Social Network Analysis of Crowds

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14. ABSTRACT
We will present findings from our ongoing experimentation using the Crowd Behavior Testbed. For the last two years, the Target Behavioral Response Laboratory has conducted laboratory research on crowd behavior in response to simulated non-lethal weapons. Data and results from this testing will be presented. Subjects participated in an experiment investigating crowd behavior and response to a control force. During the entire time that subjects were participating, crowd behavior and interactions were videotaped. Videotape recordings of interactions during engagements with control force and informal interactions between crowd members were coded for inter-member interactions. These social communications and interactions were subjected to social network analysis to identify leaders and other influential crowd members, hubs, isolates, dyads, triads, and clusters of nodes (individuals). Two other sources of data were analyzed using network analysis. Before the study, subjects identified the individuals they had known before the test. After the main crowd-control force experiment, subjects also identified those they thought acted as leaders or were highly capable of influencing the crowd. Social network analysis was then conducted to identify patterns of pre-existing social bonds as well as to identify informally nominated leaders in the group. Procedures to characterize crowds based on social network analysis methods will be presented.

15. SUBJECT TERMS
non-lethal weapons; social network analysis; crowd; control force; videorecording; human experimentation; Target Behavioral Response Laboratory laboratory method; behavior coding

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Crowd Research

- Large numbers
- Heterogeneous
- Individual Actors
- Interdependence
- Language Barriers
- Empirical testing is difficult
- Simulations require models based on real data, otherwise they are fiction

Gather <u>empirical data</u> on <u>real human behavior</u> in response to non-lethal weapons and systems with real people in tactically relevant situations

TBRL

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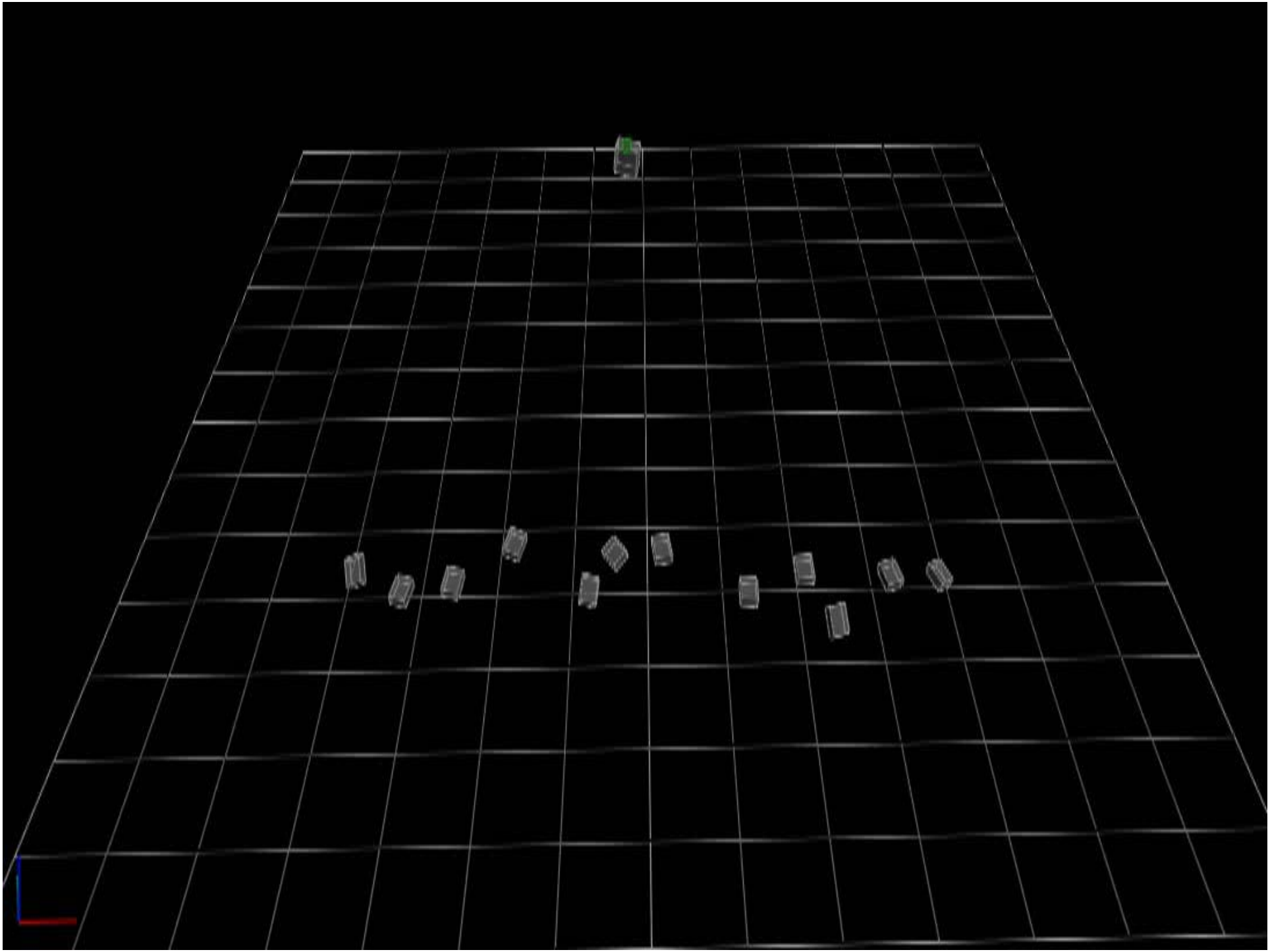
Method: Lab Experimentation

- Group of 19 individuals
- Halt Approach Scenario ("Deny access into/out of an area to individuals" JNLE/CBA)
- Video recording of crowd-control force interaction
- Simulated stand-off weapon
- Self-Report Questionnaires

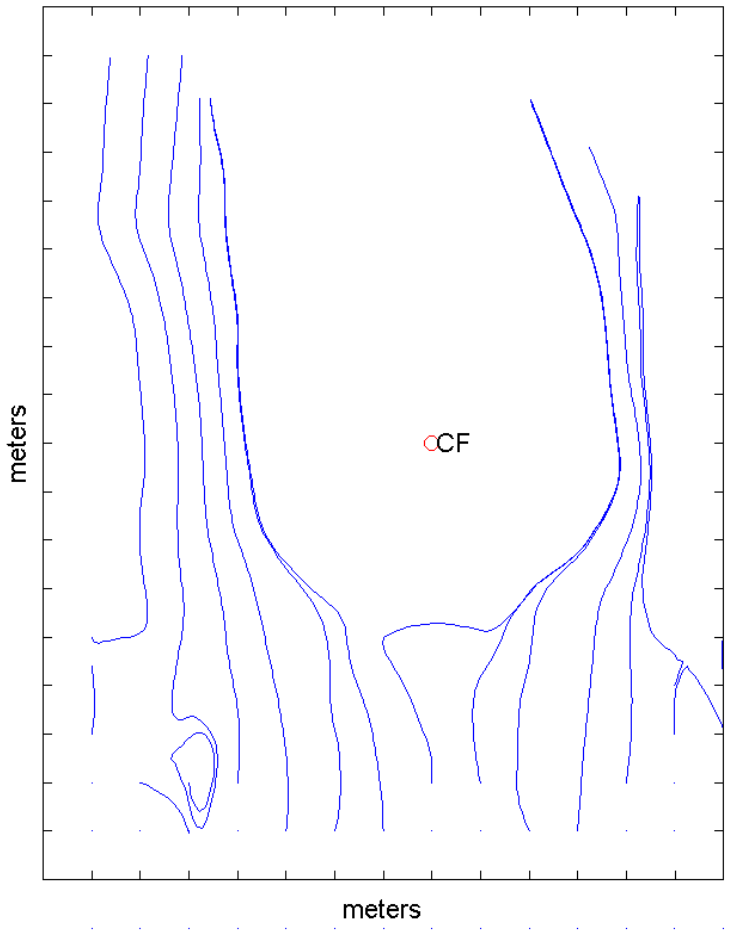

Indoor Crowd Behavior Testbed Layout

Video Cameras on Trusses

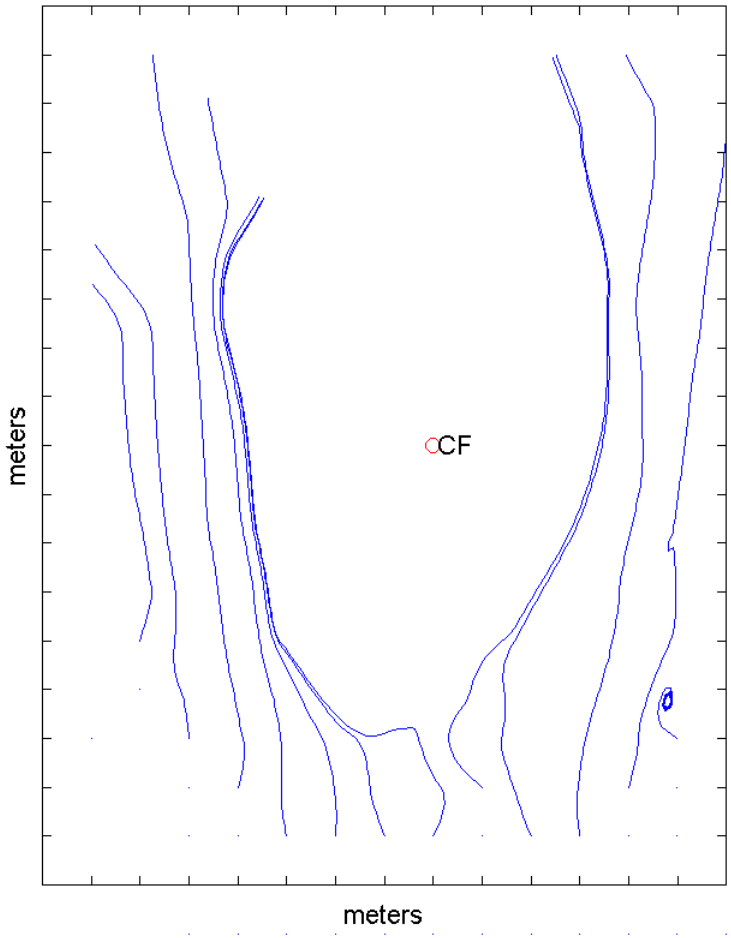


Threat Streamlines

Hand-to-Hand Combat Weapon



Stand-off Weapon



Importance of Social Factors

- Response to non-lethal weapons fire depends on social relationships among crowd members
  - Pre-existing Personal Relationships
  - Ongoing Real Time Social Interactions
  - Formal/Informal Hierarchies

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- Therefore need method to assess social factors
- Social Network Analysis

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Data Measurement

- Social Bonds
  - Self-Report
- Crowd Social Interactions
  - Observed on Video

- Leader Nomination
  - Questionnaire

Social Network Analysis

- 19 x 19 matrix submitted to networking analysis software
- ORA Version 1.9.5.4.3, Dr. Kathleen M. Carley, Center for Computational Analysis of Social and Organizational Systems (CASOS), Institute for Software Research International (ISRI) School of Computer Science (SCS) Carnegie Mellon University
- Visualization for insight
- Numerical Sociometrics outputted for formal analyses: density, isolates, linkages among nodes

Social Bonds

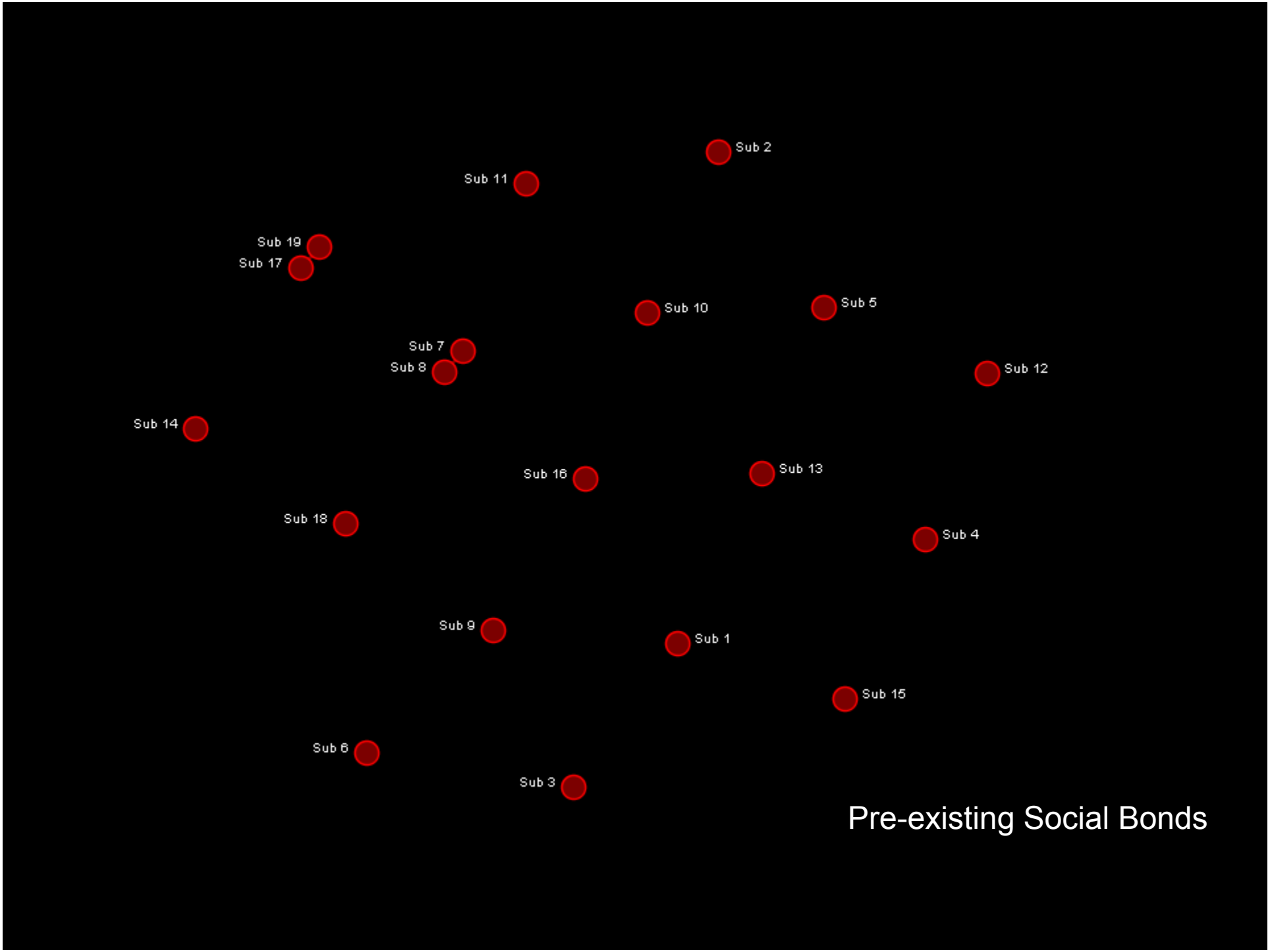
Do you know anyone else who is participating in the study today?

Yes No

If yes, please indicate who you know based on the subject number assigned to them (on their tee shirt or folder). Please circle their numbers below:

1 2 3 4 5 6 7 8 9 10

11 12 13 14 15 16 17 18 19 20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Sub 11
Sub 19
Sub 17
Sub 10
Sub 5
Sub 7
Sub 8
Sub 12
Sub 14
Sub 16
Sub 13
Sub 18
Sub 4
Sub 9
Sub 1
Sub 15
Sub 6
Sub 3
Pre-existing Social Bonds

Social Interactions

- Videotapes coded for pair-wise social interaction among crowd members:
  - Verbal communication, physical contact, gestures, non-verbal auditory signaling
  - Scored three 2-minute epochs before/during crowd-control force interaction
  - Inter-rater reliability .94

	Sub 1	Sub 2	Sub 3	Sub 4	Sub 5	Sub 6	Sub 7	Sub
Sub 1	0	0	0	0	0	1	0	
Sub 2	0	0	0	0	0	0	0	
Sub 3	0	0	0	0	0	0	0	
Sub 4	0	0	0	0	0	0	0	
Sub 5	0	0	0	0	0	0	0	
Sub 6	1	0	0	0	0	0	0	
Sub 7	0	0	0	0	0	0	0	
Sub 8	0	0	0	0	0	0	1	
Sub 9	0	1	1	0	0	0	0	
Sub 10	0	0	0	0	0	0	0	
Sub 11	0	0	0	0	0	0	1	
Sub 12	0	0	0	0	0	0	0	
Sub 13	0	0	0	0	0	0	0	
Sub 14	0	0	0	0	0	0	0	
Sub 15	0	0	0	0	0	0	0	
Sub 16	0	0	0	0	0	0	0	
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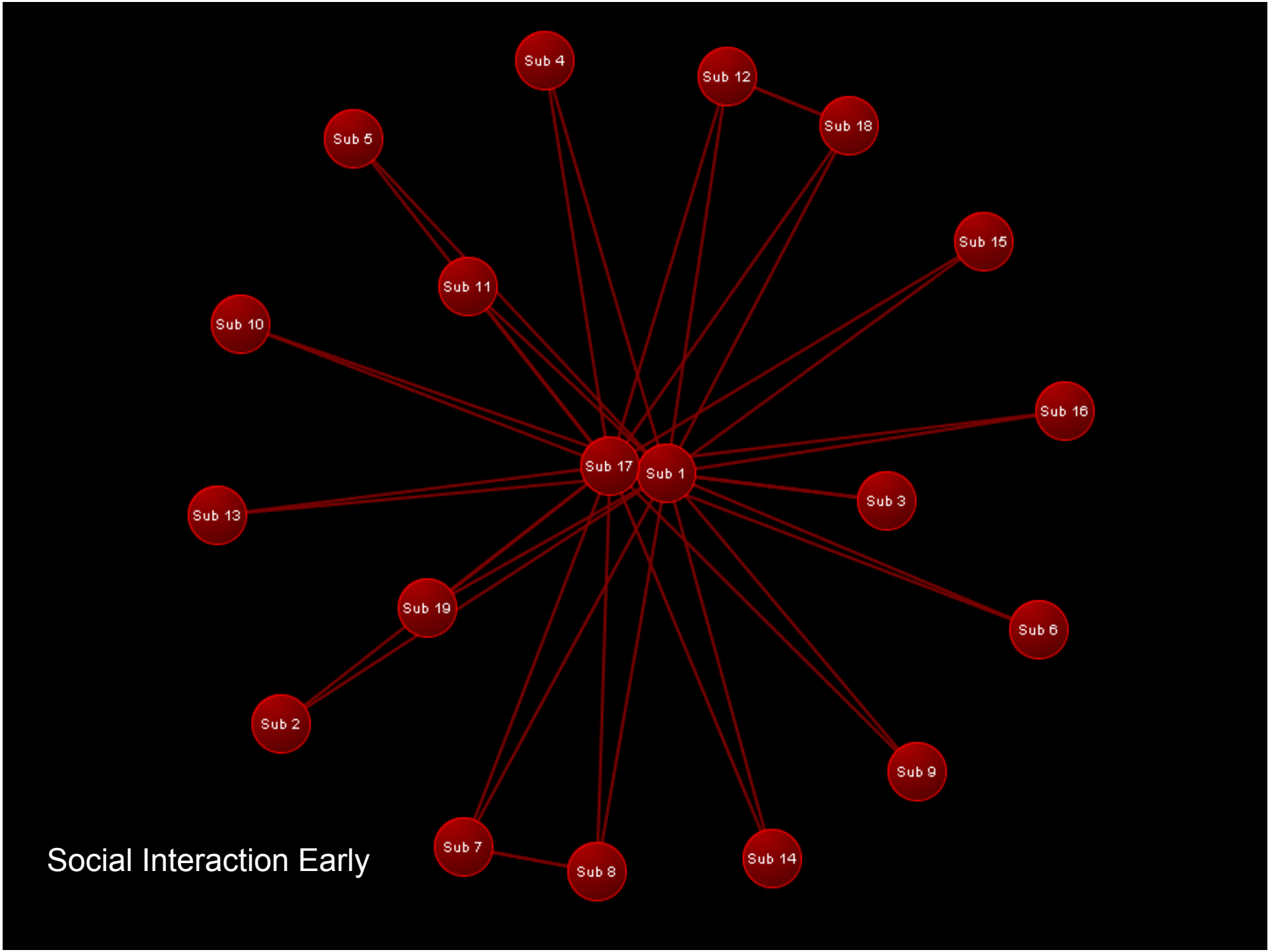
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Sub 18
Sub 5
Sub 15
Sub 11
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Sub 16
Sub 17
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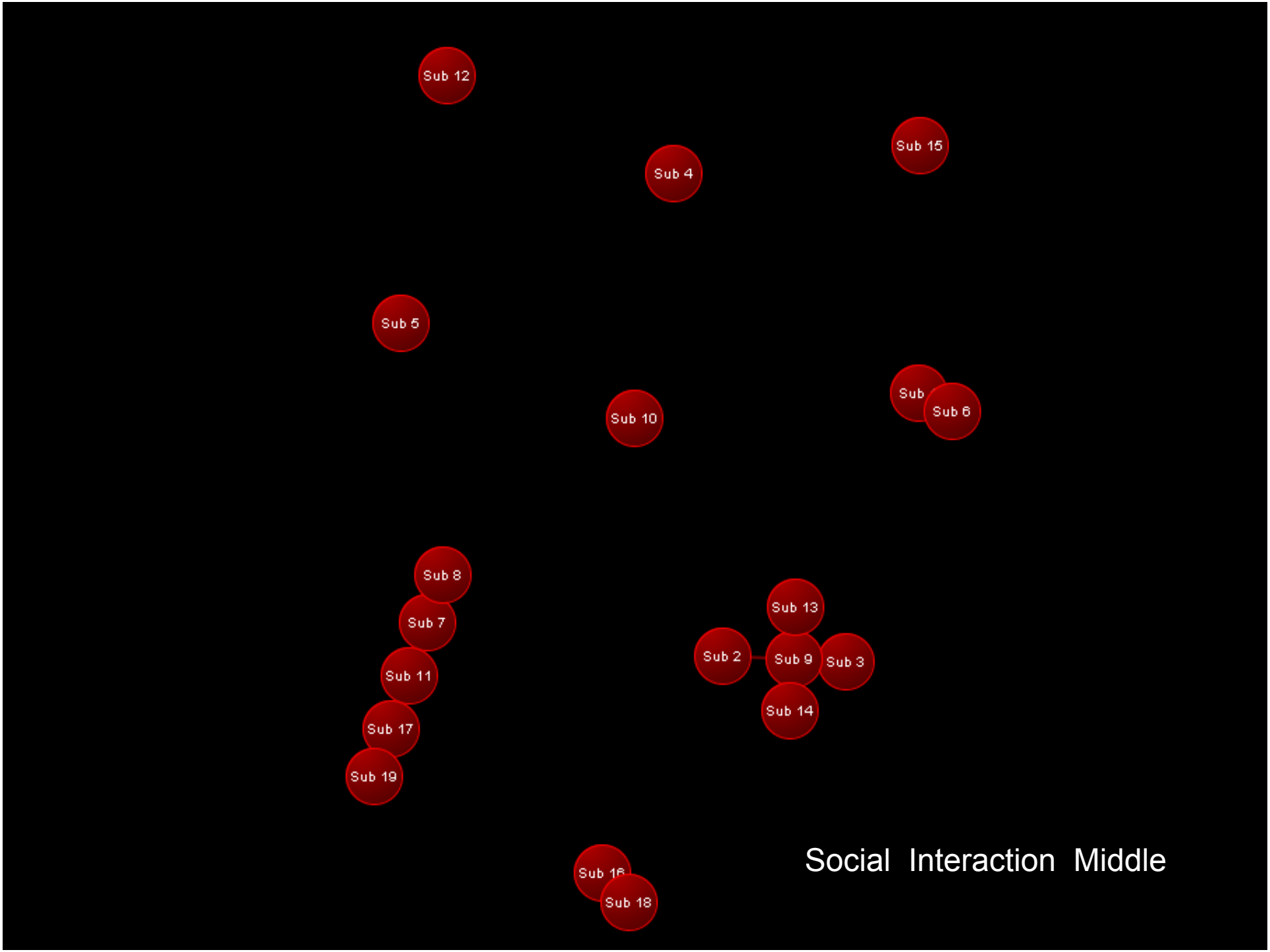
Sub 13
Sub 3
Sub 19
Sub 6
Sub 2
Sub 9
Sub 7
Sub 8
Sub 14
Social Interaction Early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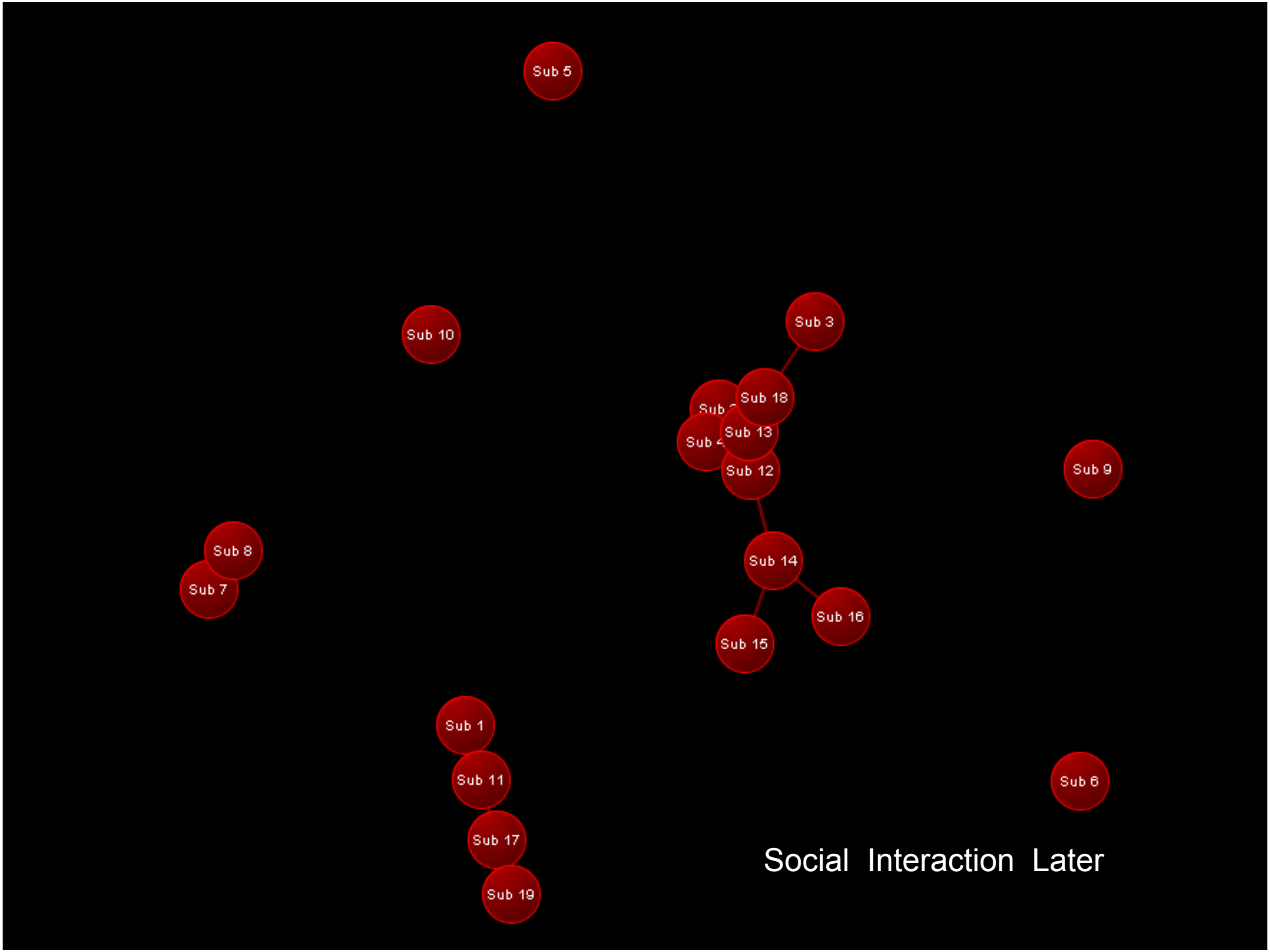
Sub 19
Sub 18
Social Interaction Middle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Sub 12
Sub 9
Sub 8
Sub 7
Sub 14
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Sub 15
Sub 1
Sub 11
Sub 17
Sub 19
Sub 6
Social Interaction Later

Leader Nominations

Was there a person (or people) in your group that you considered to be a leader (or leaders)?

Yes No

If yes, please indicate all the people that you thought were leaders.

Please circle their numbers below:

1 2 3 4 5 6 7 8 9 10

11 12 13 14 15 16 17 18 19 20


Sub 13
Sub 2
Sub 5
Sub 4
Sub 3
Sub 10
Sub 11
Sub 15
Sub 1
Sub 9
Sub 8
Sub 12
Sub 6
Sub 17
Sub 19
Sub 18
Sub 14
Sub 7
Sub 16
Leadership Nominations

Numerical Sociometrics

	Social Bonds	Early Interactions	Late Interactions	Leadership
Node Count	19	19	19	19
Density	0.0117	0.1257	0.0936	0.0526
Fragmentation	0.9883	0	0.7485	0.4678
Isolate Count	15	0	4	5
Link Count	4	43	32	18
Centralization	0.049	0.5114	0.2059	0.1585

Social Network Analysis of Crowds

- Ongoing experimentation
- Network analyses yield quantitative methods for crowd psychosocial characterization
- Can be used to examine questions of social factors that moderate crowd responses to non-lethal weapons and systems
  - Prior, existing social relationships
  - Real time social interactions
  - Formal/informal hierarchies

Back-up Slides

TBRL

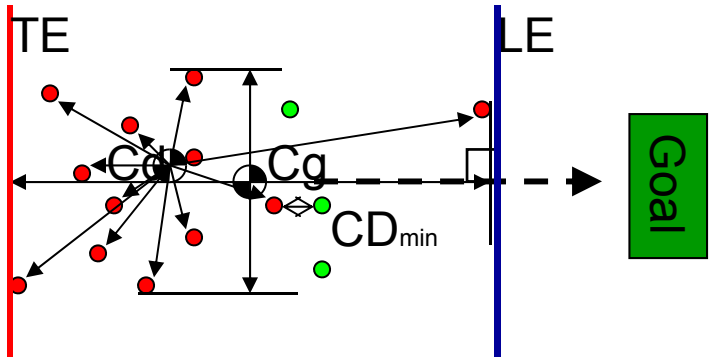
Individual Metrics

$S_{t,Sa}$	Distance covered in interval
$V_{t,Sa}$	Instantaneous Velocity
$ID_{t,Sa,Sb}$	Interpersonal Distance between any pair of subjects
$CD_{t,c,Sa}$	Distance between control force-subject pairs
$CID_{t,c,c}$	Interpersonal Distance between any pair of control force

Crowd Metrics

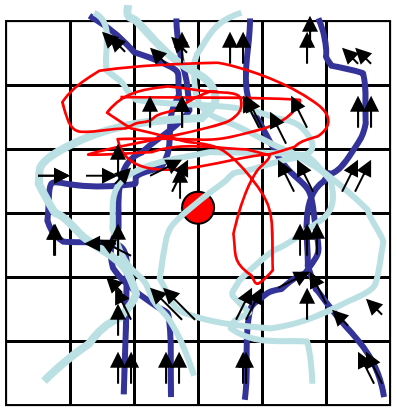
Cg_t	Geometric Center- middle of extrema
Cd_t	Centroid- mean of subject positions
D_t	Dispersion- mean subject radii from centroid
LE_t TE_t	Leading/Trailing edge- max/min along the approach axis
ρ_t	Density- $\rho_t = N / \pi D_t^2$
$CDmin_t$	Minimum distance between any subject-control force pair
σO_t σV_t	Deviation of Orientation/Velocity- StDev of all subjects head orientation or velocity
Vc_t	Bulk velocity of crowd- rate of change of centroid

Defined time periods based on events dependent on the construct or scenario used.

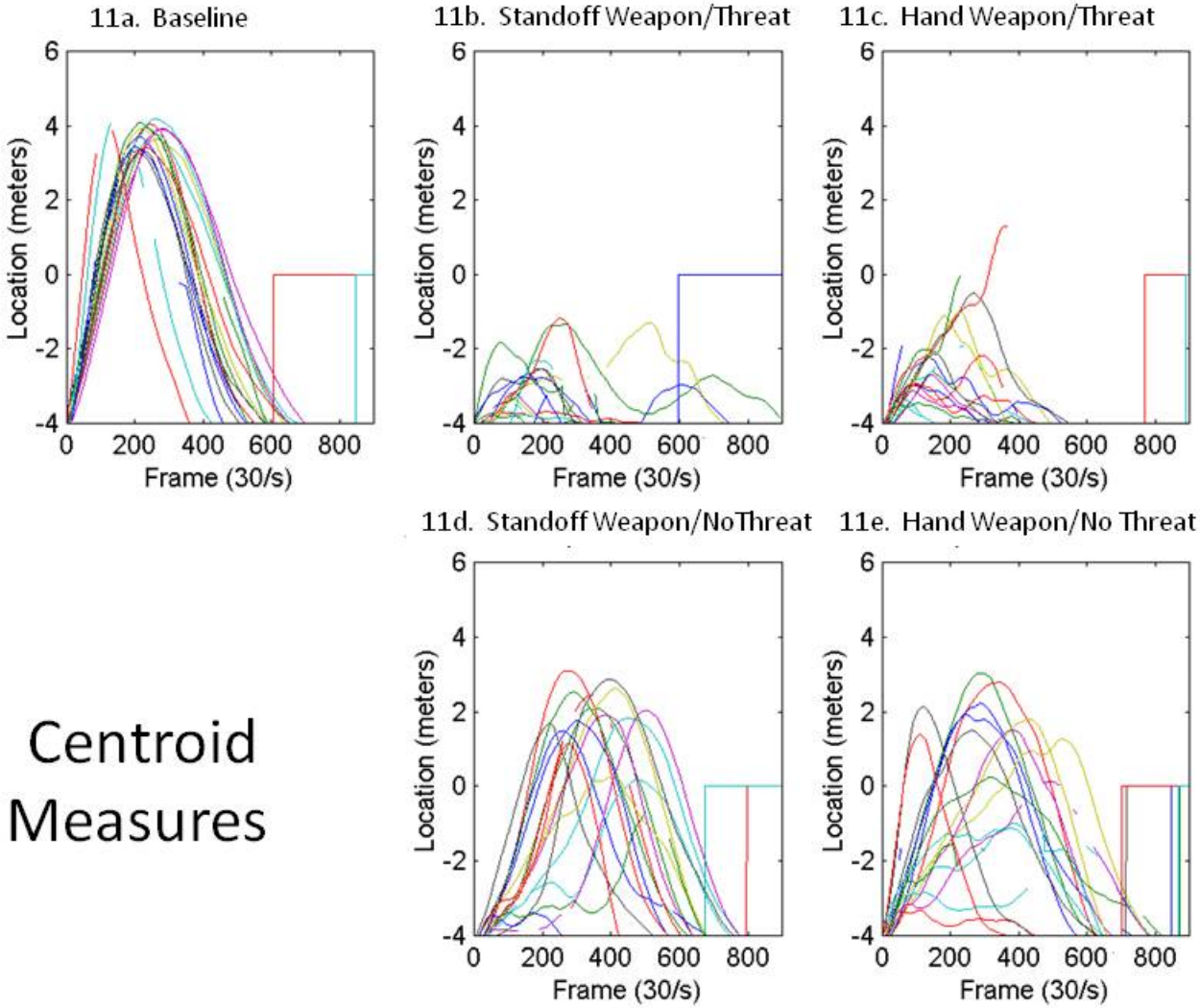


Vector Fields

- Each subjects path of movement considered separately.
- Coordinate conversion so Control Force is origin.
- Subject locations grouped into cells.
- Resulting vector for a cell is the average vector from all data in that cell.
- Stream lines built from Vector Field.

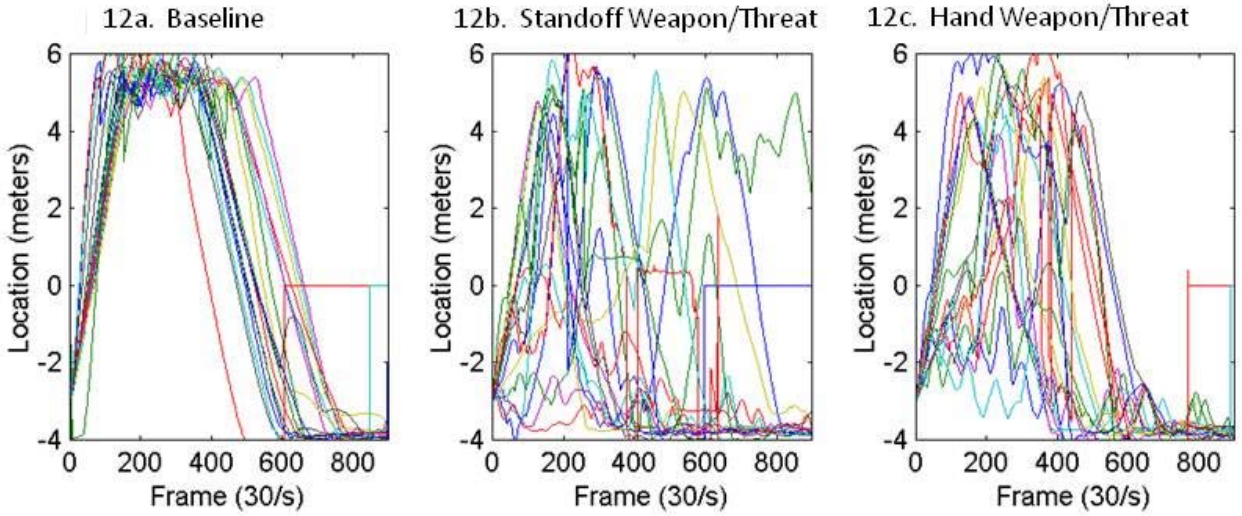


Centroids

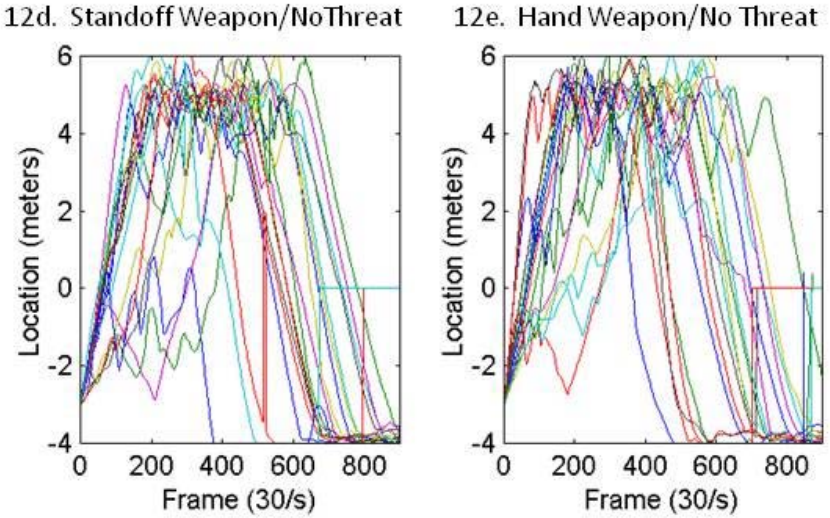


Centroid Measures

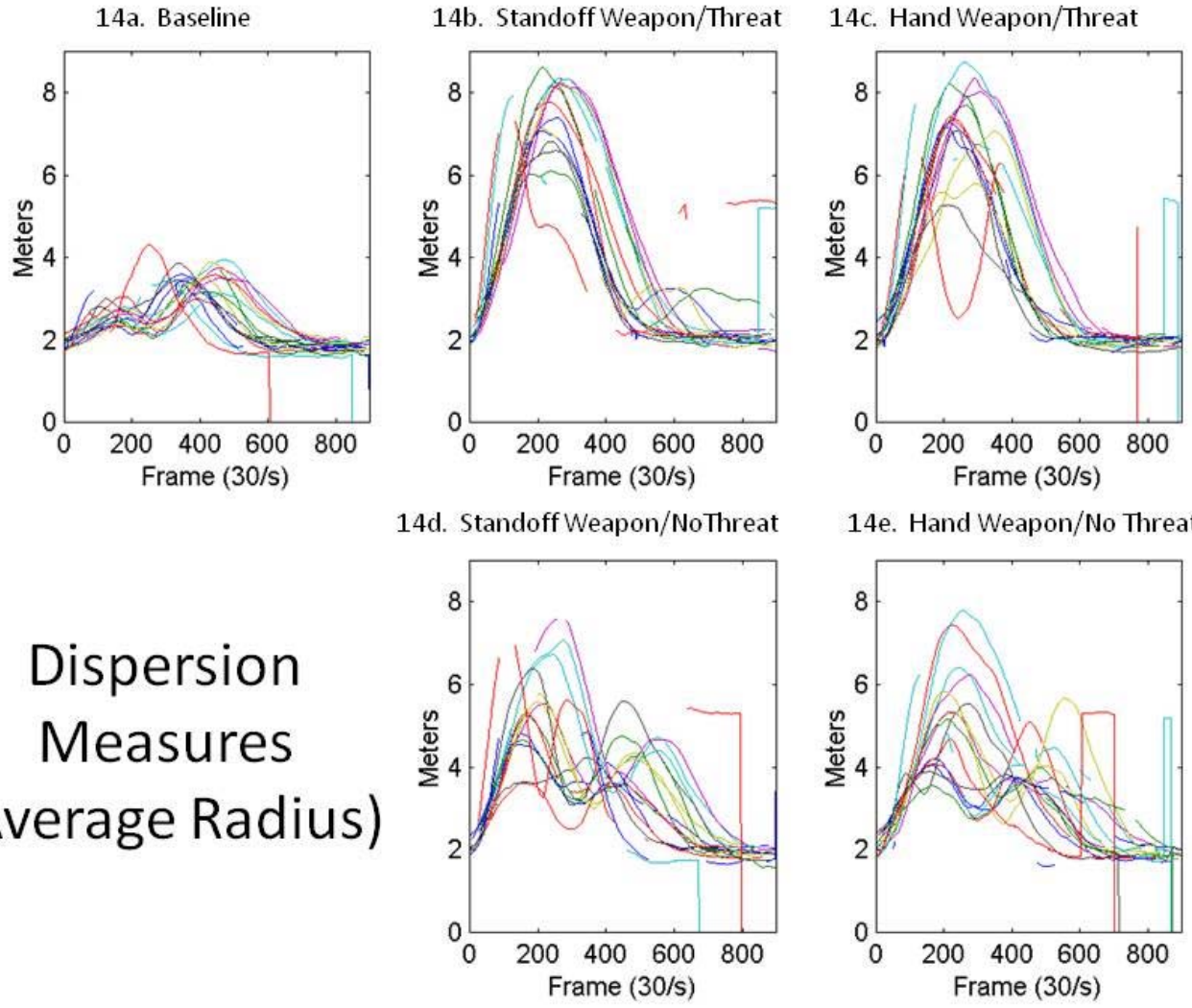
Leading Edge



Leading Edge Measures

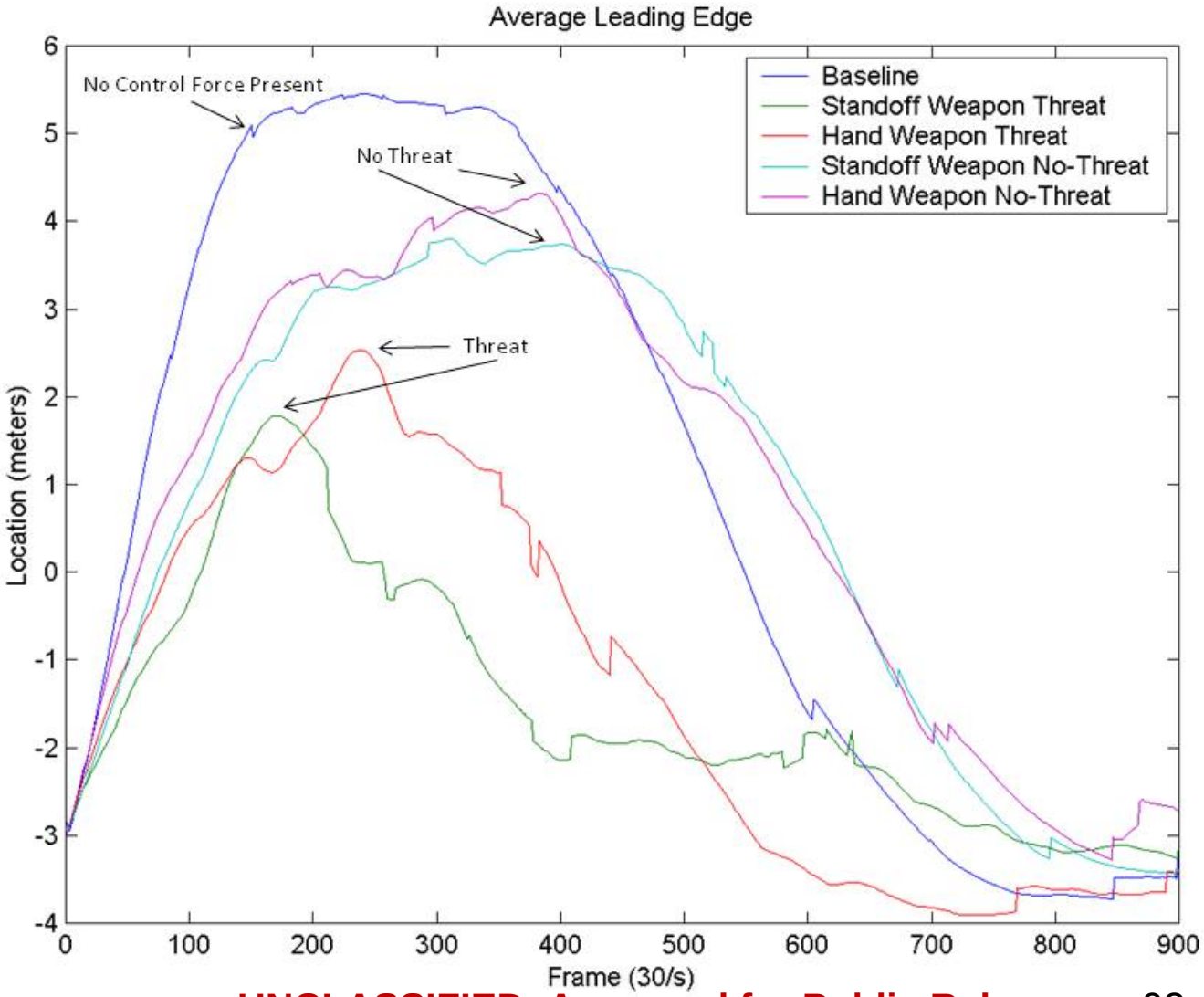


Dispersion

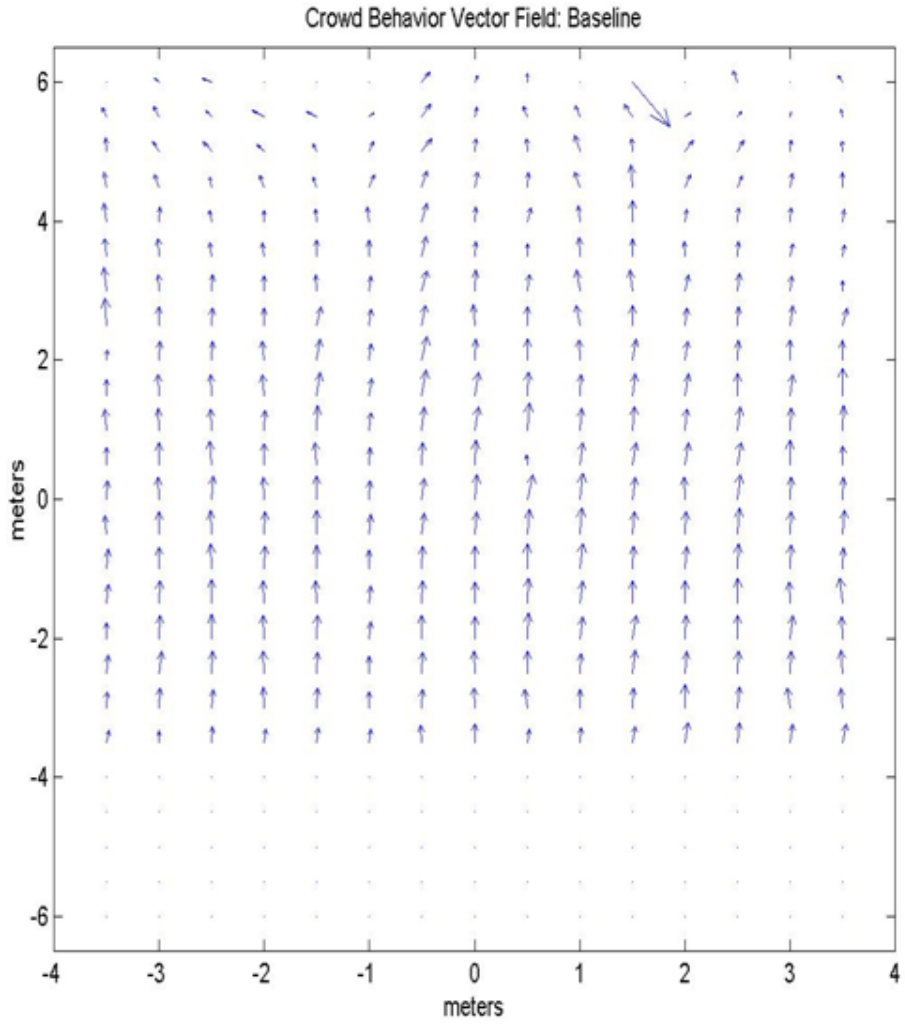


Dispersion Measures (Average Radius)

Leading Edge Comparison



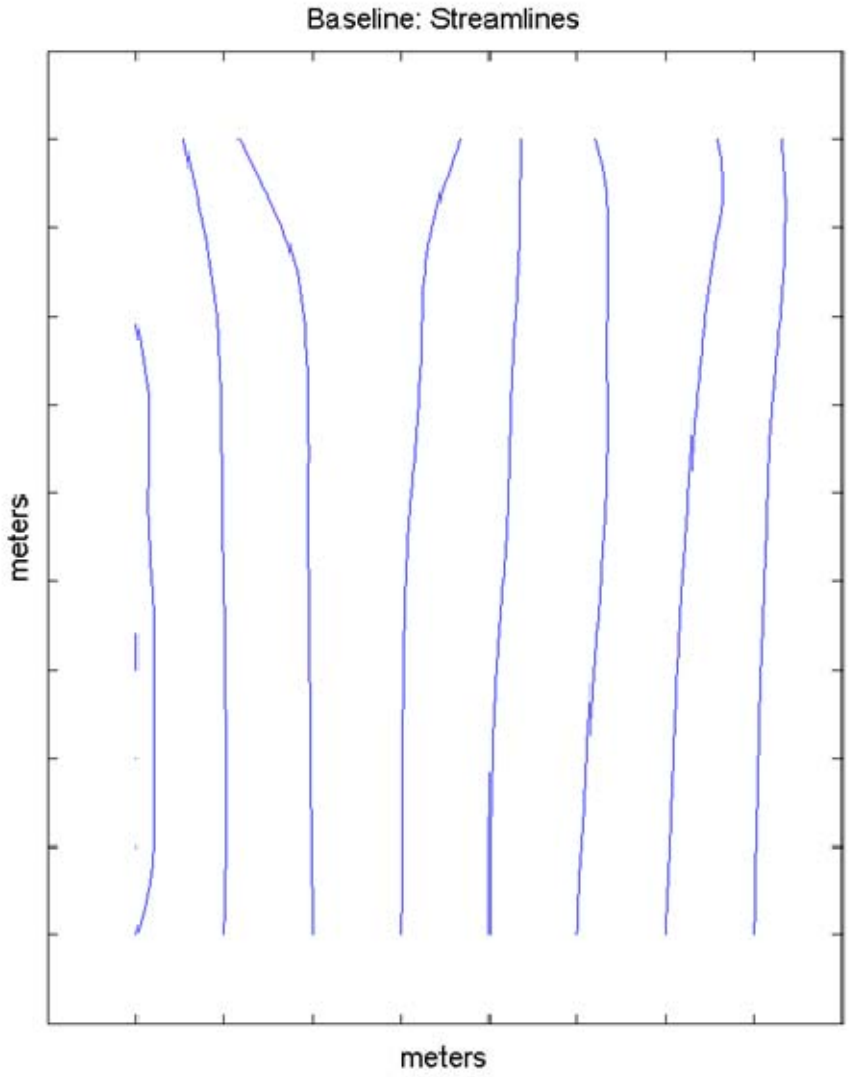
Baseline Vector Field



Goal End

Start End

Baseline Vector Field

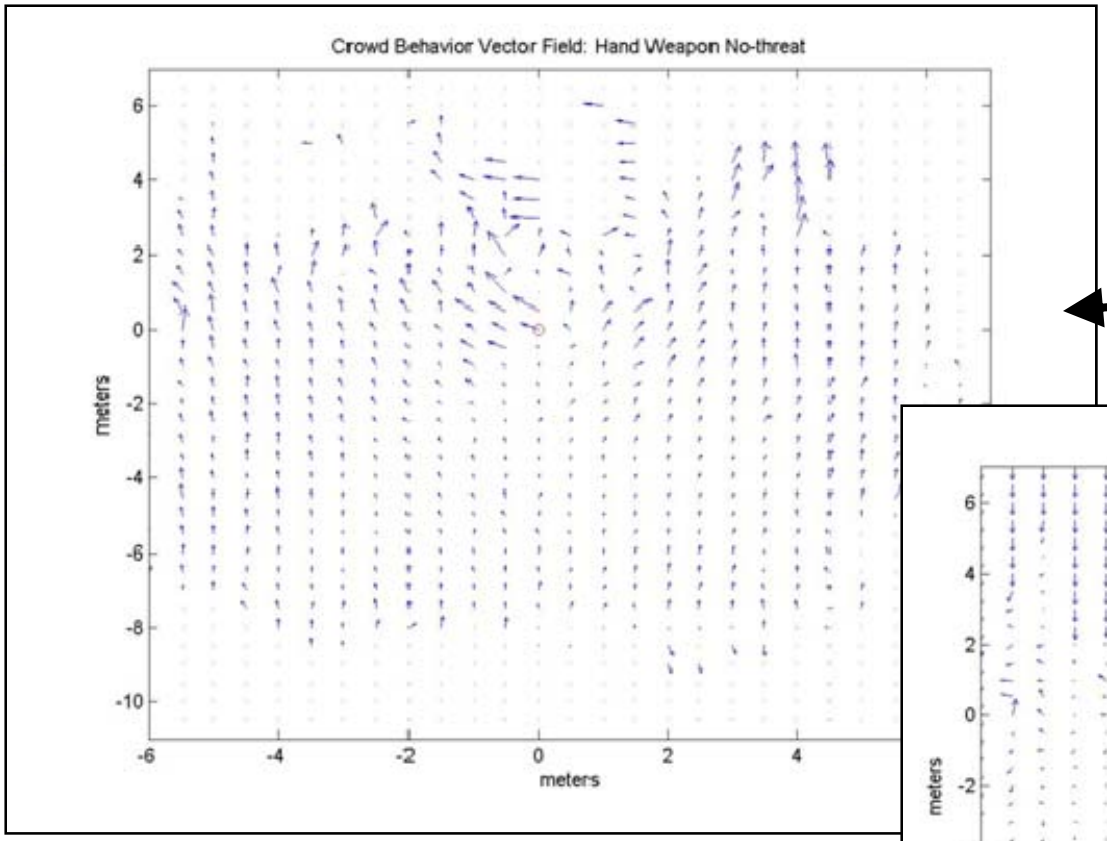


Goal End

Streamline View

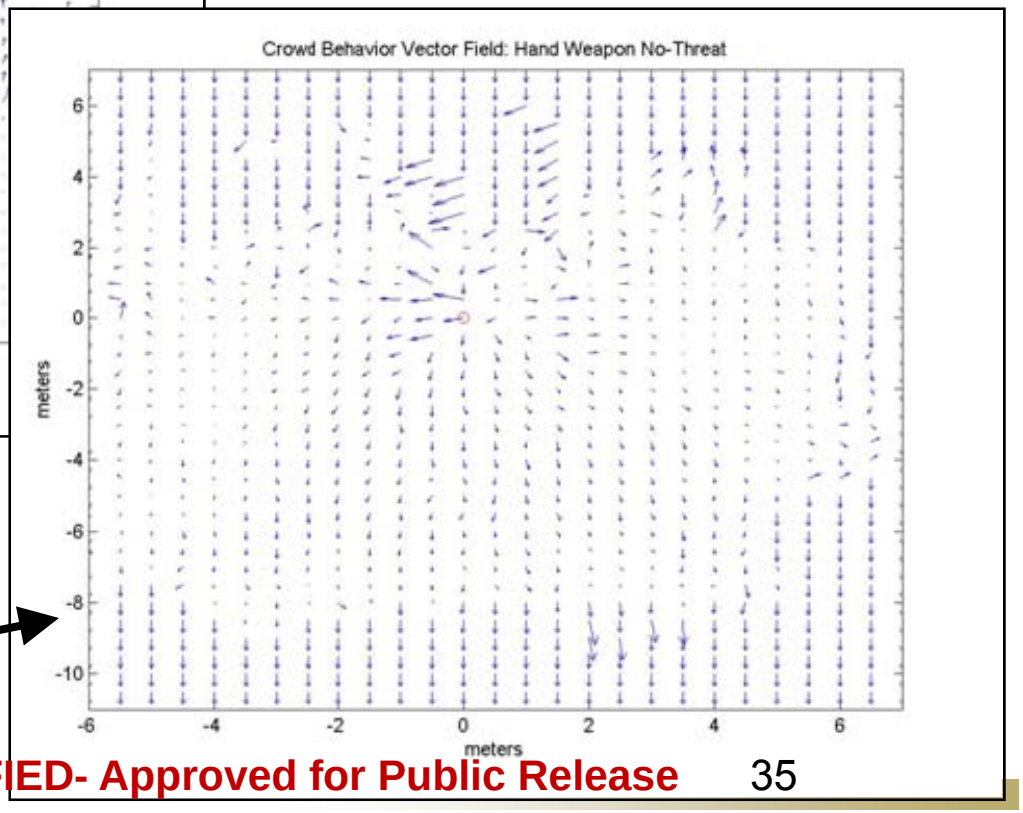
Start End

Vector Fields



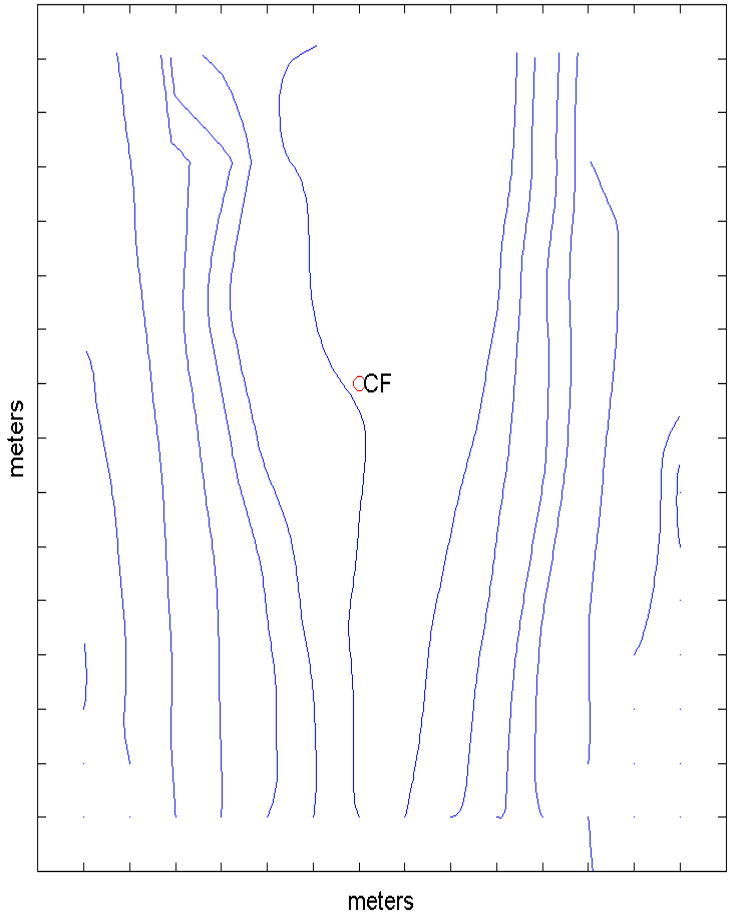
Recorded vector fields are combined behavior towards the goal and avoid the control force.

Can subtract baseline (towards goal) to find the vector field only avoiding the control force.



No Threat Streamlines

Hand-to-Hand Combat Weapon



Stand-off Weapon