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Genetic Algorithm Applied to Multi-Agent War Gaming Simulation

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Agenda

IR&D Project and Goal

Brief description of COTS/GOTS analysis software employed

Modeling of an urban rescue scenario

How “Darwin” Genetic Algorithm was used

Pareto-optimal solutions obtained + description

Summary and thoughts

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IR&D Project and Goals

Develop a New Capability for Operations Research Design and Analysis

Apply a Genetic Algorithm to a Multi-Agent Theatre-Level Simulation

- Design optimal traits of networked interoperating agents
- Evolve agent/platform traits (capabilities) that must achieve a desired effect (EBO is implicit)
- Co-evolution of adversary = predict adversarial response

Provide Capability-Based Evaluation of System-of-Systems

- Multiple interacting networked platforms/agents form a SoS
- No modeling of specific technologies, only the *capabilities* they bring
- Satisfaction not tied to a specific technology solution (but could be)

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Tools Applied

SEAS

- GOTS Multi-agent theatre-level simulation
- Programmable rule-based behavior (actions & re-actions)
- http://teamseas.com/

ModelCenter

- COTS framework for MDAO
- Provides "Darwin" genetic algorithm (among others)
- http://phoenix-int.com/

MatLab

- Provided easy interface between ModelCenter and SEAS
- Provided statistical collation of MC trials and post-analysis
- http://www.mathworks.com/

Excel

- Host application for a simple/notional cost model
- Hook for more complex cost models

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What is a Multi-Agent Simulation?

- Variety of entities that operate autonomously and independently in a simulated world
- Continuously get input, interpret it, and make decisions
- Communicate and negotiate with other agents to achieve a goal or get things done
- Agents can be programmed to learn from experience
- Outcome is not certain or entirely predictable

SEAS contains all of these properties

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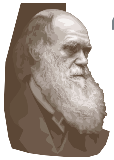


“Darwin” Genetic Algorithm

Process analogous to natural selection

Most fit designs from a population will produce offspring

- Crossover (recombination)
- Mutation

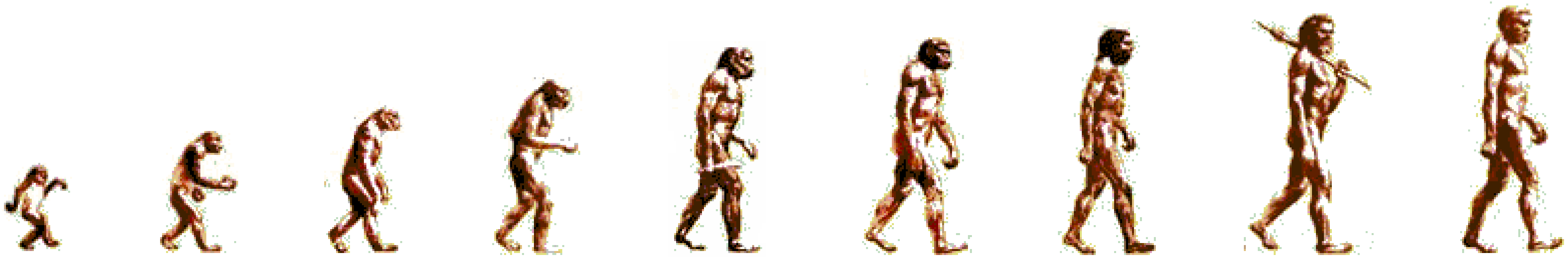
Small set of less fit designs maintain diversity

- prevent pre-mature convergence on poor solutions

Continues until improvement stops

Effective in noisy or discontinuous design spaces (uncertain outcomes)

Better chance of finding global optimum and multiple near-optimal designs



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Capabilities and Objectives

Blue Agent Capabilities (Darwin Design Traits)

- Vehicle Speed
- Vehicle Armor Hardness (probability of being killed if fired upon)
- Sensor Range
- Weapon Range
- Weapon Lethality (probability of kill when firing upon red)

Multi-Objective Optimization Goals (Effectiveness)

- Probability of Successful Rescue (maximize)
- Monetary Cost (minimize)
- Bloodshed / Lost Lives (minimize)

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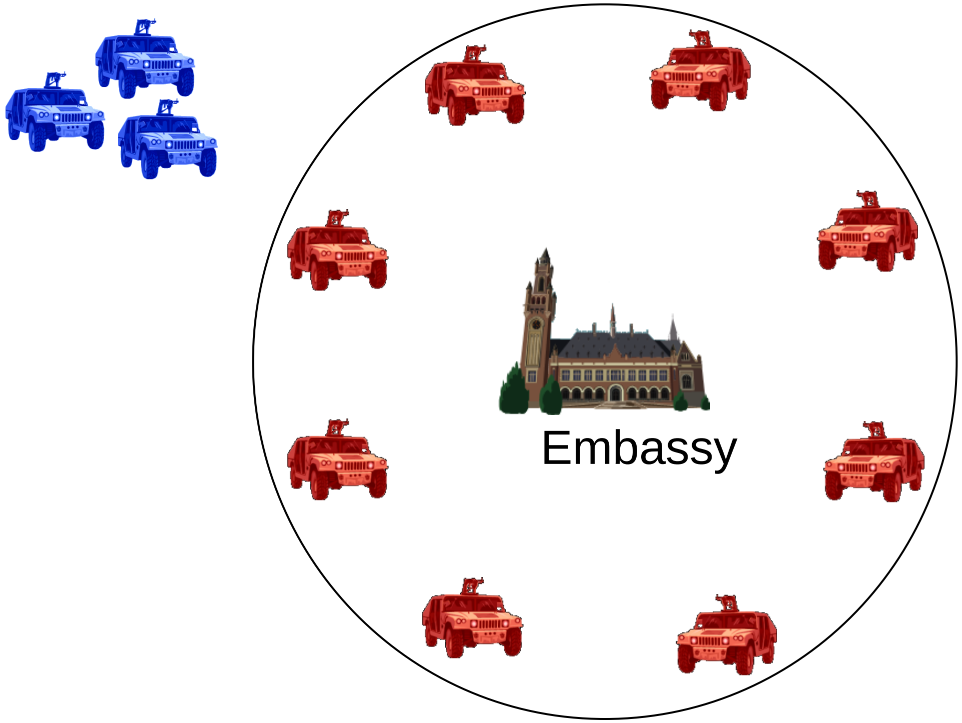
SEAS "Embassy Rescue" Scenario

Officials are trapped in an embassy following a coup

Eight red agents patrol the central area of town

Three blue agents try to covertly reach the embassy to rescue trapped personnel and covertly get them out



- **Red and Blue agents are outfitted with different capabilities**
  - Vehicle, Sensors, Weapon, Communications
- **Blue agents attempt to avoid being spotted by red agents**
- **Each side has rules for engaging the enemy should they encounter each other**

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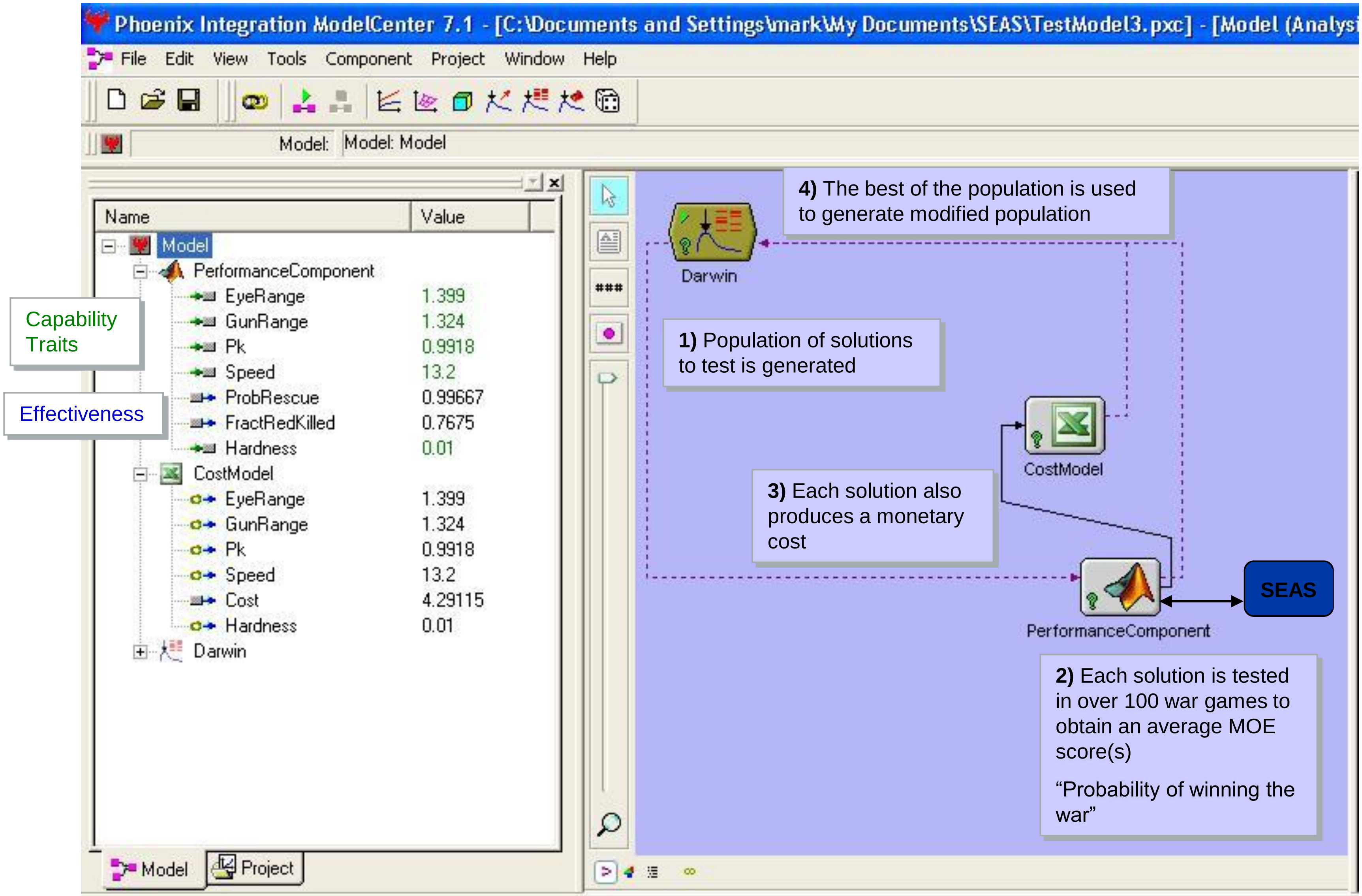
Process Overview & ModelCenter



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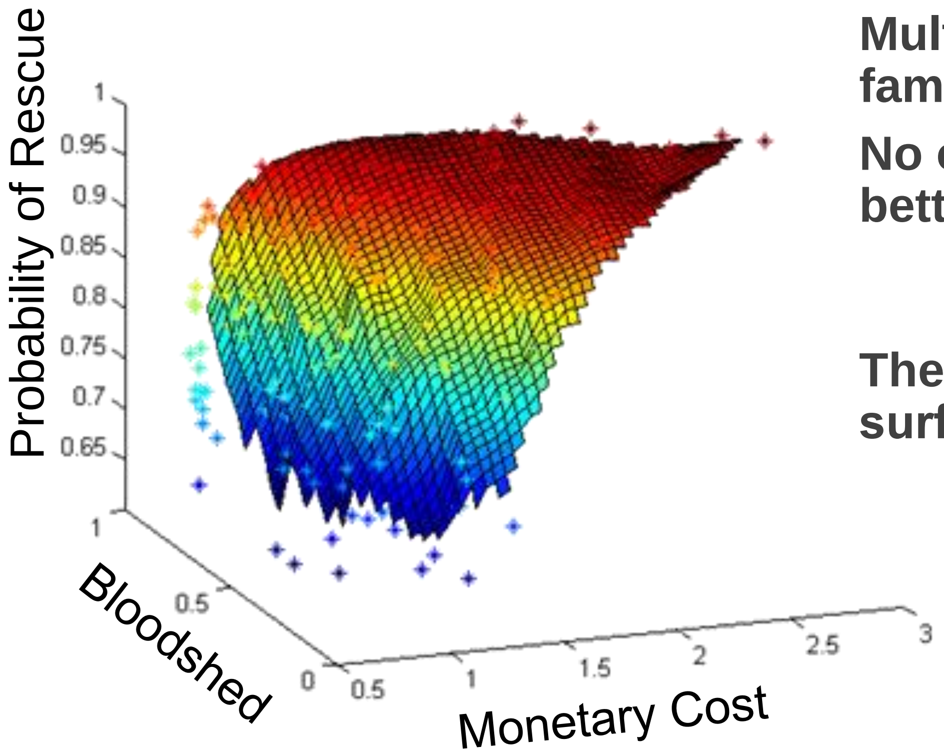
Pareto-Optimal Set and The Trade Space

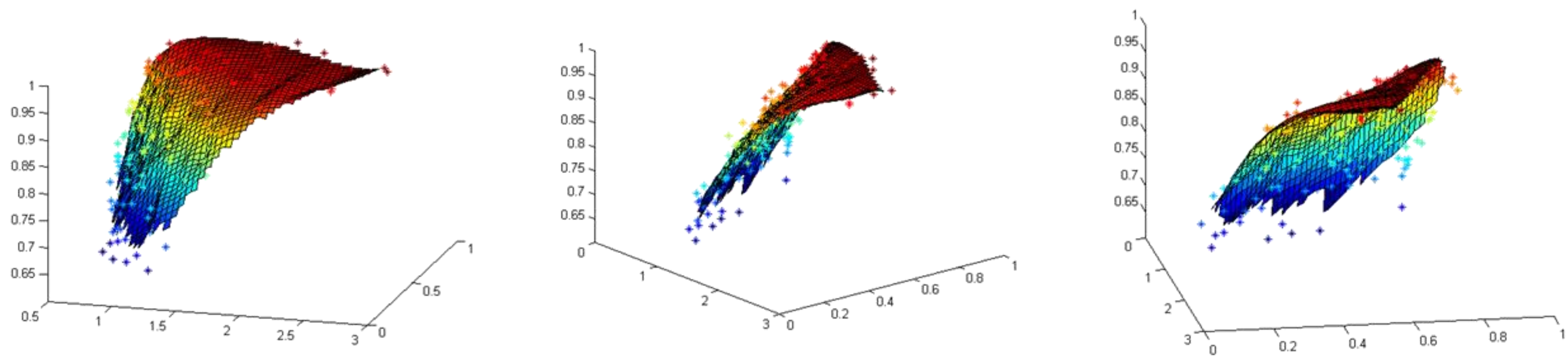


Multi-Objective optimization leads to a family of optimal design solutions

No other designs were found that were better in *all* objectives

- To continue to improve one objective, you must give up (trade) on another

These solutions tend to lay along a surface representing the "trade space"



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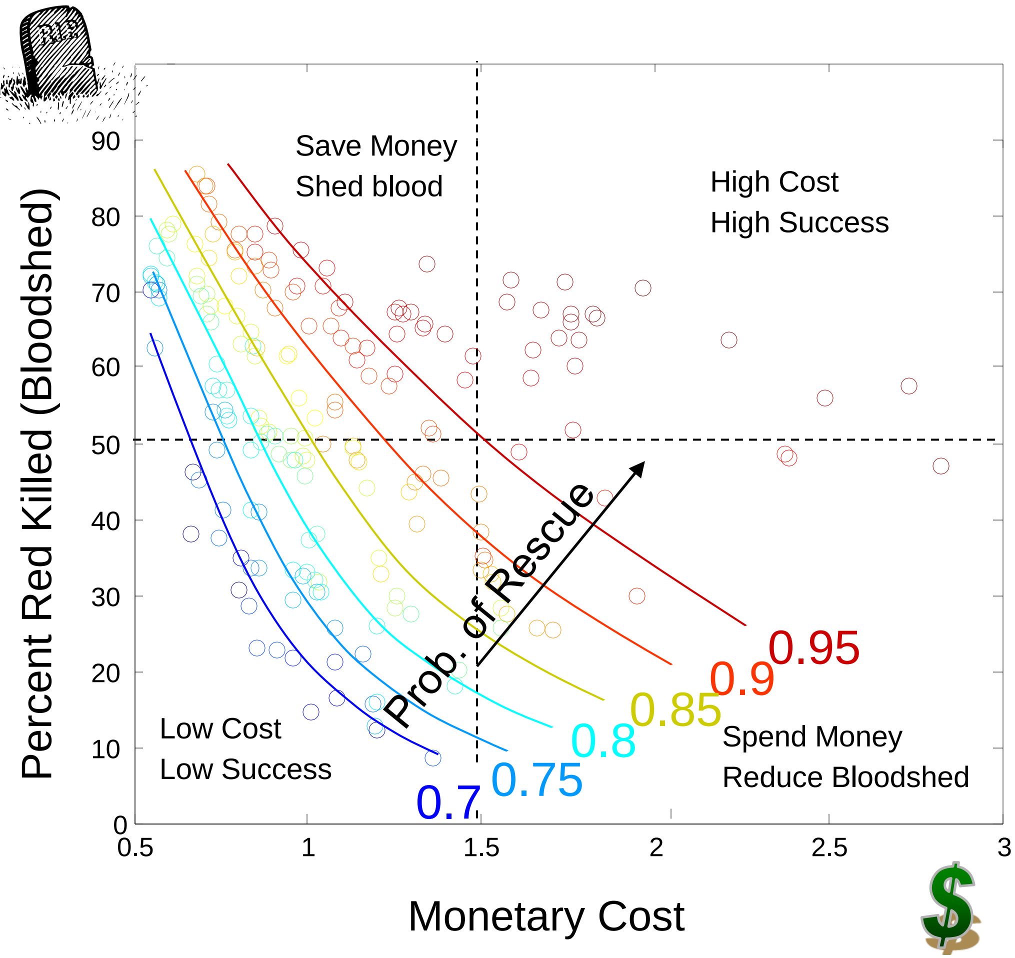
Identified "Solution Quadrants"



Optimal design set identifies where one objective must be traded against another

Solution "Quadrants" Emerge

- Highest probability of rescue comes at the cost of both money and lives
- Lowest probability of success comes at minimal cost to lives and money
- If you want to save money and have high probability of success, you must shed blood
- If you can afford to spend lots of money, you can achieve high probability of success with minimal bloodshed

Design traits (capabilities) can be examined in each of these quadrants (which is actually a continuum)

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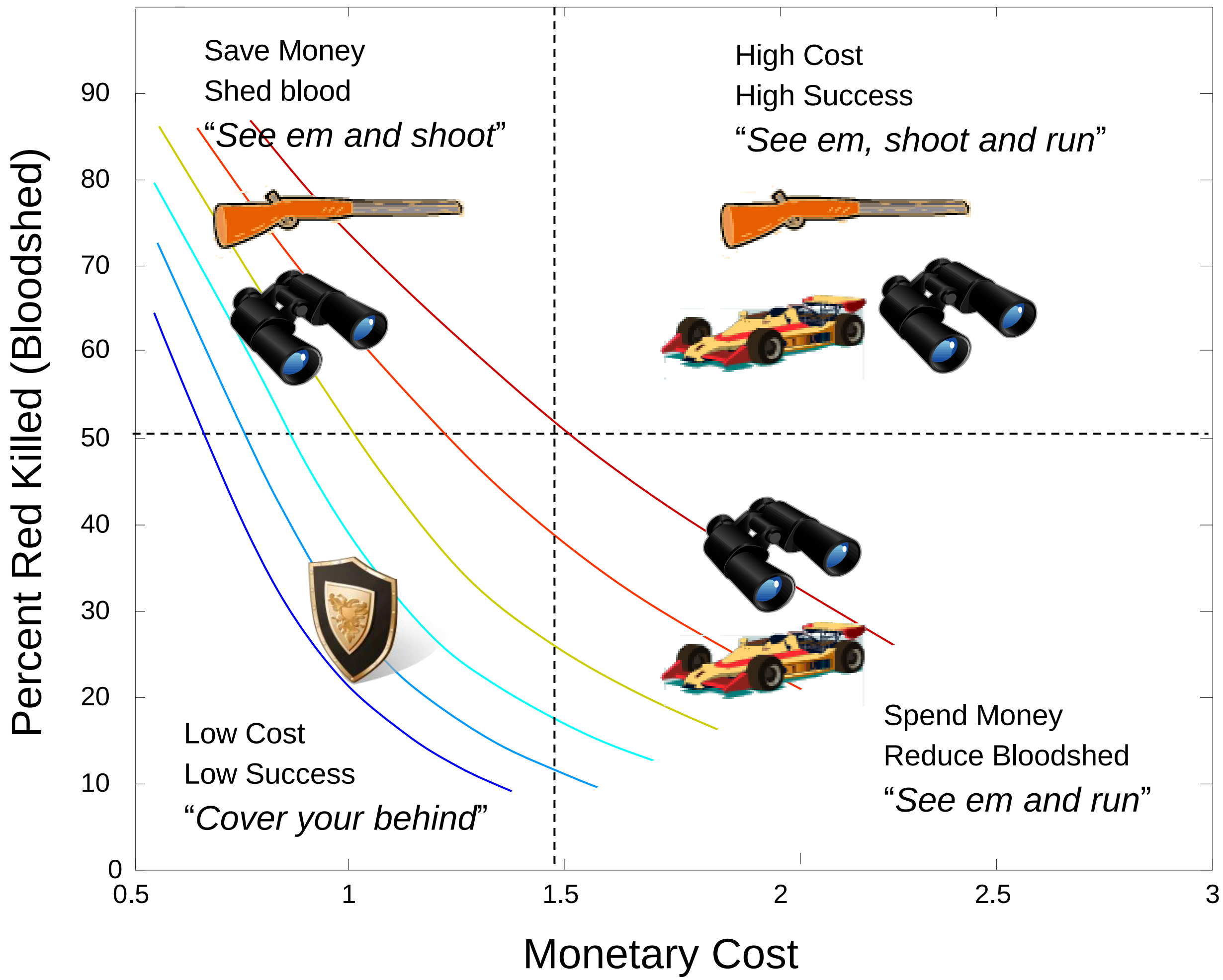
Dominate Traits in Solution Quadrants



By examining dominate traits in each quadrant, one can infer the strategy evoked

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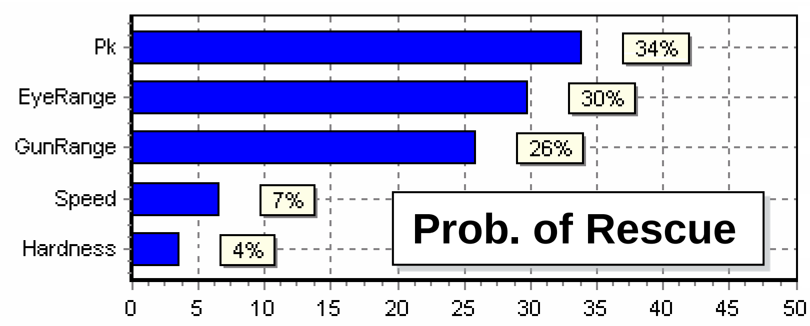
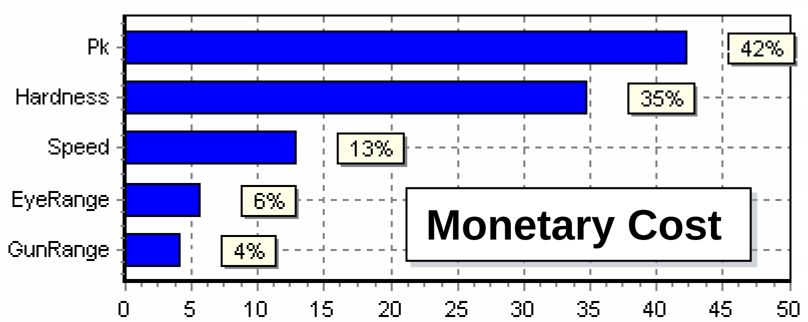
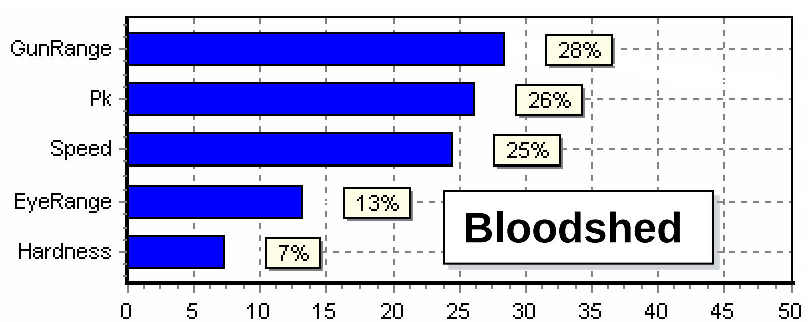
Sensitivity of Objectives to Capabilities
"Driving Capabilities"



Rescue success is most sensitive to weapon lethality, sensor range, and weapon range. Speed and armor contribute less to rescue success.



Monetary cost is driven most by weapon lethality and armor. Speed, sensor range, and weapon range play a lesser roll.



Bloodshed is most sensitive to weapon range, weapon lethality and speed. Sensor range and armor play a lesser role.

*Pareto Front (efficient) Solutions Only

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Summary and Thoughts

A GA has been successfully applied to a multi-agent war game simulation

- Proof of concept: evolution of agents in a MAS is achievable

“Adaptation” happens over generations, not during war game scenario events

- Basis of a “complex adaptive system”
- Behavior and strategies can also evolve over generations

Solutions become specified more as required capabilities, not specific technology solutions

- Although the technological source of different capabilities can be modeled if a specific technology solution is sought.

Co-evolution of adversarial traits (capabilities) is possible, but not yet done.

- Predict the likely evolutionary responses of an adversary

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Questions?

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Biography:

M.S. in Physics from C.S.U. Long Beach, B.S. in Applied Physics from U.C. Irvine. Twenty eight (28) years experience in MS&A for ISR, remote sensing, and military operations. General skills include developing mathematical models and algorithms, developing software and simulations, planning and running simulation experiments for design and requirements analysis, and architectural and systems engineering design efforts. Specific areas include remote sensing for space and airborne EO/IR platforms, EO/IR phenomenology (natural backgrounds and targets), advanced image processing (including spectral and temporal domain processing), sensor performance, space mission analysis and orbital design. High interest in applying MDAO to multi-agent simulations.

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