U.S. Army Armament Research, Development, and Engineering Center

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Squad Modeling and Simulation for Analysis of Materiel and Personnel Solutions

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14. ABSTRACT

This presentation proposes development of methods of M&S analysis of materiel and personnel solutions for Squad decisiveness. As part of the ARDEC contribution to the effort, the Target Behavioral Response Laboratory (TBRL) was tasked with development of methods to incorporate laboratory data from human experimentation into the IWARS. This presentation will be on a literature review in support of this effort. The main goals of this literature review are to determine 1) ???entry-points??? for data into IWARS, 2) appropriate data for collection under laboratory conditions for entry into IWARS, 3) empirically derived quantitative relationships among leadership, training, and cohesiveness measures and Squad performance that can be entered into IWARS. Results It is possible to use modeling and simulation methods in systems engineering data-based analyses of solutions relevant to Squad performance. The most information for model development and simulation is gained by configuring fine-grained data collection under real operational circumstances, realistic operational training, or under controlled laboratory conditions. Use of archival data for solution effect on Squad performance is not at a high enough resolution for insertion into the IWARS simulation application. Inserting data that has been specifically collected for insertion into IWARS is the most valid approach for seeding simulations (versus use of data collected for other uses). Based on this brief review of the literature, these recommendations can be made. Design of data collection should be performed by behavioral scientists using human experimentation methods in collaboration with computational engineers familiar with IWARS or the simulation program to be used for analysis. Standardized methods and paradigms for laboratory testing of effects of materiel and personnel solutions for Squad performance and insertion into modeling and simulation should be developed. Modeling and simulation in conjunction with empirical behavioral science methods can provide the Army with the much needed tools for analysis in support of the Soldier.

15. SUBJECT TERMS					
Squad, Human Behavior Modeling and Simulation, Infantry Warrior Simulation, IWARS, Testing & Evaluation, Literature Review, Empirically derived Models, Cohesiveness, Leadership, Training, Materiel Solutions, Personnel Solutions, Target Behavioral Response Laboratory					
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ARDEC's Role


RESEARCH


DEVELOPMENT


PRODUCTION


FIELD SUPPORT


DEMILITARIZATION

Advanced Weapons:
Line of sight/beyond line of sight fire; non line of sight fire; scalable effects; non-lethal; directed energy; autonomous weapons

Ammunition:
Small, medium, large caliber; propellants; explosives; pyrotechnics; warheads; insensitive munitions; logistics; packaging; fuzes; environmental technologies and explosive ordnance disposal

Fire Control:
Battlefield digitization; embedded system software; aero ballistics and telemetry

ARDEC provides the technology for over 90% of the Army's lethality and a significant amount of support for other services' lethality

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BLUF – Bottom Line Up Front

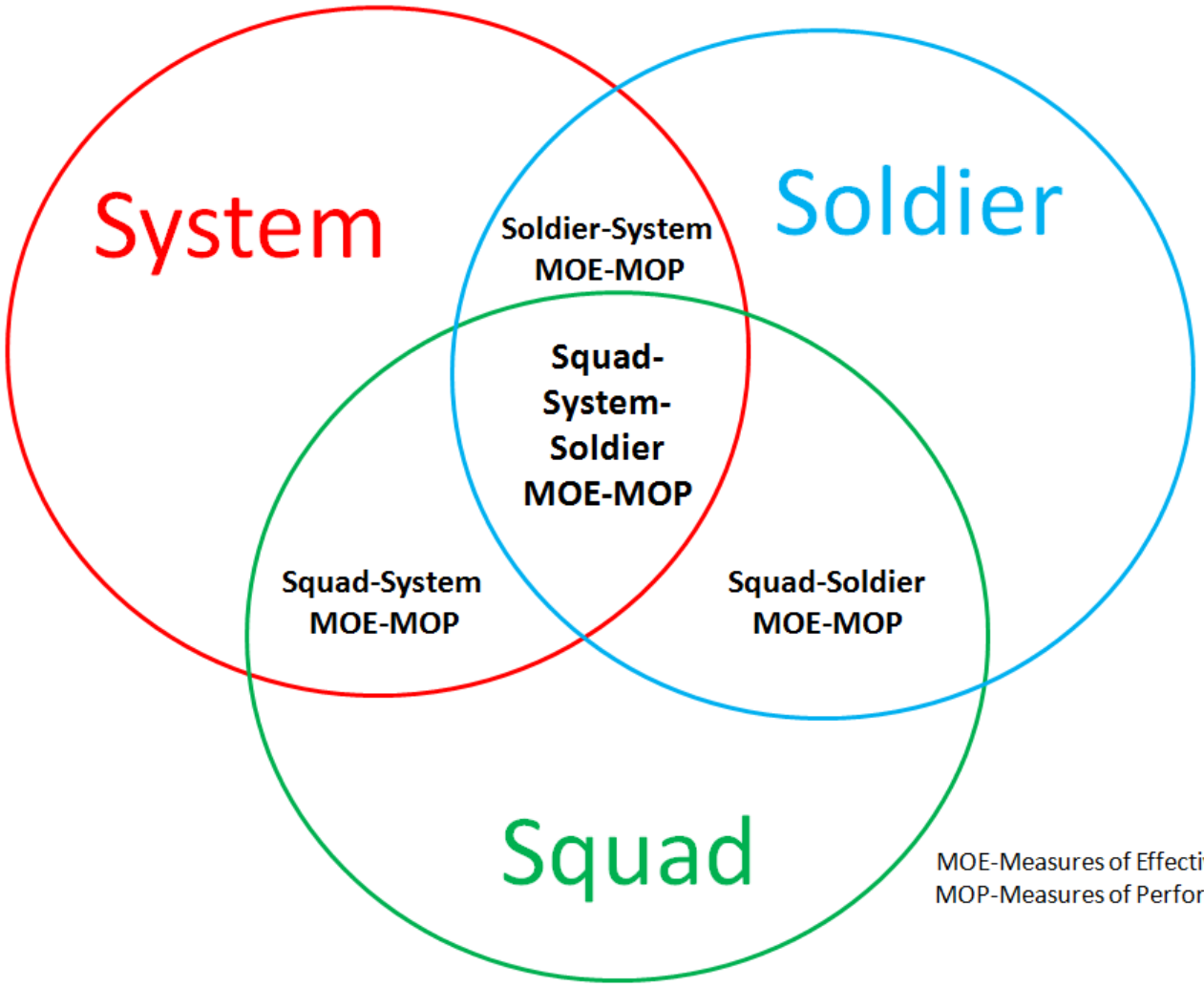
- Army has an interest in the Modeling and Simulation of squads in support of acquisition and training decisions
- Leadership, training, and cohesiveness are variables of interest
- An initial review of the literature reveals that archived information is of insufficient granularity to simply “insert” into Modeling and Simulation of squads
- Data collection under controlled conditions is necessary to collect empirically derived quantitative relationships among leadership, training, and cohesiveness measures and squad performance
- An initial proposal for methods and procedures to collect this data is presented

Background Effort
Squad Measures of Formation Effectiveness

- Develop an Integrated decision support layout that maximizes squad capabilities and enhances squad portfolio management across full Doctrine, Training, Leadership, Organizations, Materiel, and Personnel, Facilities (DTLOMP-F):
  - Establish squad objective measures that set the conditions to generate command consensus and vision for squad
    - Performance attributes
    - Enabling attributes
    - Measures of formation effectiveness
  - Mechanism that recognizes, uses, feeds and builds body of knowledge IRT Leadership, Training, and Materiel for the squad
- Assess potential leadership, training, and products/technologies and measure the payoff for the squad
  - Incorporate an operational context / language for assessments
    - Enables effective communication of resource requirement decisions and priorities across stakeholders community (aka Squad Capability Portfolio Review)
- Establish habitual relationships within the acquisition & operational communities to ensure currency & relevancy for squad

From A. Taylor "**Squad Measures of Formation Effectiveness"**

Interaction



MOE-Measures of Effectiveness
MOP-Measures of Performance

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Modeling and Simulation of Squads

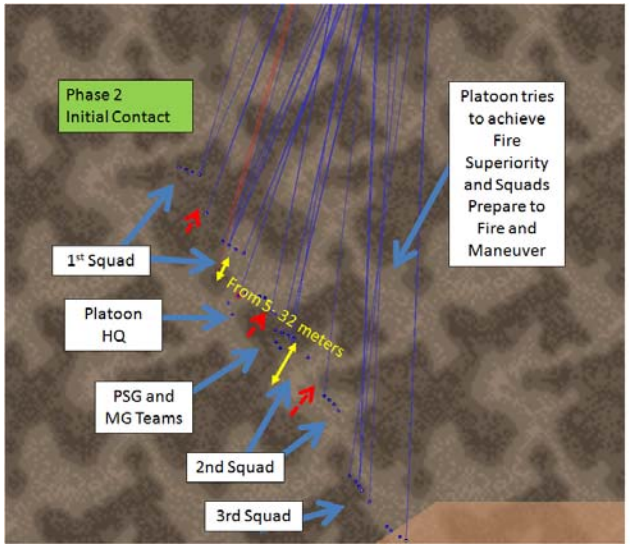
- The ARDEC effort in systems engineering and analysis is proposed to be an integral part of analyses of candidate materiel and personnel solutions
- Because of its focus on small unit modeling and simulation, the Infantry Warrior Simulation (IWARS) software application was selected as the software platform to conduct these systems analyses
- The intent is to demonstrate the utility of M&S, in particular, IWARS in analysis of candidate solutions, especially in the area of determining effectiveness and realizing cost savings
- As part of the ARDEC contribution to the effort, the Target Behavioral Response Laboratory (TBRL) was tasked with the development of methods to incorporate laboratory data from human experimentation into the IWARS

Leadership, Training, and Cohesiveness Factors

- Leadership, Training, and Cohesiveness Factors are particularly problematic
- TBLR Effort = Two Approaches
  - Review of the literature for previous work on how these factors relate to squad performance
  - Empirical approaches for gathering data
- Analysis of how these factors could be incorporated into modeling and simulation of squads

Infantry Warrior Simulation (IWARS)

- A constructive, force-on-force, combat simulation
- Used to model individual Soldier, team, and small-unit combat operations in complex environments, including Military Operations on Urban Terrain (MOUT), to support analysis of warrior systems
- Key measures of interest for analyses performed using IWARS include survivability, lethality, command and control, situation awareness, mobility, and sustainability



from IWARS 4.0 User Guide

IWARS Modeling Behavior

- The primary IWARS simulation objects are intelligent agents that are semi-autonomous, which allows realistic modeling of soldier and unit behaviors
- The behavior engine uses goal-driven behaviors that can be interrupted and adapted as the combatant's needs and goals change over the course of a scenario
- Agents can also interact with each other, which could potentially affect decision-making activities

- IWARS agents have the ability to perform operational tasks related to:
  - movement
  - engagement
  - communication
  - perception
  - decision-making

from IWARS 4.0 User Guide

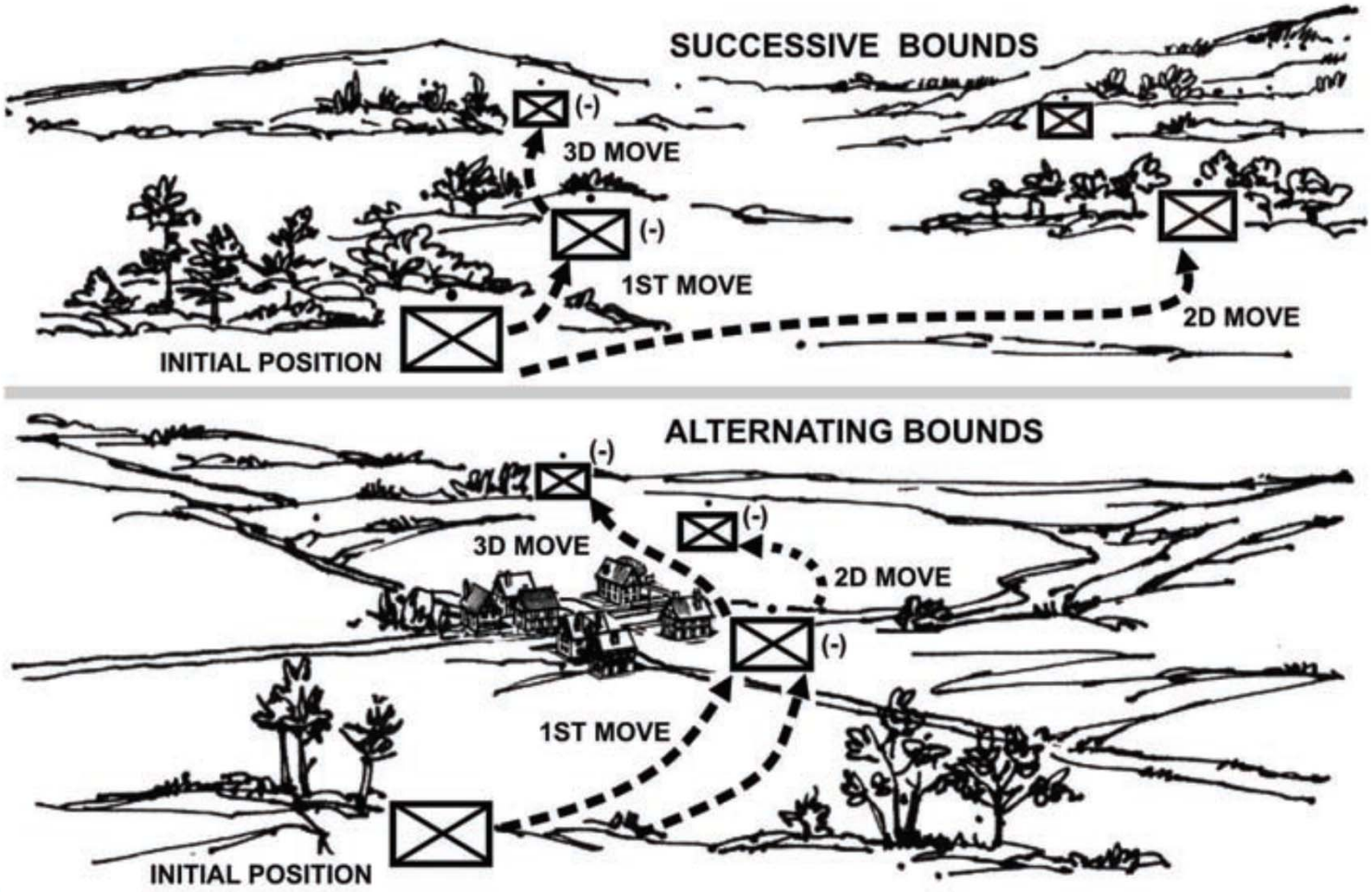
IWARS Skills

- Skills are the most basic behaviors available to agents
- When a skill is added to a mission, it becomes an activity that can be renamed and modified
- IWARS skills include:

IWARS Skills		
• Activate Motion	• Change Agent Facing	• Change Field of
• Change Posture	• Change Vehicle Facing	• Change Visual
• Communicate	• Configure COP Access Point	• Dismount Vehicle
• Drive Vehicle	• Follow	• Light Flare
• Look for Shield	• Mount Vehicle	• Move
• Reload	• Remove Message	• Select Weapon
• Set Behavior	• Set Formation	• Set Path
• Set UDOP Profile	• Shoot	• Take Over a Slot
• Throw Grenade	• Use Shield	• Use UDOP Device
• Wait		

from IWARS 4.0 User Guide

React to Contact



Warrior Battle Drills 2011

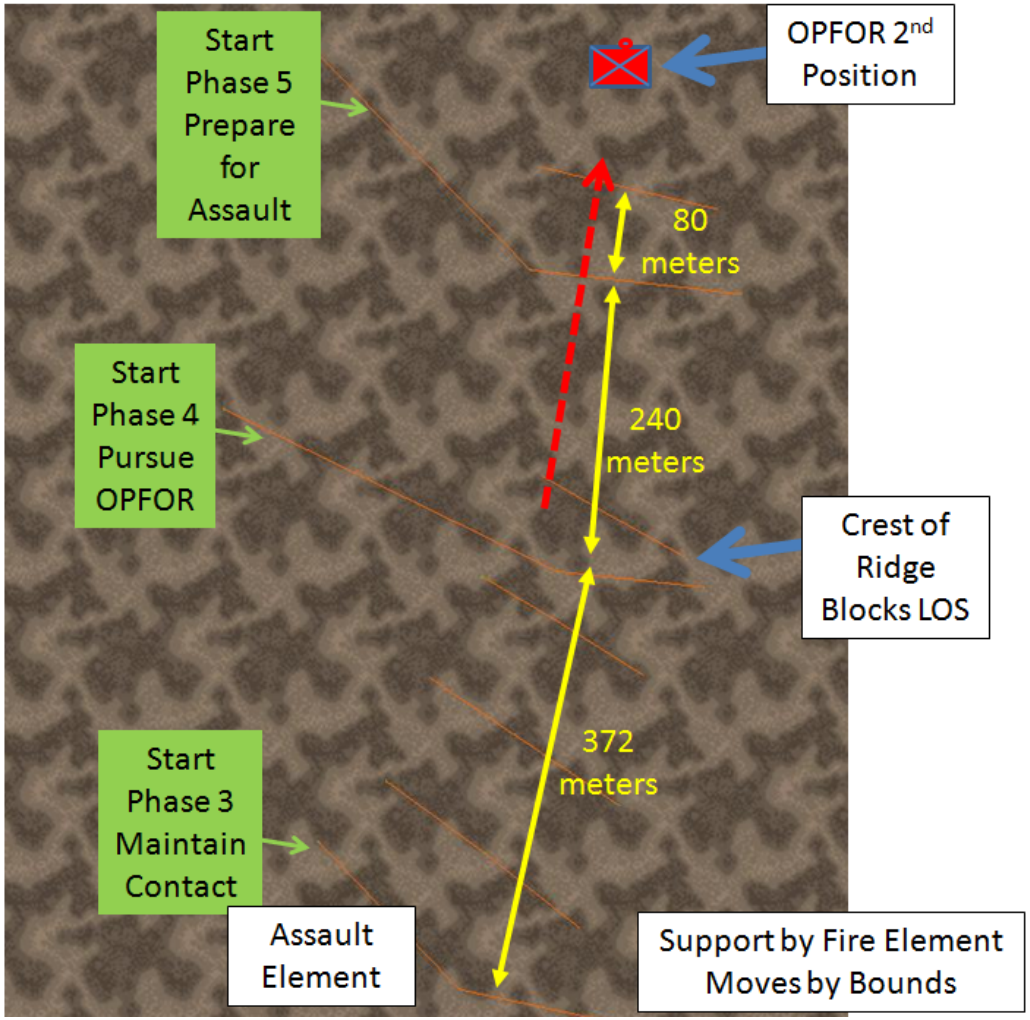
Subject Area 16: (Battle Drills) React to Contact:			
Task Number	*Title*	*Training Location*	*Sustainment Training Frequency*
071-410-0002	React to Direct Fire While Mounted (Repeat)	BCT/OSUT	SA
071-326-0513	Select Temporary Fighting Positions (Repeat)	BCT/OSUT	SA
071-100-0030	Engage Targets with an M16-Series Rifle/ M4 Series Carbine (Repeat)	BCT/OSUT	SA
071-326-0608	Use Visual Signaling Techniques (Repeat)	BCT/OSUT	AN
071-326-0502	Move under Direct Fire (Repeat)	BCT/OSUT	SA
071-326-0503	Move Over, Through, or Around Obstacles (Except Minefields) (Repeat)	BCT/OSUT	SA
071-326-0510	React to Indirect Fire While Dismounted (If Applicable) (Repeat)	BCT/OSUT	SA
071-326-3002	React to Indirect Fire While Mounted (If Applicable) (Repeat)	BCT/OSUT	SA
113-571-1022	Perform Voice Communications (Repeat)	BCT/OSUT	AN
071-326-0501	Move as a member of a Fire Team (Repeat)	BCT/OSUT	SA
071-325-4407	Employ Hand Grenades (Repeat)	BCT/OSUT	AN

Live, Virtual, Constructive (LVC) Simulated Testing

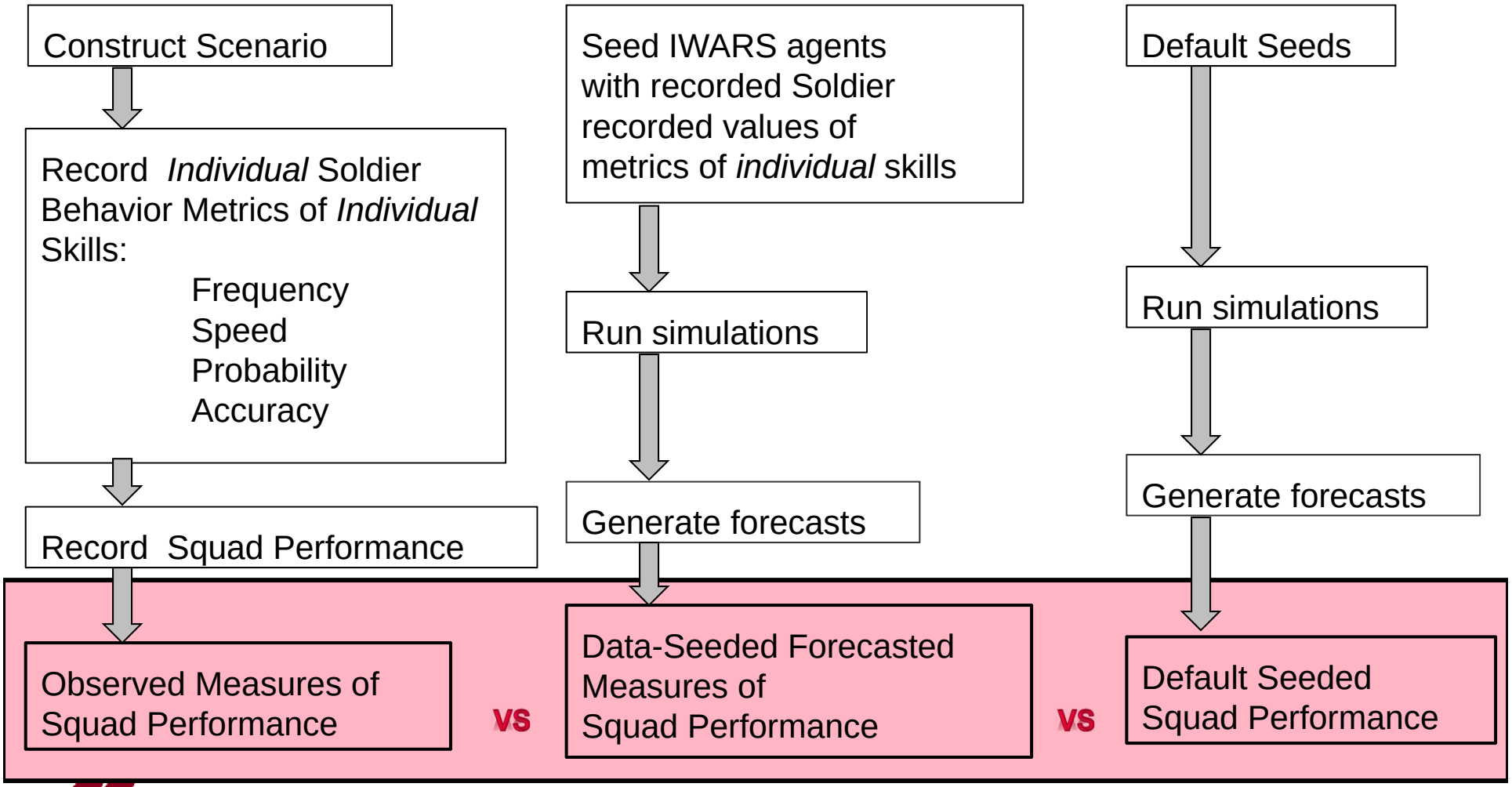
- Real individual Soldier behavior vs IWARS Soldier behavior

IWARS Skills		
• Activate Motion	• Change Agent Facing	• Change Field of
• Change Posture	• Change Vehicle Facing	• Change Visual
• Communicate	• Configure COP Access Point	• Dismount Vehicle
• Drive Vehicle	• Follow	• Light Flare
• Look for Shield	• Mount Vehicle	• Move
• Reload	• Remove Message	• Select Weapon
• Set Behavior	• Set Formation	• Set Path
• Set UDOP Profile	• Shoot	• Take Over a Slot
• Throw Grenade	• Use Shield	• Use UDOP Device
• Wait		

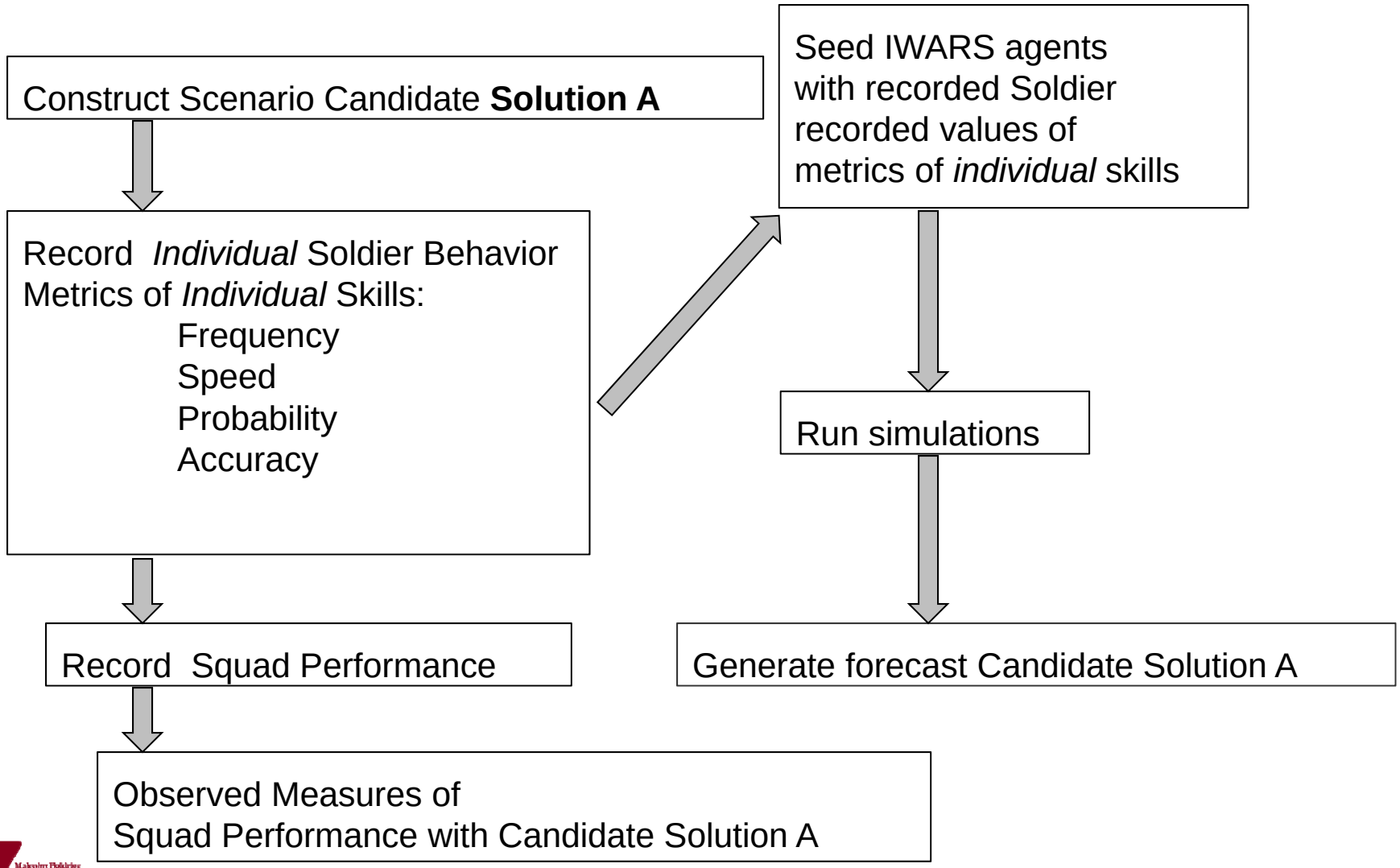
IWARS React to Contact



Proposed Methods



Solution Analyses



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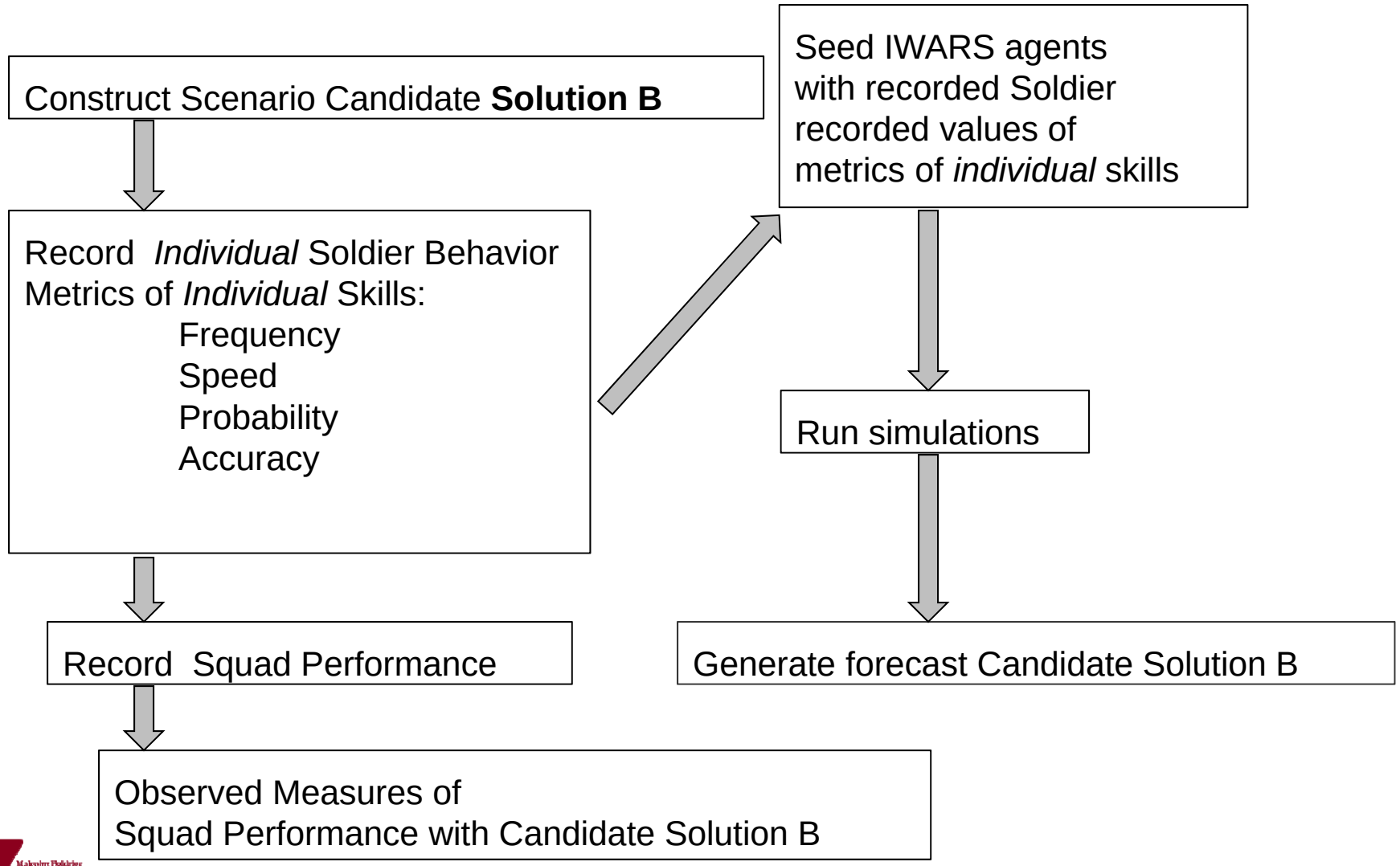
Solution Analyses



IWARS: Modifying Behaviors

- Each skill/activity has associated parameters that are to be set by the user prior to running the simulation
- These parameters function as the “insert” for Leadership, Training, and Cohesiveness
- Requires information about the association between these variables and squad performance
- Requires information about these variables and Soldier and squad level parameters of behaviors

Literature Review

- The terms Leadership, Cohesiveness, and Training were used to search databases
  - The Army Research Institute for Behavioral and Social Science (ARI) online archives
  - Military Psychology
  - Defense Technology Information Center (DTIC)
  - PsychInfo
- Studies of military groups were specifically targeted
- Articles that contained metric values that could be in some way inserted into the IWARs were targeted

Quantitative metrics of effect of leadership on performance

- Task-focused leadership was positively correlated with perceived team effectiveness and team productivity (r=.333 and.203) (Burke, 2006)
- Leader effectiveness was positively correlated with group performance measures (r=.39, .43) (Vogelaar, 1997)
- Leadership cohesion (cohesive bonds among platoon leaders) was found positively associated with ratings of their unit's performance by outside observers (r=.52). (Mael, 1993)
- Finally, toxic leadership was negatively associated with confidence to follow the toxic leader in life-or-death situations (r=-55) (Stelle, 2011)

Quantitative metrics of effect of training on performance

- No articles addressing effects of specific military skills training on specific task performance were found
- In contrast team training/team process training effects studies were numerous
- Team process was positively correlated with number of targets destroyed (r=.30) (Stout, 1994)

Quantitative metrics of effect of cohesiveness on performance

- Using a well-validated measure of military group cohesiveness, horizontal cohesion among Soldiers was positively correlated with mission performance (r=.52) (Siebold G. , The evolution of the measurement of cohesion, 1999)

- Meta-analytic studies also show a consistent moderate correlation with performance (around r=.4) (Siebold G. , Key questions and challenges to the standard model of military group cohesion, 2011)(Oliver, 1999)

Insertion of Information

- The literature reveals moderate correlations between these psychosocial variables and collective (squad, platoon, and team) performance

- While there exist numerical values representing the relationship between psychosocial variables and team performance, the questions revolve around the appropriate methods for inserting these data into IWARS or other modeling and simulation programs

Possible Insertion Methods

- Locate Army standards or normative data on leadership, training, and cohesiveness measures (Siebold G. , The evolution of the measurement of cohesion, 1999) (Oliver, 1999) and Squad performance in the react to contact battle drill, if they exist
- Simulation experiments examining the effects of varying degrees of leadership, training, or cohesiveness solutions on squad performance can create input data seeds to IWARS by derivations using standards/norms multiplied by the correlational factors reported in the previous section
- A similar method is to designate seed data as representing squads that are categorized at different points on the spectrum for these variables (High, Med, and Low), again with relative values inputted based on the correlational factors, and anchored at one of these points based on standard or normative data

Challenges

- Difficulty in locating standard or normative data (?)
- Heterogeneity of leadership, training, and cohesiveness, as well as performance measures may also present problems
- Static vs Dynamic Issues
  - Archives are static measures, M&S is a dynamic scenario.
- Granularity Issues
  - Archives are overall relationship, M&S requires relation to specific behaviors

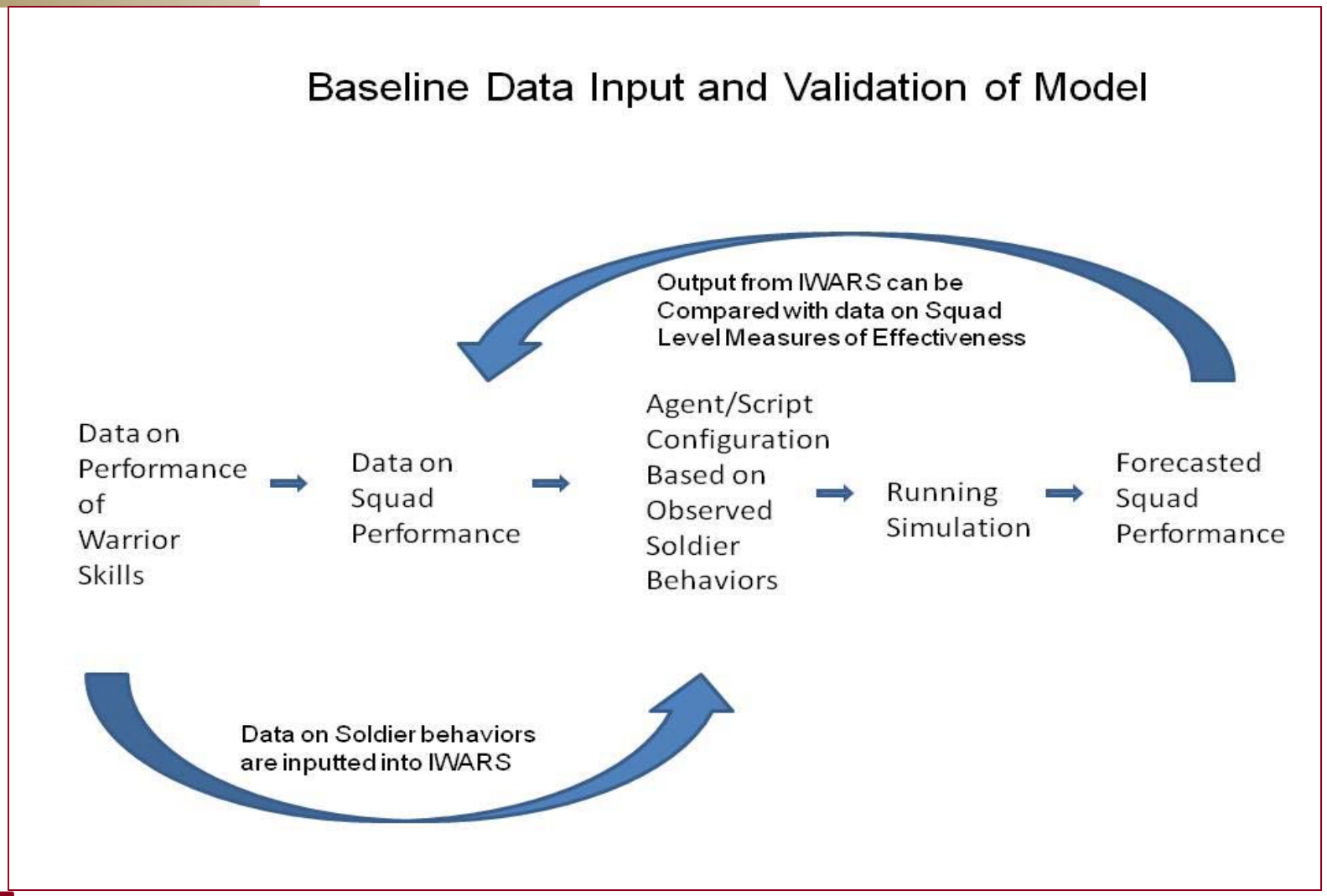
Generation of Baseline Empirical Data

- Data collection in the laboratory should then focus on recording execution of these component performance skills
  - Test bed set up must allow for observation or recording of these skills
    - motion capture methods and video recording methods
- Data are processed to yield numerical values indicating Soldier and squad behavior
  - distance between Soldiers, time between commands given and commands executed, frequency of Soldiers going prone, number of trigger pulls, and speed of movements
  - numerical indices of overall squad performance
- These numerical values are then used to configure parameters of the skills and activities in IWARS
  - options and parameters controlling the agents' activities are set to match those recorded in the lab

Example of Alignments among Performance Step, Data Collection and Processing, and Skill Configuration for Task 071-326-0501 - Move as a Member of a Fire Team

Doctrinal Performance Step	Type of Laboratory Data Collected	Data Processing for Quantitative Metrics	Skill Configuration in IWARS
1. Assume your position in the fire team's current formation...d. Assume your position within the fire team file formation.	Motion Capture	Distance between Soldiers, Leading Edge/Trailing Edge Dispersion	Activate Motion, Set Formation
NOTE: The normal distance between Soldiers is 10 meters.	Motion Capture	Distance between Soldiers, Leading Edge/Trailing Edge Dispersion	Activate Motion, Set Formation
NOTE: When the fire team leader moves left, you move to the left. When the fire team leader gets down, you get down.	Motion Capture/Video Recording	Latency between Fire Team Lead and Soldier Behaviors	Move, Wait, Change Agent Facing, Communicate, Follow

Baseline Models

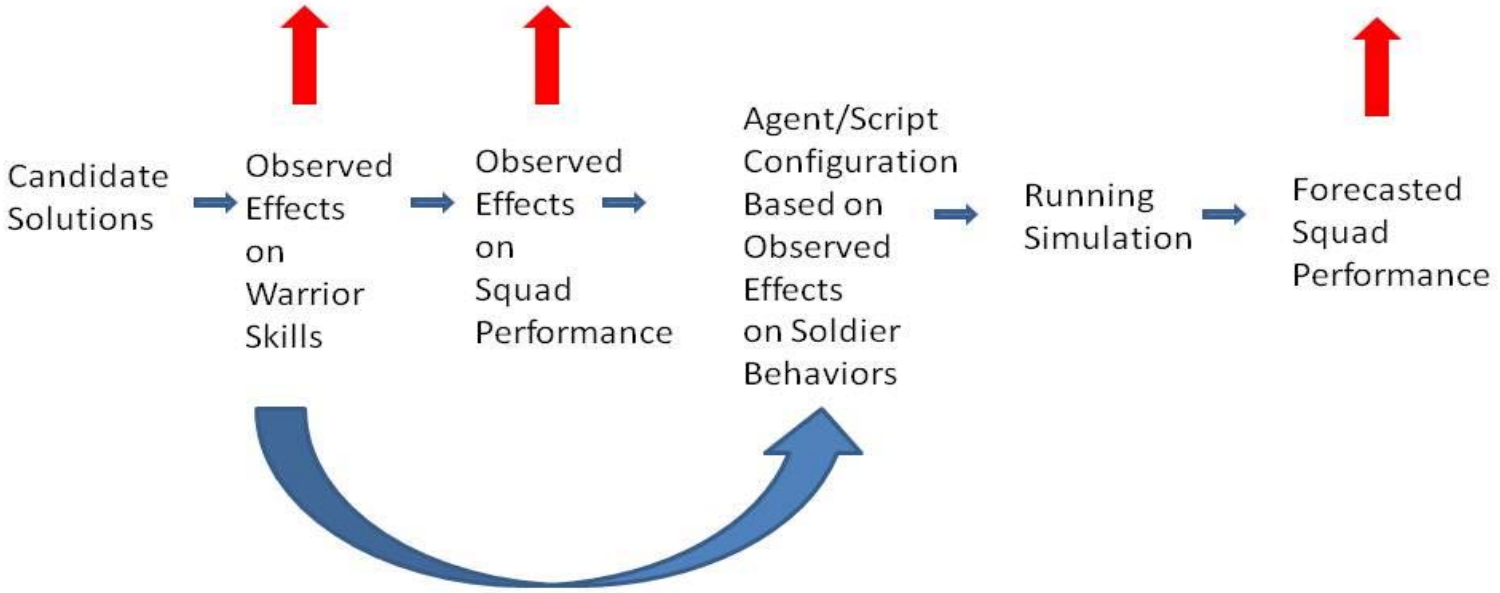


Comparison Models

Comparisons of Candidate Solutions

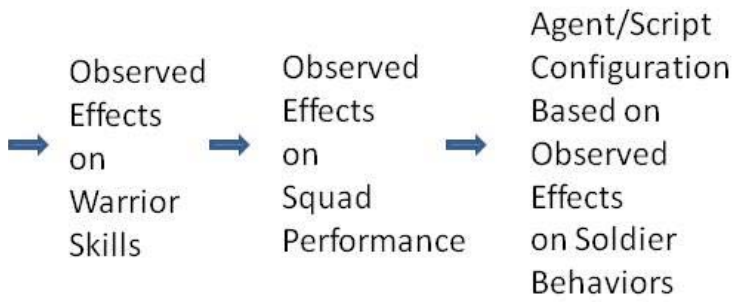
Statistical analyses comparing Soldier and Squad performance using candidate solutions can be done on data recorded in the lab.

Statistical analyses comparing Soldier and Squad forecasted performance using candidate solutions can be done on outputs from IWARS.



Insertion of Leadership, Training, and Cohesiveness Factors into IWARS

Soldier's and Squad's Differing Levels of Leadership, Training, and Cohesiveness are run in the laboratory.



Squad Performance Test Bed

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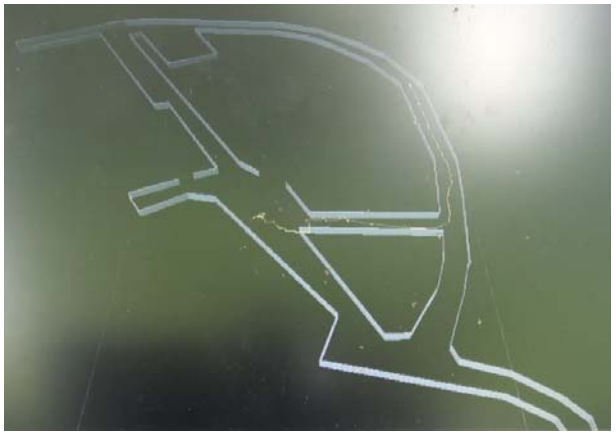
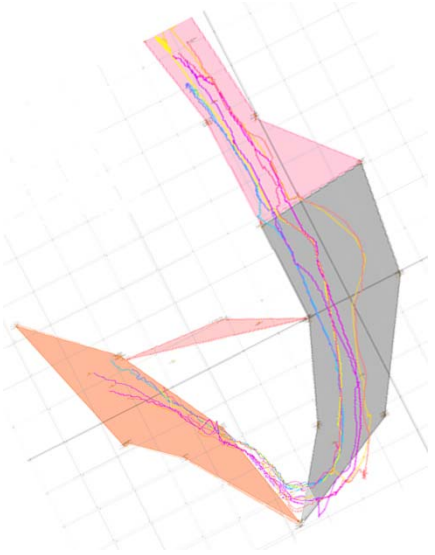
Outdoor Test Bed

Squad Performance Test Bed

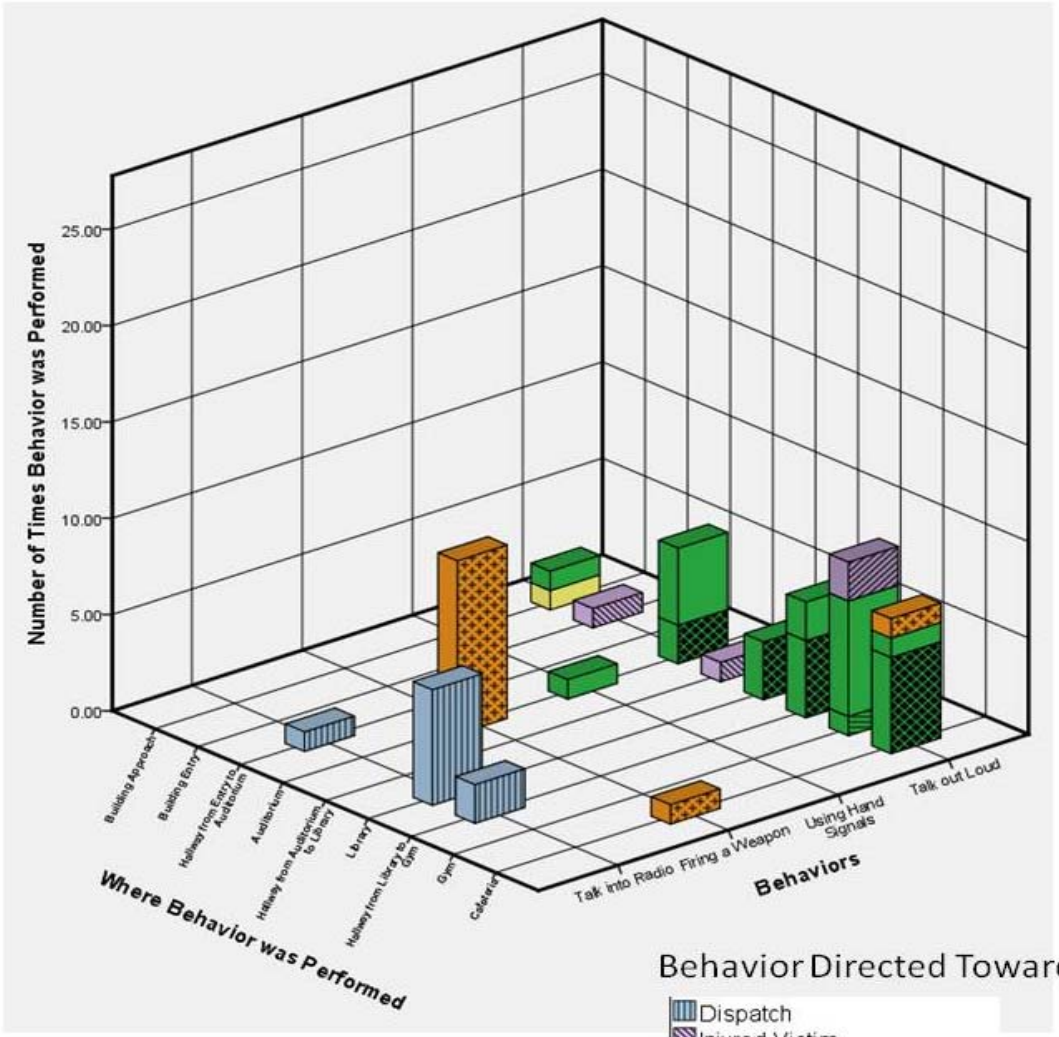
Ubisense Tracking





Behavioral Coding

- Noldus Observer XT
- Behavioral Coding Example:



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Federation with Behavioral Programs

- Federate IWARS with other simulation software programs that are specifically configured for human behaviors, such as Brahms, PMF, Imprint, ACT-R, SOAR, etc (Cassenti, 2010; Schamburg, 2005; Laird, 2012)

Conclusions

- There exist methods of inserting data into IWARS simulation in order to conduct systems engineering analyses of solutions for enhancing squad performance
- Inserting data that has been specifically collected for insertion into IWARS is the most valid approach for seeding simulations (versus use of data collected for other uses)

Recommendations

- Based on this review of the literature, these recommendations can be made:
  - Design of data collection should be performed by behavioral scientists using human experimentation methods in collaboration with computational engineers familiar with IWARS or the simulation program to be used for analysis
  - Standardized methods and paradigms for laboratory testing of effects of materiel and personnel solutions for squad performance and insertion into modeling and simulation should be developed.

Questions?

US Army - Target Behavioral Response Lab

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Target Behavioral Response Laboratory MORSS Presentations

- Virtual Employment Test Bed: Operational Research and Systems Analysis to Test Armaments Designs Early in the Life Cycle
- Method and Process for the Creation of modeling and Simulation Tools for Human Crowd Behavior
- Squad Modeling and Simulation for Analysis of Materiel and Personnel Solutions
- The Squad Performance Test Bed
- Crowd Characteristics and Management with Non-Lethal Weapons: A Soldier Survey
- Effectiveness Testing and Evaluation of Non-lethal Weapons for Crowd Management
- Effects of Control Force Number, Threat, And Weapon Type on Crowd Behavior