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Modeling Chemical Environments and Effects on Mobile Forces Using an Agent-based Simulation

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Agenda

- Research questions
- Scenario review
- DOE
- Findings
- Future work

ABC NEWS

Gas Tanker Blast Kills Nine in Iraq

Bomb Rips Through Tanker Carrying Chlorine Gas, Killing Nine, Filling Hospital Beds in Iraq

Why relevant?

- Eight chlorine gas attacks since Jan '07
- 25 civilians killed
  - –550 civilians exposed
  - –6 soldiers exposed
- "Poor man's WMD"

A car bomb and a suicide attacker killed at least 11 people across Baghdad Tuesday, Feb. 20, 2007 as militants show increasing defiance to a major security operation.

By BRIAN MURPHY Associated Press Writer
BAGHDAD, Iraq Feb 21, 2007 (AP)

Research Questions

Primary Research Question: How does the level of chemical SA impact combat effectiveness of a Future Force Warrior (FFW) platoon?

Supporting Questions:

- How to model chemical agents?
- How to model chemical detection, protection, and effects on soldiers?
- How to represent chemical SA?
- Is Pythagoras a viable tool in modeling a chemical environment?

Model Assumptions & Constraints

- Assumptions
  - Mask provides 100% protection from chemical
  - Chemical SA affected by detector distribution and intelligence estimates
- Constraints
  - The only protective gear modeled is mask
  - No civilians modeled
  - Enemy not affected by chemical

Battlespace

*not to scale

Measures of Performance

- Detection
  - Self-detection after 2 min exposure[1]
  - Mechanical JCAD detection varied from 2 – 14 sec exposure[2]
- Protection
  - State change sets vulnerability to zero (100% protection)
  - Easily varied for future studies using this model
- Performance effects
  - Donning mask degrades speed 20%, marksmanship 20%, and field of view 40%[3]

[1] Medical Aspects of Chemical and Biological Warfare

[2] JCAD Operational Requirements Document

[3] Military Psychology, 9(4) & CANE Study

Measures of Effectiveness

- Percent blue kinetic (hostile fire) casualties
- Percent soldiers lethally dosed
- Percent soldiers incapacitated

Design of Experiment

Traditional Approach:

- Limit number of factors or scenario alternatives
- “Fix” all other factors in the simulation to specified values
  - Isolate factors
- Limit number of replications for each design point
  - “2^{100} is forever”, Gen J. Welch

Emergent Analysis:

- Examine multiple factors simultaneously
  - Identify significant factors and *interactions*
- Technique: NOLH design
  - Use relatively few design points with space filling properties
  - Achieve (nearly) orthogonal design points
- Apply *distillation simulations*
  - Low resolution, agent-based

Kleijnen, Sanchez, Lucas & Cioppa 2005

Robust Quick Turn Analysis

Factors

8 design factors

Factor	Settings	Description
Blue Speed	1.2 – 4.15	Ground speed of blue forces (km/hr)
Obedience in Mask	0.2 - 0.9	Probability of soldiers to follow orders after masking
Number UAVs	0 - 2	Number of UAVs available
Number of UGVs	0 - 4	Number of armed unmanned ground vehicles available
JCAD sensitivity	2 - 14	Time until JCAD detects (sec)
Mask marksmanship	0.4 - 0.8	Marksmanship of blue forces after they mask
Internal communications	0.5 - 1.0	Internal communications effectiveness
External communications	0.5 - 1.0	External communications effectiveness

Experiment

- Applied 8 factors to Nearly Orthogonal Latin Hypercube – 65 design points
- Crossed 65 design points with 2 categorical factors each at 2 levels:
  - Chemical intelligence estimate (none or near perfect)
  - Distribution of JCAD (UGV with JCAD or without JCAD)
- 65 design points x 4 scenarios = 260 total design points.
- 260 design points x 30 replications each = 7,800 computational runs

60 hours total run time

Full factorial = 5.3 years!

Data Analysis

Methodology

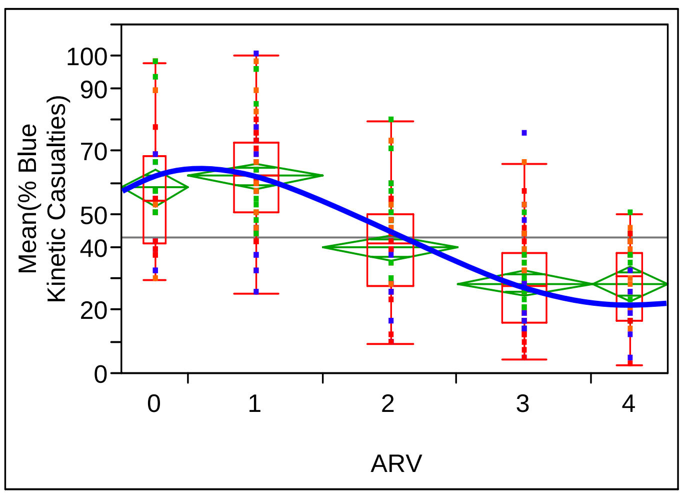
- Step-wise regression against means by MOE
  - Identify interactions & higher order effects
- ANOVA on dominating factors
- Regression tree
  - Identifies the factor that explains most variation in MOE
  - Useful finding most ‘important’ factors

MOE: Percent Blue Kinetic Casualties

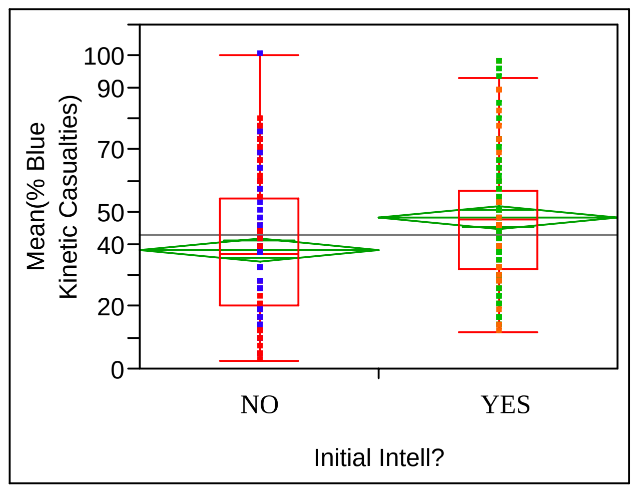
Kinetic casualties decrease when number of ARV increase

Masking sooner increases kinetic casualties

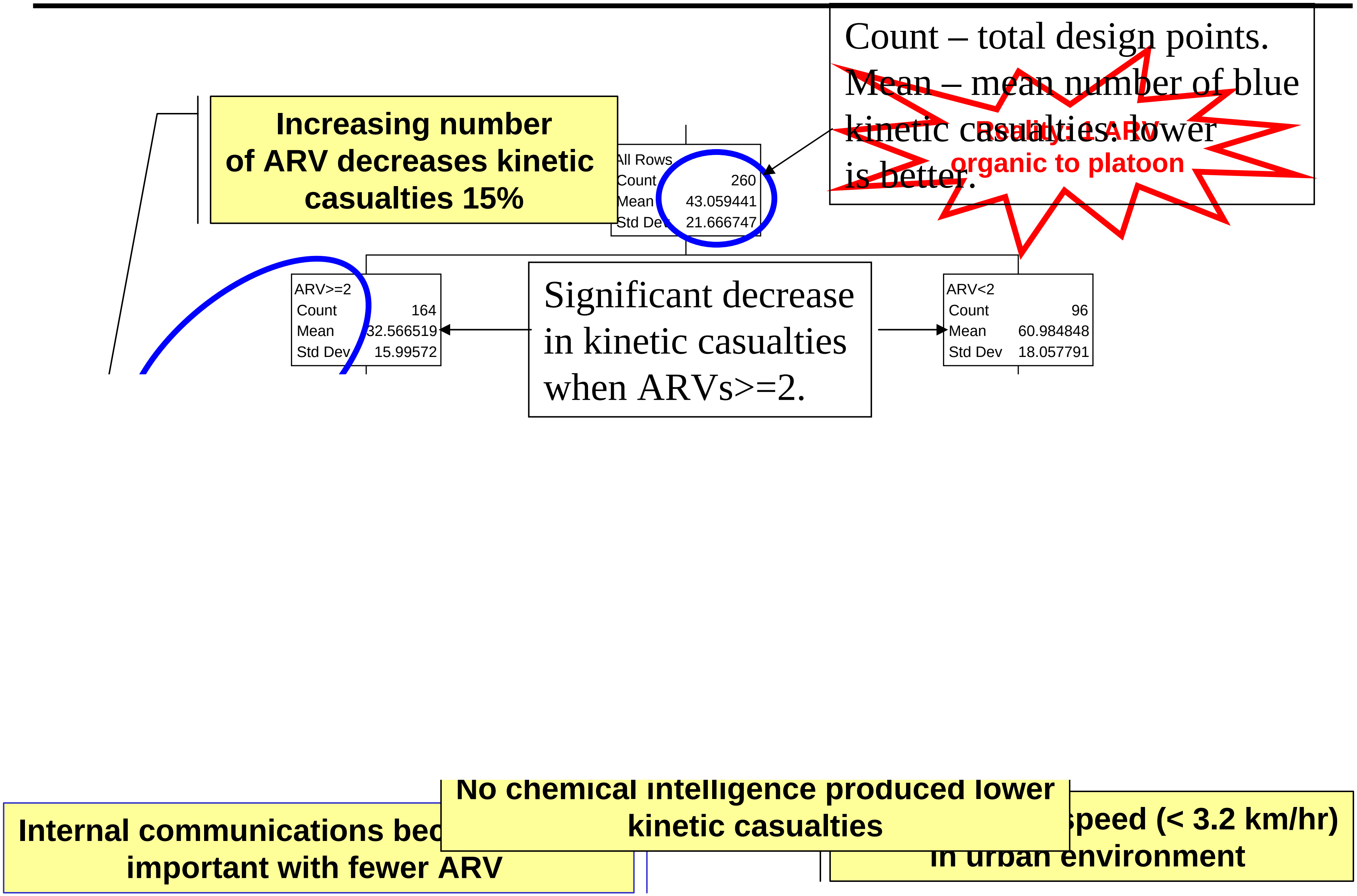
By Number of ARV



By Level of Chemical Intelligence



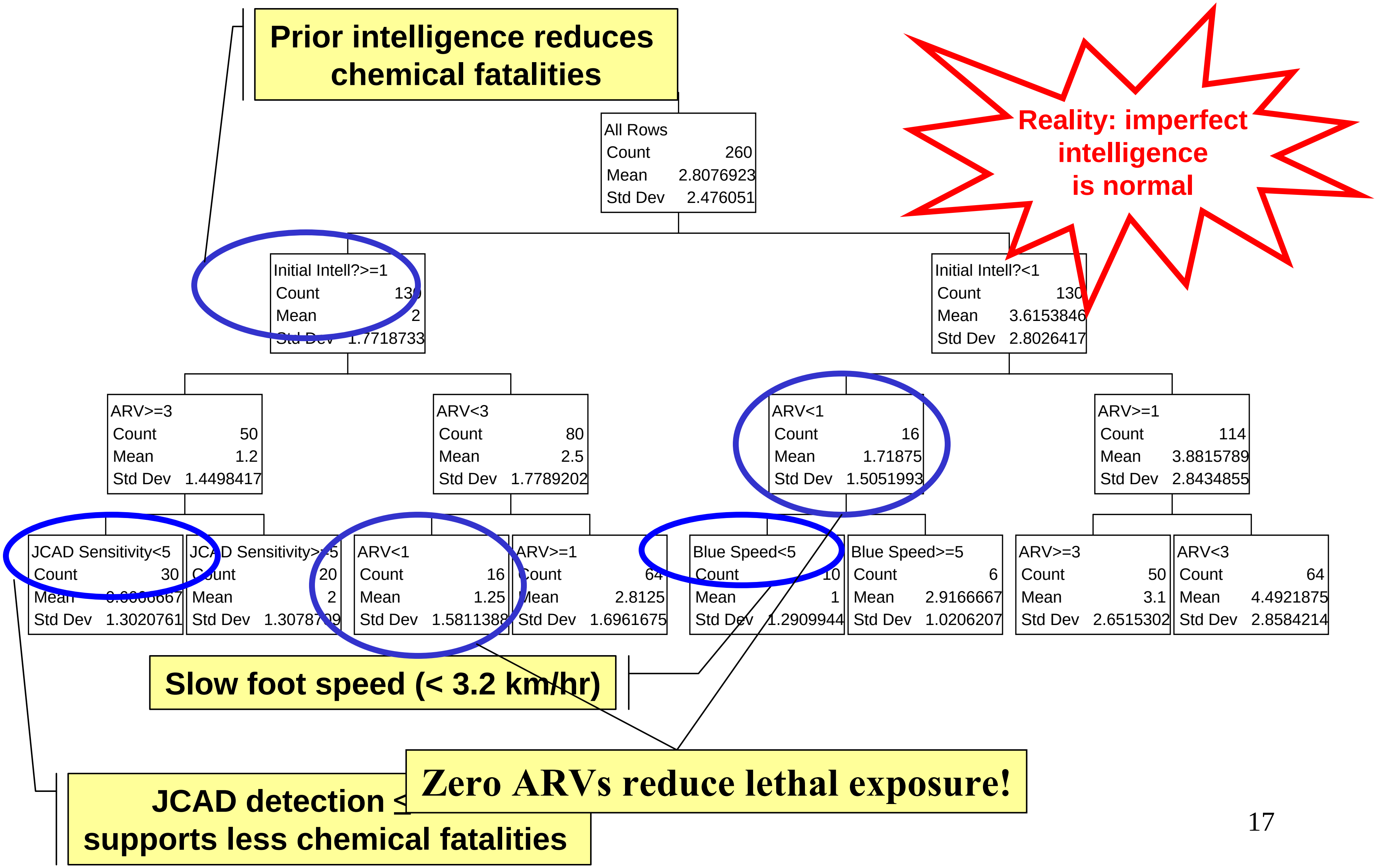
MOE: Percent Blue Kinetic Casualties



Findings (1 of 3)

- Finding: Prior intelligence of chemical threat reduced chemical casualties but not overall casualties.
- Interpretation: Degraded functionality while masked contributed to increased kinetic casualties. *Methodology of applying simple behaviors to agents produced complex results*.
- Recommendation: Consider greater risk against non-persistent agent.

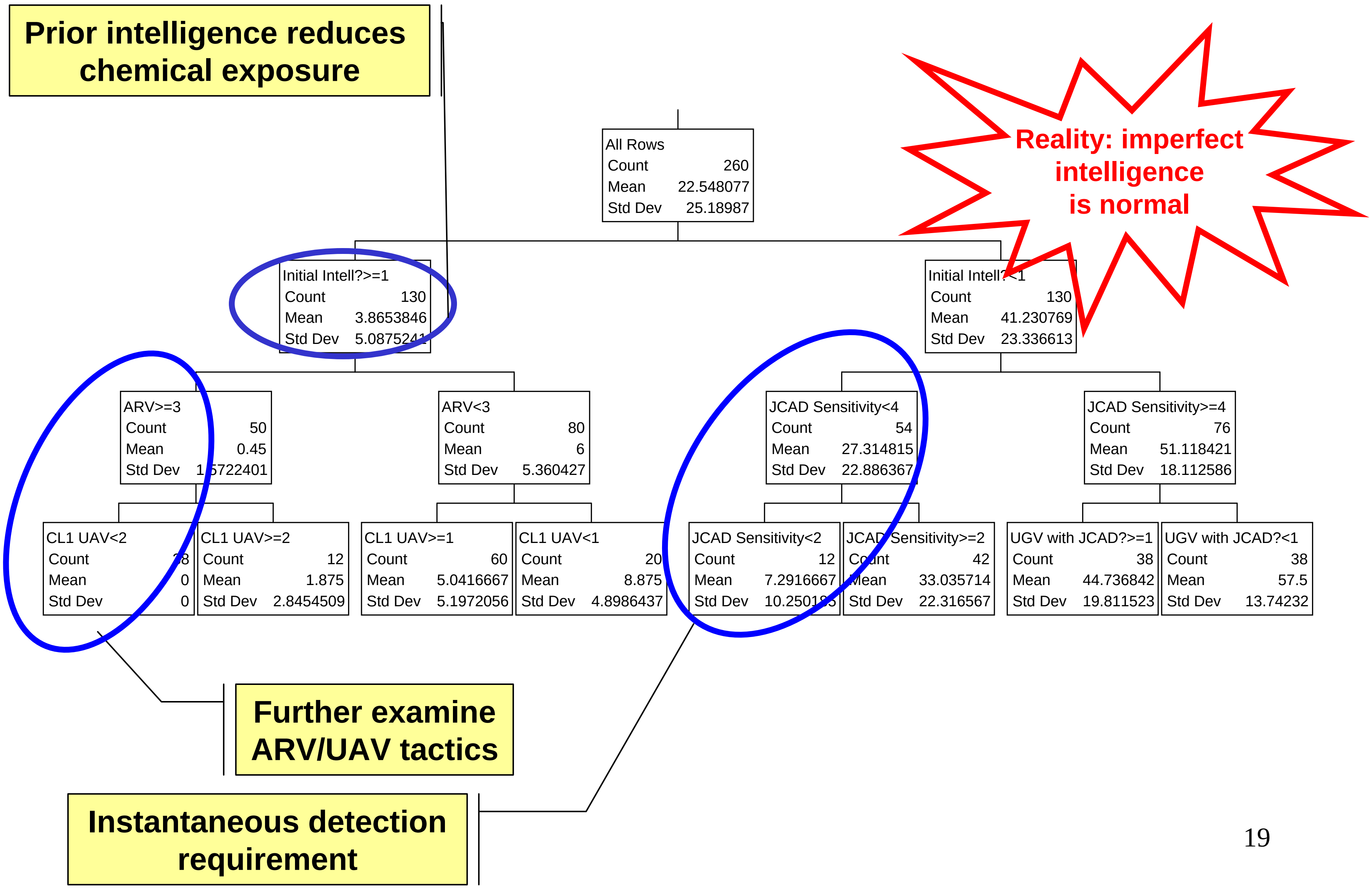
MOE: Percent Soldiers Lethally Dosed



Findings (2 of 3)

- Finding: No ARVs in scenario resulted in lower chemical casualties (not intuitive).
- Interpretation: Unclear…but places to start include model artifacts, tactics, employment. *Methodology supports quick 'what if' analysis.*
- Recommendation: Explore the 'what if' questions.

MOE: Percent Soldiers Incapacitated



Findings (3 of 3)

- Finding: While quicker JCAD detections uniformly reduced chemical casualties, detection threshholds between 6-8 seconds showed appreciably reduced casualties.

- Interpretation: What is impact of achieving instantaneous JCAD requirement? Are alternate threshholds reasonable requirements? *Methodology enables rapid 'what if' analysis and examination of factors at multiple levels.*

- Recommendation: Conduct further research on JCAD sensitivity.

Conclusions

- Pythagoras provides a framework that is easily adapted to modeling efforts and low resolution effects in the CBRN realm
- DOE research at NPS provides ground-breaking methods to experimental design
- Recommend future work:
  - Review employment tactics of ARVs and UGVs
  - Introduce civilians to the battlefield
  - Examine physiological/psychological effects of extended operations in MOPP
  - Introduce false alarms into current model

Questions