



ARROYO CENTER

***Exploring Communications in an Urban Environment with Agent Based and High Resolution Simulations***

**June 2009**

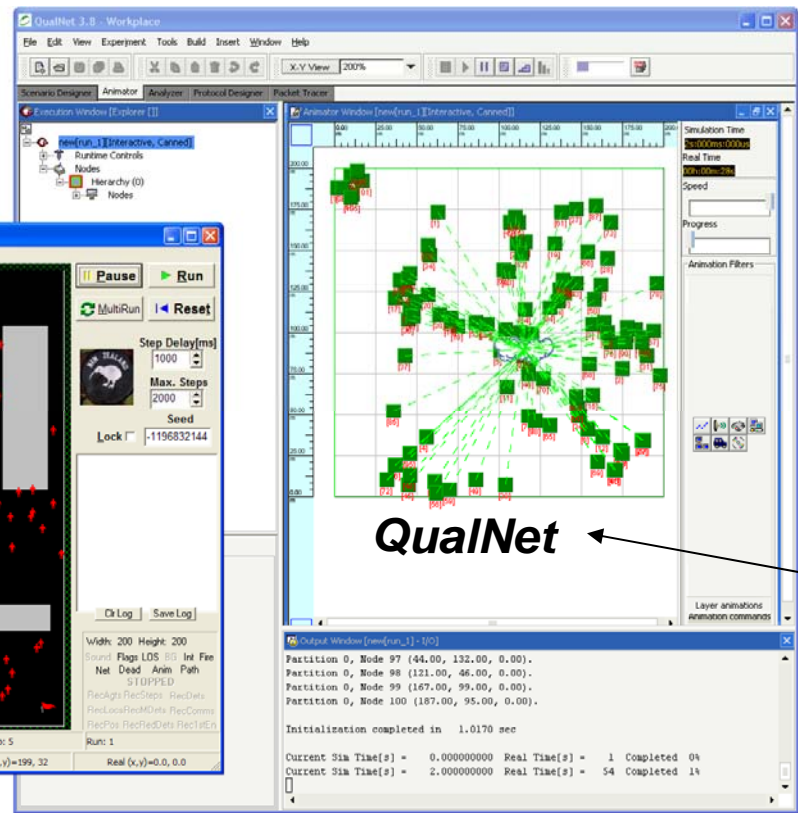
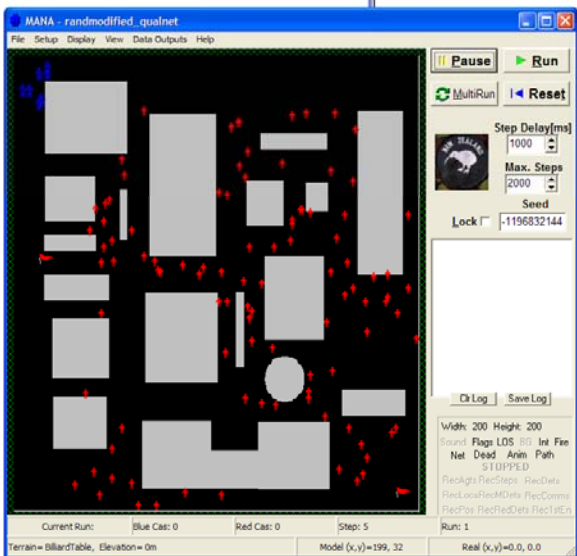
**14<sup>th</sup> International Command and Control Research and Technology Symposium**

# ***Exploring Communications in an Urban Environment***

- **The objective of this research is to better understand the impact of communications assumptions within the context of an urban environment.**
- **Many modeling tools assume a static level of communications capability throughout a run, and even worse a perfect level of capability**
- **We have developed a skeleton scenario with agents representing a mobile convoy, infantry, and unmanned aerial support that deploy and cordon a building.**

# MANA-QualNet: In 2005, We Directly Integrated QualNet with an Agent Based Force-on-Force Simulator

**MANA**  
Agent-based  
model



**QualNet**

- Research results: demonstrated the negative impact of static comms network assumptions on analysis w/ force on force models

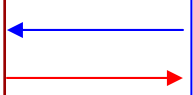
Scalable; designed to run on parallel machines

**Node status (alive?)**

**Msg status (received?)**

**Force-on-force Model**

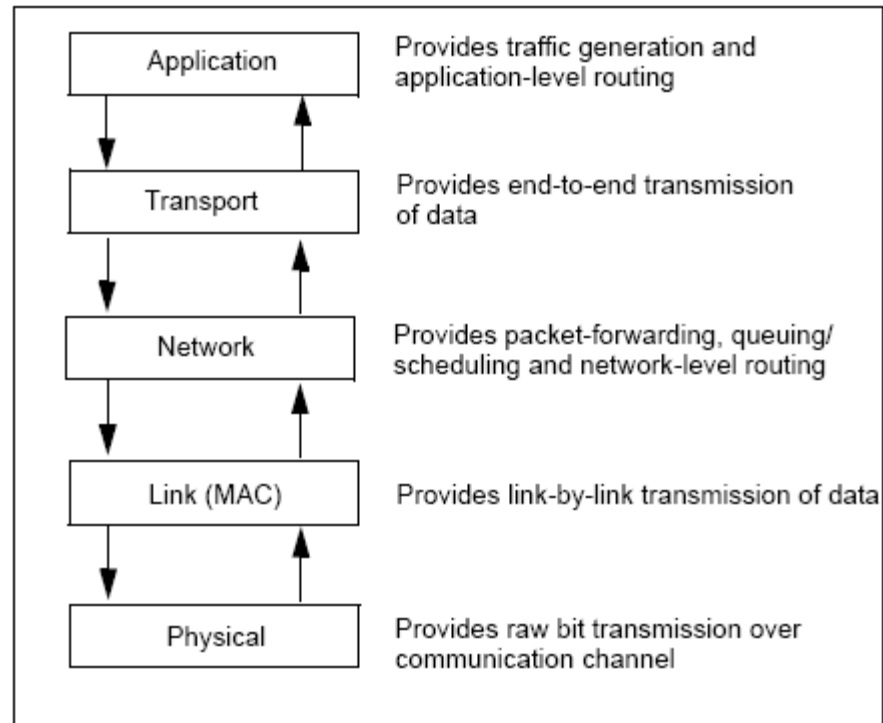
**Network Model**



Porche et al, "Integrating High Resolution Network Simulation with Force on Force Combat Models: Connecting MANA and QualNet", 10th ICCRTS, July 2005.

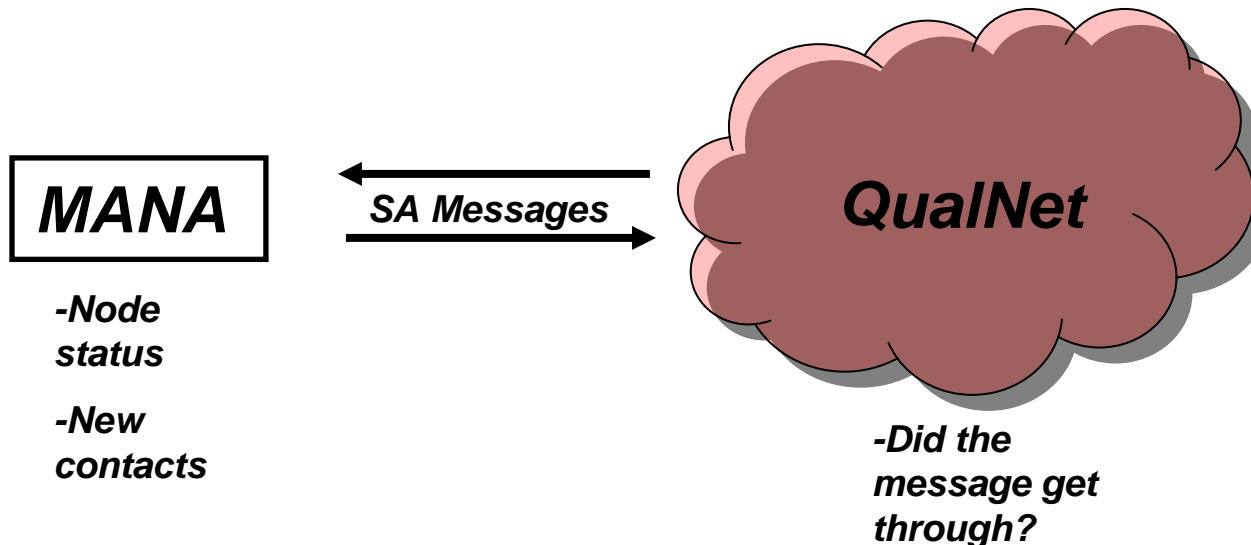
# ***QualNet is a High Fidelity Network Simulator***

- **Predicts network performance by emulating the protocol stack**
- **Scalable, accommodates tens of thousands of nodes, supports parallel architectures**

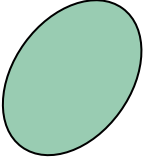




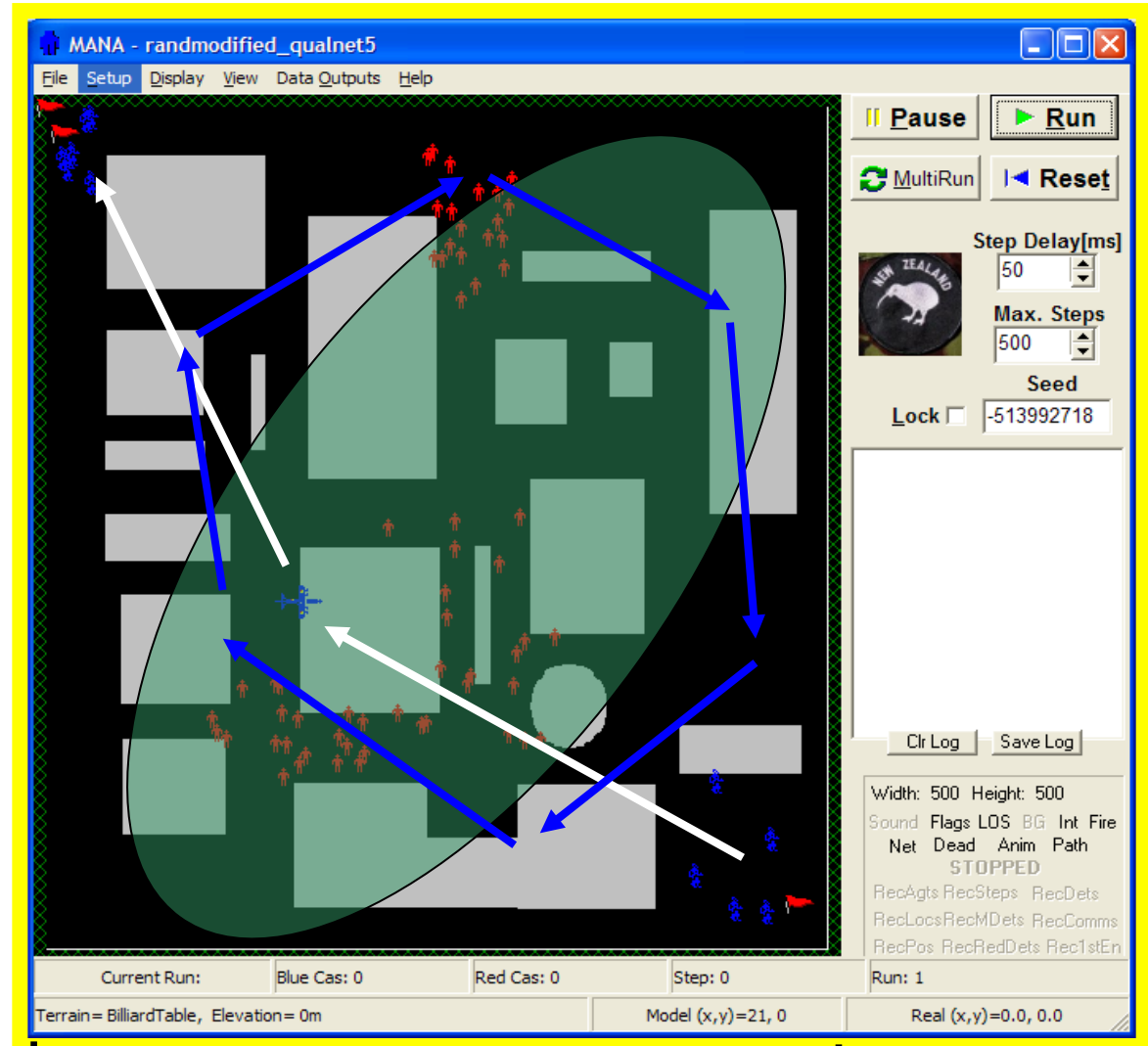
# ***Agents Generate Traffic Which QualNet Simulates Across its Network***

- **Messages are derived from agents making contacts (friend, enemy, neutral, or unknown)**
- **The contact is then represented as a message of fixed or variable size in QualNet**
- **Delay can be artificially created based on expected network conditions**



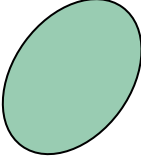
# Example: UAV Relay In Support of Infantry Maneuver In an Urban Environment

-  = Effective UAV Forwarding Range
-  = Messages
-  = UAV Flight Path



0.5 km

# UAV Relay Position Effects Communications & Unit Mission Performance

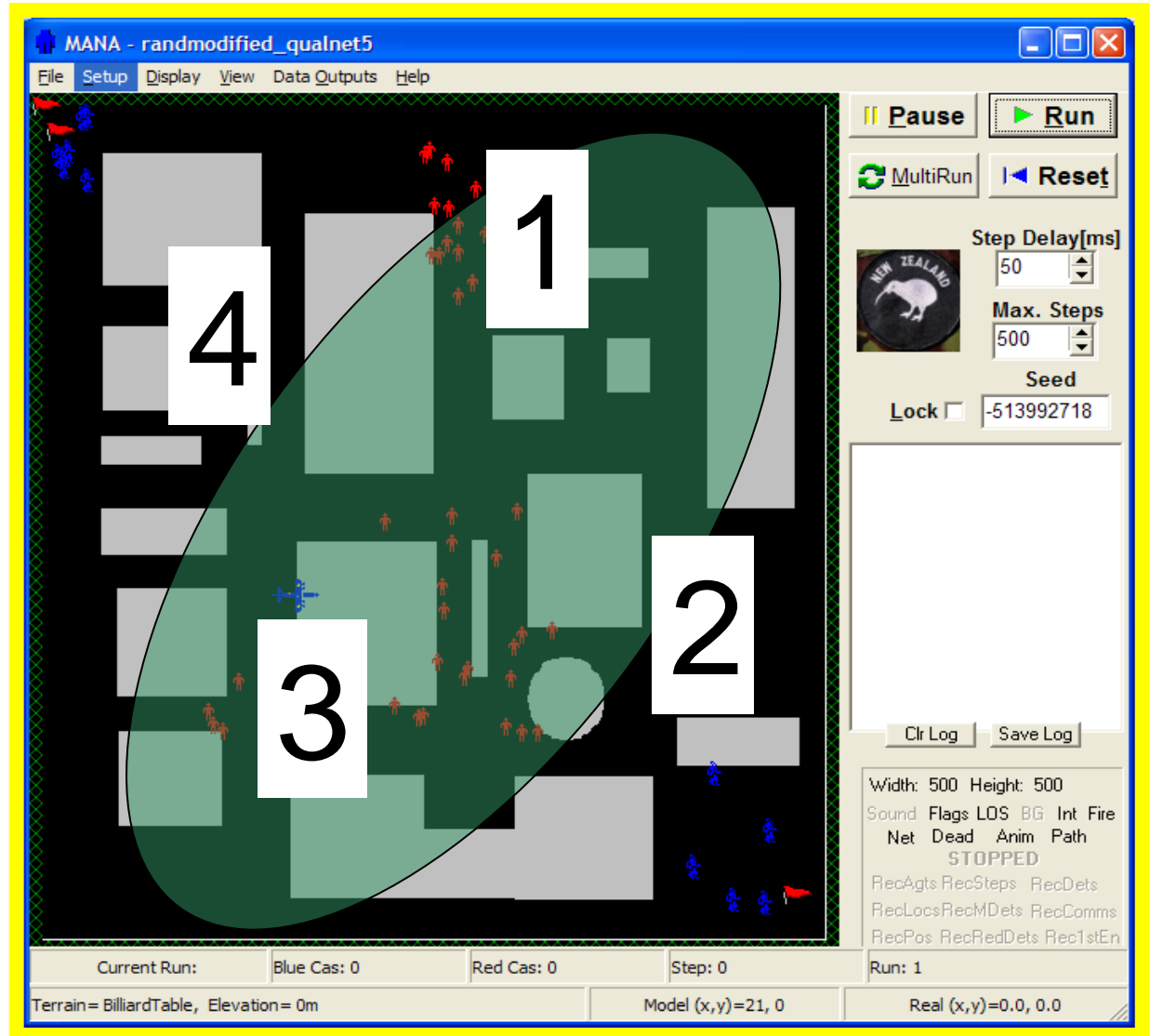
 = Effective UAV Forwarding Range

1 = UAV Moves Into Range

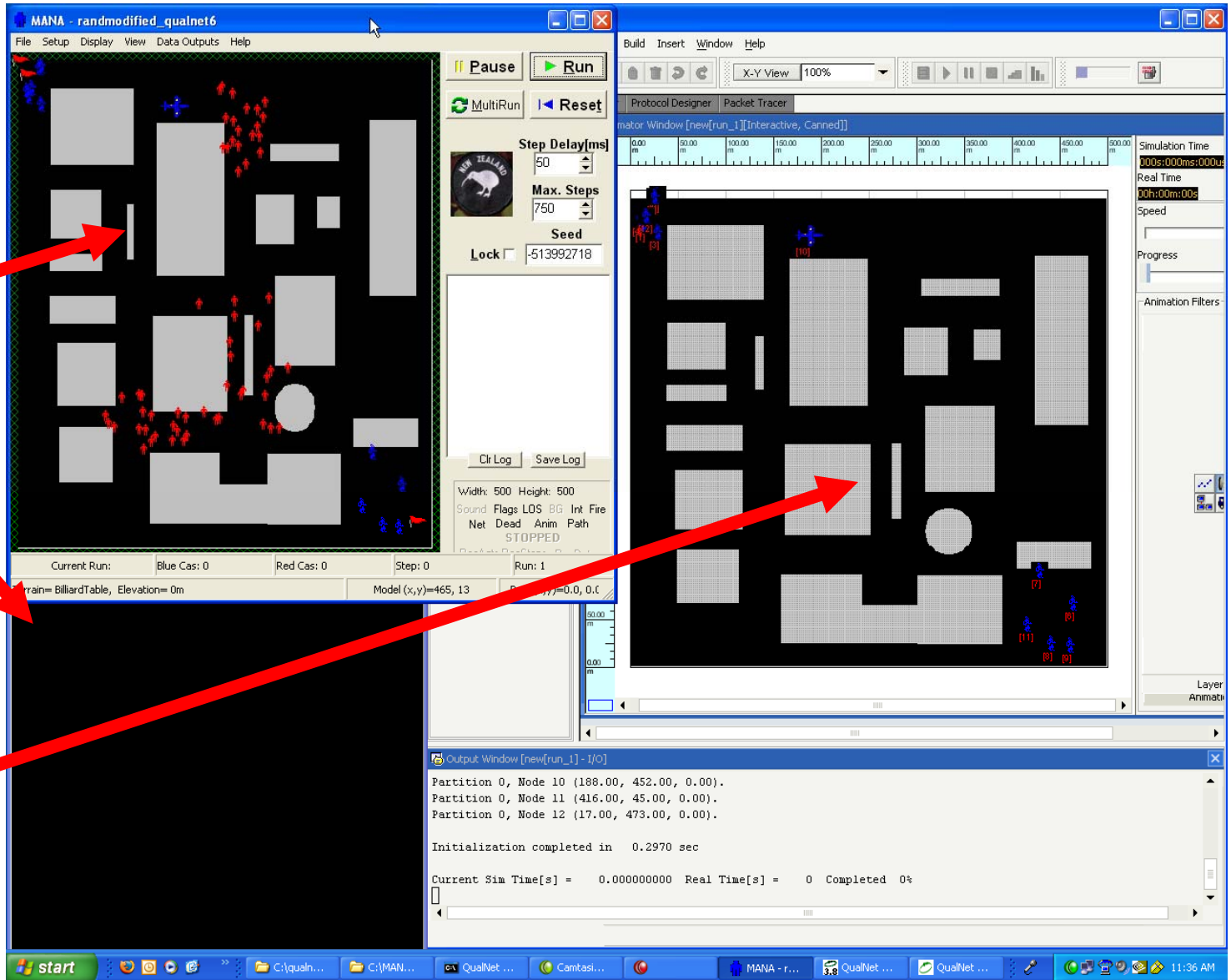
2 = Limited Performance Area

3 = Peak Performance Area

4 = Out of Range



# Force on Force Tied Into Network Simulator

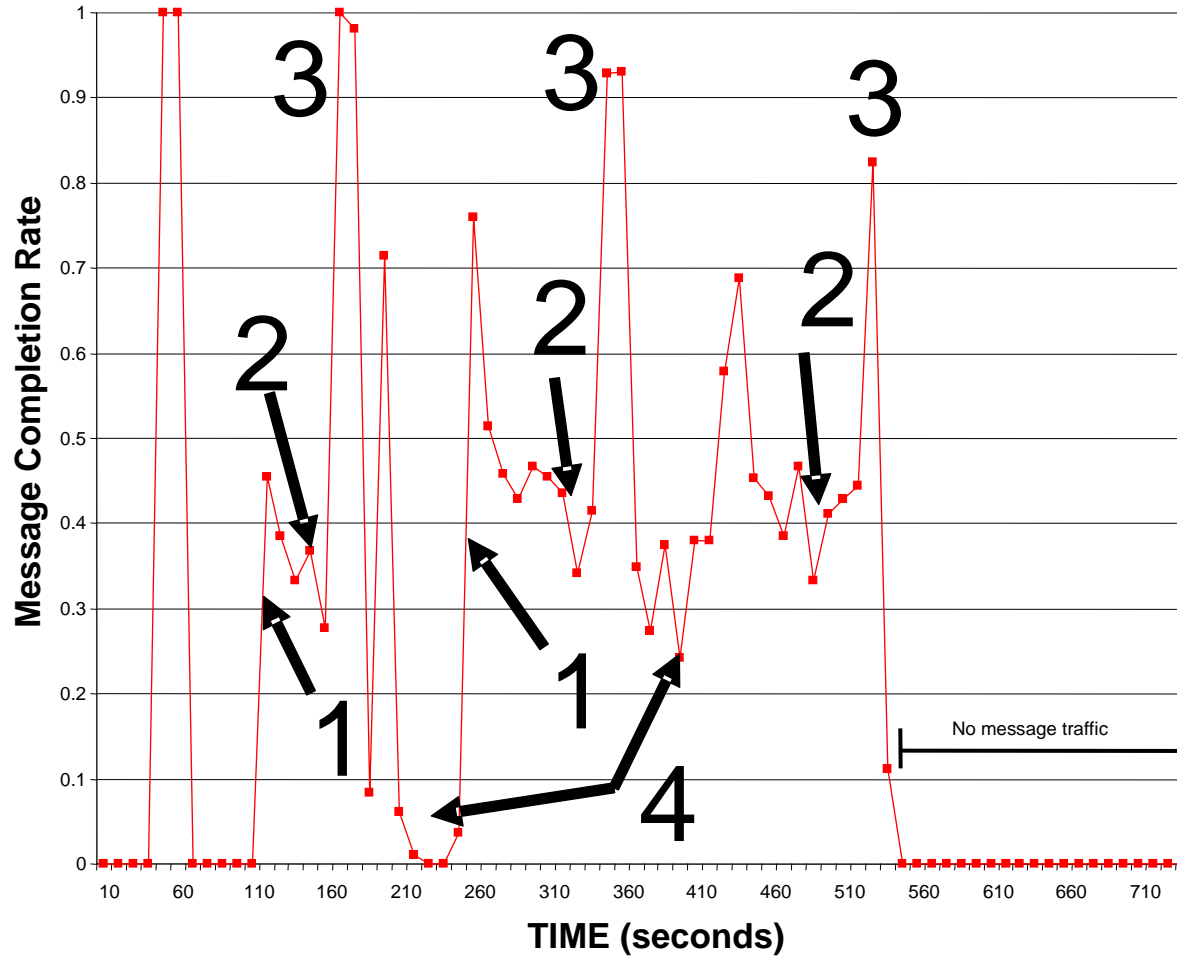


**MANA**  
-Indirect  
Fire SA  
Map

**QUALNET**

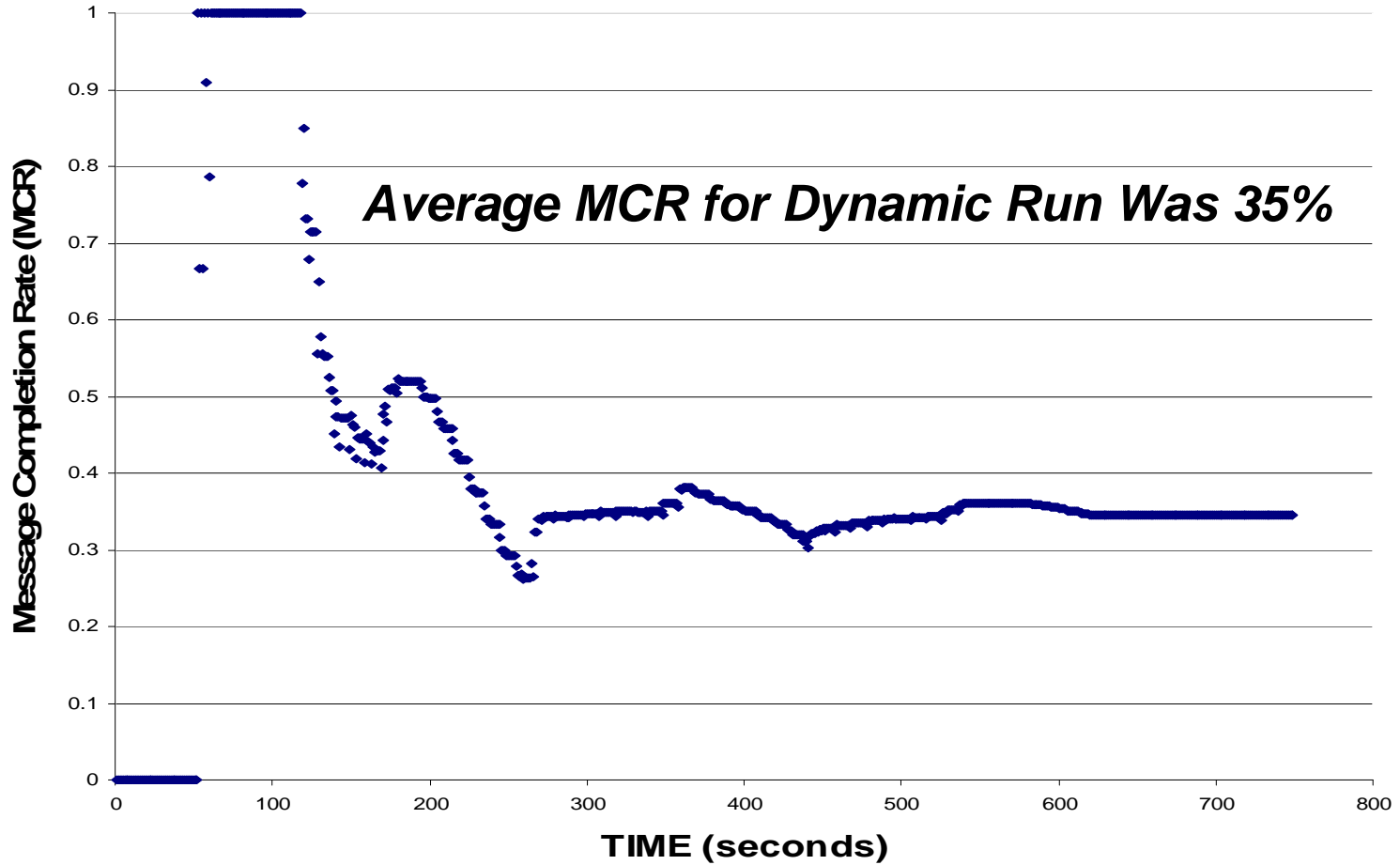


# Message Completion Varies Over Time Based on the UAV's Position




- 1 = UAV Moves Into Range**
- 2 = Limited Performance Area**
- 3 = Peak Performance Area**
- 4 = Out of Range**

# ***Simulation Output: Running Average of MCR Was Calculated***



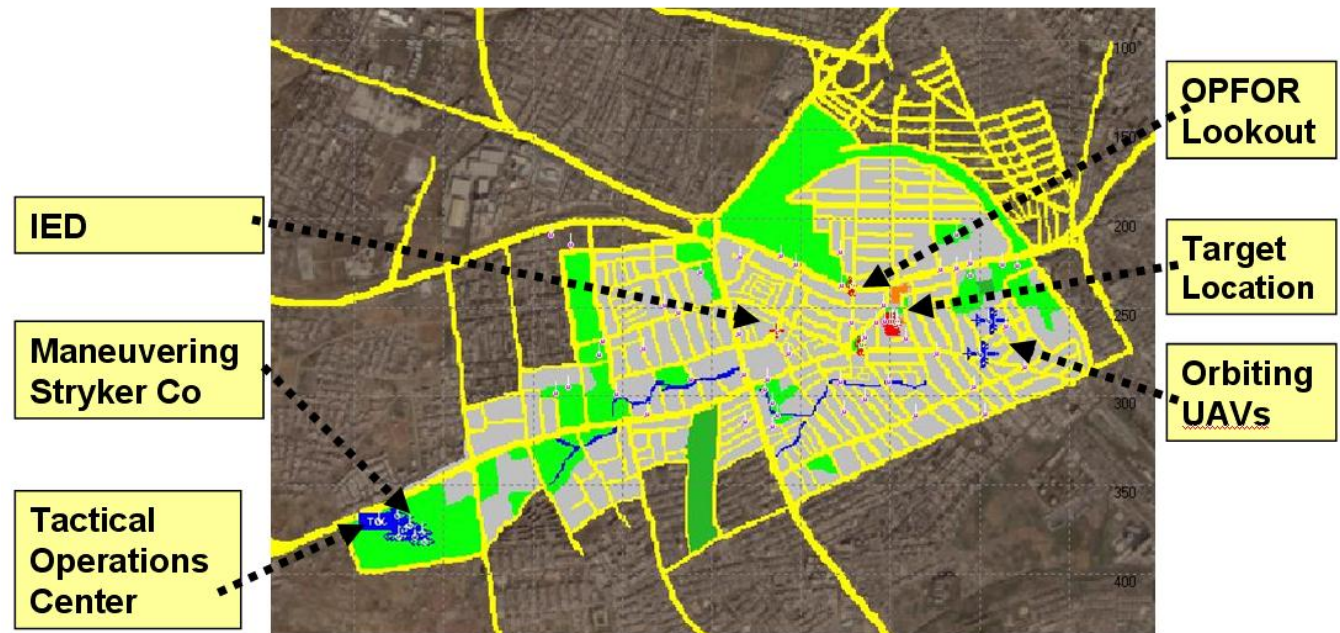
# ***More Experiments: We Inserted MCR's Statically and Compared to Dynamic Calculation***

<b>Static vs. Dynamic</b>			
<b>MCR</b>	<b>BLUE</b>	<b>RED</b>	<b>LER</b>
0%	8	34	4
10%	4.5	52	12
25%	2.8	58	21
50%	2.5	58.4	23
100%	2.2	59.1	27
 <b>Dynamic w/QualNet</b>	<b>5</b>	<b>46</b>	<b>9.2</b>

***Bottom-Line: Static assumptions of networking capability are invalid***

# Overview of Urban Operations Scenario

- Analyze impact of emitters such as:
  - Radios (digital and analog)
  - UAV RF Control links
  - IEDs RF Control link
  - Radar



**Stryker Bn  
operating in an  
urban  
environment**

**Target**

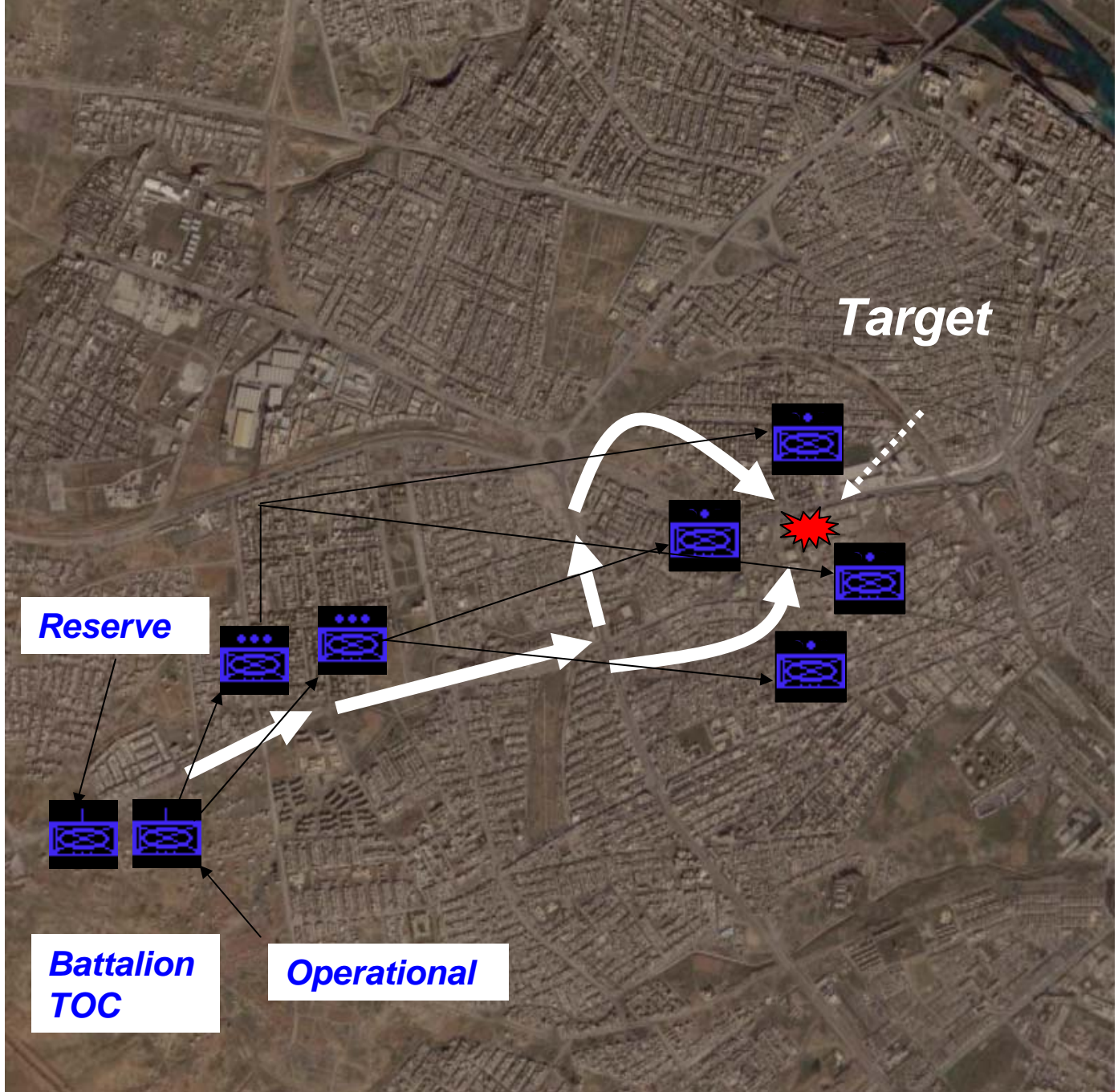
**Reserve**

**Battalion  
TOC**

**Operational  
TOC**

5 km

5 km

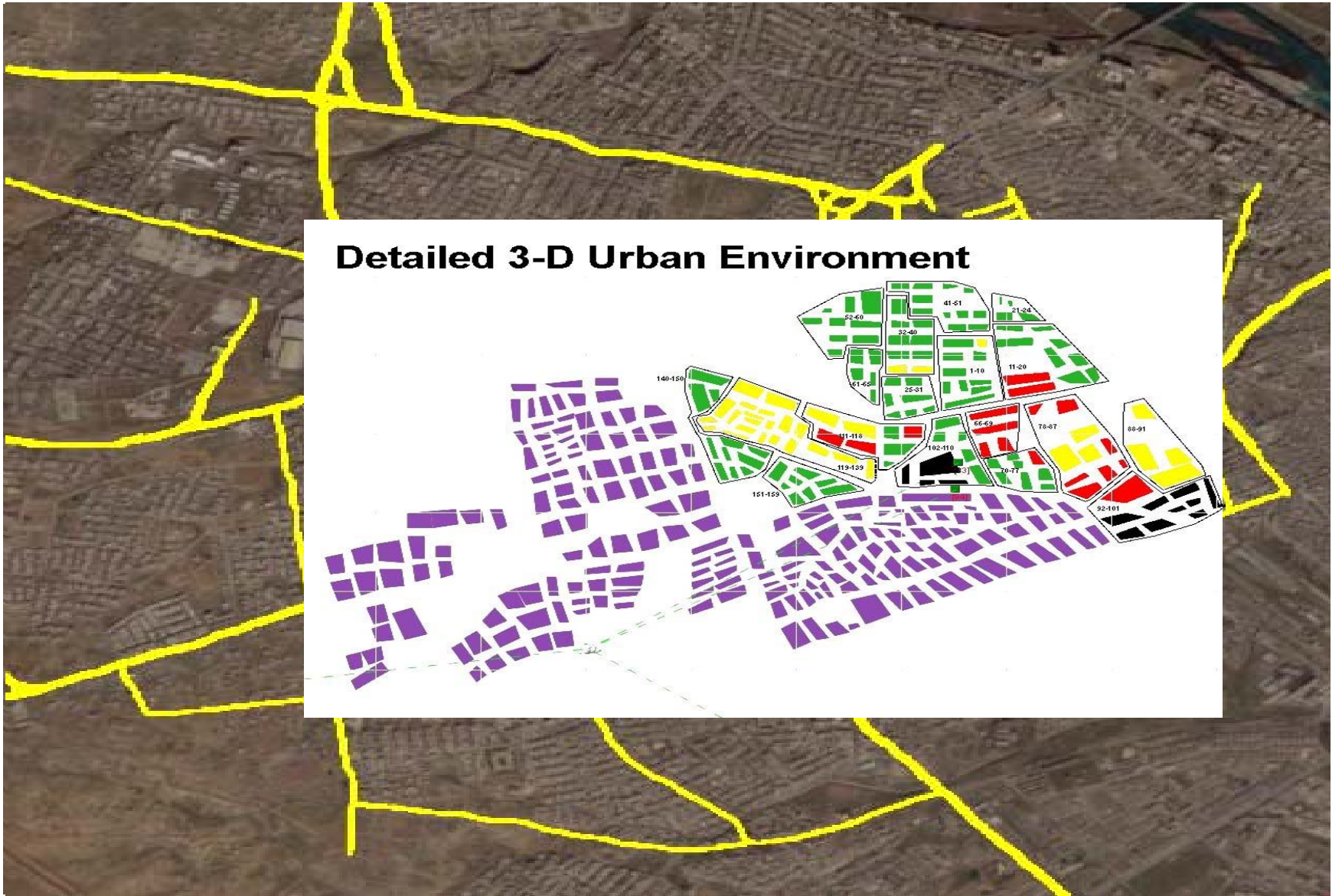




# *Blue Positions*

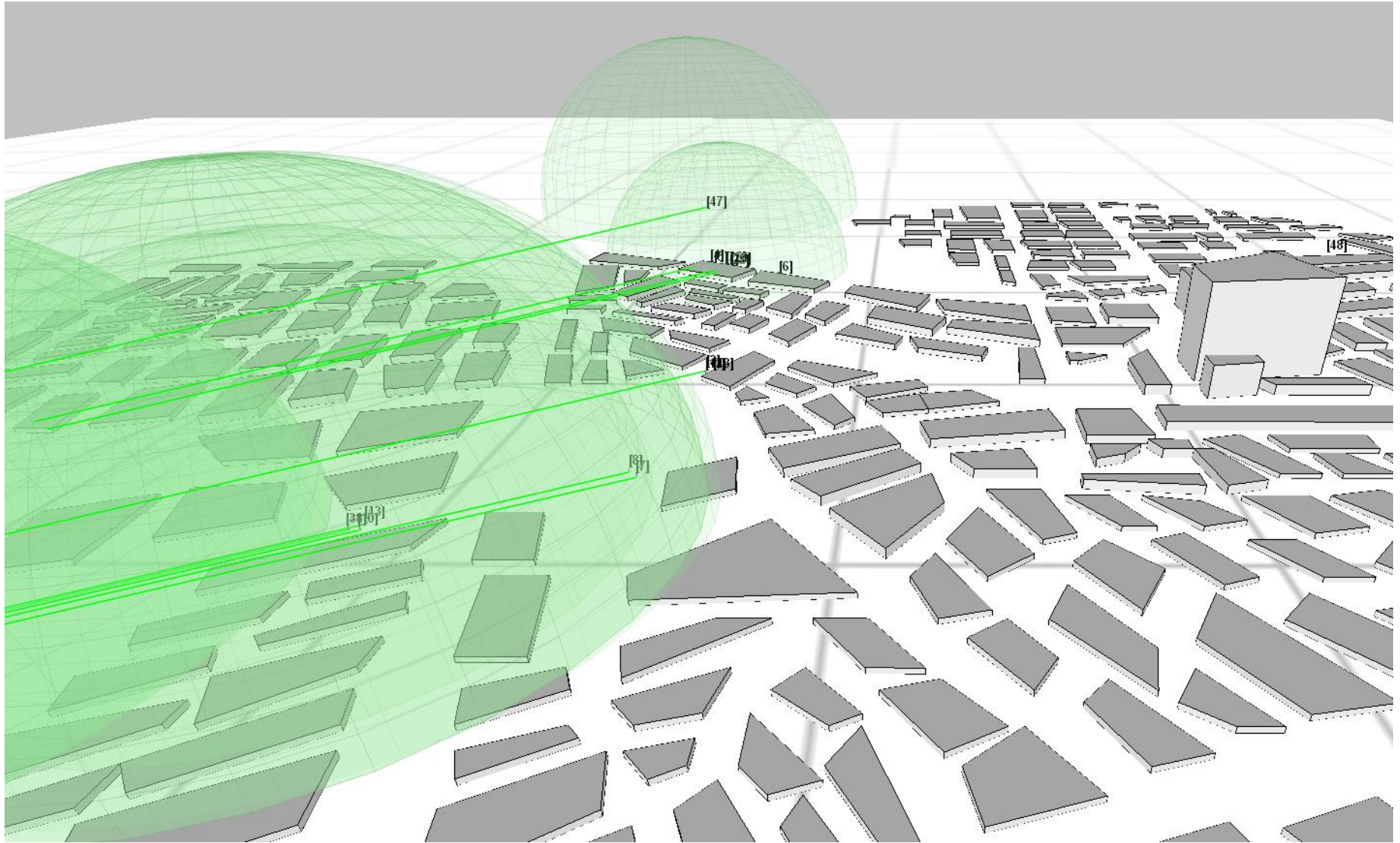


# Urban Environment





# 3D View in QualNet





# ***Scenario Refinement***

- **Added “lookout” agents to alert OPFOR of BLUFORCE movements (presumably some type of cell phone communication)**
- **Clarified BLUE communications hierarchy**
- **Added messages so that if a UAV passes info to a TOC, the TOC processes it, and can re-task agents using MANA’s Alt. Wypt.**

# ***Experiment Designs – Farming in Multiple Models Concurrently***

- **Used full factorial and NOLH designs**

## **MANA Data Farming Set 1 – 64 excursions**

- **Capacity**
- **Accuracy**
- **Message Processing Time**
- **Reliability**
- **Latency**
- **Comms Range**

<b>Parameter</b>	<b>Design Points</b>
Capacity	1,20
Accuracy	75,100
Latency	0,30,60
Reliability	30,100
Range	10,300

# Experiments – Farming Multiple Models Concurrently

## MANA Data Farming Set 1 – 64 excursions

- Capacity
- Accuracy
- Message Processing Time
- Reliability
- Latency
- Comms Range

## MANA – QualNet Data Farming Set 1 – 16 excursions

- *Capacity*
- Accuracy
- Message Processing Time
- *Reliability*
- *Latency*
- *Comms Range*

- Channel Size (kHz)
- Radio Power (dBm)

Parameter	Design Points
Channel Size (Bandwidth)	200,500
Accuracy	75,100
Power	30,40
Processing Time	10,300

# Analysis – MANA Excursions

High latency is the most important factor, and the blue force performs better?

It is more important to stop red force comms than enhance blue force comms

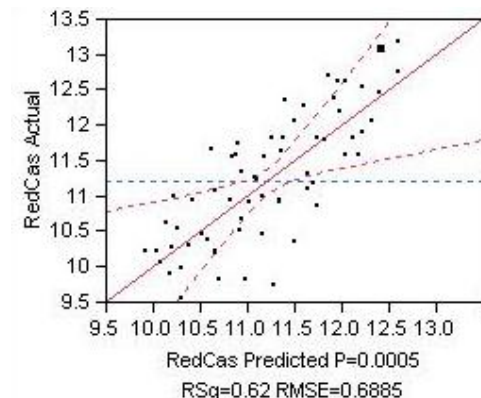
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Edge case with 93% red CAS shows successful FRAGO to blue agents

Edge case with 6% red CAS shows a blue vehicle getting stuck

Diagnosis: More farming

Experiments	$r^2$
MANA Set 1	.62
MANA Set 2	.61



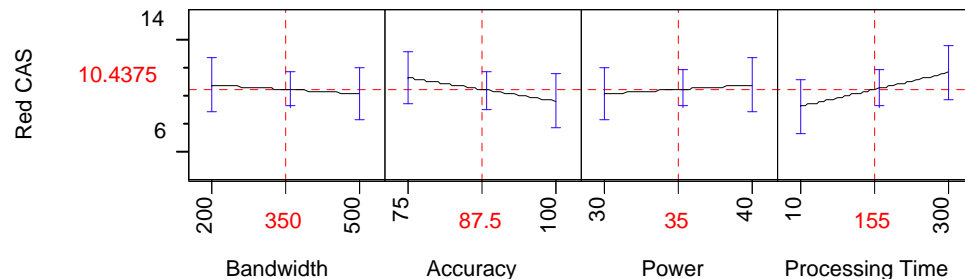
# Analysis – MANA – QualNet Excursions

*The difference between a 1W and 10W radio is minimal - Why?*

*Processing time is the most important factor - Why?*

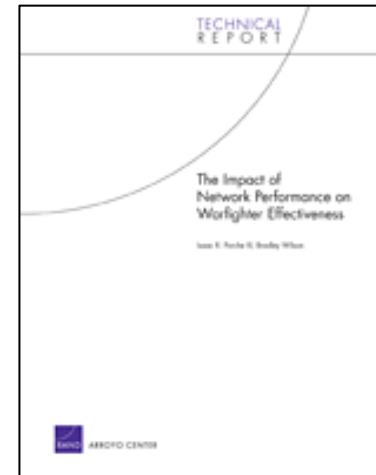
Comparison	Mean Red CAS	MCR	E-E Delay
MANA Only	11.21	30%-100%	1-30s
MANA-QualNet	10.43	12%	.3-350s

•  $r^2 = .73$



# References

- Pending ICCRTS, “Exploring Communications in an Urban Environment with Agent Based and High Resolution Simulations”, June 2009. (Wilson, Porche).
- MORS Journal, Volume 12 (2007) No 3.
- Porche, Isaac and Brad Wilson, “The Impact of Network Performance on Warfighter Effectiveness” , RAND TR-329-A, 2006.  
[http://www.rand.org/pubs/technical\\_reports/TR329/](http://www.rand.org/pubs/technical_reports/TR329/)
- Porche, Isaac, Brad Wilson, and Susan Witty, “*Integrating High Resolution Network Simulation with Force on Force Combat Models: Connecting MANA and QualNet*”, 10th International Command and Control Research and Technology Symposium, July 2005
- Porche, Isaac, and Brad Wilson, “*Measuring The Marginal Utility of Dynamic Network Management In An Urban Environment Using MANA*”, June 2005
- Porche, Isaac, Lewis Jamison and Tom Herbert, “Framework for Measuring the Impact of C4ISR Technologies and Concepts on Warfighter Effectiveness Using High Resolution Simulation”, ICCRTS 2004, <http://handle.dtic.mil/100.2/ADA466098>



# ***Backups***

# *Situational Awareness Messages are Generated in MANA by Battlefield Contacts*

- Types of messages
  - Friend, enemy, unknown, neutral
  - Organic
  - Inorganic
- QualNet determines when these messages are delivered

