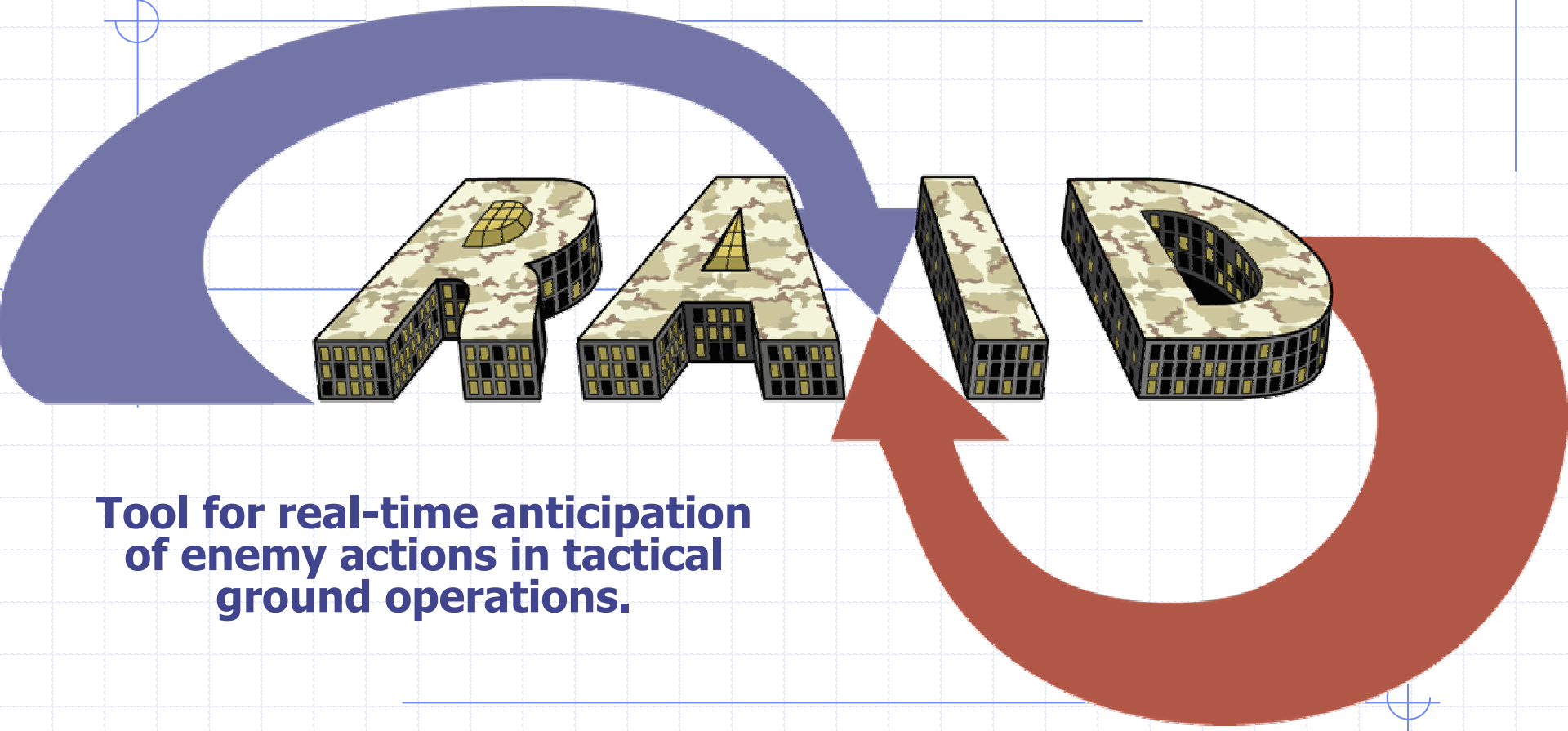
RAID

Real-time Adversarial Intelligence & Decision making



Tool for real-time anticipation of enemy actions in tactical ground operations.

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DARPA/Information Exploitation Office (IXO)

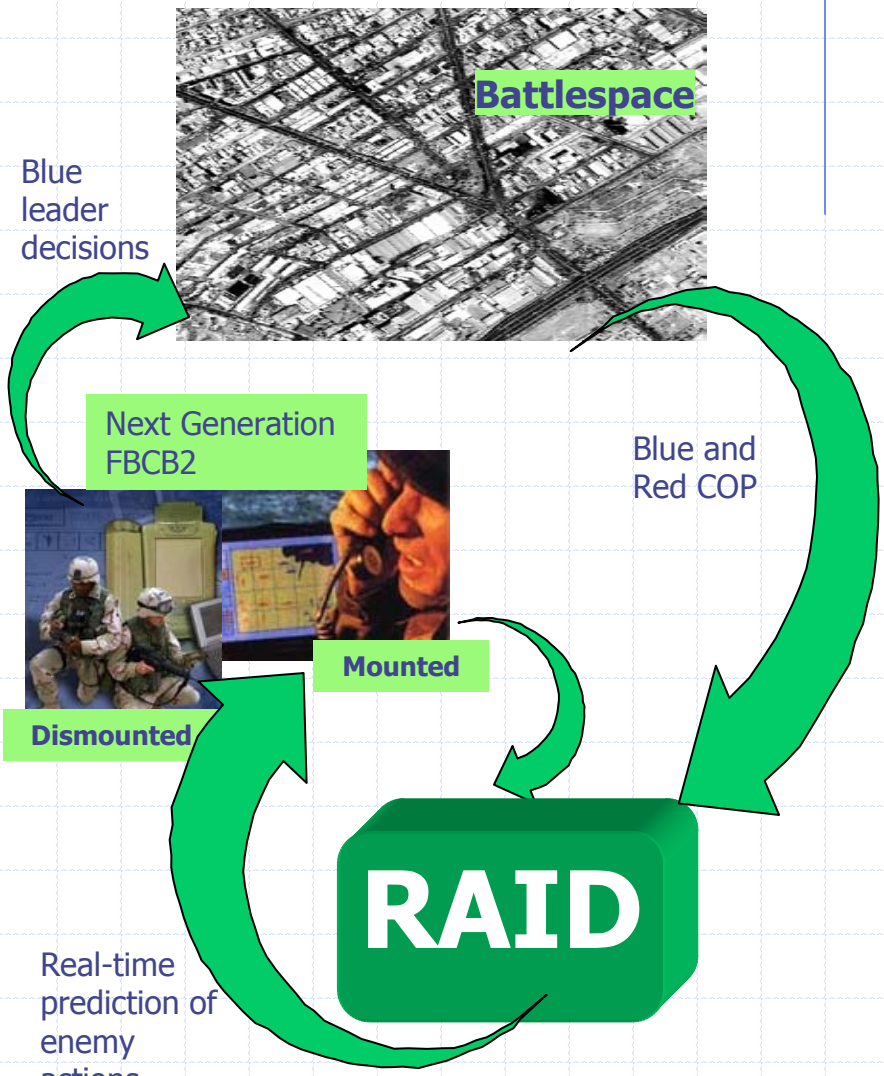
Approved for Public Release – Distribution Unlimited

Program Summary
Predict probable enemy actions in urban ops

Problem:
- Provide predictive, anticipative analysis of enemy future actions
- Identify attempts to conceal assets and actions and to deceive
- Monitor and continuously confirm, or not, and update the predictive analysis

Solution:
- Generate sets of Red predictions (including most dangerous and most likely courses of actions) and recommendations for Blue courses of action
- Identify probable enemy deceptions, decoys, feints, etc., concealed enemy assets, movements and actions within the currently available information

Approach:
- Leverage game-theoretic and cognitive model approaches to generate anticipations and counteractions
- Implement deception robust estimation techniques to detect enemy deceptions
- Experimental proof of predictive capabilities: human-in-the-loop OneSAF-based wargames compare humans and RAID
- Integrate the predictive analysis tools into warfighter's C2 and intelligence support systems



Military Rationale: need for predictive analysis technology

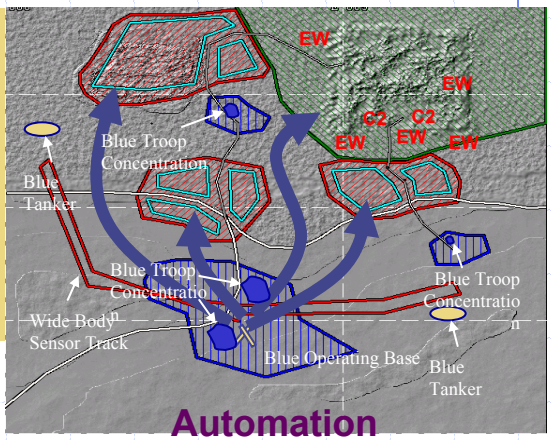
Army – Predictive Analysis

- **"...must provide ... running estimate ... incorporating predictive analysis ..." -- FCS ORD (1064, 3153, 3465)**
- "...shall predict near-future enemy positions and actions at intervals ..." -- DCGS-A ORD (127)
- "...shall have tools ... for performance of semi-automated predictive analysis ..." -- TRADOC Force Operating Capabilities (FOC) Pamphlet

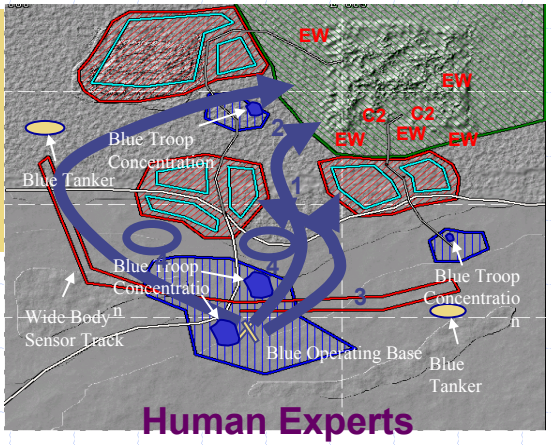
Air Force – Predictive Awareness

- "...means to predict adversary intentions and anticipate adversary reactions ..." -- Combat Air Forces CONOPS for Predictive Battlespace Awareness
- "...visualizing the future of the battle ... is the 'sucking chest wound' of a JFACC and his staff." -- LG Croker, USAF (Ret)

Today's Automation:
- Detailed optimization of allocation, times, routes
- No attempt to infer or to influence the actions of the Red



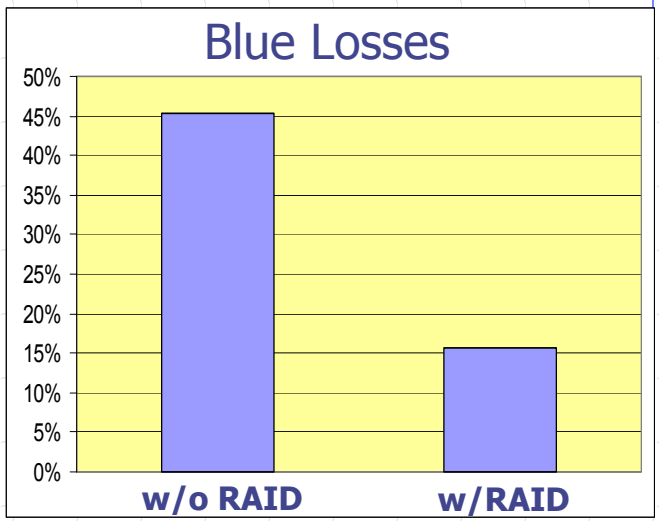
Humans:
- Focus on predicting and impacting actions of the Red, by deception and exploiting errors



Enhanced Operational Agility and Survivability with Predictive Analysis

If predictive analysis could enable dramatically faster response times, what would be the impact?

- We explored the impact in a simulation wargame:
  - Urban environment
  - Red irregulars
  - Blue Co attacks along 2 AAs
  - Fire support helicopters
- Assumption: real-time predictive analysis will help to preposition helicopters and reduce the time required to respond to ground troops' calls for fire
- Outcome: Reduced blue losses and reduced time to complete the mission.

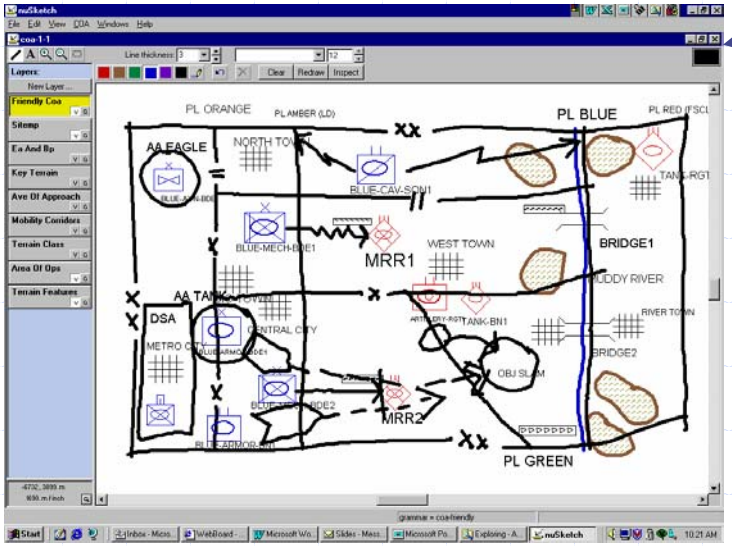


When we know what the enemy is going to do or where he is going to be, we can be:

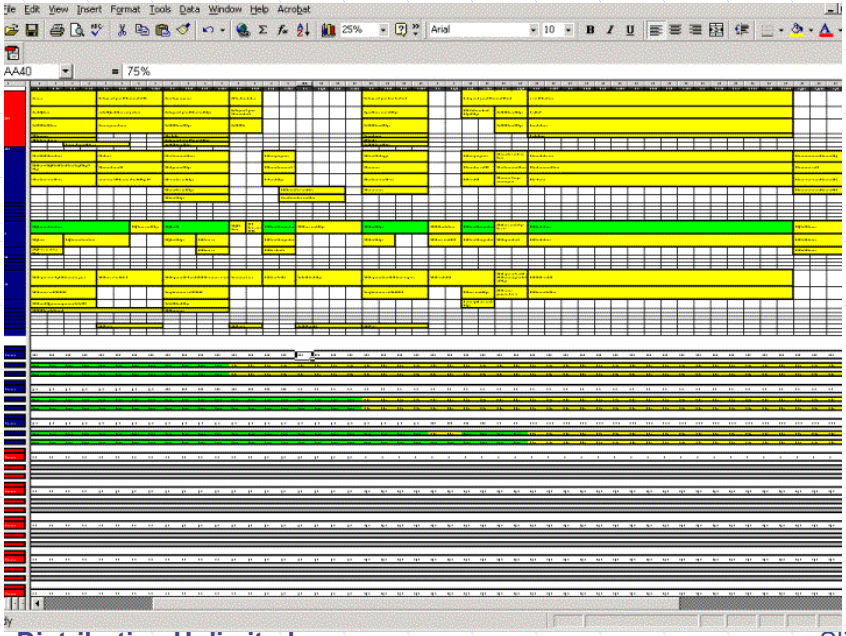
- More aggressive
- More agile
- More proactive
- More effective
- More survivable
- More assured of the outcome

The CADET – An Exploration in Adversarial Reasoning

CADET – Course of Action Development and Evaluation Tool - a system for semi-automated planning of US Army ground operations



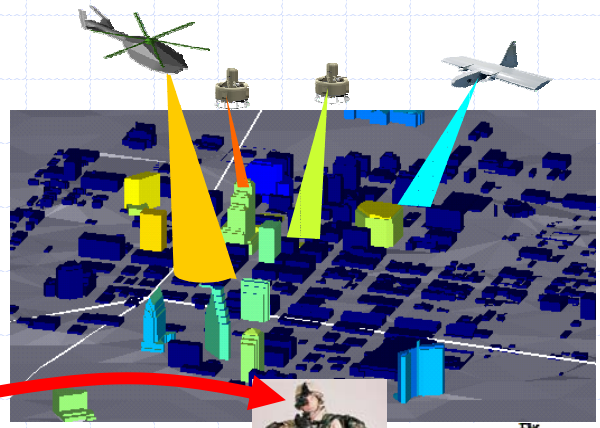
Using a Course of Action sketch as the input, the CADET develops a detailed plan and presents it as a synchronization matrix



The CADET's technical core is an algorithm for tightly interleaved, incremental planning, routing, time estimating, scheduling, estimates of attrition and consumption, and **adversarial reaction estimation**.

Graphics courtesy of BBN LLC

RAID CONOPS for tactical urban ops



Urban Battlefield

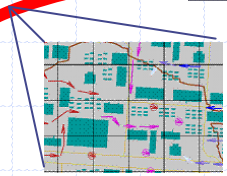
Airborne Sensors

Ground Sensors

Humans
Every soldier a sensor

ISR Data Feeds

Co Cmdr



Red Predictive Estimates

Small Unit Leader

Fused, Filtered, Sequenced Red Predictive Estimates

Battalion Command

S3 Cell
C2 System(s)
FCS C2
CPOF
ABCS
FBCB2
M&D C2

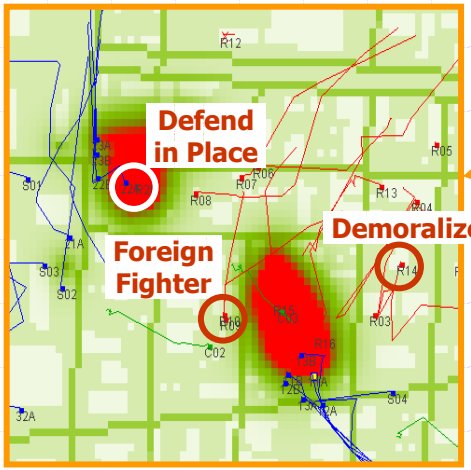
Blue COAs

S2 Cell
DCGS-A
Fusion
RAID
App-X

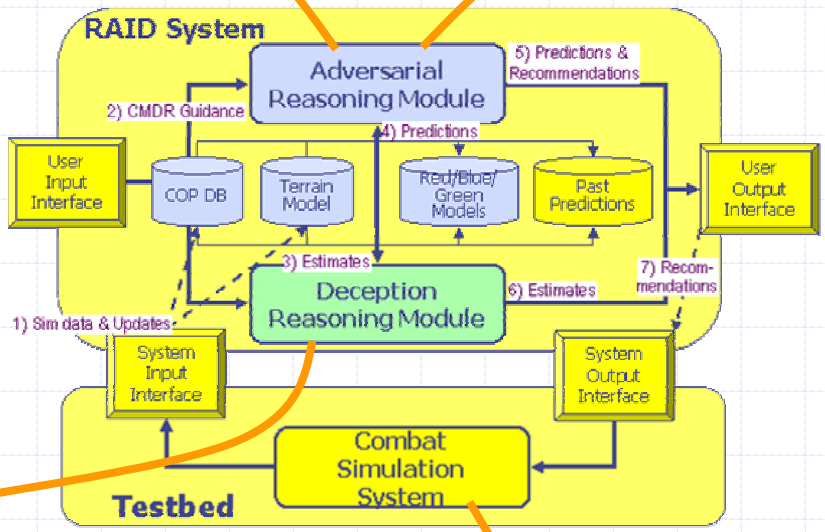
Red Intel

RAID System and Technologies

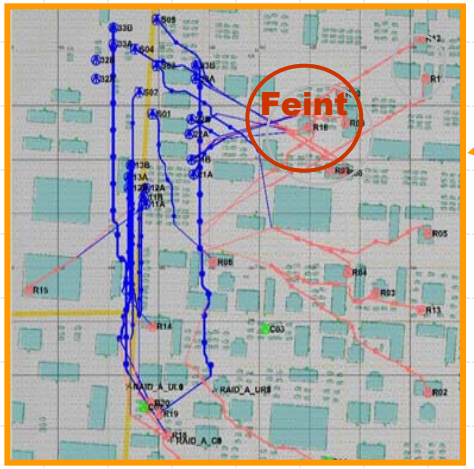
The current RAID system comprises deception detection, enemy cognitive estimates, action-reaction reasoning, and OneSAF-based testbed



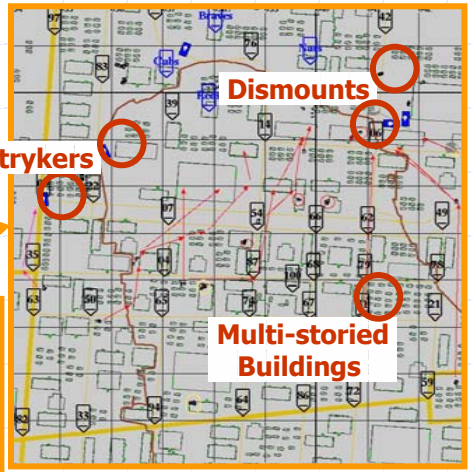
Cognitive modeling infers the enemy's desires, goals, and morale from his behaviors.



Game-theoretic action-reaction reasoning determines the enemy's most dangerous future movements and fire engagements.

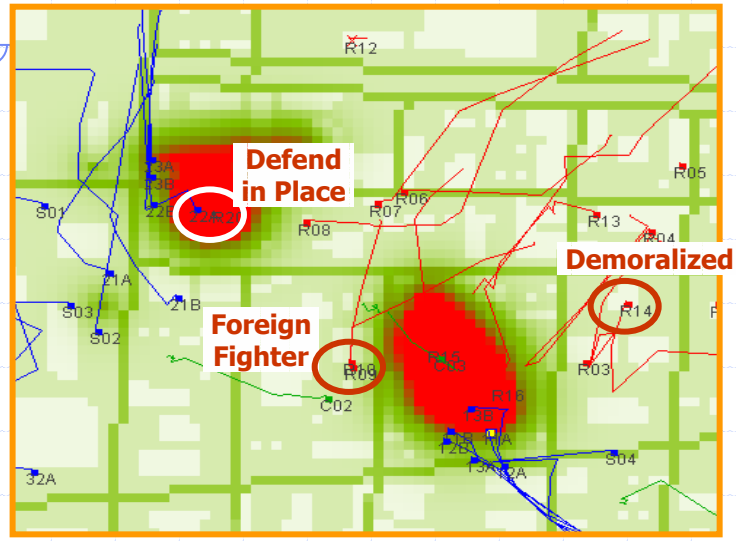


Deception reasoning identifies feints and diversions.



Urban-capable version of OneSAF provides a realistic experimental environment.

Cognitive Modeling



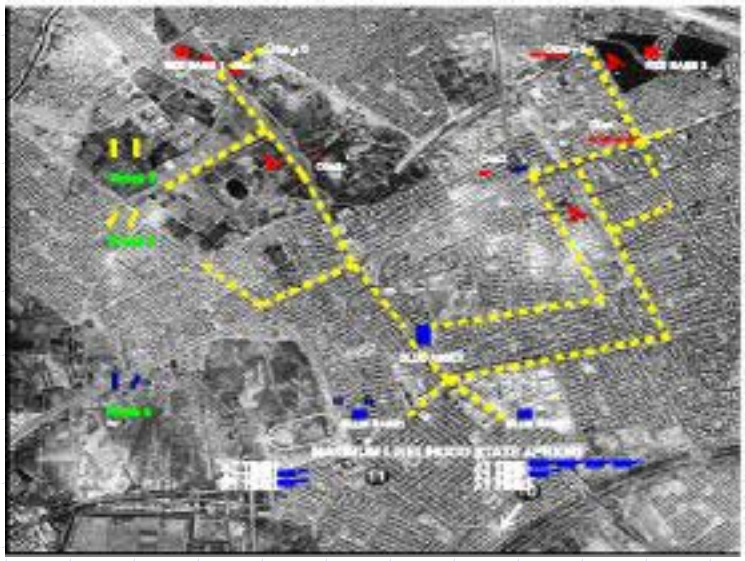
Strengths

- Cognitive, emotional, cultural, doctrinal modeling of fighters and leaders
- Integration with physical factors
- Non-myopic behaviors, look-ahead for cognitive agents
- Proven capabilities of key components

Approach

- Explicitly handles "human" aspects of battlefield behaviors: cognitive model (Bayesian belief net) propagates relations between actions, emotions, goals, desires and dispositions
- Captures implicit cultural and doctrinal preferences
- Connects observed behaviors and estimated mental state; projects mental state into probable incipient goals
- Pheromone-analogy algorithm prunes and clarifies past mental state of the enemy by fitting past behaviors
- Projects future "broad-brush" physical behavior and mental state evolution by exploring multiple roll-outs (ghosts)
- Approximates fighters' look-ahead, avoids being myopic, limits need for knowledge bases

Deception Reasoning



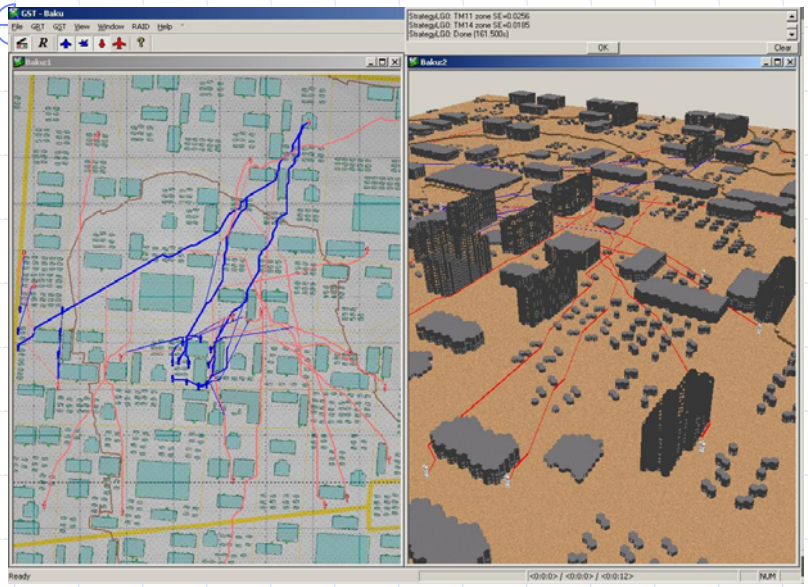
Strengths

- Rigorous, novel theoretical foundation
- Demonstrated in two small-scale prototypes
- Avoids extensive knowledge bases

Approach

- Deception robustness estimator applies stochastic game theory to state estimation to discern underlying deception strategies
- Combines several considerations: observations, cost for Red to deceive, value to Red if deception works
- Novel risk-sensitive theory for recognition and analysis of deception potentials and likelihoods
- Includes limited-cognition technique to detect no-concealment feints and demonstrations
- Non-symmetric evaluation function: value functions produces, initially through SME heuristics, then through automated learning

Action-Reaction Reasoning



Strengths

- Substantial theoretic basis
- Fully-implemented, general-purpose gaming engine worked in several different domains
- Prototypes confirm feasibility of large-scale real-time performance
- Avoidance of large knowledge bases
- Strong role of terrain and other physical factors
- Includes elements of deception reasoning

Approach

- Novel, highly efficient abstraction (linguistic geometry) of action space for non-zero-sum game solution
- Small number of general-purpose heuristics guide low-branching search
- Multiple worldviews reflect partial observability of Red and Blue
- Cultural and SOP preferences accounted via features of abstracted action space
- Elements of Deception Reasoning via forming a solution for Red in Red's partial worldview

Experimental Approach: increasing capability measured against human operators

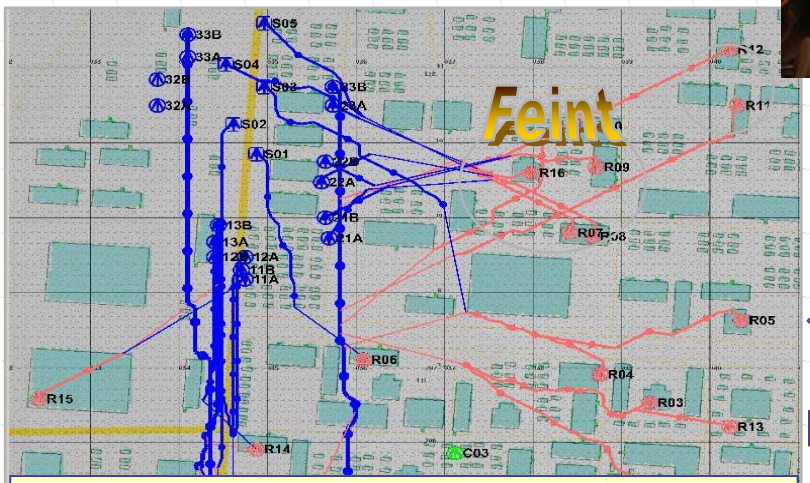
Control Cell (3 personnel)
enforces realism and integrity of the wargame

Blue Cell
4 personnel w/o RAID

Experiment Switch

Commands

Situation



Commands

Situation

Red Cell
4 personnel

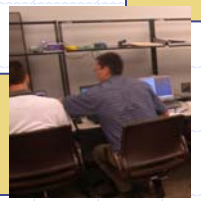
Commands agile and aggressive Red Force

Blue Cell
2 personnel
w/ RAID

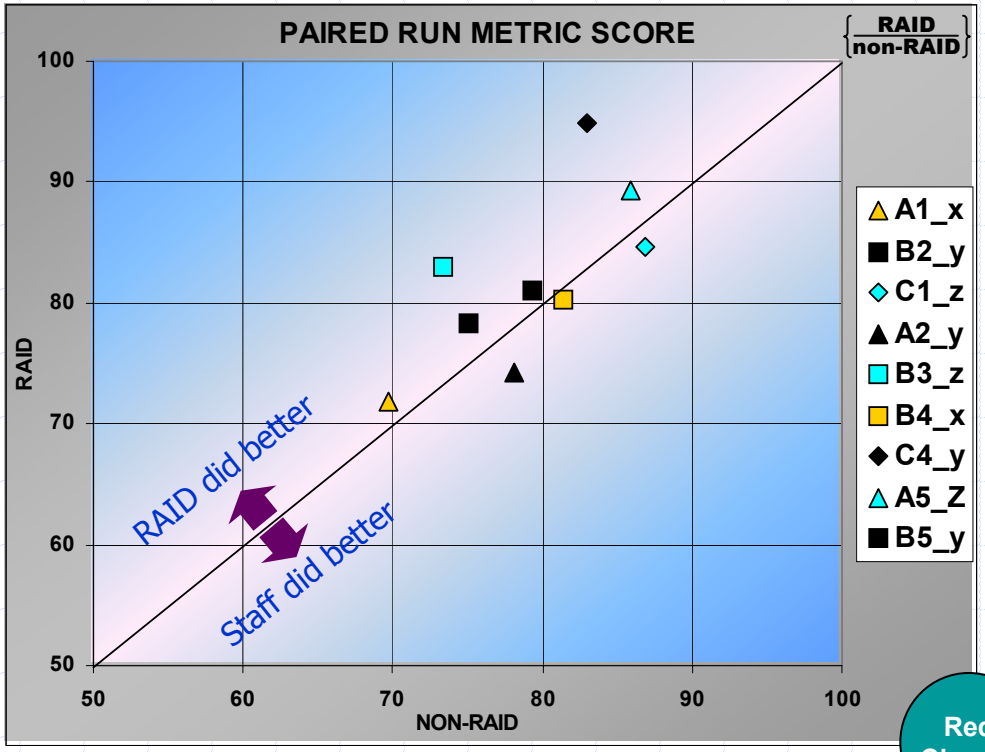
RAID

- This series was 9 benchmark games (without RAID) and 9 test games (with RAID), duration 2 hrs
- Simulation software: OTB
- 3 mission types: point attack, zone attack, point defense
- Wargame scores: mission completion; enemy destroyed; friendly losses and distance.

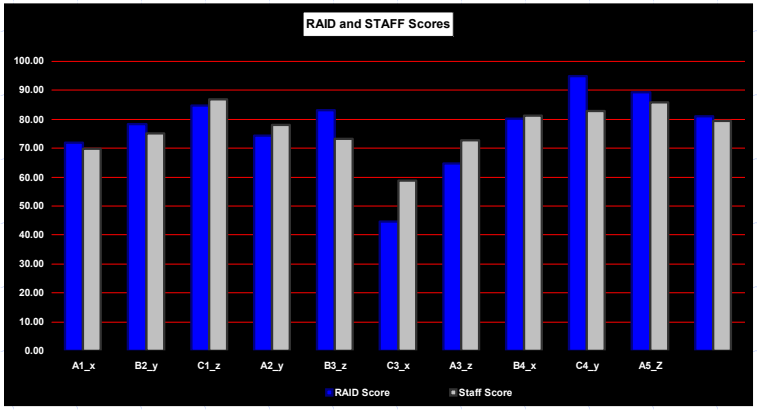
Data collection and analysis cell (2 personnel)
computes scores and predictive accuracy w/ and w/o RAID

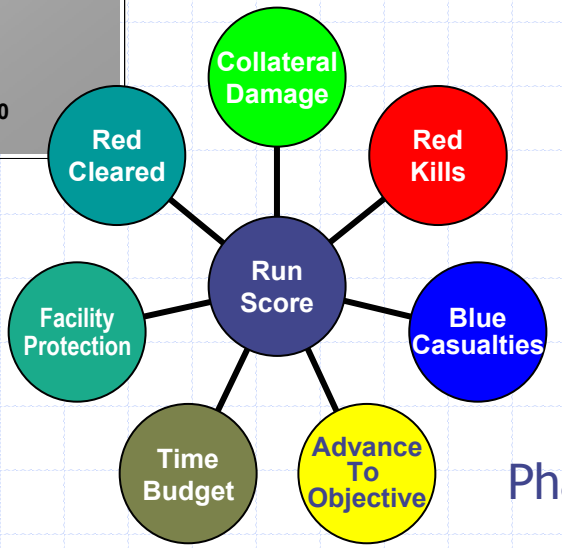


Results of the first experiments are remarkably positive



Type	Pair #	RAID	Non-RAID
A1_x	1	71.91	69.76
B2_y	2	78.34	75.07
C1_z	3	84.66	86.81
A2_y	4	74.22	78.11
B3_z	5	83.04	73.35
B4_x	6	80.25	81.41
C4_y	7	94.83	82.93
A5_Z	8	89.31	85.92
B5_y	9	81.09	79.30





# of valid Run Pairs = 9

Mean = 2.777

StDev = 5.210

Data Normal (tested using Shapiro-Wilk)

Results Significance Parametric: 92.6%

Results Significance Non-Parametric: 91.3%

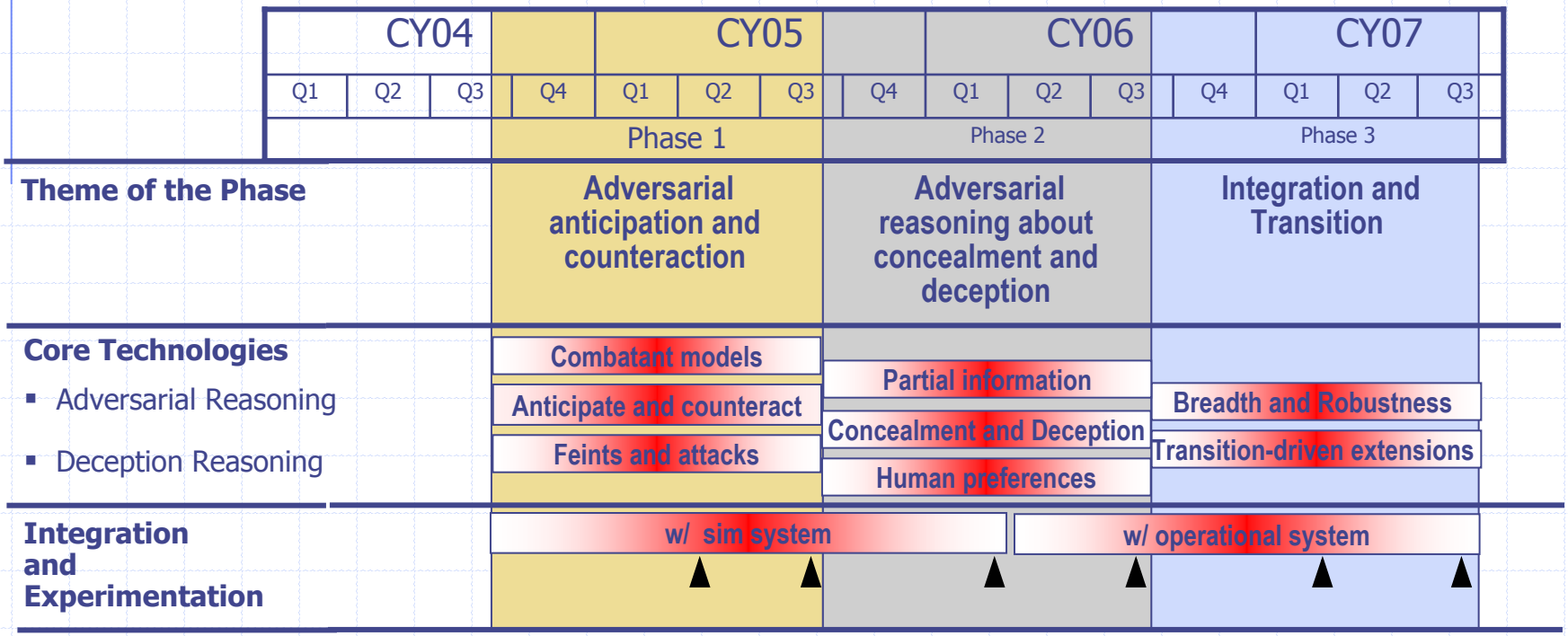
Phase I, Experiment 1
1-14 April 2005

Experimental Plan:
rigorous proof of capabilities

	Phase 1	Phase 2	Phase 3
Thrust	Action-reaction-counteraction	Concealment and deception	Breadth, robustness, transition
Experiment Design	10 benchmark, 10 test games, compare scores	Add: compare accuracy of predictive estimates	In CPX-like setup, integrated with FCBC2, ASAS-L / DCGS-A
Location Exp 1 Exp 2	System Integrator Site (Orlando FL) System Integrator Site (Orlando FL)	Army BCBL-L (Ft Leavenworth KS) Army BCBL-H (Ft Huachuca AZ)	System Integrator Site (Orlando FL) JRTC MOUT site (Ft Polk LA)
Terrain	Digital Baku data	Digital Jakarta (JFCOM data), 1,800,000 buildings	Digital (Exp 1), Physical (Exp 2) JRTC MOUT site (Ft Polk LA)
OPFOR	Up to 20 teams of 3 fighters each w/ small arms, RPGs	Up to 30 teams of 3-7. Add sniper 5 rifles, 5 HMGs, 5 MANPADS	200 fighters, dynamically formed teams. Add 10 mortars.
BLUFOR	Company-sized force w/ 5 armored vehicles	Add air support (4 helicopters)	Add CAS (10 2-ship sorties), joint close support fires, air mobility
Terrain Representation	Buildings and floors, aggregated interiors	Add breached openings in bldgs; basements, internal passages	Add underground corridors of mobility, overpass, fences, walls, urban clutter
Intel Capabilities	Full state known to both sides	Observations by troops	Add UGS and UAV sensors
Organization	Flat organization of fixed small teams with single command node	Company w/ three fixed platoons	Dynamic reorganization and reattachment (10 events)
Communications	Implicit idealized instant broadcast	Comms and info processing delays	Differentiated nets with realistic delays and sporadic loss
Casualty Mgmt	Implicit immediate evacuation	Treatment, delayed evacuation	Add explicit medevac actions
Logistics	Implicit continuous resupply	Run out of ammo, delays in resupply	Explicit resupply actions
Civilians	Random presence and reactions	Civilians help red resupply, intel	Blue actions to manage civilians
Concealment, Deception	Feint movements and attacks	Concealment, stealthy moves	Decoys, civilians do diversions
Timing	Game 2 hours, slower than real	Each game lasts 2 hrs, real time	Game lasts 4-6 hrs, real time
Look ahead into future	At least 30 min	At least 60 min	At least 5 hours
Problem Complexity	over 10**8,000	over 10**20,000	over 10*50,000
Solution speed	Within 300 sec	Within 120 sec	Within 30 sec
Key Gate	RAID-assisted small staff scores as high as large unassisted	RAID-assisted small staff scores as high as large unassisted	RAID-assisted small staff scores as high as large unassisted

Program Plan

- **Development Areas:**
  - **System:** Integration and Experimentation
  - **Technologies:** 1) Adversarial Reasoning 2) Deception Reasoning
- **Three 12-month phases:**



- **Transition RAID into Army systems**

RAID Program Summary

- **Operational Challenge**
  - In-execution predictive analysis of enemy probable actions in urban operations
- **Program Objectives**
  - Leverage novel approximate game-theoretic, deception-sensitive, and cognitive modeling algorithms to provide real-time alternatives to tactical commander
- **Technical Challenges**
  - Adversarial Reasoning: continuously identify and update predictions of likely enemy actions
  - Deception Reasoning: continuously detect likely deceptions in the available battlefield information
- **Realistic Evaluation**
  - Human-in-the-loop OneSAF-based wargames compare humans and RAID
- **Transition:** Army DCGS-A