



Modeling Potentially Hostile Crowds to Explore Effects of IFCs and ROEs

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The Crowd Dynamics Modeling Group,
<https://nps.edu/web/crowdmodeling>

IFCs and Crowds



- Effectiveness of IFCs in support of the mission varies with crowd behavior
- Responses of crowds to the use of IFCs is complex and difficult to predict
- Aspects of identity and group membership influence crowd response, often unexpectedly
- Existing IFC effects models generally focus on effects of IFCs on individuals
- Crowd modeling research usually focuses on individuals or assumes the crowd behaves as a unified mob

The Social in Crowds



In Reality:

- Crowds composed of sub-groups or smaller social identity groups (SIGs)
- Individuals remain individuals in crowds but are influenced by others in their group as well as others nearby
- SIGs, can emerge in the crowd anew
- Group members stay together, live/die together in the crowd unless very compelling reasons arise to leave the group
- People's actions affected by SIG and attitude toward forces
- IFCs affect not just the individual directly impacted, but also those who witness the impact
- Individual assessment of IFC impact depends on who is hit and their perceptions of that individual

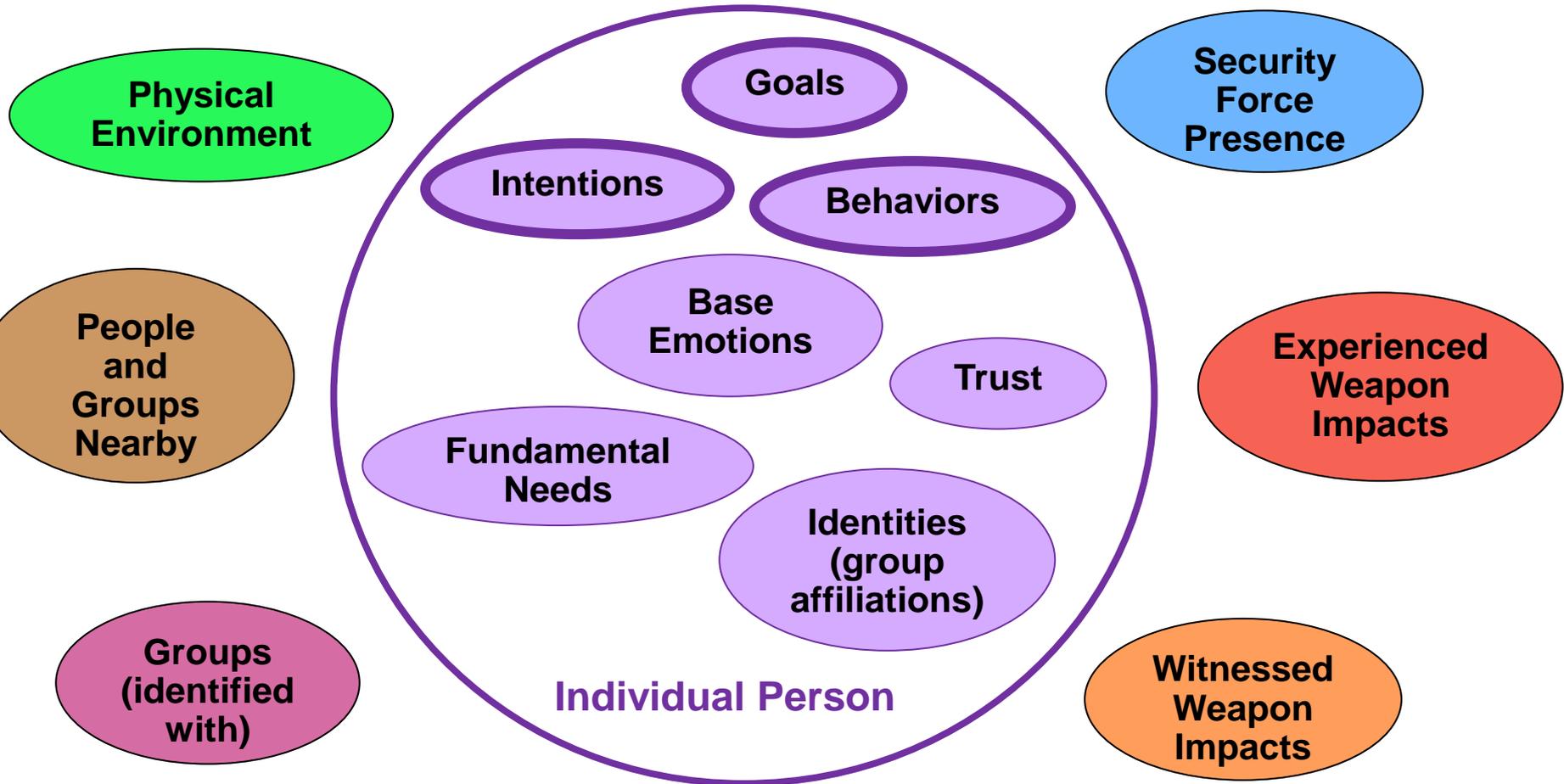
Social Dynamics in Crowds



To understand and model crowds, need to:

- Use a multi-agent model; including both individual & SIG behavior
- Break down by different types participants – gender, age
Need to model SIGs as dynamic agents
- Include effects of SIG on member individual as well as social effects of nearby individuals and groups
- Include intentional and unintentional weapons effects
- Track attitudes/beliefs toward authority & security forces
- Represent a variety of beliefs and objectives of individuals within crowd that change dynamically

Factors Influencing Human Behavior



Agent-Based Simulation Modeling



- ‘Bottom-up’ modeling method:
 - decision-makers are individual agents
 - agents act independently of each other
 - agents are influenced by interactions with other agents
- Crowd behavior emerges as a result of individual agent actions and interactions
- Can include random, stochastic elements to more accurately simulate reality
- Best simulation method for modeling human behavior



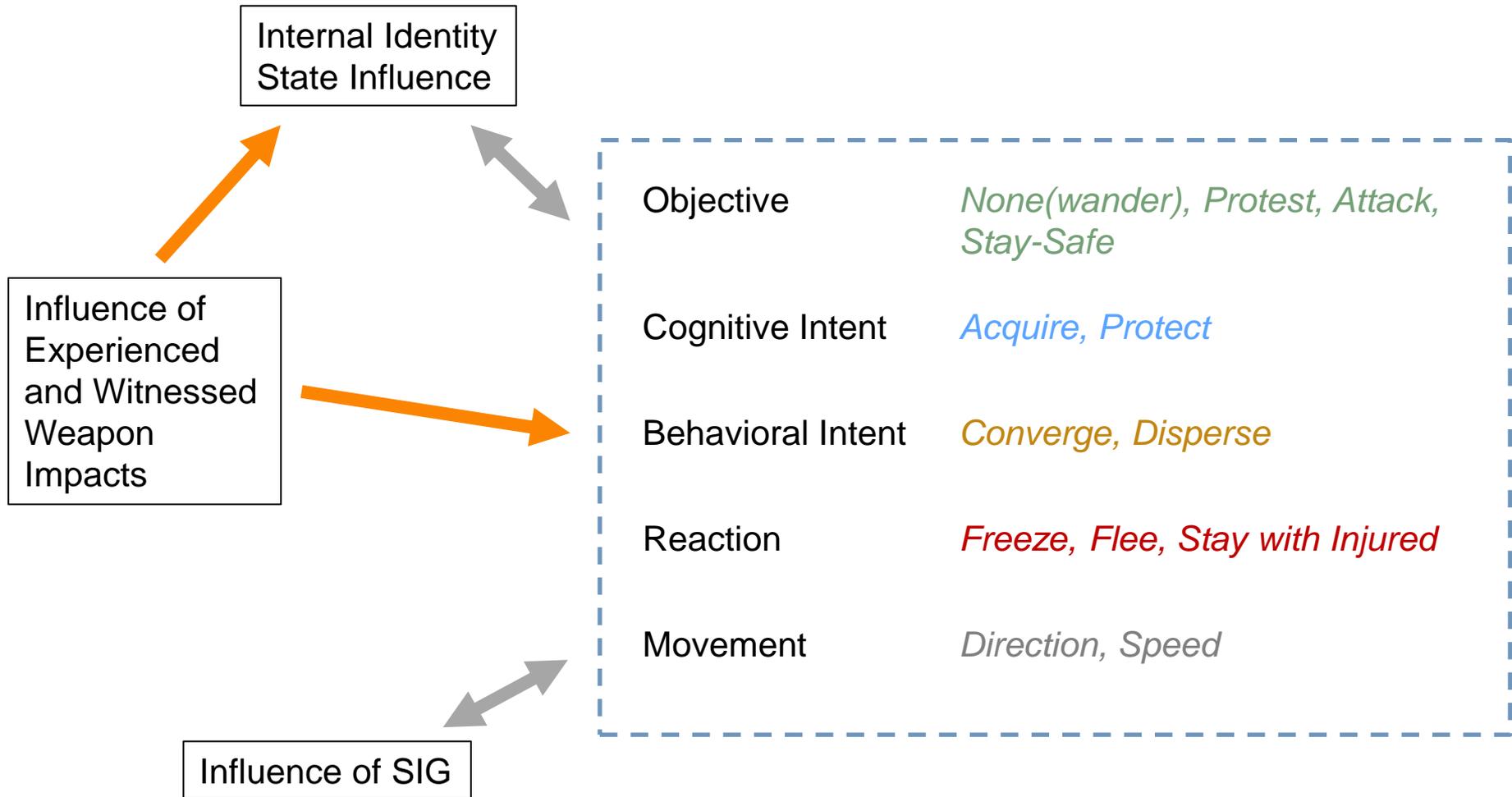
Workbench for refining Rules of Engagement against Crowd Hostiles:

- Is the agent-based simulation model we have developed and coded in NetLogo (a top agent-based modeling platform);
- Explicitly models:
 - individual people, social identity groups, and security force members as independent agents,
 - who interact in a physical environment designed using GIS data,
 - where security forces can use intermediate force capabilities according to specified rules of engagement in response to hostile crowds.



- Incorporates multiple aspects of PMESII-PT
(Political, Military, Economic, Social, Information, Infrastructure, Physical environment, and Time)
- WRENCH explicitly models:
 - Military force structure, activities, ROEs and use of IFCs
 - Social needs and desires of individuals, dynamic SIG membership, emotional contagion, etc.
 - Information communicated among SIG members and within Security Force structure
 - Physical environment designed using GIS data, person and vehicle movement influenced by other people and buildings/roads, consideration of line-of-sight, etc.
 - Time with one second time-steps, communication and decision delays, movement happening over time, etc.

Individual Cognition and Behavior



Individual People



Objective:

None (wander)

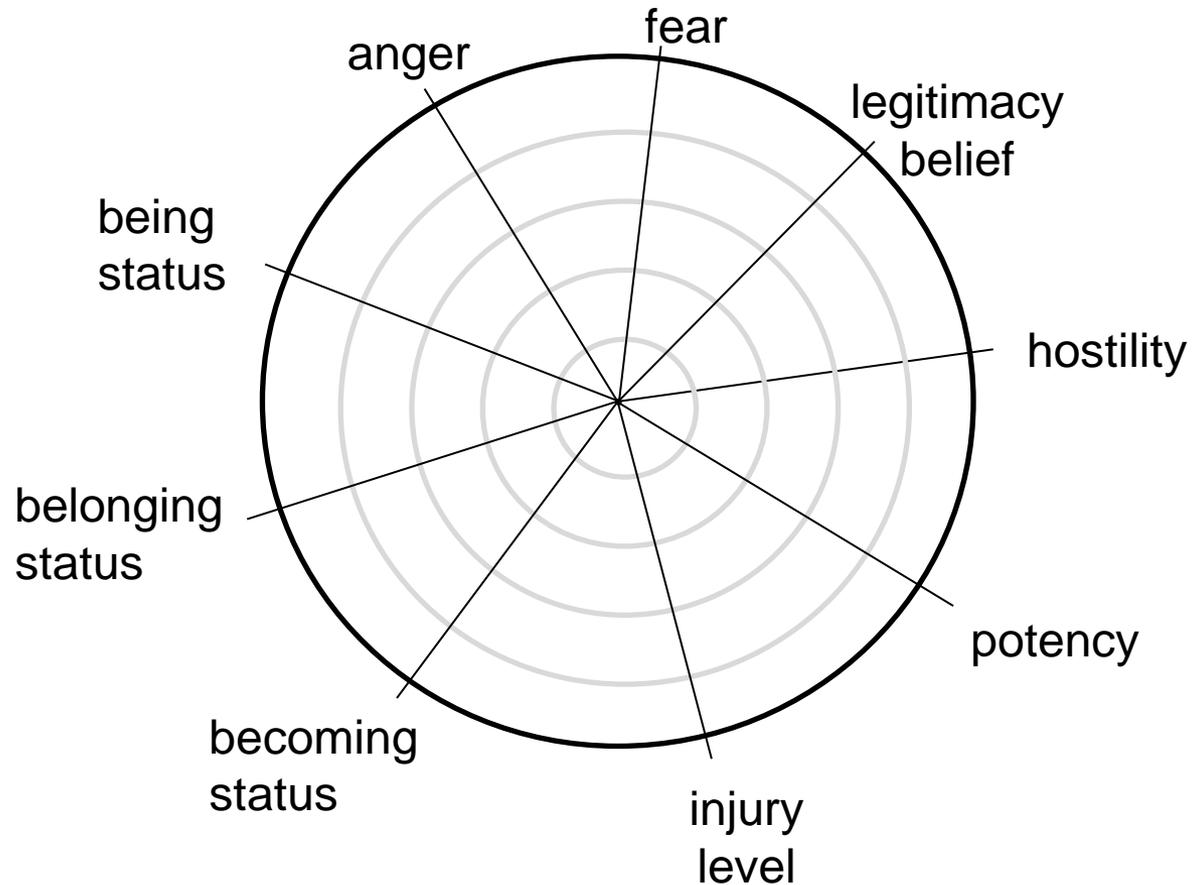
Protest

Attack

Stay safe

Intentional State

Behavioral State



Individuals and SIGs



Individual (person with level 0 identity):
man, woman, or mother with kid(s)



Family SIGs (level 1):

Nuclear Family: man and mother with kid(s)



Mid Family: mother with kid(s) and 1-4
other Mid or young adults



(Inter)generational Family: mother with
kid(s) and 5-9 other adults of any age

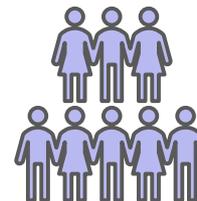


Social SIGs (level 1):

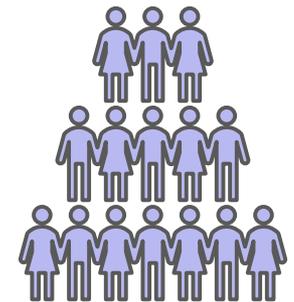
Small: 2-5 Adults of any age



Medium: 6-10
Adults of any age

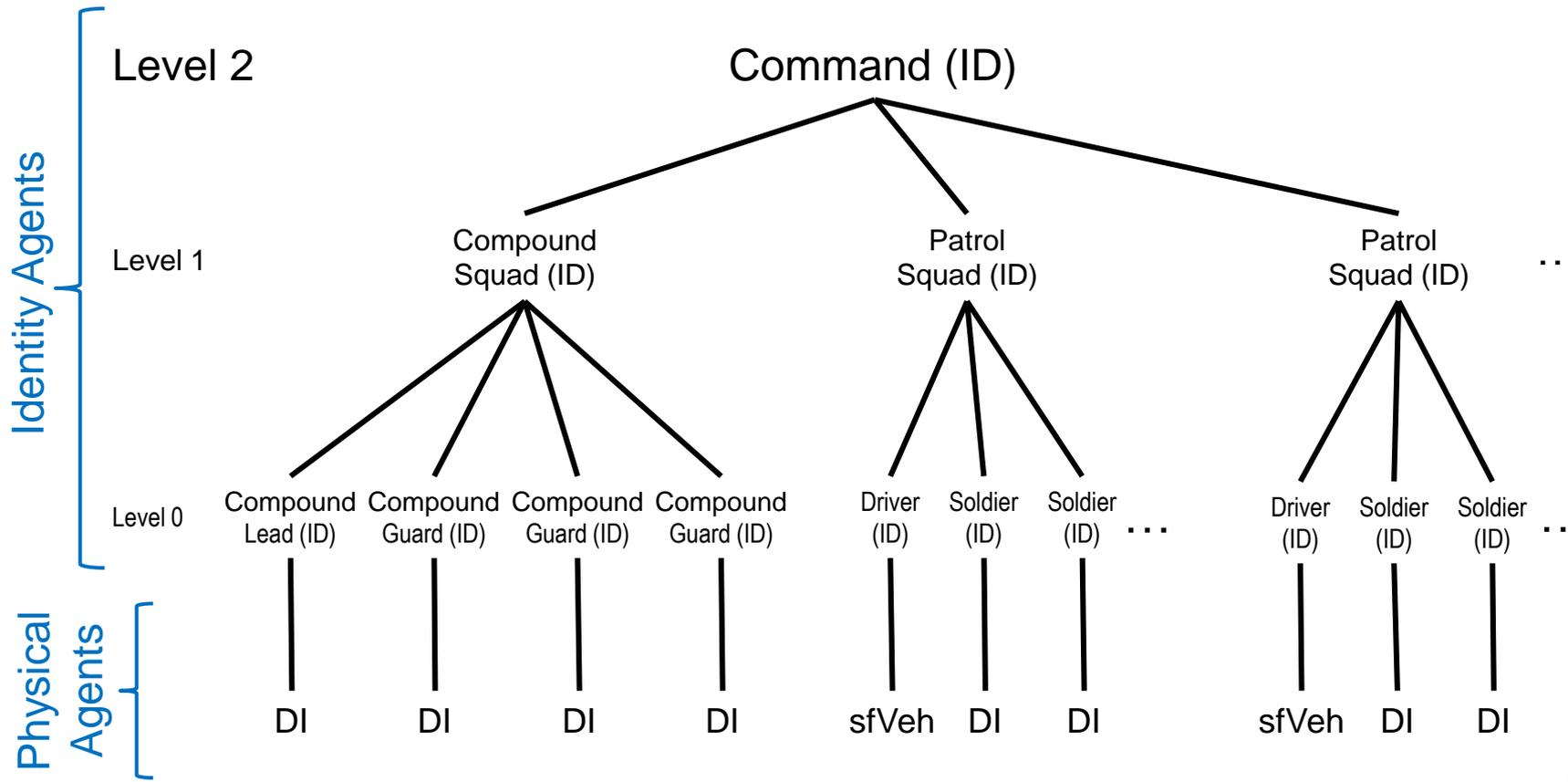


Large: 11-20
Adults of any age



Social SIGs may form based on age, gender, or ideology

Security Force



Key	ID:	Identity
	DI:	Dismounted Infantryman
	sfVeh:	Patrol Vehicle

Security Force



Compound Squad



Patrol Squads





SF engagement decision-making:

- Discerning Hostile Intentions -> Threat Assessment
- Deciding which threat to address -> Target selection
- Deciding method of engagement -> Weapon selection

Tactical ROEs specify target selection and weapon selection rules

WRENCH User Interfaces



WRENCH has three user interfaces:

- Main interface:
 - animation screen
 - sliders, menus and switches to control aspects of:
 - security forces configuration and operating characteristics,
 - population demographics and attitudes, and
 - social identity group composition
- IFC selection interface allowing choice of which IFCs forces have, also provides information on each IFC
- Tactical ROE selection interface allowing design of custom ROEs

WRENCH Main Interface

Gate guards initiating defense during run



WRENCH 5.0
Work.bench for refining Rules of Engagement against Crowd Hostiles

Simulation Time: 2022-04-11 14:48:11 | Elapsed Sim Min: 1.6 | tick: 96 | Mouse_Query? Off | Map Coords (deg/meters): N/A

Population: 154 | Stunned/Down: 18 | Deceased: 1 | Avg Injury Level: 0.649350649350649 | Total Base Intruders: 1 | TimeOfFirstInvader: 71

Adults: 147 | Fleeing: 66 | Attack Obj.: 0 | Protest Obj.: 135 | Stay Safe Obj.: 12 | None (no) Obj.: 0

Population Composition: Bar chart showing counts for various demographic groups (Females, Males, MidAdults, SeniorAdults, Babies, Children, Doms, SubDom1s, SubDom2s, SubDom3s, Subjugates, Conservatives, Neutrals, Progressives, YoungAdults).

Total Applied Coercive Force: Stacked bar chart showing force levels for different groups (wgn, men, seniors, adults, yng-adlt, kids, babies, doms, subdm1, subdm2, subdm3, consery, neutr, prog15).

Mean Anger of People-related-Identities: Line graph showing Mean Anger vs Elapsed Time (min).

Mean Fear of People-related-Identities: Line graph showing Mean Fear vs Elapsed Time (min).

Mean hostility of People-related Identities: Line graph showing Mean Hostility vs Elapsed Time (min).

Mean SF Legitimacy Belief of People-related-Identities: Line graph showing Mean SF Legitimacy vs Elapsed Time (min).

Command Center: observer

Experimentation with WRENCH



- WRENCH can also be run in a ‘headless’ mode to facilitate experimentation using data farming methods
- Efficient experimental designs test many input and software parameters, over many levels, to produce a wealth of data
- Some key output metrics for WRENCH include:

*operational
implications?*

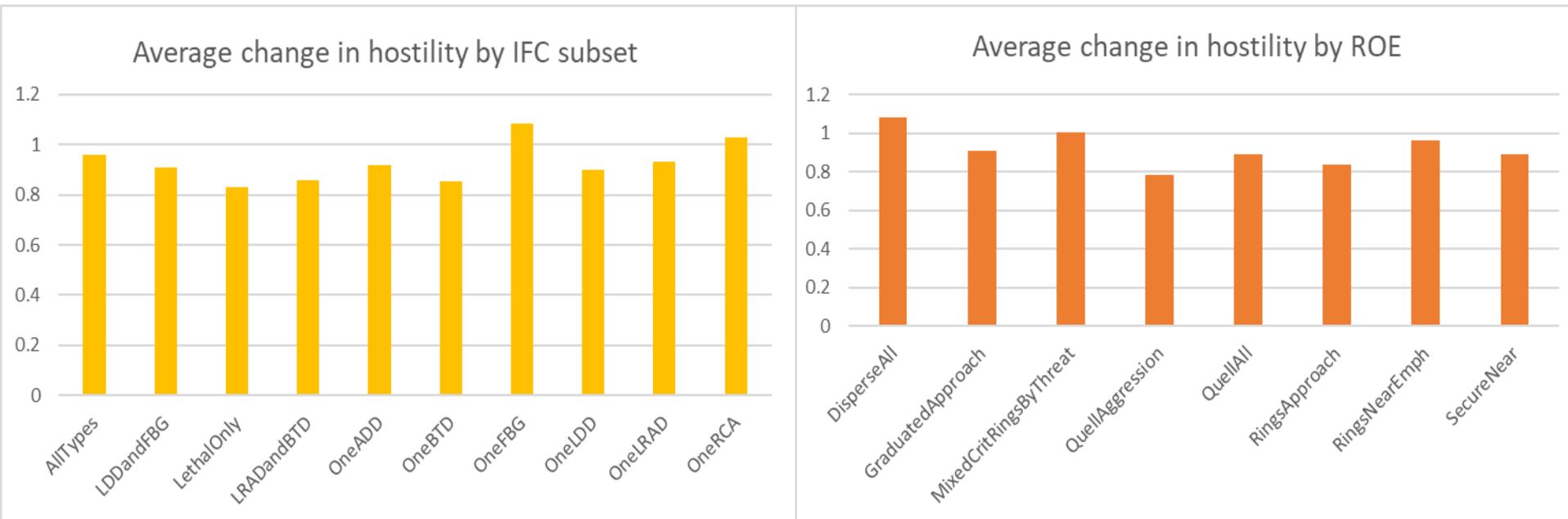
- frequency of security force use of IFCs
- severity levels of IFCs used
- People’s current hostility
- People’s objectives
- People’s anger levels
- People’s fear levels
- Change in people’s beliefs about the legitimacy of the security forces

*strategic
implications?*

Select Experiment 6 Results: change in hostility



- Average change in people's hostility depending on subset of IFCs used
- Average change in people's hostility depending on ROE used

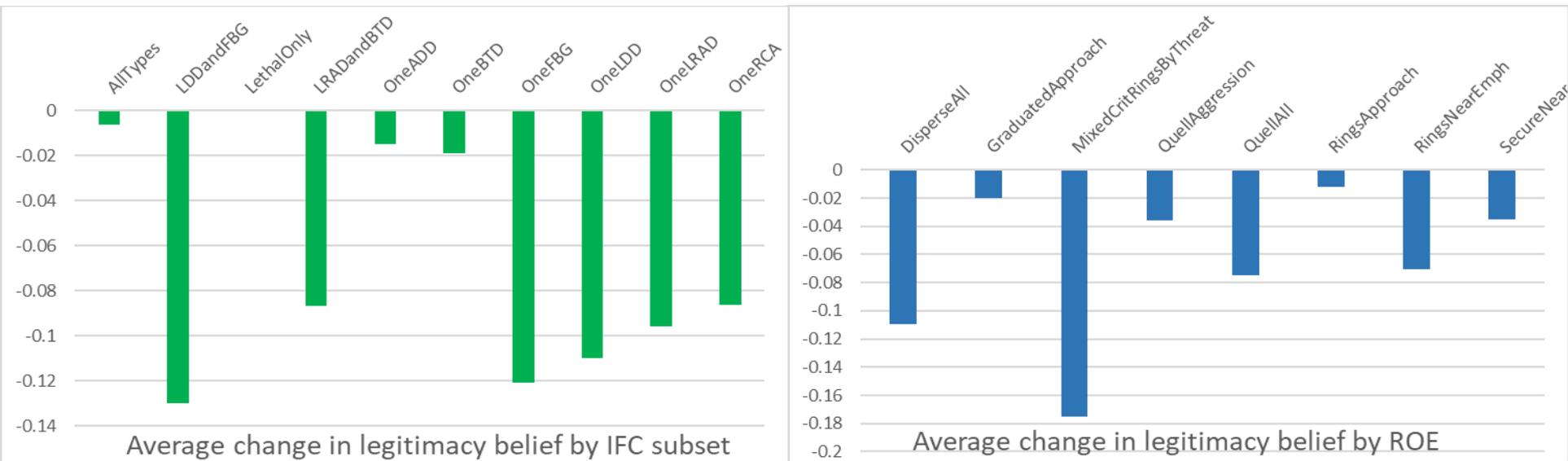


Time-series data shows larger hostility changes (rise then fall)

Select Experiment 6 Results: change in legitimacy beliefs



- Average change in people's legitimacy beliefs depending on subset of IFCs used
- Average change in people's legitimacy beliefs depending on ROE used



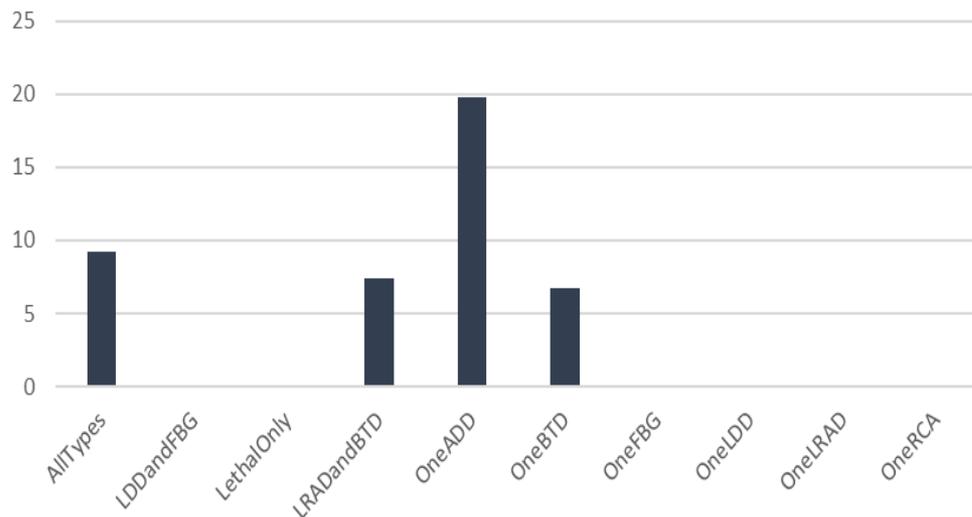
Legitimacy beliefs didn't decrease in all cases, just when averaged

Select Experiment 6 Results: number of unintended deaths

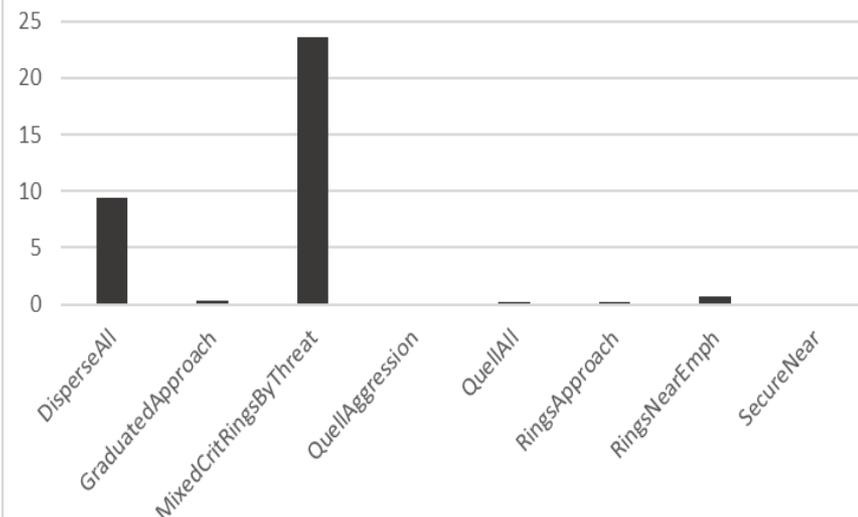


- Average number of deaths due to accumulated injury depending on subset of IFCs used
- Average number of deaths due to accumulated injury depending on ROE used

Mean Deaths From Accumulated Injury by IFC subset



Mean Deaths From Accumulated Injury by ROE

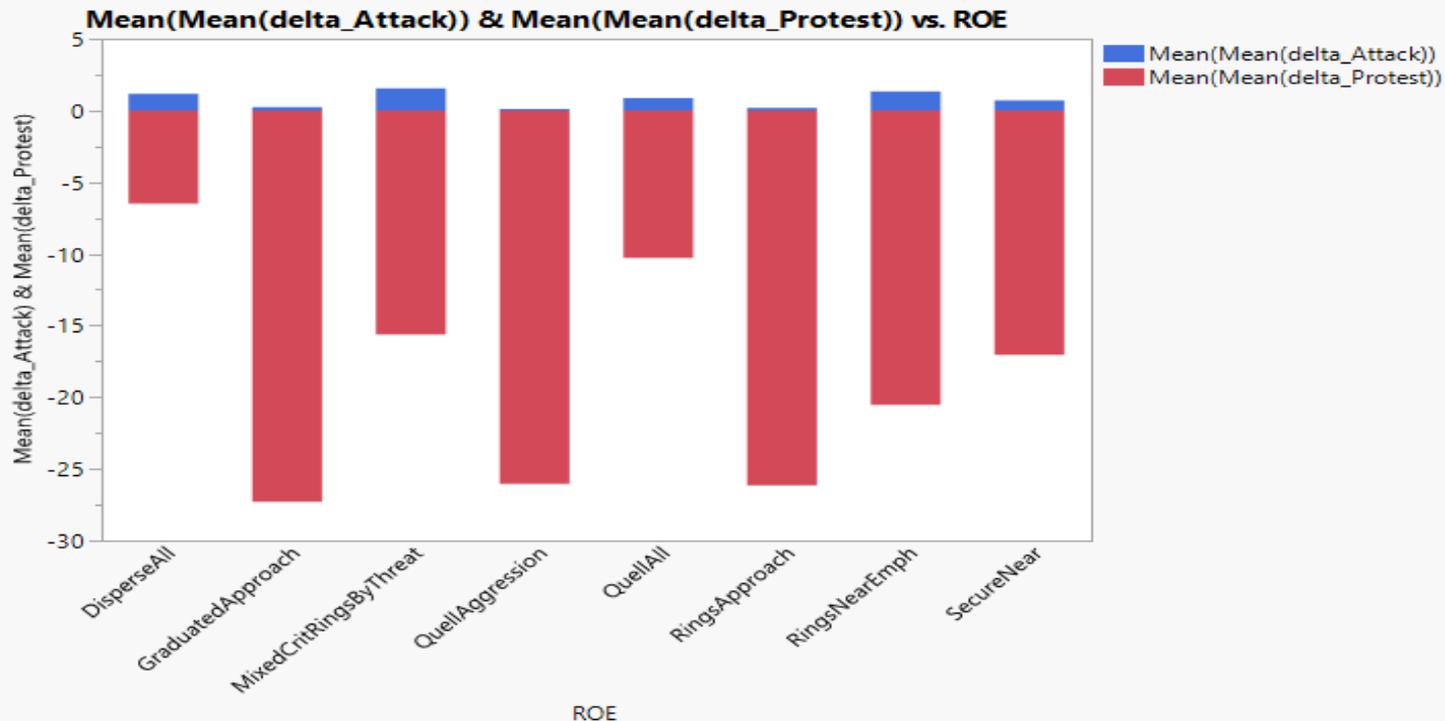


In WRENCH code only the more severe IFCs can cause an accumulated death (i.e. tip a Person from injured to dead)

Select Experiment 6 Results: change in objectives



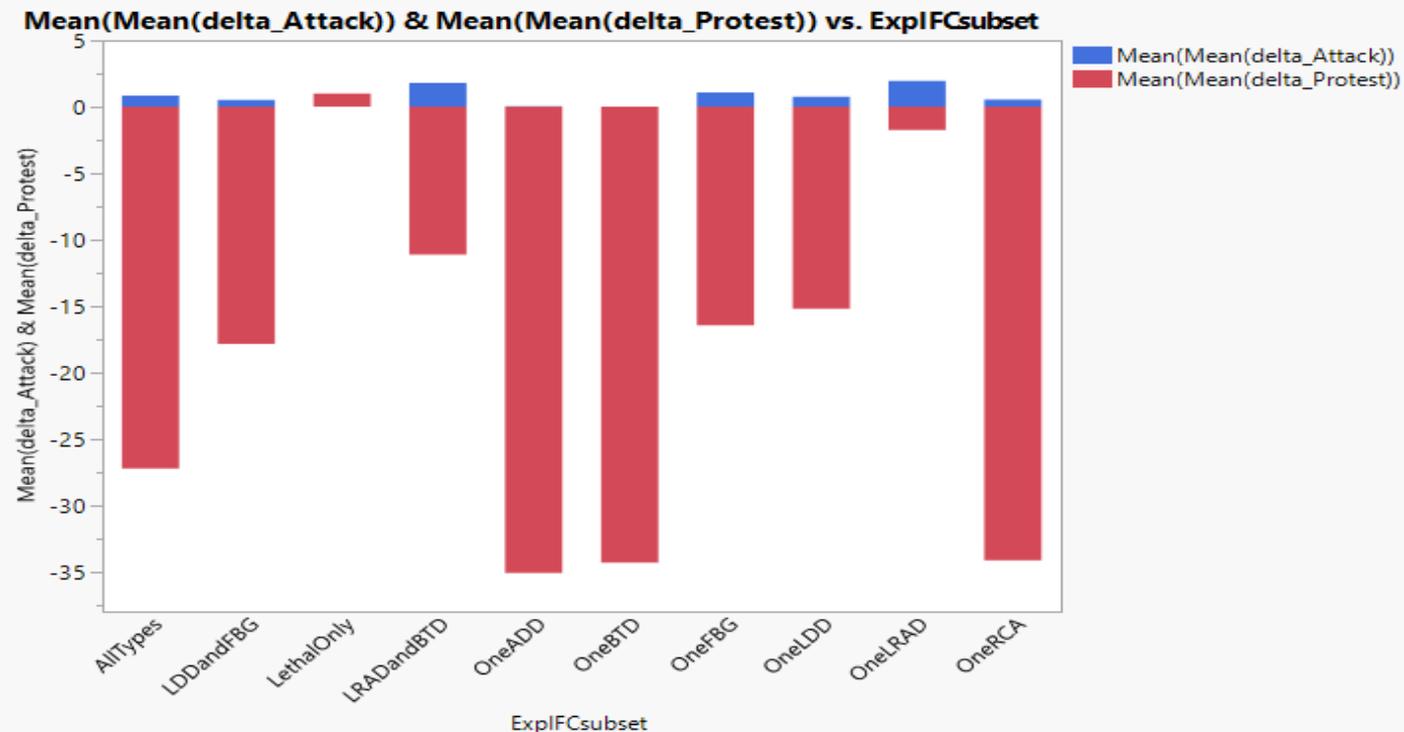
- Average change in the number of people with an Attack objective (blue) depending on ROE used
- Average change in the number of people with a Protest objective (red) depending on ROE used



Select Experiment 6 Results: change in objectives



- Average change in the number of people with an Attack objective (blue) depending on subset of IFCs used
- Average change in the number of people with a Protest objective (red) depending on subset of IFCs used



Future Plans



- Continue researching, testing, and experimentation to improve validity
- Ongoing research into IFC and ROE effects
- Enhance various aspects of model
 - force member psychological drivers, identity dynamics and will to fight
 - enhance needs modeling of people and resource acquisition behaviors
 - incorporate latest social research on crowd adaptation, e.g. post-traumatic growth
- Inform combat models such as COMBATXXI (NRP proposal)
- Assist other research organizations per sponsor's request
- Acquire new sponsors to explore additional use cases

Interdisciplinary Research Team



Dr. Susan K. Aros, DDM (co-lead)

Operations research, agent-based simulation, psychology

Dr. Anne Marie Baylouny, NSA (co-lead)

Social movement theory, crowd dynamics

Dr. Anshu Chatterjee, NSA

Social movements, case studies

Mr. Terry Norbraten, MOVES

Simulation, computer science

Dr. Deborah Gibbons, DDM

Psychology, cross-cultural social influences

Dr. Susan Sanchez, SEED Center

Statistics, design of experiments (Co-Director of NPS SEED Center)

Mr. Chris Ketpongkard, NSA

Research associate, weapons effects research

Mr. Steve Upton, SEED Center

Simulation, data farming

Ms. Mary McDonald, SEED Center

Data farming, data analysis

Dr. Matt Zefferman, DA

human culture, cooperation, and conflict, math modeling

Questions?



WRENCH Main Interface



WRENCH_5.0 - NetLogo (C:\0 new since Sept 2020\Research Projects\2022-2023 JIFCO\NetLogo 22-23\WRENCH 5.0)

File Edit Tools Zoom Tabs Help

Interface IFC Selection and Display ROE Selection and Display Info Code

Edit Delete Add *abc Button normal speed view updates on ticks Settings...

ScenarioFocus: Kansas ScenarioDate: Now Setup

Start/Pause Stop/Reset

Other GUIs

Choose IFCs Edit SF's ROEs

Restore All GUI Defaults

display-SIGLinks: 1

display-Colleagues: 0

display-objective?: On

display-fear?: On

display-hostility?: On

display-cogIntents?: On

EnlargePeople ShrinkPeople

Toggle Siege Attractant

Toggle Gate Attractants

PeopleDensity?: On

Crowd Density: 0 Density Mean: 0

Level_Of_Zoom: 3 Redraw

WRENCH 5.0

Work-bench for refining Rules of Engagement against Crowd Hostiles

Simulation Time: 2022-04-11 14:46: Elapsed Sim Min: 0 tick: 0

Mouse_Query?: On Map Coords (deg/meters): N/A

Population: 154

Stunned/Down: 0

Deceased: 0

Avg Injury Level: 0

Total Base Intruders: 0

TimeOffFirstInvader: 1000000

Adults: 147

Fleeing: 0

Attack Obj.: 0

Protest Obj.: 147

Stay Safe Obj.: 0

None (no) Obj.: 0

Trigger Invader

Population Composition

Total Applied Coercive Force

Mean Anger of People-related-Identities

Mean Fear of People-related-Identities

Mean hostility of People-related Identities

Mean SF Legitimacy Belief of People

Deploy More People And Security Forces

Deploy Agents: Deploy Agents button can be used multiple times before and during a run to create force and/or population agents. Variable settings in this GUI area only apply to the agents being newly created when Deploy Agent button is clicked. If only people are desired set Force-Size to 0. If only force squads are desired set PopDensity to 0. Security force compound squad (gate guards) is only created once per run.

Security Force: Force-Deployment: Primary Roads Force-Size: 3 VehicleOccupants: 4

Dynamically Changeable Variables

Dynamically Changeable Population Characteristics: People_Attitude_Toward_Forces: Cautious Required_Personal_Space: 1.0 (M) People_Tend_Toward_Others?: On

Dynamically Changeable Security Force Characteristics: Force_Stance_Toward_People: Cautious Firing_Rate: 20 / minute Level_Of_Crowd_Sensing_Tech: None

The Trigger Invader button can be used to artificially prompt the security force to go into defense mode.

Command Center: observer

Interface During Run: People gathering to protest



WRENCH 5.0
Workbench for refining Rules of Engagement against Crowd Hostiles

Simulation Time: 2022-04-11 14:47:01
Elapsed Sim Min: 1.02
tick: 61

Population: 154
Stunned/Down: 0
Deceased: 0
Avg Injury Level: 0
Total Base Intruders: 0
TimeOfFirstInvader: 1000000

Population Composition

Category	Count
Females	99
Males	55
MidAdults	0
Senior Adults	0
Babies	0
Children	0
Doms	0
SubDom1s	0
SubDom2s	0
SubDom3s	0
Subjugates	0
Conservatives	0
Neutrals	0
Progressives	0
YoungAdults	0

Total Applied Coercive Force

Mean Anger of People-related Identities

Mean Fear of People-related Identities

Mean hostility of People-related Identities

Mean SF Legitimacy Belief of People-related Identities

Deploy Agents

Security Force

Force-Deployment: Primary Roads

Force-Size: 3

VehicleOccupants: 4

Dynamically Changeable Population Characteristics

People_Attitude_Toward_Forces: Cautious

Required_Personal_Space: 1.0 (M)

People_Tend_Toward_Others?: Off

Dynamically Changeable Security Force Characteristics

Force_Stance_Toward_People: Cautious

Firing_Rate: 20 / minute

Level_Of_Crowd_Sensing_Tech: None

Trigger Invader

Command Center

Interface During Run: Gate guards begin defense



* WRENCH_5.0 - NetLogo (C:\0 new since Sept 2020\Research Projects\2022-2023 JIFCO\NetLogo 22-23\WRENCH 5.0)

File Edit Tools Zoom Tabs Help

Interface IFC Selection and Display ROE Selection and Display Info Code

normal speed view updates on ticks Settings...

ScenarioFocus: Kansas ScenarioDate: Now Setup

WRENCH 5.0
Workbench for refining Rules of Engagement against Crowd Hostiles

Simulation Time: 2022-04-11 14:48: Elapsed Sim Min: 1.6 tick: 96 Mouse_Query? Map Coords (deg/meters): N/A

Population: People in Population: 154 Stunned/Down: 18 Deceased: 1 Avg Injury Level: 0.649350649350649 Total Base Intruders: 1 TimeOfFirstInvader: 71

Population Composition: Bar chart showing total counts for various categories: Females, Males, MidAdults, SeniorAdults, Babies, Children, Doms, SubDom1s, SubDom2s, SubDom3s, Subjugates, Conservatives, Neutrals, Progressives, YoungAdults.

Other GUIs: Choose IFCs, Edit SF's ROEs, Restore All GUI Defaults, display-SIGLinks: 1, display-Colleagues: 0, display-objective?: On, display-fear?: On, display-hostility?: On, display-cogIntents?: On, EnlargePeople, ShrinkPeople, Toggle Siege Attractant, Toggle Gate Attractants, PeopleDensity?: On, Crowd Density: 0, Density Mean: 0, Level_of_Zoom: 3, Redraw, Force-Deployment: Primary Roads, Security Force: Force-Size: 3, VehicleOccupants: 4, Dynamically Changeable Population Characteristics: People_Attitude_Toward_Forces: Cautious, Required_Personal_Space: 1.0 (M), People_Tend_Toward_Others?: On, Dynamically Changeable Security Force Characteristics: Force_Stance_Toward_People: Cautious, Firing_Rate: 20 / minute, Level_of_Crowd_Sensing_Tech: None, Trigger Invader: 1

Command Center: observer

Interface During Run: Defense with patrolling squads at gates



* WRENCH_5.0 - NetLogo (C:\0 new since Sept 2020\Research Projects\2022-2023 JIFCO\NetLogo 22-23\WRENCH 5.0)

File Edit Tools Zoom Tabs Help

Interface IFC Selection and Display ROE Selection and Display Info Code

Edit Delete Add abc Button normal speed view updates on ticks Settings...

ScenarioFocus: Kansas ScenarioDate: Now Setup

Simulation Time: 2022-04-11 14:49: Elapsed Sim Min: 3.25 Tick: 195 On Mouse_Query? Map Coords (deg/meters): N/A

Population: People in Population: 154 Stunned/Down: 4 Deceased: 4 Avg Injury Level: 1.707792207792207 Total Base Intruders: 1 TimeOfFirstInvader: 71

Population Composition: Bar chart showing counts for various demographic groups like Females, Males, MidAdults, etc.

Total Applied Coercive Force: Stacked bar chart showing force levels for different categories like wgnst, men, seniors, etc.

Mean Anger of People-related-Identities: Line graph showing anger levels over time.

Mean Fear of People-related-Identities: Line graph showing fear levels over time.

Mean hostility of People-related Identi...: Line graph showing hostility levels over time.

Mean SF Legitimacy Belief of People...: Line graph showing legitimacy belief levels over time.

Adults: Adults: 147 Fleeing: 120 Attack Obj.: 0 Protest Obj.: 56 Stay Safe Obj.: 91 None (no Obj.): 0

Trigger Invader

Command Center: observer

Deploy Agents button can be used multiple times before and during a run to create force and/or population agents. Variable settings in this GUI area only apply to the agents being newly created when Deploy Agent button is clicked. If only people are desired set Force-Size to 0. If only force squads are desired set PopDensity to 0. Security force compound squad (gate guards) is only created once per run.

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Security Force: Force-Deployment: Primary Roads Force-Size: 3 VehicleOccupants: 4

Recent Publications



- Aros, Susan, Anne Marie Baylouny, Deborah E. Gibbons, and Mary McDonald, “Toward Better Management of Potentially Hostile Crowds,” Winter Simulation Conference, December 14, 2021. *Peer-reviewed conference proceeding.*
- Baylouny, Anne Marie and Anshu Chatterjee, “The mob made me do it? Collective identity, agency, and crowd theories in the Capitol siege and Black Lives Matter protests,” American Political Science Association conference, October 1, 2021. *Conference paper.*
- Baylouny and Aros, “Modeling protest-security forces dynamics: Agency, collective identities, and sub-groups in the Capitol Siege and BLM.” presentation to International Studies Association conference, April 2, 2022, Nashville, TN. *Conference paper.*
- *Upcoming:* Baylouny, Anne Marie and Susan Aros. “Advances in Modeling Conflict Interaction Using Social Psychology,” American Political Science Association Conference, Montreal, Canada, September 2022. *Conference paper.*

Recent Presentations



- Aros, “Complex Agent Based Simulation for Management of Potentially Hostile Crowds using IFCs,” presentation to the Military Operations Research Society Emerging Techniques Forum, December 7, 2021.
- Aros, “Workbench for refining Rules of Engagement against Crowd Hostiles”, presentation to the NATO Modeling and Simulation Group MSG-198, December 22, 2021.
- *Upcoming:* Aros, Susan. “Modeling Potentially Hostile Crowds” presentation to the 90th Military Operations Research Society Symposium, as part of the Human Behavior and Performance Community of Practice Session. conference, June, 2022.