US Army
TRADOC Analysis Center (TRAC)
Objective Force Urban Operations
Agent Based Simulation Experiment

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Purpose

Determine the suitability of agent based simulations (ABS) and gain insights into Objective Force small unit operations in an urban environment.

Intermediate goals included:

- Study of ABS (in general)
- Assessment of ABS as exploratory tool and precursor to high-resolution runs

Concepts & Requirements Development

Investigate & Refine

Validate & Confirm

Agent based simulations can aide in maturing the warfighting concept

Identify & Explore

Computer MAPEX (CAMEX) Simulation Exercise (SIMEX)

Constructive Modeling

TNG

ICD

CDD

525

Map Exercise (MAPEX)

Develop & Assess

Qualitative

Quantitative

Defined Options

Insights & Findings

Strategic Guidance

Ideas

Issues & Questions

Mature organization structure

TNG: Training Strategy ICD: Initial Capabilities Document CDD: Capability Development Document 525: Concepts

Participating Organizations

- TRAC-Monterey
- US Army Infantry Center Dismounted Battlespace Battle Lab (USAIC DBBL)
- US Marine Corps Warfighting Lab (Project Albert)
- US Naval Postgraduate School

Agent Based Simulations

Strengths:

- Quick scenario set up time and fast run times
- Non-scripted simulation runs
- Ability to rapidly consider many alternatives

Limitations:

- Some data does not correlate well to real world data
- Computation demands increase rapidly with large entity counts and large battlefield representations

Urban Experiment

- **Use a series of new models/analytic tools developed under Marine Corps Warfighting Lab's Project Albert and existing high-resolution simulations.**
  - Across Simulations or Distillations
    - MANA
    - Pythagoras
  - Between levels of resolution
    - JANUS
- **Exploit advances in computing power and visualization tools.**
  - Maui High Performance Computer Center (MHPCC)
- **Look at questions from the perspective of conducting exploratory analysis using many data points from a robust design of experiments with replications.**
  - 16 variable / 65 run design and 7 variable / 17 run design

Urban Experiment EEAs

- **Objective Force (OF):**
  - What is the appropriate squad size and number of squads?

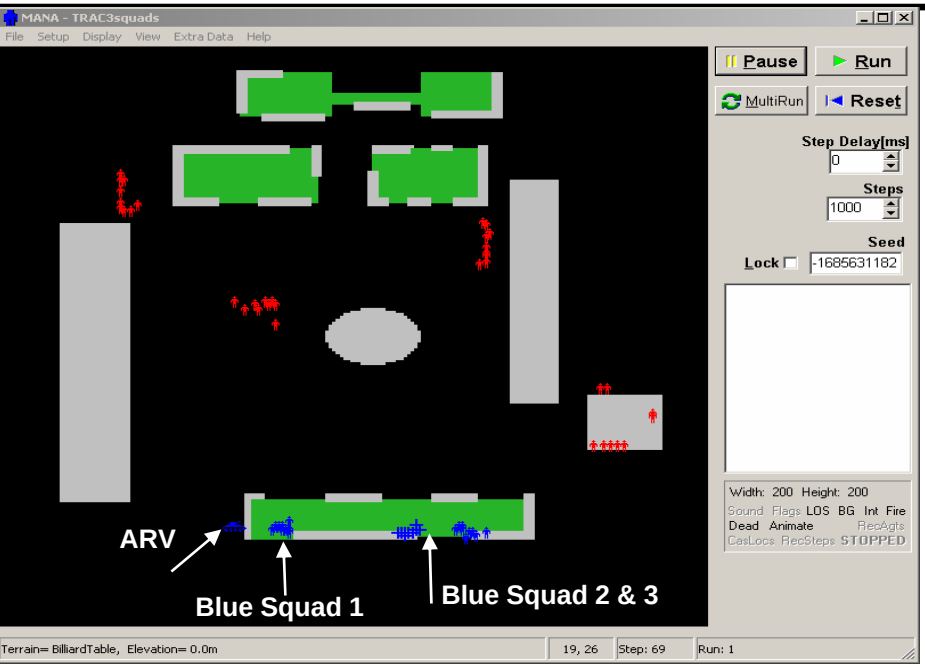
- **Armed Robotic Vehicle (ARV) FCS Issues**
  - What is the best Operational Employment Concept?

Basic Scenario

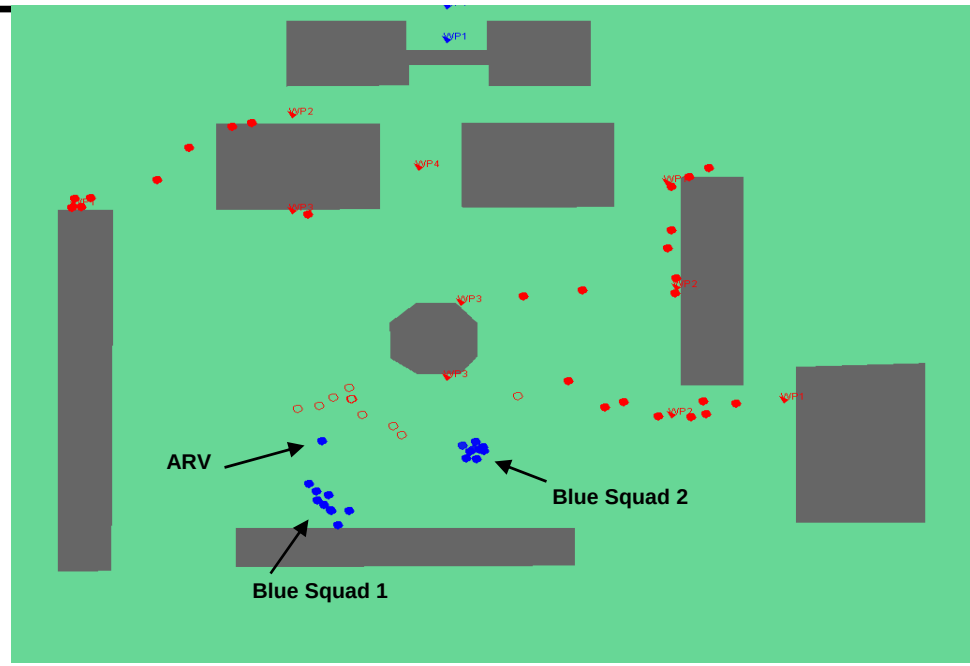
Basic scenario developed with guidance from DBBL's Chief of Analytical Simulations: Reference document – Army FCS Unit of Action Systems Book ver 1.2 - 1.6

- **Objective Force infantry platoon with Armed Robotic Vehicle (ARV) against an organized threat in an urban environment. Blue to red force ratio (~1:1)**
- **Blue forces maneuver through urban environment to an seize an objective**
  - Blue squad size varied (7, 9, 12 per squad)
  - Blue number of squads varied (2, 3, and 4 squads)
    - Blue soldiers maneuver to avoid red contact
  - ARV operates in coordination with blue squads
    - ARV maneuvers to engage red forces when red is within specified operating ranges of blue forces
- **Red forces organized into 4 groups of 9 which patrol the urban area**
  - Red engages blue forces when blue is within red sensor range

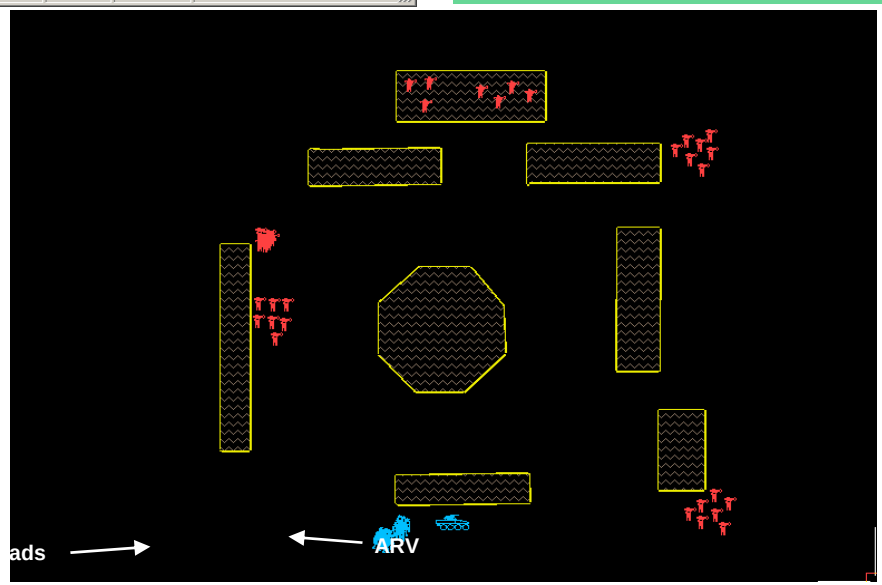
Three Simulation Scenarios



MANA Scenario



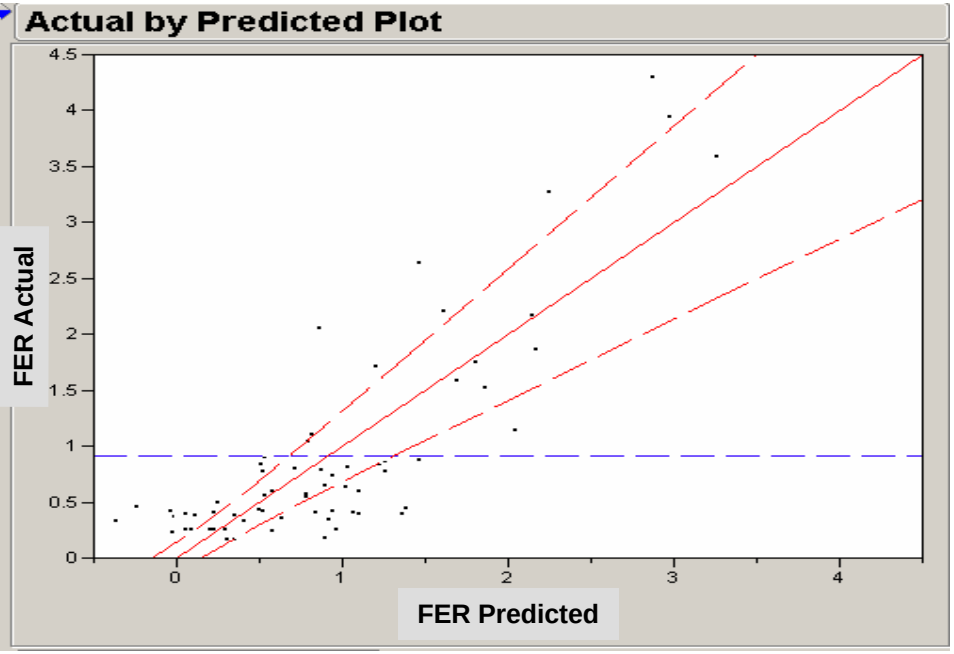
Pythagoras Scenario



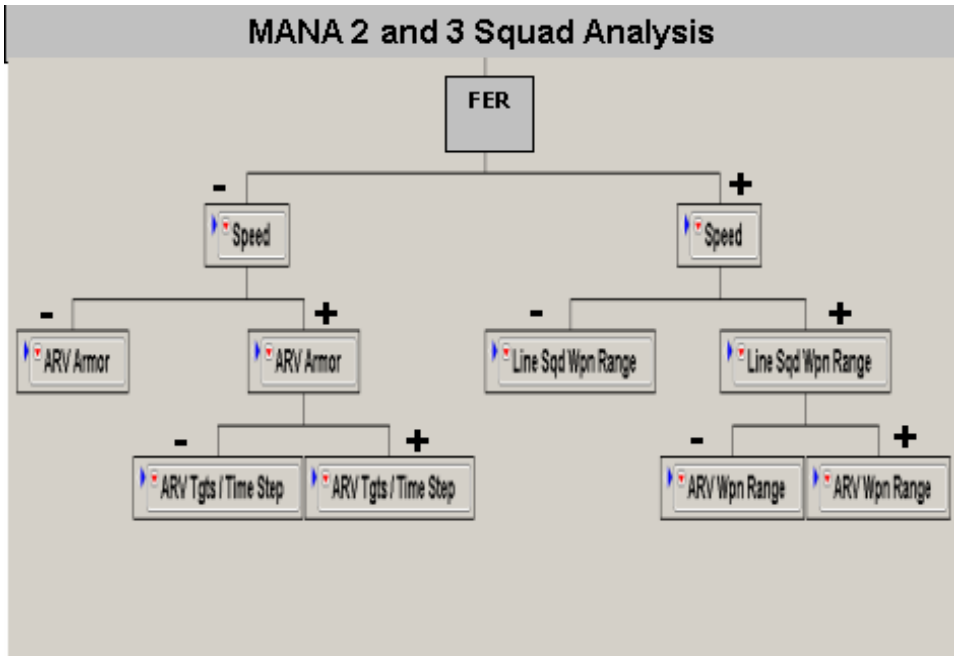
JANUS Scenario

MANA Data Analysis – (2 and 3 Squads)

Regression equation found using stepwise approach to identify significant effects. Results below show differences in predicted response (FER) and actual response (FER).



The classification tree illustrates the significant relationships in the identified effects.

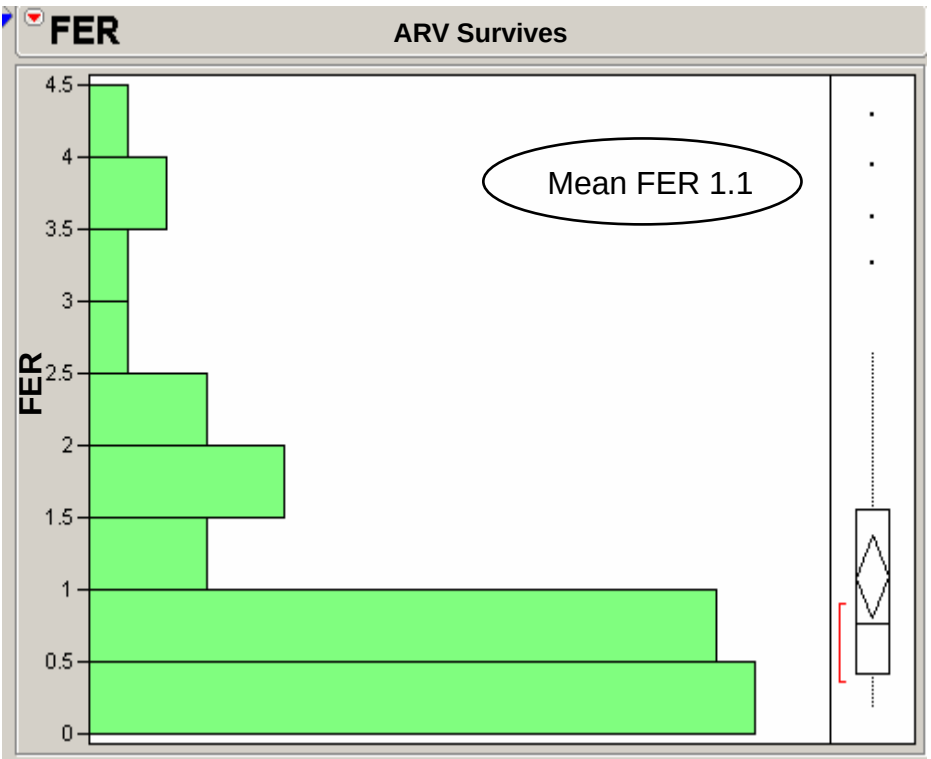


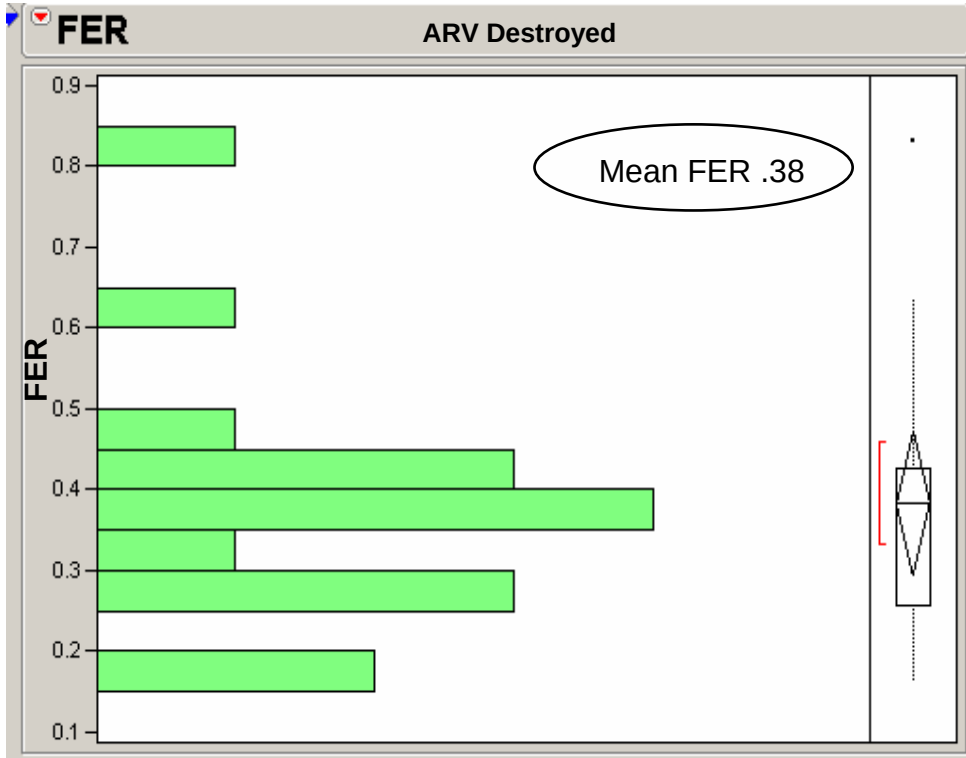
- **Armed robotic vehicle (ARV) speed**
- **Armor thickness of the ARV**
- **Squad size**
- **Combined effect of the ARV's primary weapon and firing rate of line squad**
- **Combined effect of M240 maximum effective ranges (MER's) and line squad's firing accuracy**

- **When ARV operating at low speeds, ARV armor thickness key to increased blue survivability.**
- **When ARV operating at high speeds, MERs of line squad(s) and ARV primary weapon key to increased blue survivability.**

MANA Data Analysis – FER (2 and 3 Squads)

Comparison of FERs when ARV survives and when ARV is destroyed





Blue survivability is most related to the survivability of the ARV in this urban scenario. When the ARV survives, the Force Exchange Ratio (FER) is nearly 3 times greater.

Potential Insights from MANA Data Analysis

- **Objective Force (OF):**
  - What is the appropriate squad size and number of squads?
    - When the ARV survives, no significant differences in survivability for squad sizes of 9 and 12 exist.
    - When the ARV is destroyed, squad sizes of 12 offer significantly improved survivability.

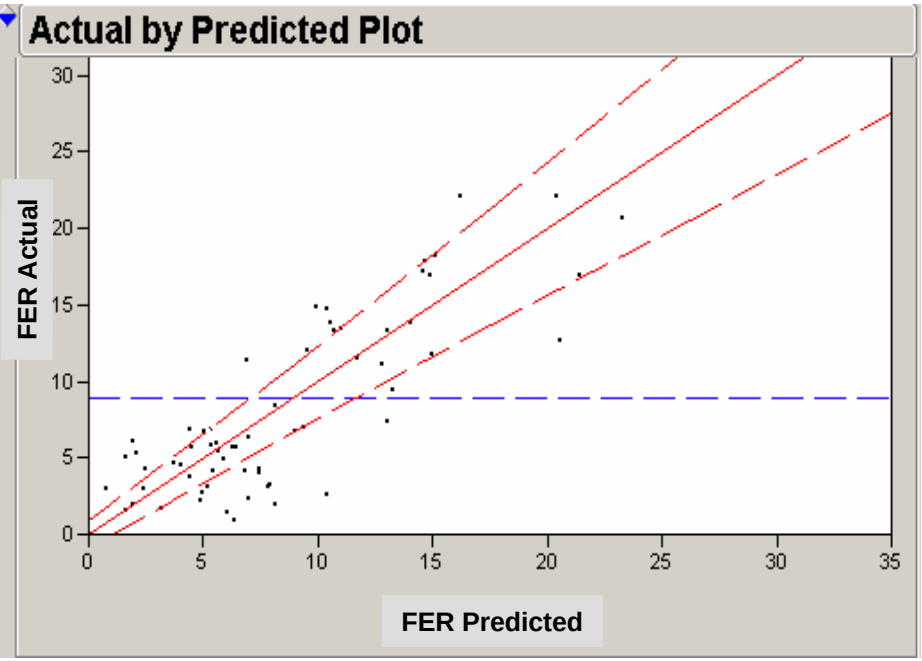
- **Armed Robotic Vehicle (ARV) FCS Issues**
  - What is the best Operational Employment Concept?
    - If the ARV operates at roughly the same speed and in close proximity to the dismounted infantry, then the ARV's armor thickness and ability to engage multiple targets are significantly important to improved FER.
    - As the ARV operates forward of and faster than the speed of the dismounted infantry, the ARV's 25mm cannon is the primary contributor to an improved FER.

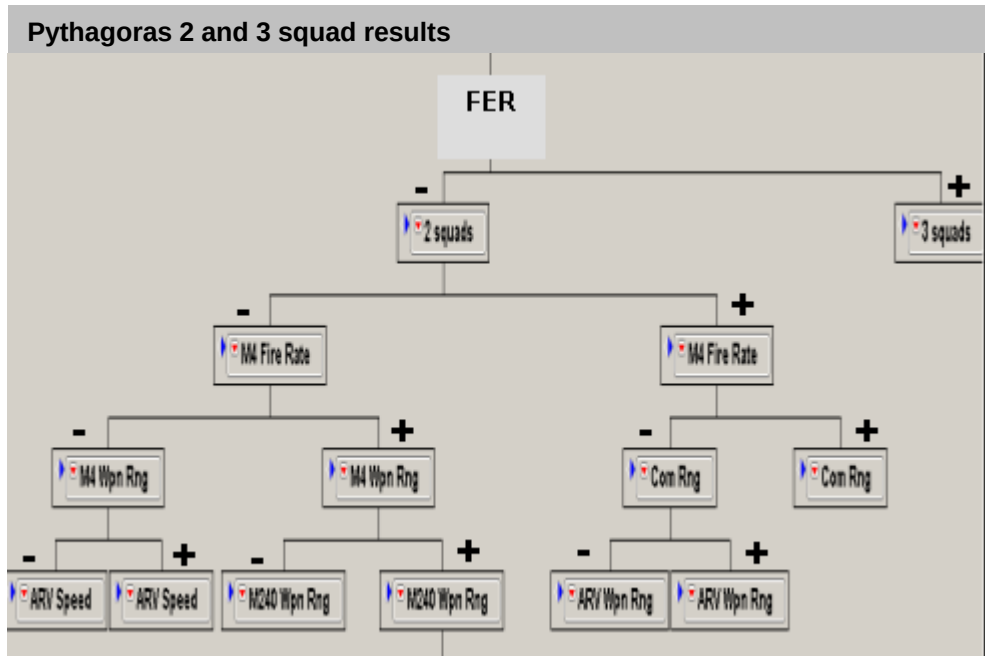
Higher FER {

Pythagoras Data Analysis – (2 and 3 Squads)

Regression equation found using stepwise approach to identify significant effects. Results below show differences in predicted response (FER) and actual response (FER).

The classification tree illustrates the significant relationships in the identified effects.



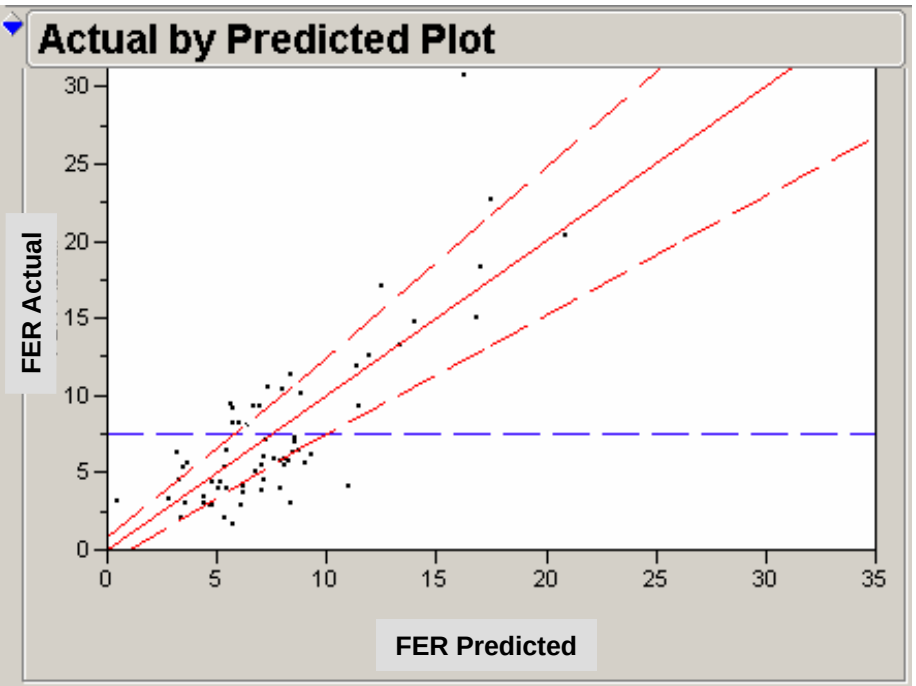


- **Number of squads and squad size**
- **Weapon squad's automatic weapon (M4) firing rate**
- **Weapon squad's automatic weapon (M240) MER**
- **ARV speed**
- **Combined effect of number of squads and M240 MER**

- **With only 2 squads, then weapon squad firing rates, weapon squad MERs, and ARV speed are keys to blue survivability.**

Pythagoras Data Analysis – (3 and 4 Squads)

Regression equation found using stepwise approach to identify significant effects. Results below show differences in predicted response (FER) and actual response (FER).



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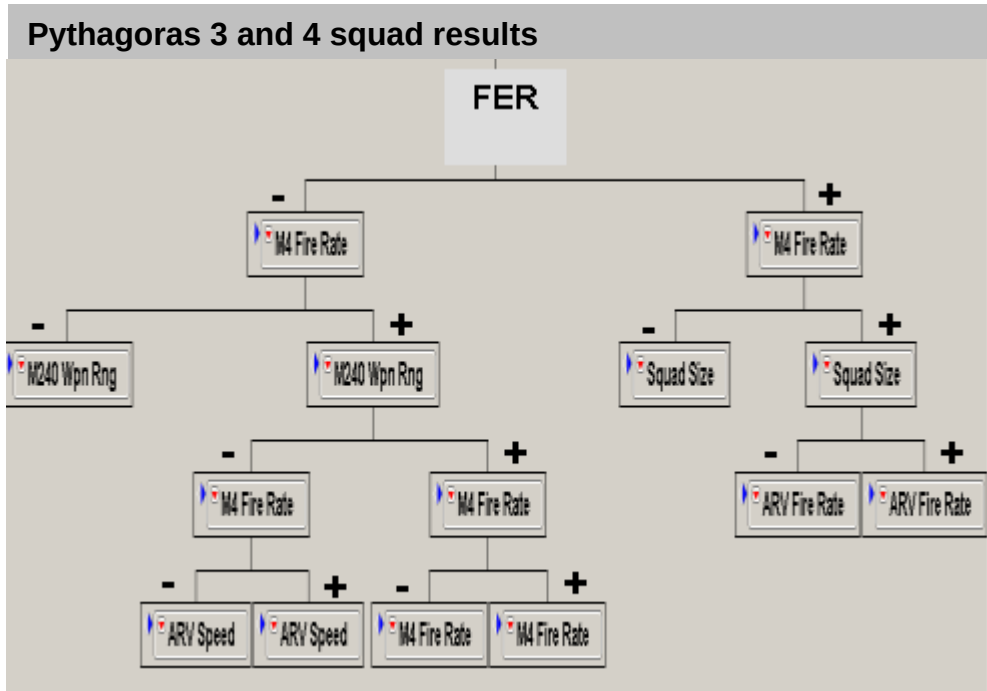
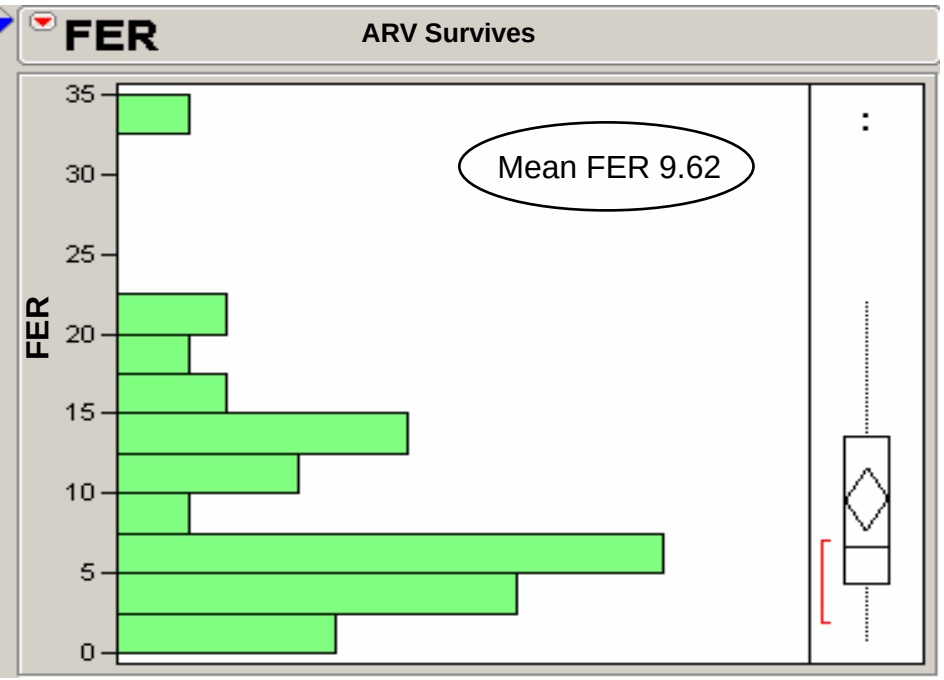


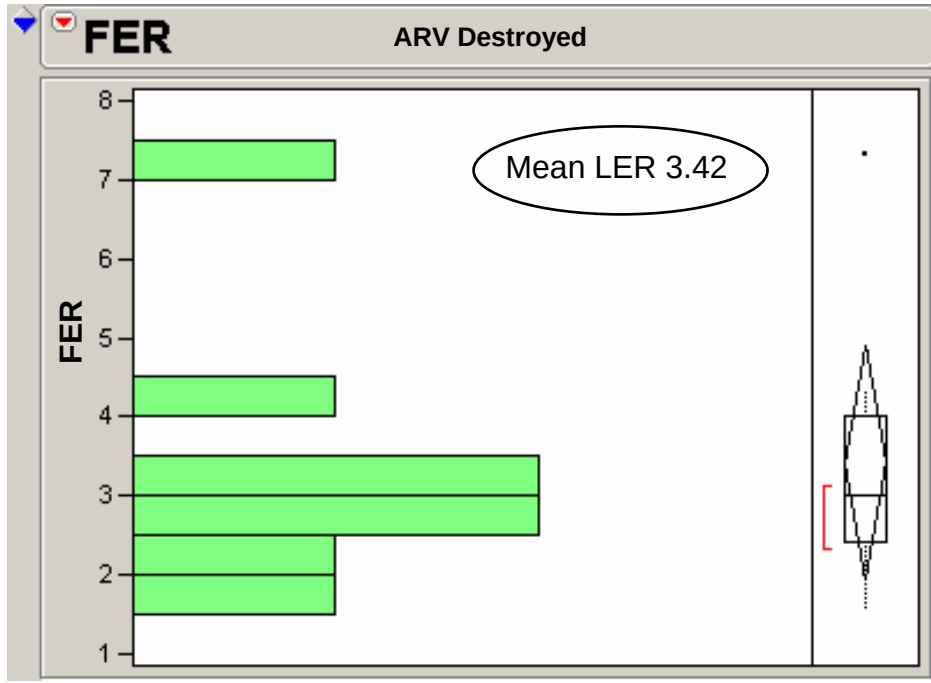
- **Weapon squad M4 firing rate, M4 MER, and M240 MER**
- **Squad size and number of squads**
- **ARV speed and ARV primary weapon firing rate**
- **Combined effect of squad size and wpn sqd (M4) firing rate**
- **Combined effect of number of squads and line sqd firing rate**

- **When M4 firing rates are high, effect of larger squad sizes on blue survivability is mitigated.**
- **When M4 firing rates decrease, M240 MER and ARV speed improve blue survivability.**

Pythagoras Data Analysis - FER (2 and 3 Squads)

Comparison of FERs when ARV survives and when ARV is destroyed

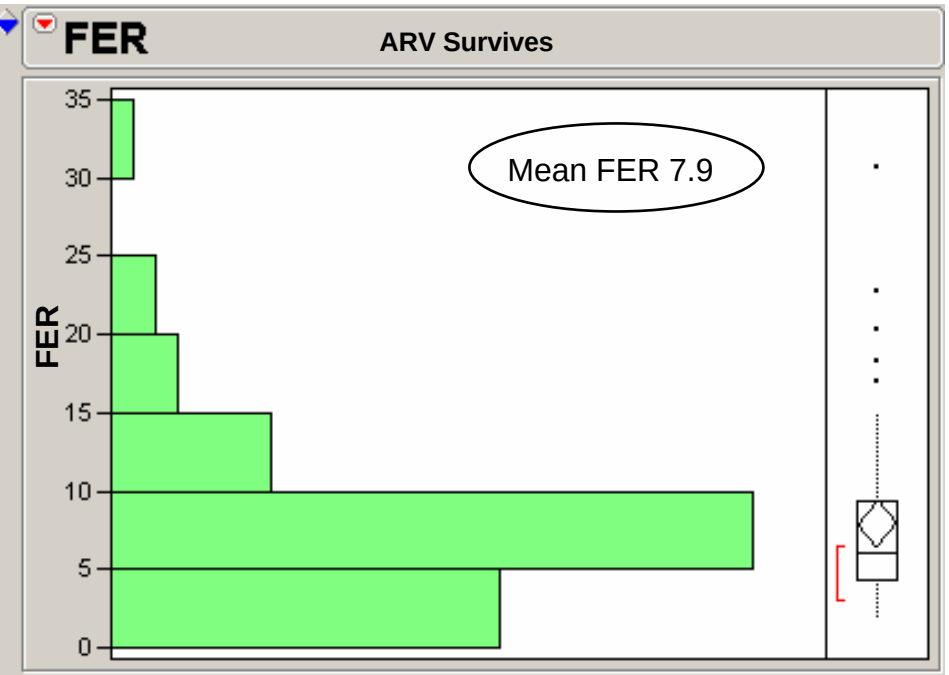


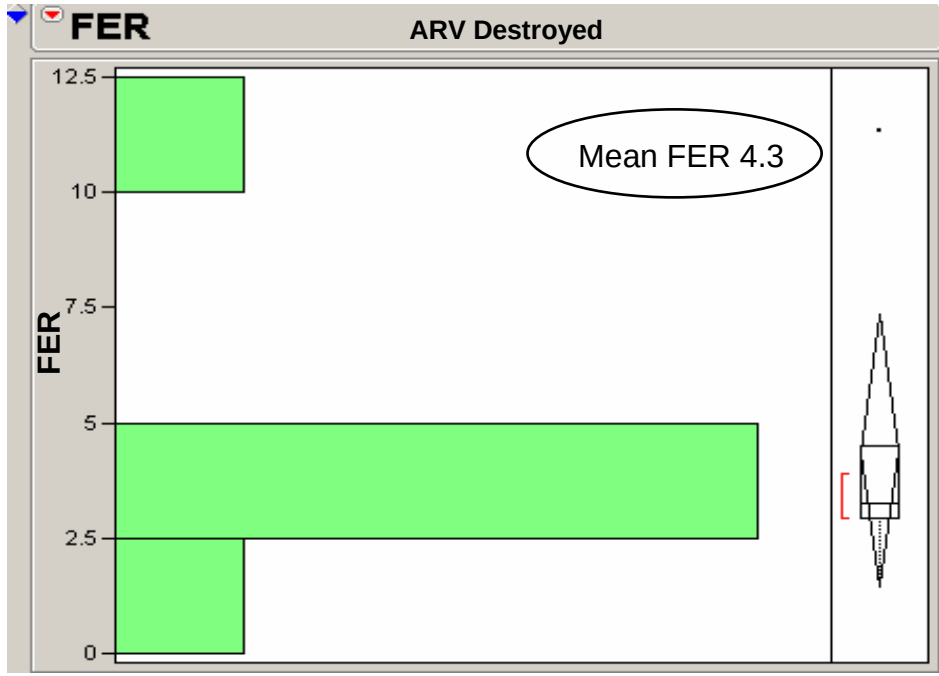


Similar to previous result, Blue survivability is most related to the survivability of the ARV in this urban scenario. When the ARV survives, the Force Exchange Ratio (FER) is nearly 3 times greater.

Pythagoras Data Analysis - FER (3 and 4 Squads)

Comparison of FERs when ARV survives and when ARV is destroyed





Even with an increased number of squads, Blue survivability is most related to the survivability of the ARV in this urban scenario. When the ARV survives, the Force Exchange Ratio (FER) is nearly 2 times greater.

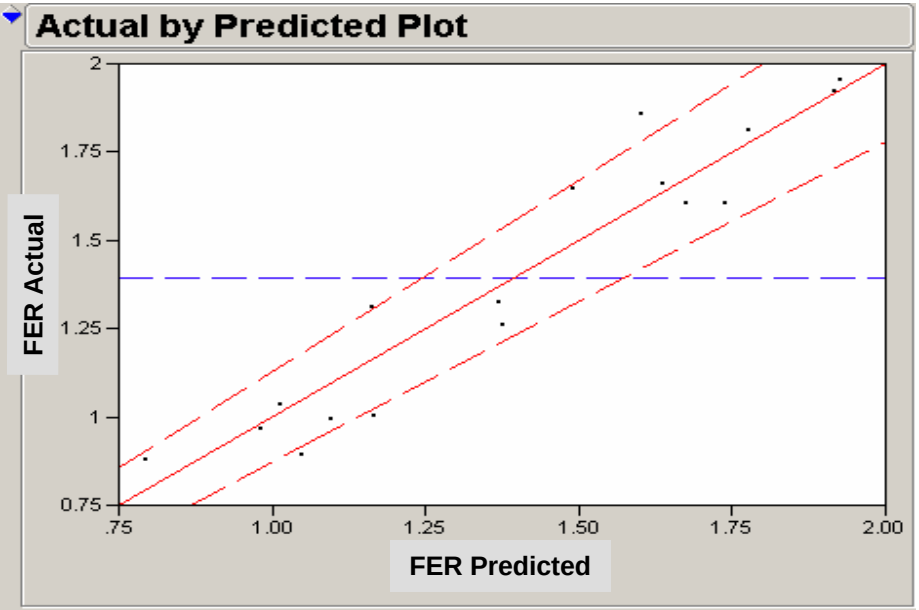
Potential Insights From Pythagoras Data Analysis

- **Objective Force (OF):**
  - What is the appropriate squad size and number of squads?
    - With 4 squads of 12 soldiers each, the survivability of the ARV does not significantly impact the FER.
    - When the ARV is destroyed, squad sizes of 12 offer significantly improved survivability.
    - Improved marksmanship with the M240 and M4 offsets the need for increased squad sizes.

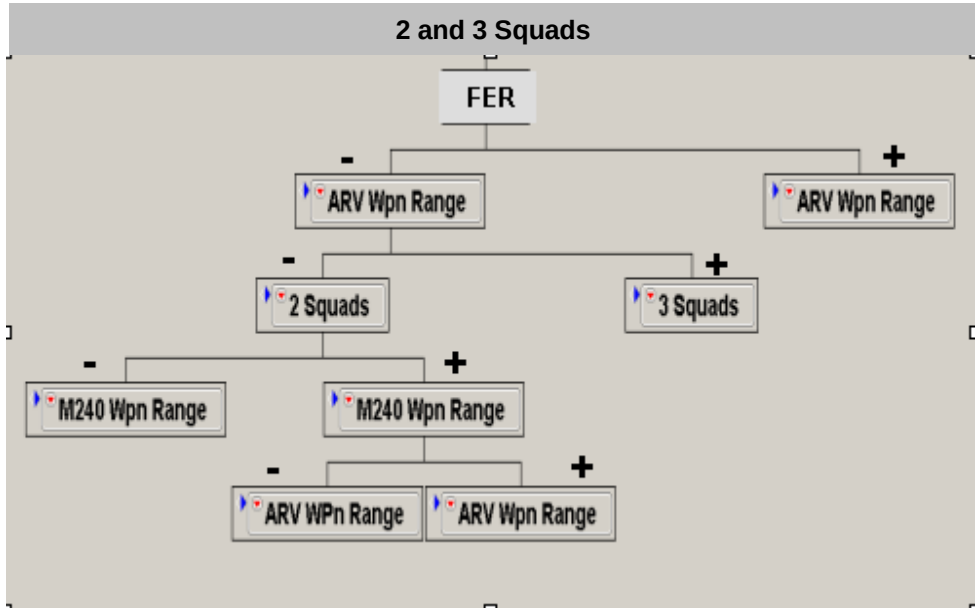
- **Armed Robotic Vehicle (ARV) FCS Issues**
  - What is the best Operational Employment Concept?
    - As the ARV operates forward of and faster than the speed of a dismounted infantry platoon with 2 or 3 squads, the increased speed of the ARV and its ability to provide fire support offsets the reduced organic firepower of the platoon.

JANUS Data Analysis – (2 and 3 Squads)

Regression equation found using stepwise approach to identify significant effects. Results below show differences in predicted response (FER) and actual response (FER).



The classification tree illustrates the significant relationships in the identified effects.



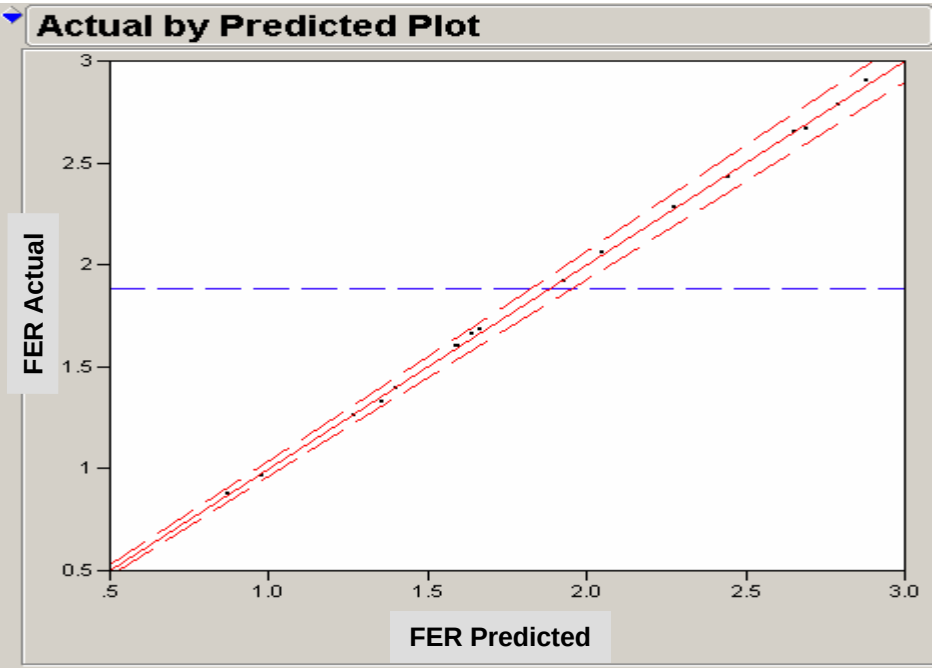
- **ARV primary weapon MER**
- **Number of squads and squad size**
- **Weapon squad's M240 MER**
- **Combined effect of squad size and ARV primary wpn range**
- **Combined effect of Scheme of Maneuver (SoM) and single shot kill probability of ARV**

- **ARV primary weapons MER is critical regardless of number of squads**
- **With only 2 squads present, weapons squad's MERs and ARV weapon range are keys to blue Survivability**

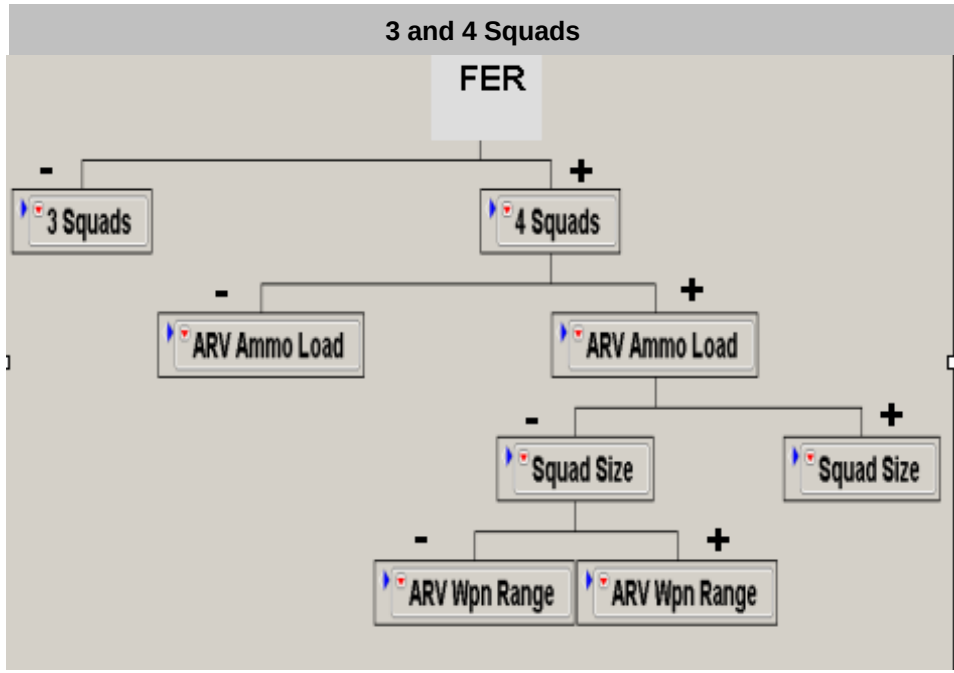
***JANUS runs executed in closed form**

JANUS Data Analysis – (3 and 4 Squads)

Regression equation found using stepwise approach to identify significant effects. Results below show differences in predicted response (FER) and actual response (FER).



The classification tree illustrates the significant relationships in the identified effects.



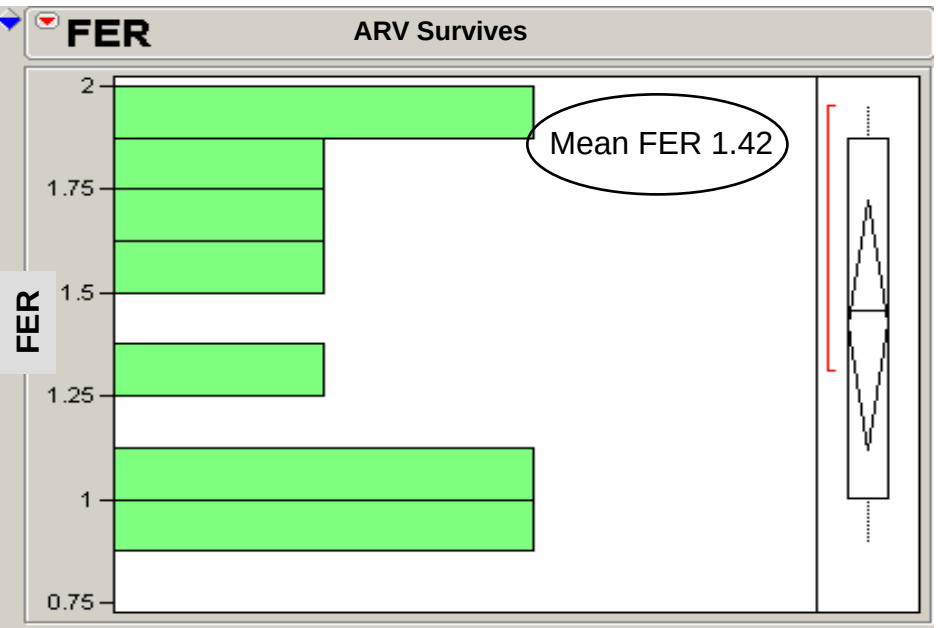
- **Number of squads**
- **ARV primary weapon range**
- **Combined effect of squad size and M240 MER**
- **Combined effect of number of squads, squad size and Scheme of Maneuver**

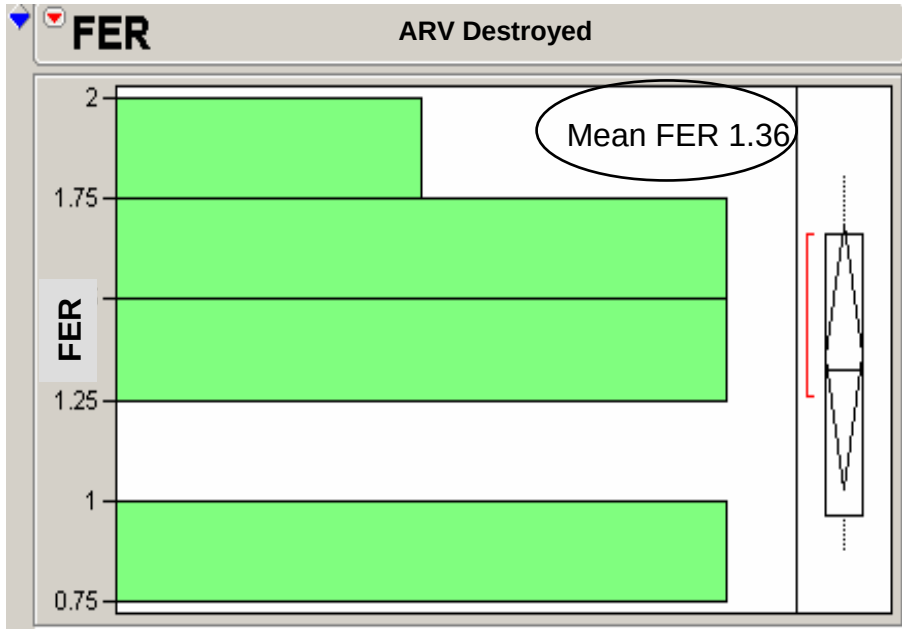
- **Number of squads is primary factor in blue survivability.**
- **With 4 squads present:**
  - **ammunition usage increases significantly**
  - **squad sizes less than 12 indicate need for greater ARV MER**

***JANUS runs executed closed form**

JANUS Data Analysis- FER (2 and 3 Squads)

Comparison of FERs when ARV survives and when ARV is destroyed

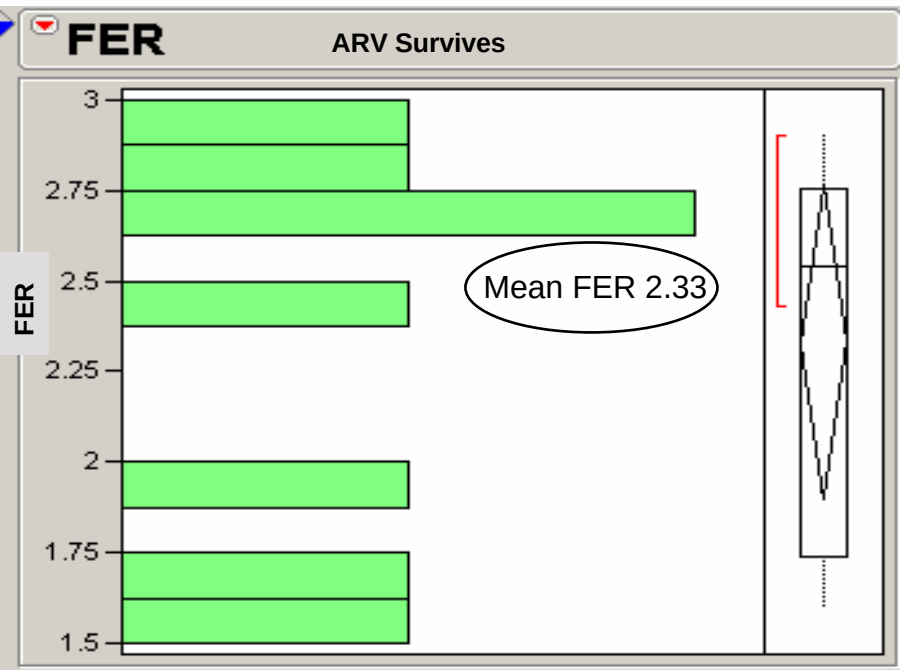


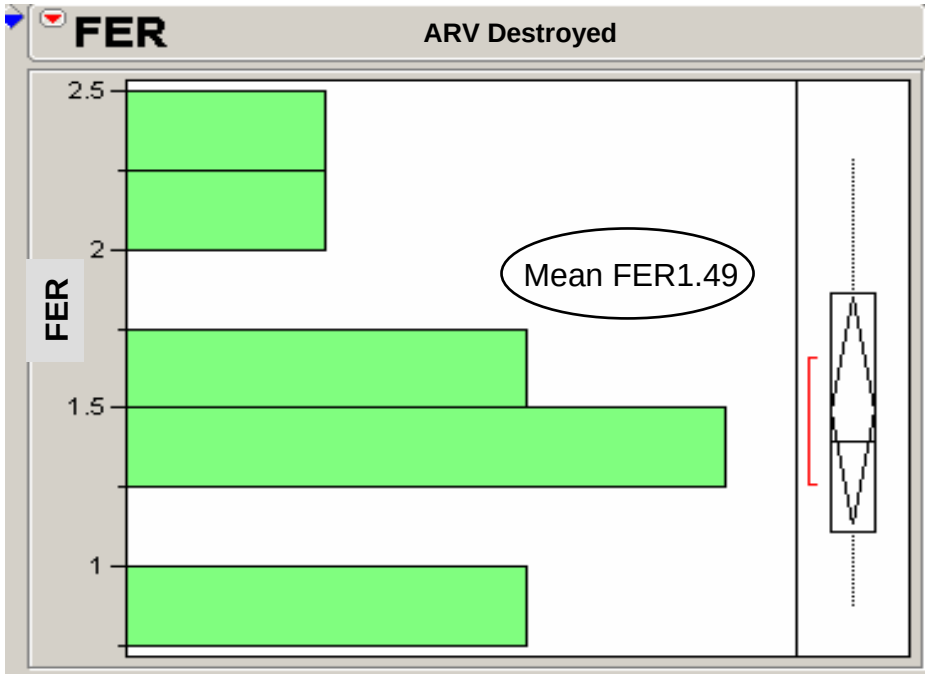


These results indicate there is not a significant difference in FER's between 2 and 3 squads and ARV survivability.

JANUS Data Analysis - FER (3 and 4 Squads)

Comparison of FERs when ARV survives and when ARV is destroyed





Even with an increased number of squads, Blue survivability is most related to the survivability of the ARV in this urban scenario.

Potential Insights From JANUS Data Analysis

- **Objective Force (OF):**
  - What is the appropriate squad size and number of squads?
    - 4 squads had the highest FERs, but consumed 30% more ammunition.
    - If ARV is destroyed, squad sizes of 12 suffered minimal decrease in FER (in these cases, Blue had a 1.3:1 force advantage).
    - Improved marksmanship with the M240 and M4 offsets the need for increased squad sizes.

- **Armed Robotic Vehicle (ARV) FCS Issues**
  - What is the best Operational Employment Concept?
    - When the ARV had greater stand-off advantage and better capability withstanding anti-armor weapons, FERs were improved.

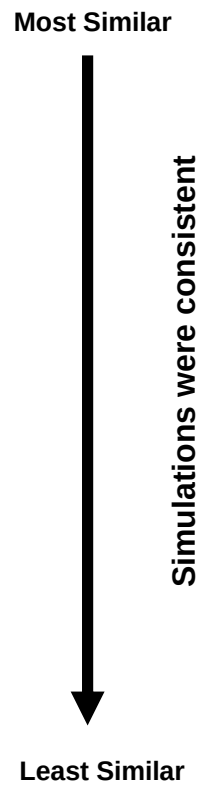
Note: JANUS Scheme of Maneuver and scripting of routes for both soldiers and ARV can greatly influence outcome.

Analysis Summary

	Significant Factors	Potential Insights
MANA	- ARV armor thickness -Wpn's sqd max weapon ranges and firing rates -ARV speed -ARV wpn max range and sqd firing rates - Squad size	- ARV survives, no difference in squad survivability - ARV destroyed, squad size of 12 improved survivability - ARV operates at low speeds, armor thickness key - ARV operates at high speeds, weapon range key
Pythagoras	-Squad size -Number of squads -Number of sqds and sqd firing rates -Sqd firing rates and squad size Wpn's sqd max weapon ranges and sqd firing rates - ARV speed	- With 4 squads of 12, ARV does not significantly impact FER - Improved wpn's sqd firepower can offset need for increased squad sizes - ARV destroyed, squad size of 12 improved survivability - ARV operates at high speeds, offsets reduced sqd organic firepower
JANUS	- Number of squads - Squad size - ARV wpn max range - Scheme of Maneuver (SOM) -Wpn's sqd max weapon ranges -ARV armor thickness	- With 4 squads, highest FER but large ammo consumption - ARV destroyed, squad size of 12 improved survivability - Improved wpn's sqd firepower can offset need for increased squad sizes - Increased ARV wpn max range improved FER

Simulation Comparison

	MANA	Pythagoras	JANUS
Squad Size	S	M	M
Number Squads	NS	M	M
ARV Armor Thickness	M	NA	S
ARV Speed	S	S	S
ARV Wpn Max Range	S	S	S
Wpn Max Ranges and Sqd Firing Rates	S	S	NA
Wpn Max Ranges	NS	S	S
Sqd Firing Rates and Squad Size	NS	S	NA
Number of Sqds and Sqd Firing Rates	NS	S	NA
Scheme of Maneuver	NA	NA	S



M = Most Significant S = Significant NS = Not Significant NA = Not Applicable

Insights Summary

OF Platoon and FCS Summary:

•ARV survivability has a significant impact upon blue squad survivability in this type of urban scenario. ARV survivability is enhanced by its weapon's max effective range and protection against anti-armor weapons.

• If the ARV survives, there is little difference in LER for squad sizes of 9 and 12. However, if the ARV is destroyed, squad sizes of 12 have better survivability.

• In general, if the ARV meets future specifications, 3 squads are sufficient.

ABS Summary:

• Agent based simulations allow a more robust exploration of the possible outcomes for urban operations. They allow the generation of ideas and insights prior to bringing significant resources to bear on an issue.

• In this example, agent based simulation results are relatively consistent with high resolution combat simulations.

Future Research

- **Use of agent based simulations for screening analysis**
  - FCS Key Performance Parameter analysis
- **ABS representing millions of agents in an urban environment.**
  - Drafting DARPA Proposal with Los Alamos National Laboratory
- **Use of new experimental designs for high resolution simulations.**
  - AMSAA's FCS System-of-Systems metrics
- **Facilitate Project Albert's research into ABS for urban operations.**
  - Command and Control research (1 and 2 levels higher than basic agent)
  - More robustly capturing sensor and targeting information
  - Logistics and humanitarian assistance operations

Historical Reference - Squad Size Studies

• **WWII** – 12 man squad which consisted of 3 teams (2 ,3,5) plus a squad leader

•**1946** Infantry Conference – Recommended reduction to a 9 man squad of 2 teams(4,4) and a squad leader.
1953 T/O &E changed to 2 teams of 4 (Main reason improved controllability)

•**1956** "A Study of the Infantry Rifle Squad TOE" (ASIRS) – 11 man squad of teams (5,5) plus squad leader adopted
(Main reasons improved fire power, ability to move and cover and resiliency)

•**1960** Ft Benning, Infantry School study – conclusion: 11 man squad worked so well it should not be changed.

•**1961** US Army conducted 2 studies:

-"Optimum Composition of the Rifle Squad and Platoon" (OCRSP) – Ft Ord, California

- Conclusions: 11 man squad of 2 teams (5,5) plus squad leader was optimal. Test was qualitative and quantitative. (Main reasons fire power, resiliency, staying(absorb 25% losses), good leadership ratio)

-"Rifle Squad and Platoon Evaluation Program" (RSPEP) – Ft Benning, Infantry School

-Conclusion: 10 man squad of 2 teams (4,5) plus squad leader was optimum. No objective data used from other study. (Main reasons optimal leader to lead ratio, flexibility)

-Infantry School accepted 10 man squad. Reorganization of Active Army Division (ROAD) T/O&E 7-18E. Took into Vietnam.

•**1966-1969** US Army conducted a series of studies "Infantry Rifle Unit Study" (IRUS)for implementation in the 1970-1975 force.
Very exhaustive study looking at 10, 11, and 13 man squads with various weapons and included physiological factors.

-1973 Army acted on the IRUS studies and increased squad size to 11 man squad of 2 teams (5,5) plus squad leader (Main reasons fire power, resiliency, staying(absorb 25% losses), good leadership ratio. Close on 11/13-cost was factor)

•**1973** IRUS recommendation increased squad size to an 11 man squad.

•**1979-1980** Army conducted Division 86 study series with transition to take place in 1983. Also, 1983 Army Commanders Conference drove another study, Army of Excellence.

•**1984** Army implemented changes based on above. The Army fielded a 9 man squad of 2 (4,4) teams plus a squad leader. Decision driven by resource constraints and not by validated field test. This structure used in Panama (1989), Persian Gulf War (1990-91) and Somalia (1993)