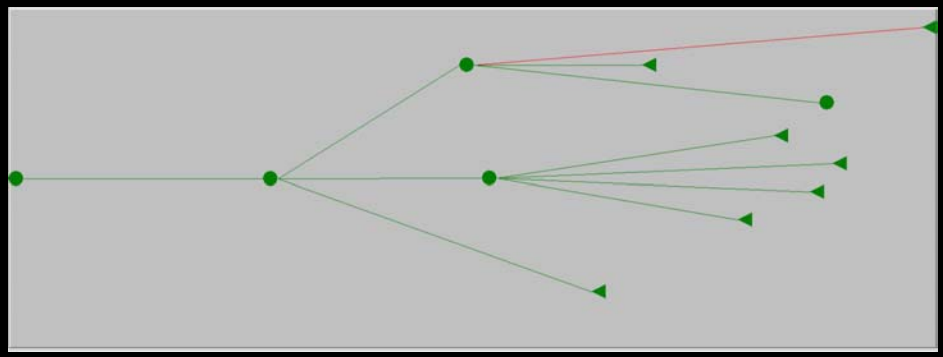


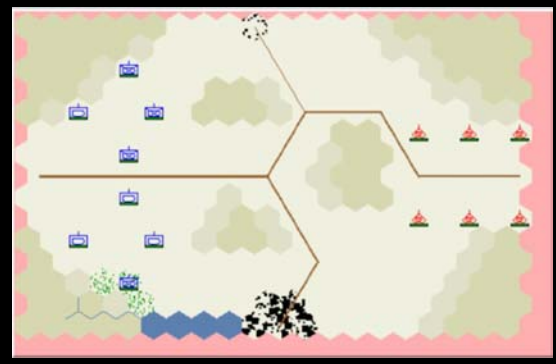
Planning Space and Planning Frontier

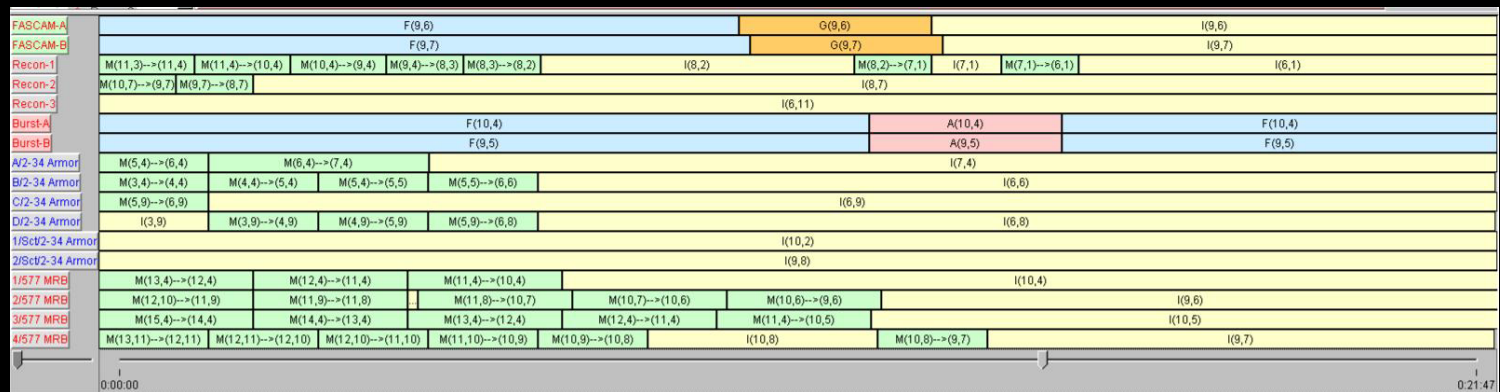


Visual Plan Development

- A *Branch* holds the collection of *TacEntityTasks* , which are assigned through drag-and-drop operations.
- A simulation is run to determine the interactions between the entitities, and the resulting status changes
- Plan Builder Application







Execution Monitor

- Forward Simulation
  - Start from Actual State, attempt to apply planned tasks
  - Compare Anticipated State with Planned State
  - Becomes too coarse with large Actual State / Planned State variance
- State Difference Analyzer
  - Analyzes differences between an Actual State and a Planned State
  - Run on the monitored node and all following nodes
  - Likelihood Recommendation
    - Weighted function of sums of distance factors and strength factors
- Monitoring Frontier
  - Need to cover *all* highest-level nodes after the Actual State timestamp
  - Eliminate bypassed nodes, reassign Execution Monitors

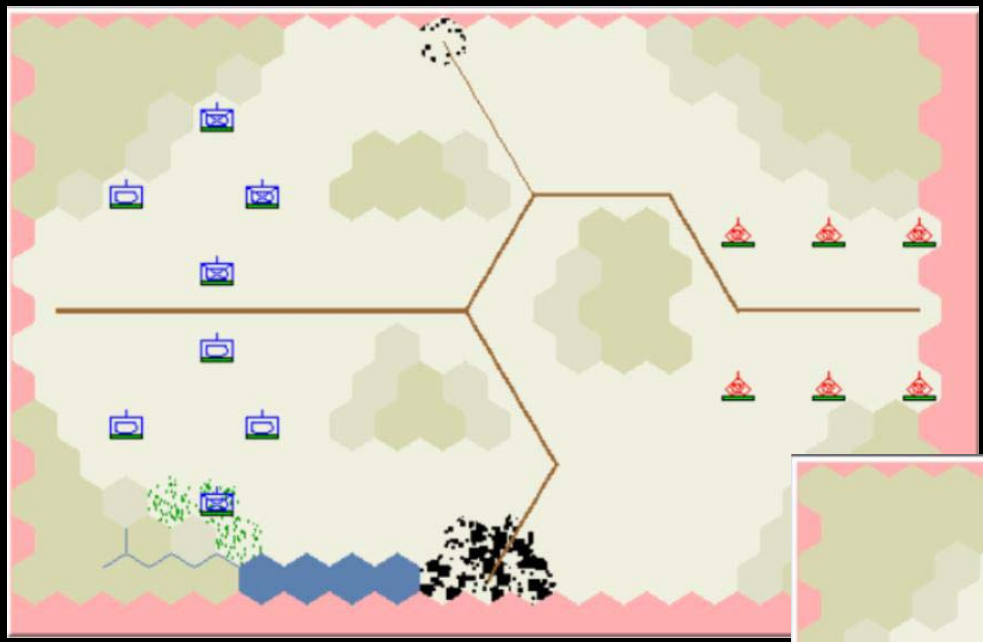
Planning Executive

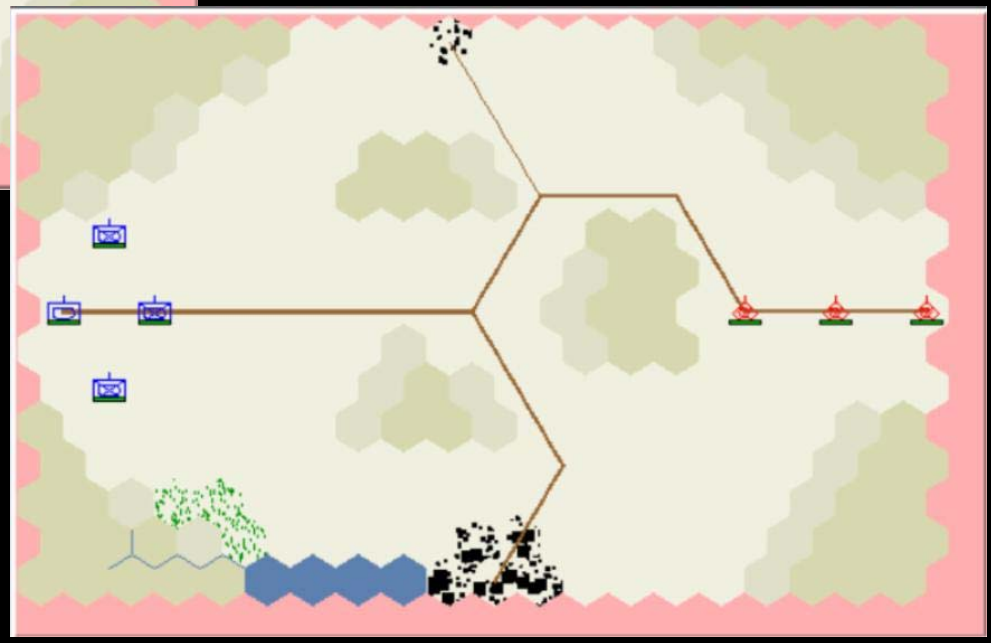
- Receives *Actual State* update from the *World View*
- Stops any *Planners* that are still running
- Adjusts the monitoring frontier
- Notifies the *Execution Monitors* that a new *Actual State* has been posted
- Waits for the likelihood measures from the *Execution Monitors*
- Determines re-planning priority based on likelihood, branching factor, and temporal proximity to the *Actual State*
- Assigns *Planners* to the *Nodes* in priority order
- Ready to receive next *Actual State* update

Planner

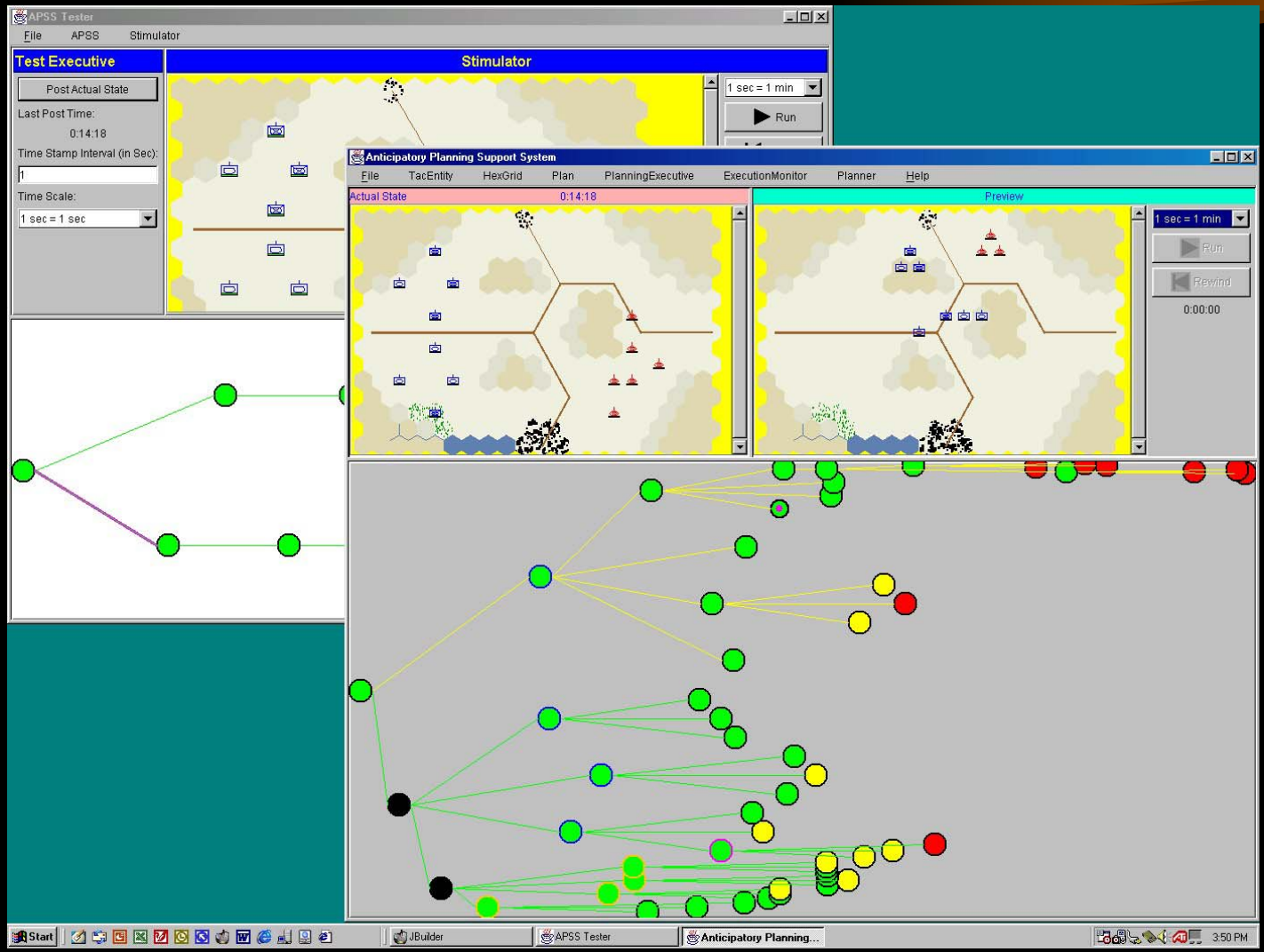
- Is placed on a *Node* to create new *Branches*
- One type of planner:
  - Uses a Genetic Algorithm (GA) to create, evaluate, and filter the "best" new *Branches*
  - A Genetic Algorithm populates a generation with candidate solutions to a problem, evaluates each candidate, then causes the "most-fit" candidates to reproduce with each other.
  - This process is repeated until some given number of generations has been produced, or time runs out

Example Scenarios



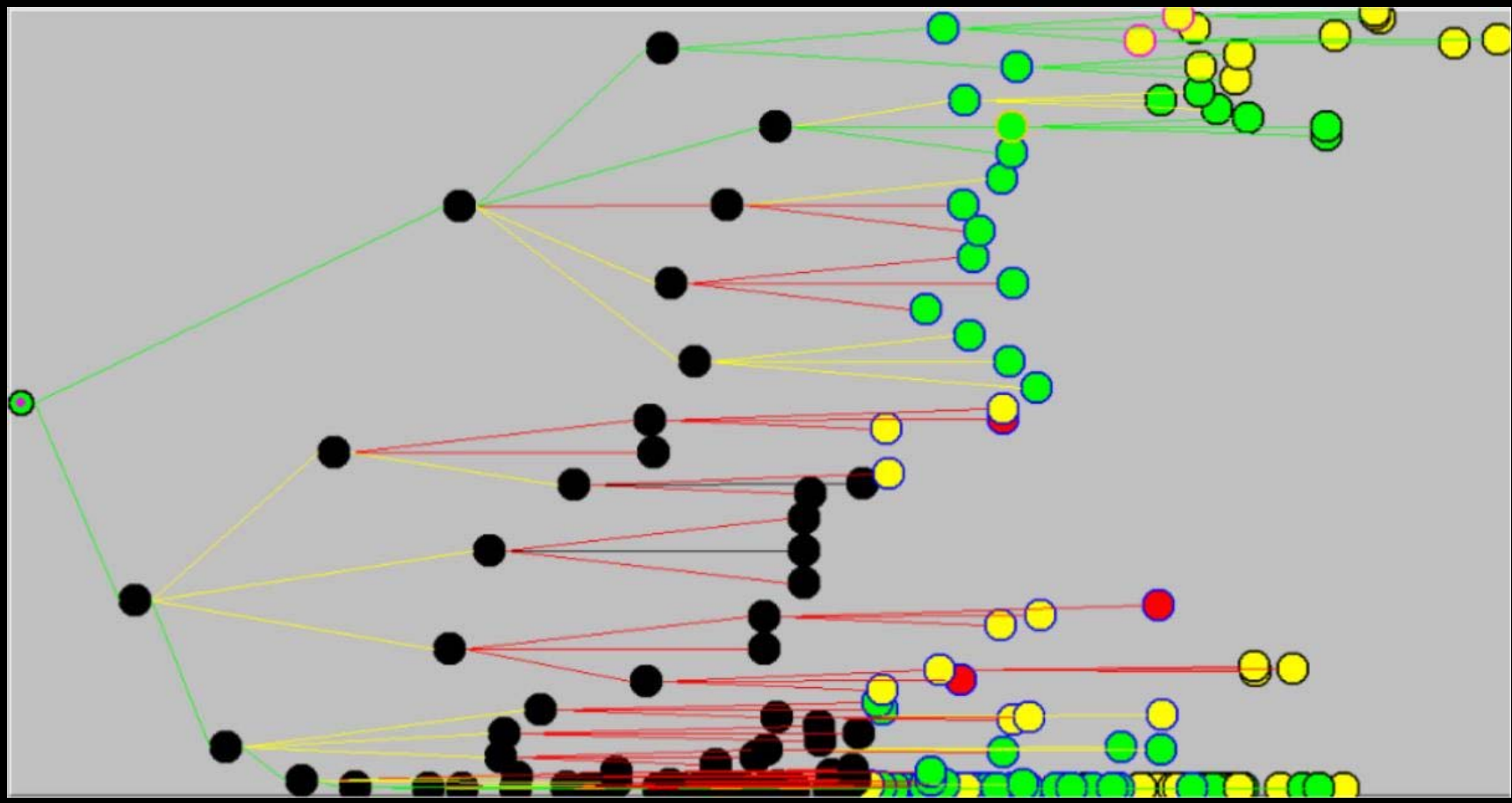


APSS in Action



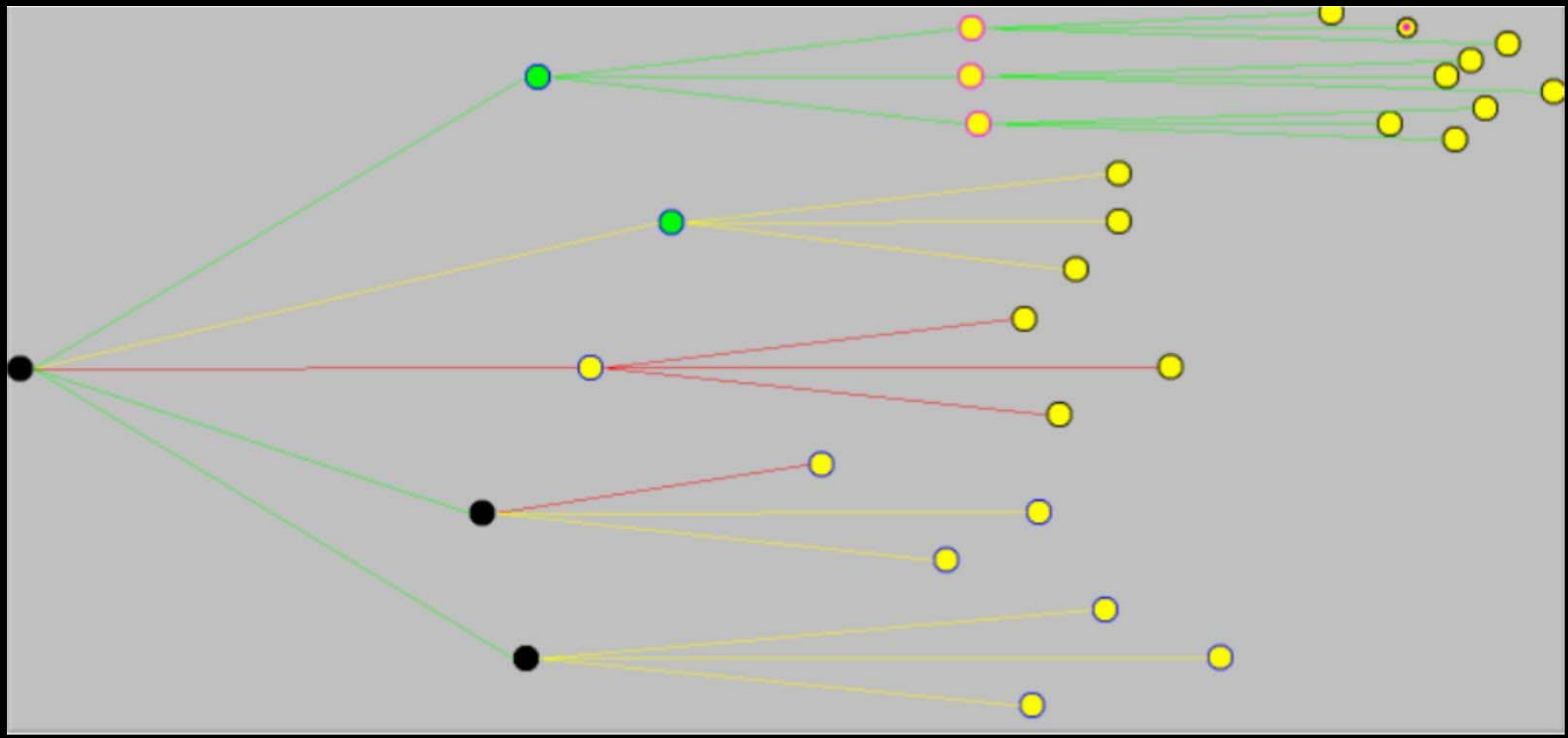
APSS in Action – Plan Description

- The color of a branch indicates how likely that branch is to occur.
- The color of a node indicates how favorable that state is (to us).



APSS in Action – Zoomed In

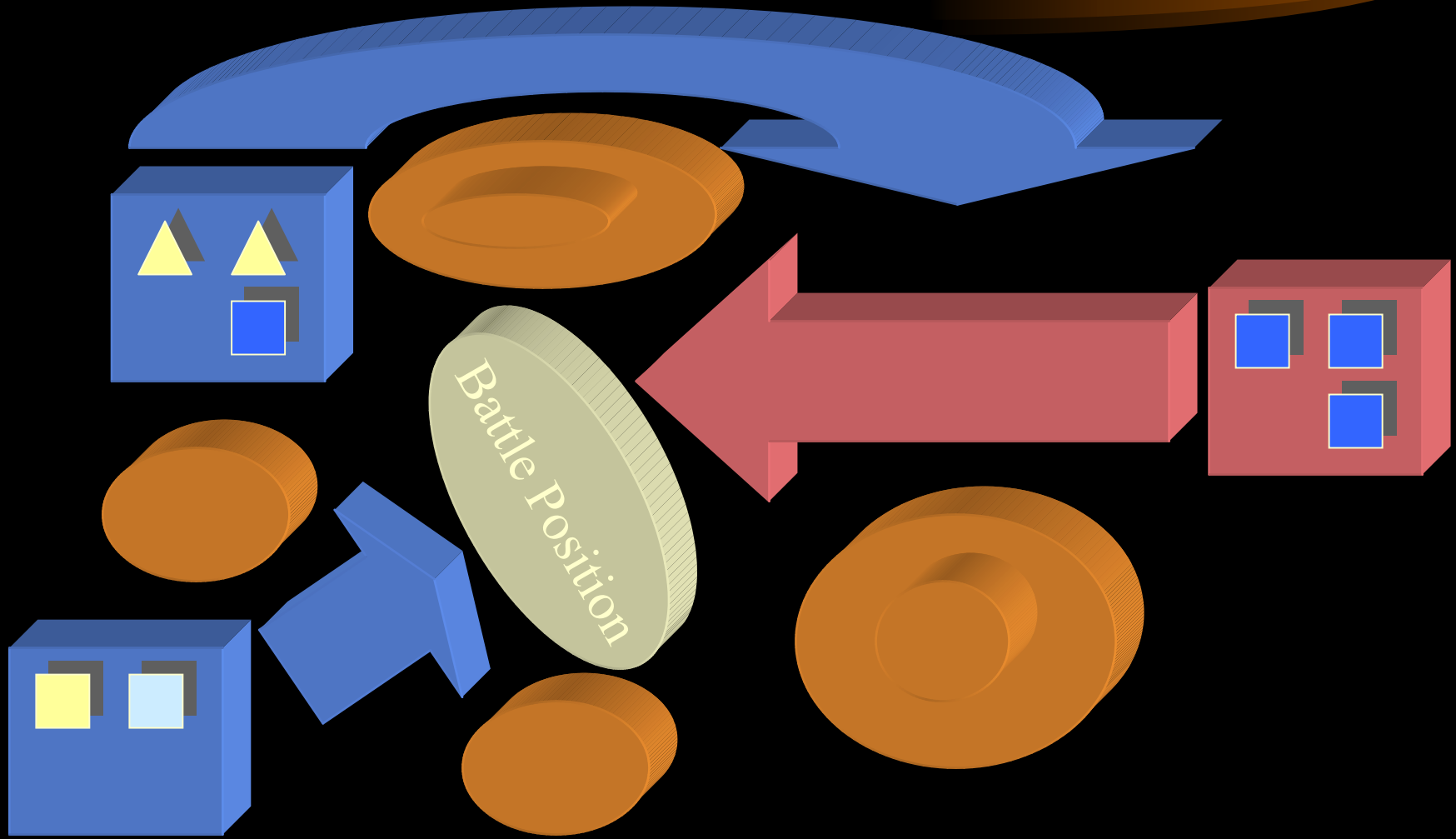
- The planner agents are focused ahead of the most likely branches.



The Next Step in APSS

- Planning Level Change
  - Operating at the entity level is too restrictive and too sensitive to minor differences
  - Move to concept-level planning
- Database Implementation
  - Scalable
  - Distributed
  - Collaborative

Planning at the Concept Level



Conclusions

- The APSS prototype system served as a good proof of concept for a new approach to planning in dynamic, complex, uncertain, adversarial, domains.
- The next generation of APSS will use concept-level planning for more flexibility, and a database implementation for collaborative planning.
- This type of research can ultimately lead to the development and implementation of a robust Anticipatory Planning Support System that will help commanders achieve and maintain option dominance.

Questions?

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