Concurrent Presentation Session
LEARNING ANALYTICS FROM DIVERSE DATA

Learning from Sensor-Based Analytics for First Responder Training

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Learning from Sensor-based Analytics for First Responder Training

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Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation

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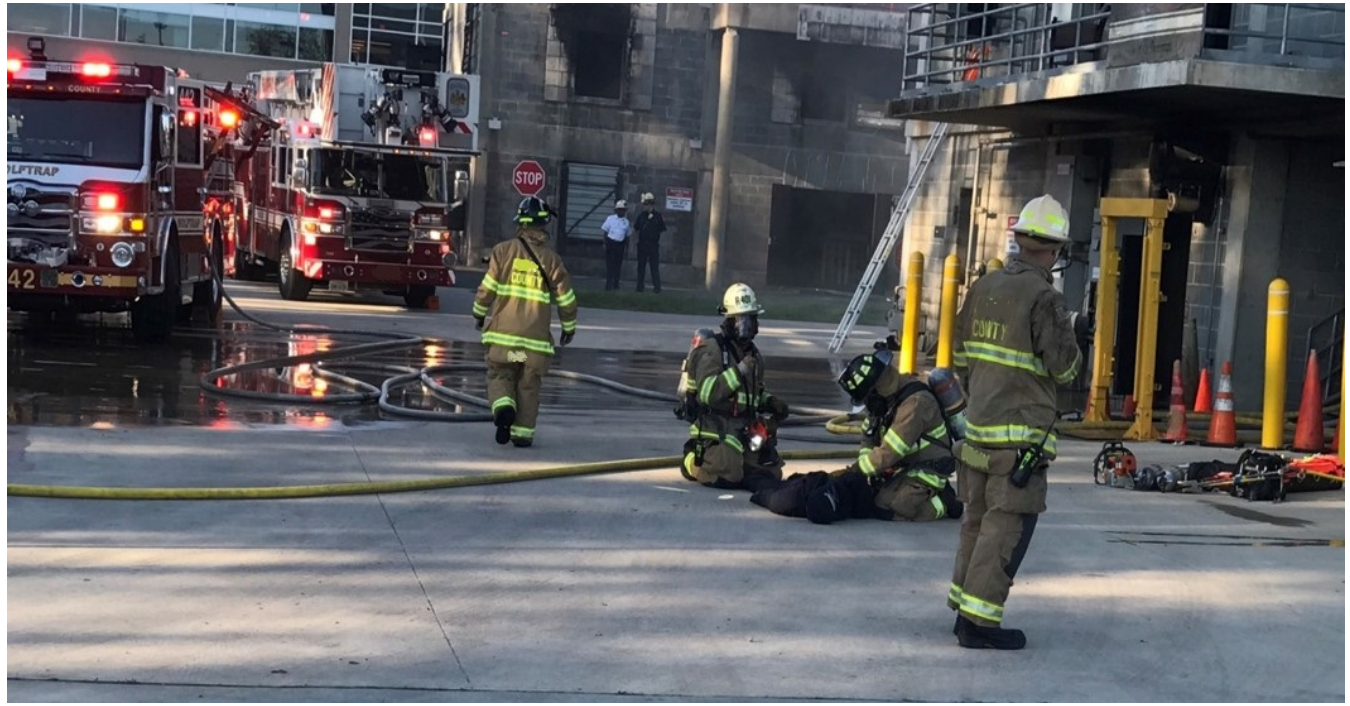
Engineering Digitally-Mediated Team Learning

Toward a Cyber-Physical System for First Responder Training

- Goal: learn from and shape individual and team behaviors/decisions, reduce cognitive bias, improve performance
- Can visualization of behavioral analytics improve within and cross-team learning in simulation debrief?
- How do we promote learning by first responders, inform and change team-based behavior in repeated, live simulation exercises?
- Can digitally-mediated teams self-monitor, adjust behavior and improve performance?

Design for Complex Sociotechnical Systems

- Operational
  - Physical setting of use
- Behavioral
  - Human activity
  - States of being
- Ecological
  - Networks of relationships
- Sociocultural
  - Shared ways of interpreting the world



Rowland, C., Goodman, E., Charlier, M., Light, A. & Lui, A. (2015). *Designing connected products: UX for the consumer internet of things*. Sebastopol, CA: O'Reilly.

Analyze distributed work & learning ecosystems

Digitally Mediated Team-based Learning – MTS System

- Multiteam Systems – Learning and Performance Across System

Stage 1

Pre-Hospital Patient Care

Stage 2

Transport to Emergency Department

Stage 3

Emergency Department Care

Stage 4

Post-simulation debrief

Team Stakeholders:
- **Citizens on scene**
- **911 Dispatcher**
- **EOC**
- **Fire & Rescue**
- **EMS**

Team Stakeholders:
- **EMS**

Team Stakeholders:
- **EMS**
- **ED/Trauma**

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Multiteam System (MTS) Definition

"Two or more teams that interface directly and interdependently… While pursuing different proximal goals, [teams] share at least one common distal goal." *(Mathieu, Marks, & Zaccaro, 2001, p. 290)*

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Individual

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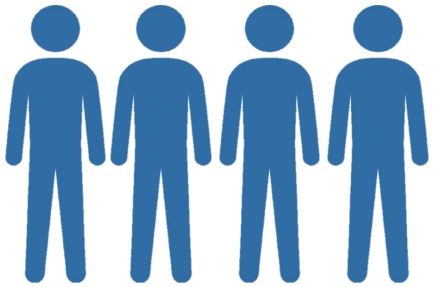
Individual

Team



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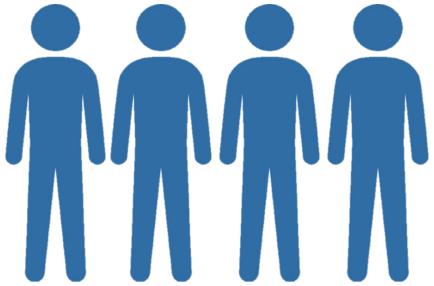
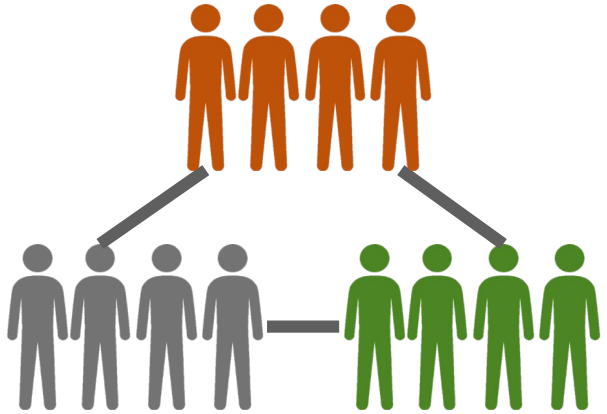
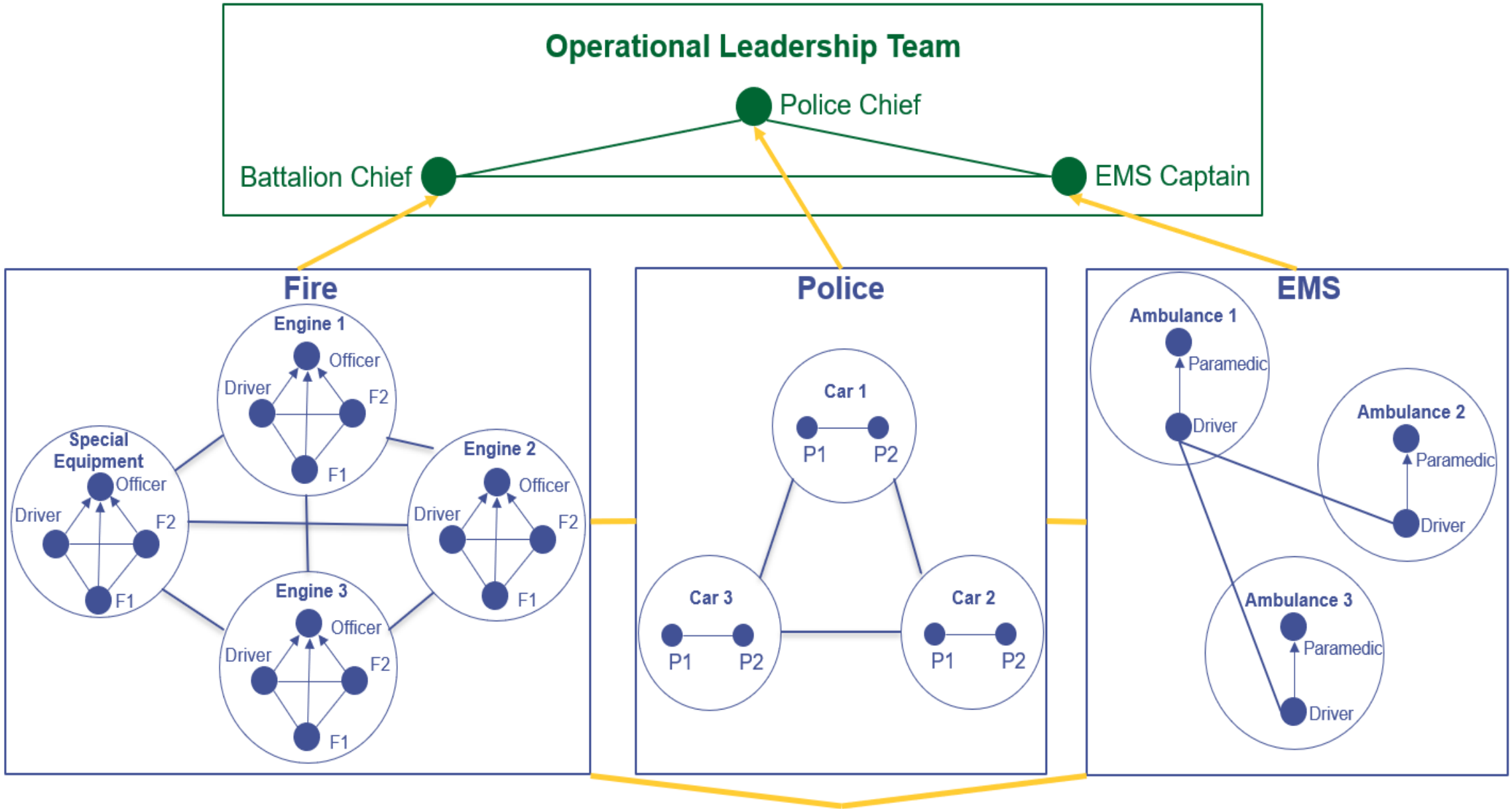
Individual

Team



MTS




Operational Leadership Team
Police Chief
Battalion Chief
EMS Captain
Fire
Engine 1
Officer
Driver
F2
F1
Special Equipment
Officer
Driver
F2
F1
Engine 2
Officer
Driver
F2
F1
Engine 3
Officer
Driver
F2
F1
Police
Car 1
P1
P2
Car 3
P1
P2
Car 2
P1
P2
EMS
Ambulance 1
Paramedic
Driver
Ambulance 2
Paramedic
Driver
Ambulance 3
Paramedic
Driver

Toward these Methods and Objectives

- ***Measurement*** of dynamic coordination and learning of emergency response component teams and MTSs

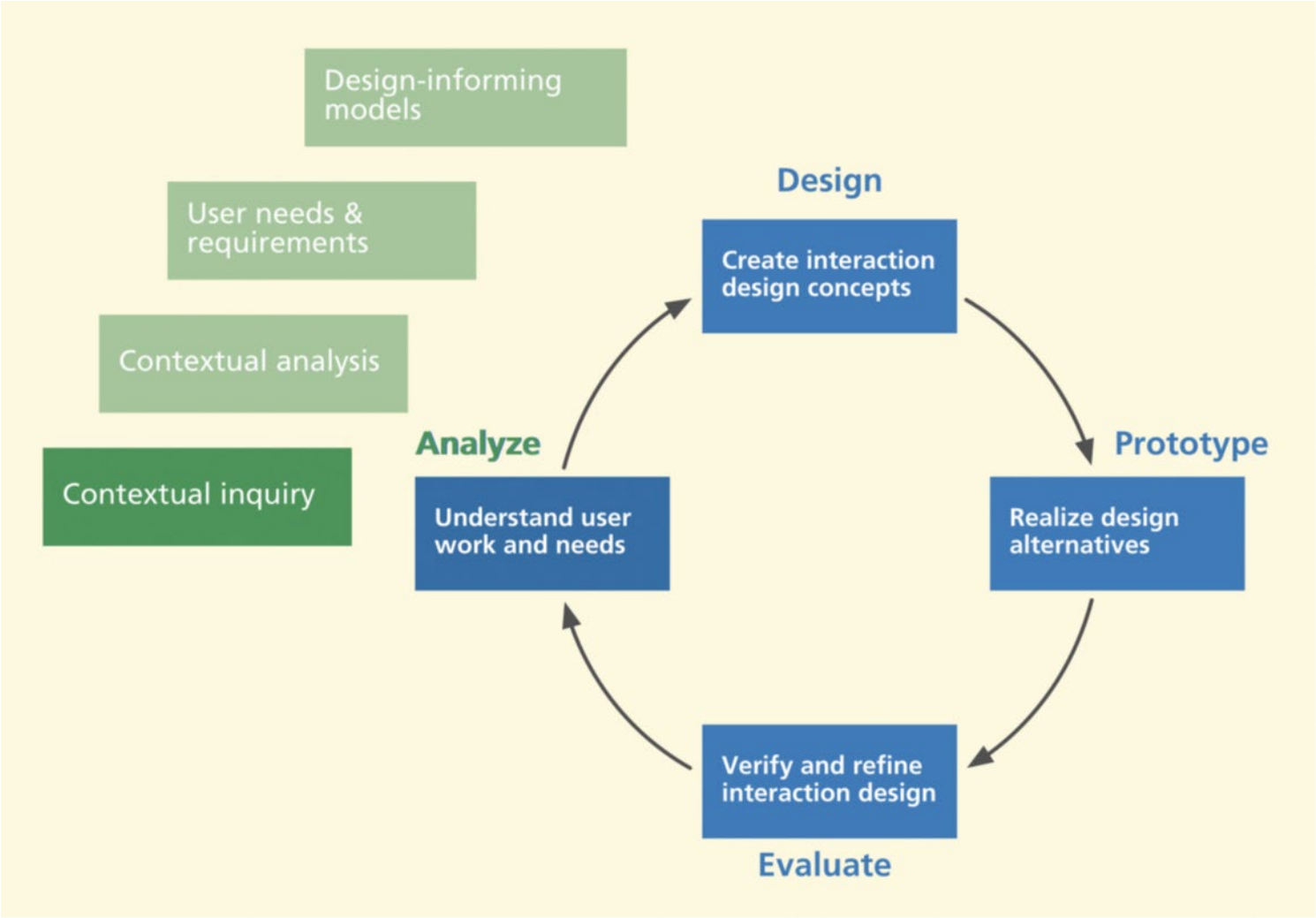
- ***Utilization*** of new forms of data collection designed to uncover the nature of within-team and between-team behaviors
  - E.g., unobtrusive sensors, digital video and audio

- ***Integration*** of multiple streams of digital data in live simulation, dynamic contexts in real-time

- ***Objective is to improve overall MTS coordination, learning & performance***

UX Design Prototype & Research Cycles

- Engineering wearable devices for learning
  - Bluetooth Proximity Beacons/
  - Location-based Sensing
- Tracing user activity and experience with connected devices
  - Determine activity trace
  - Based on real world activity and theoretical framework



Scene – Within Team Coordination

Figure 2. Officer and Firefighter/Paramedic addressing live simulated patient with observer.

Within Team Coordination

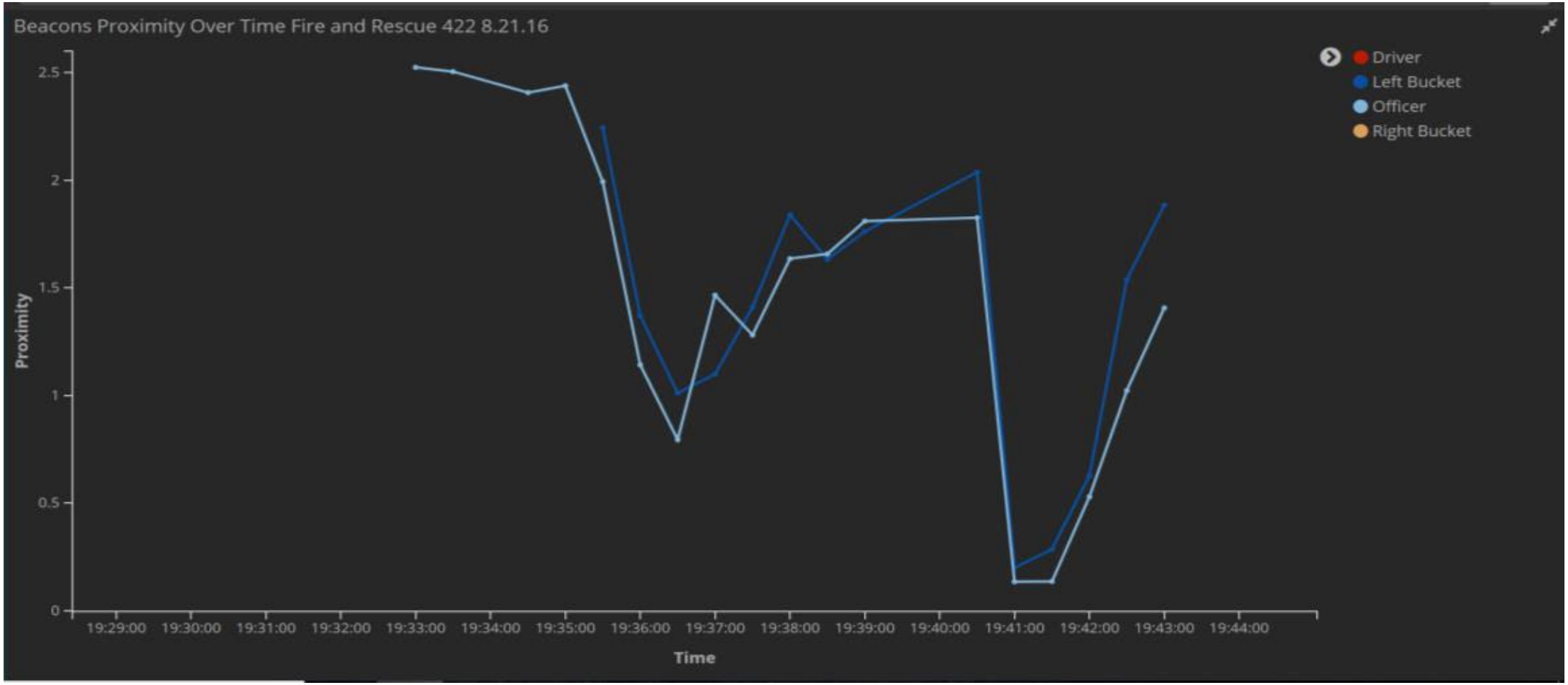
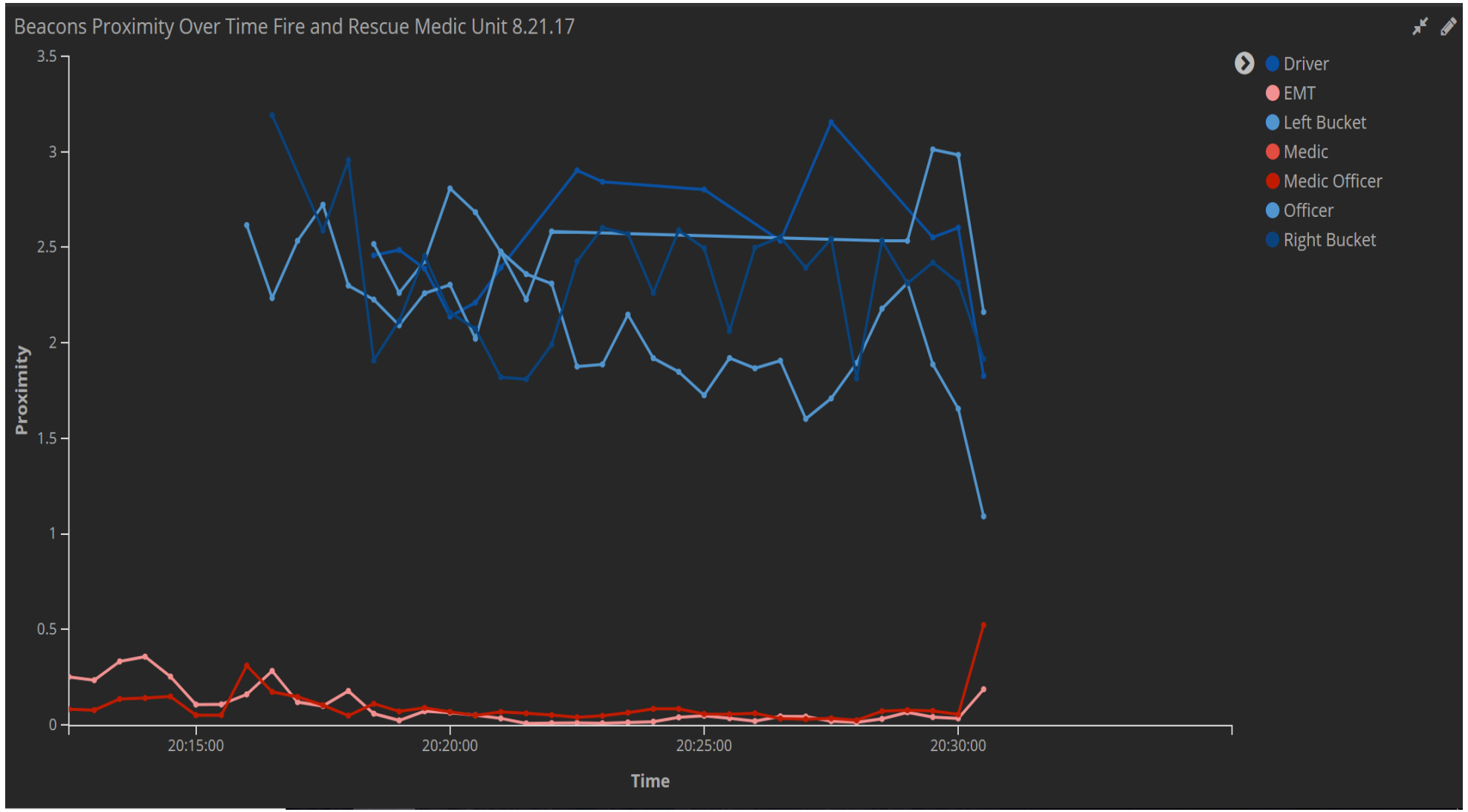


Fig. 1 Proximity sensor data from officer and left bucket firefighter/paramedic with their proximity to fire engine over time during simulation

Scene – Between Team Coordination and Patient Handoff in Field

Real-time team and individual activity tracing



Firefighter Suppression Team (blue) and Emergency Medical Services Team (red) proximity to EMS Medic (wearing listening device) visualized in near real-time on-scene.

In-the-Wild Design Research

- Active Threat (Shooter) Scenario
  - Map the team system/test IoT data collection, interrogate data for deeper analysis

Debriefing Session – Point of Learning

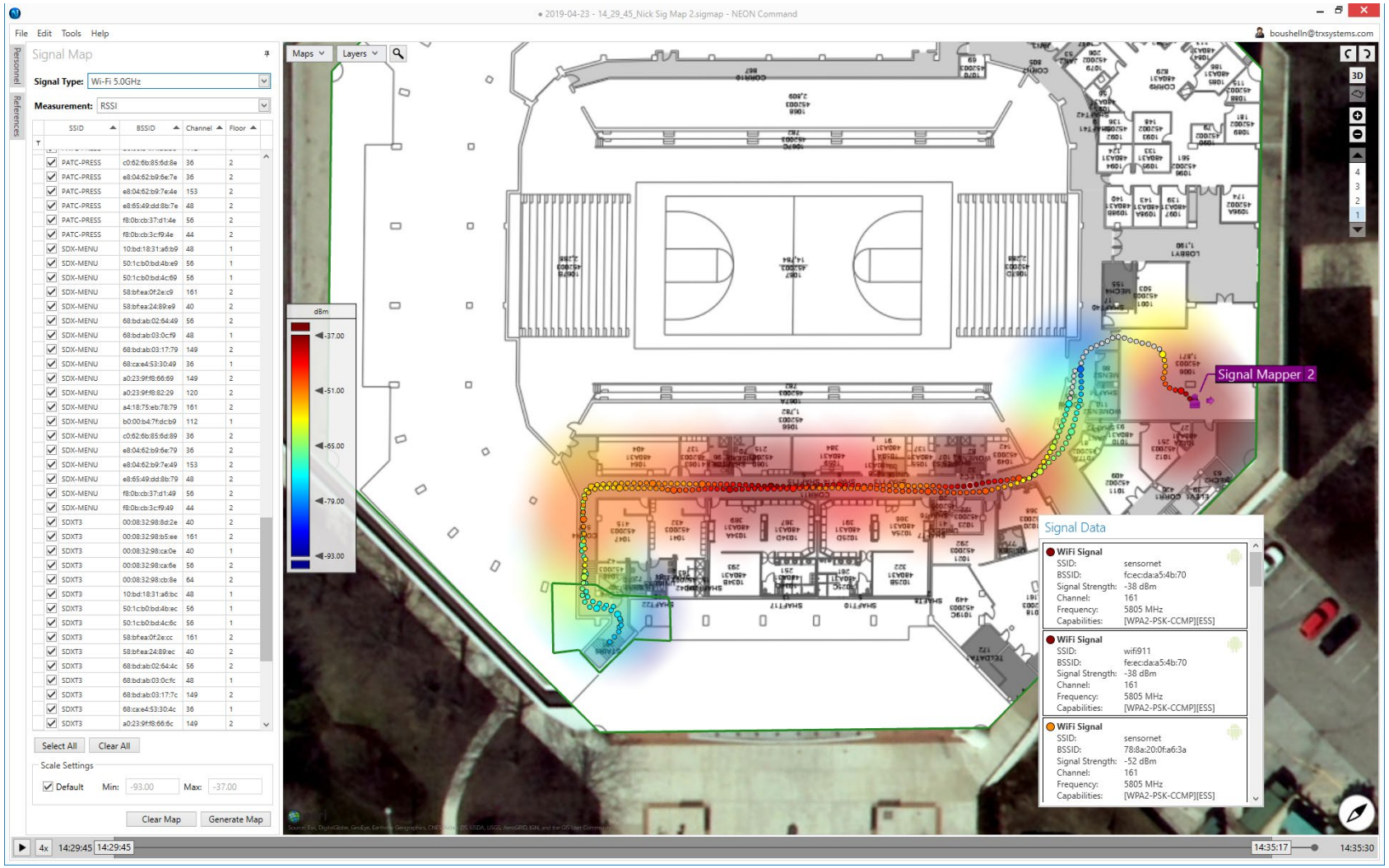
Engineering from First Responder Insights

Contextual Analysis - On-Site First Responder Interviews

- “Can we spatially see the configuration of personnel?”
- “Can we visualize tactics and how people are spread out?”
- “Are there clumps of officers congregating and not moving?”
- “First stop the killing, then stop the dying.”
- “How do we reduce time to treatment?”
- “Better facilitation of teamwork and systems.”
  - Positional timing
  - First on scene
  - How long to enter building
  - How is personnel spread out related to commands given
  - Etc.

Real-time Data Analysis of Team Behavior

- Location-based sensing – first responder in-building dynamic mapping



Courtesy of TRX Systems NEON Sensor Fusion and Dynamic Mapping for Location

Toward Integrated and Interoperable Data Streams

- Video, audio and radio communications capture, toward processing and analysis in near-real time

Courtesy of Mutualink Interoperability solution

Toward Data Stream Integration and Sensemaking

- Capture of location-based sensing, video/audio, radio communication
- Map the system initially to inform modeling/insights to inform event-based mining
- Temporally-based synchronization of data streams
- Modeling and visualization of first responder behavioral analytics for enhanced debrief
- Triangulation of data sources (e.g. human observer, sensor-based and video/audio data)
- Gathering insights that may provide impetus to move toward shared mental models to modify tactics?
- Inform labeling/event categorization – what can be machine-mined and what are human-in-the-loop processes?
- Upcoming design research iterative cycles
  - first responders reflect on their own (digitally-mediated) team behavior for enhanced learning, coordination and situation awareness – think aloud protocol
  - Examining individual and shared knowledge (e.g. mental models) as it develops through team interaction and reflection-on-action
  - provide input to help us optimally capture, label and integrate various streams of data to improve their learning, situational awareness and team coordination that matter to them?

Toward Interaction-based Team Cognition

- Human-Systems Integration
  - "…**patterns of interactions among entities of a sociotechnical system are meaningful** and can provide important indicators of a system state, such as **change in state and the characteristics of that state** (e.g. good performance, loss of situation awareness, poor coordination) (p.42)."
- Common-Operating Picture (COP)
  - "Coordinated perception occurs when team members **interact in order to assess and build a coherent picture of the situation** (p.40)."

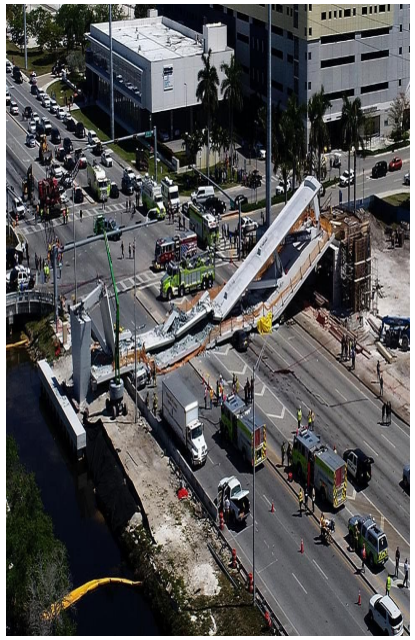
- Cooke & Gorman, 2009

- Interactive Team Cognition
  - …"team cognition is not a property of the individual, team members or the products produced by the team; **team cognition is the interactions of the team members**, and this assertion is counter to traditional approaches to studying team cognition (p.267).

  - "Thus, there is an overriding temporal component to team cognition because **team interactions unfold over time. It follows from this premise that team cognition is inherently dynamic**. Thus, computational and/or mathematical methods for **describing dynamic processes** provide the means for examining these principles of **changing coordination**….(p.268)"

- Cooke, Gorman, Myers & Duran, 2013

Engineering System - Multimodal Stream Analytics



Incident

Multimodal Sources

Social & Web Data Stream

911 Call Message Stream

Resource Sensor Stream

Streaming Data Collector

Sensor Location Collector

Incident Command System (ICS) Model

ICS model

Streaming Information & Behavior Mining

Team Coordination

What-Where-When Resource Analysis

Enhanced Situation Awareness

Experiential Learning

Personnel & Performance Management Analysis

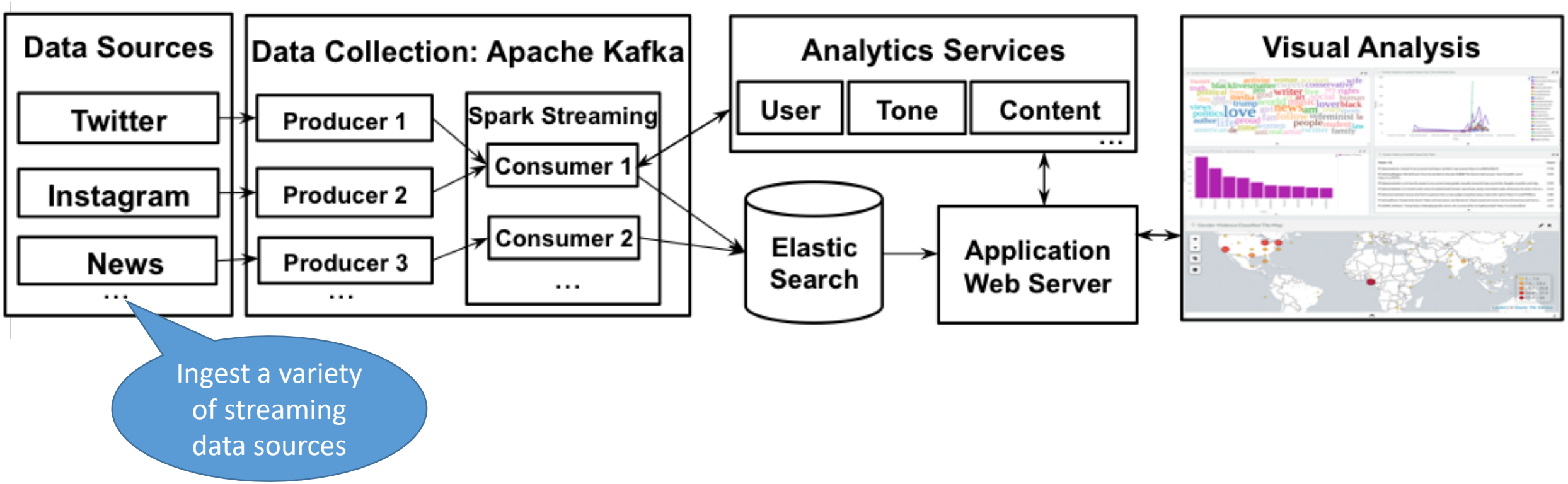
Visual Analytics along Operational Tasks

BACKGROUND KNOWLEDGE BASE

Organizational Process Knowledge, Socio-Psychological Theories, Open Gov Data, Mobile-behavioral Analytics APIs, Learning and Performance of First Responders and Medical Teams in Live Simulations

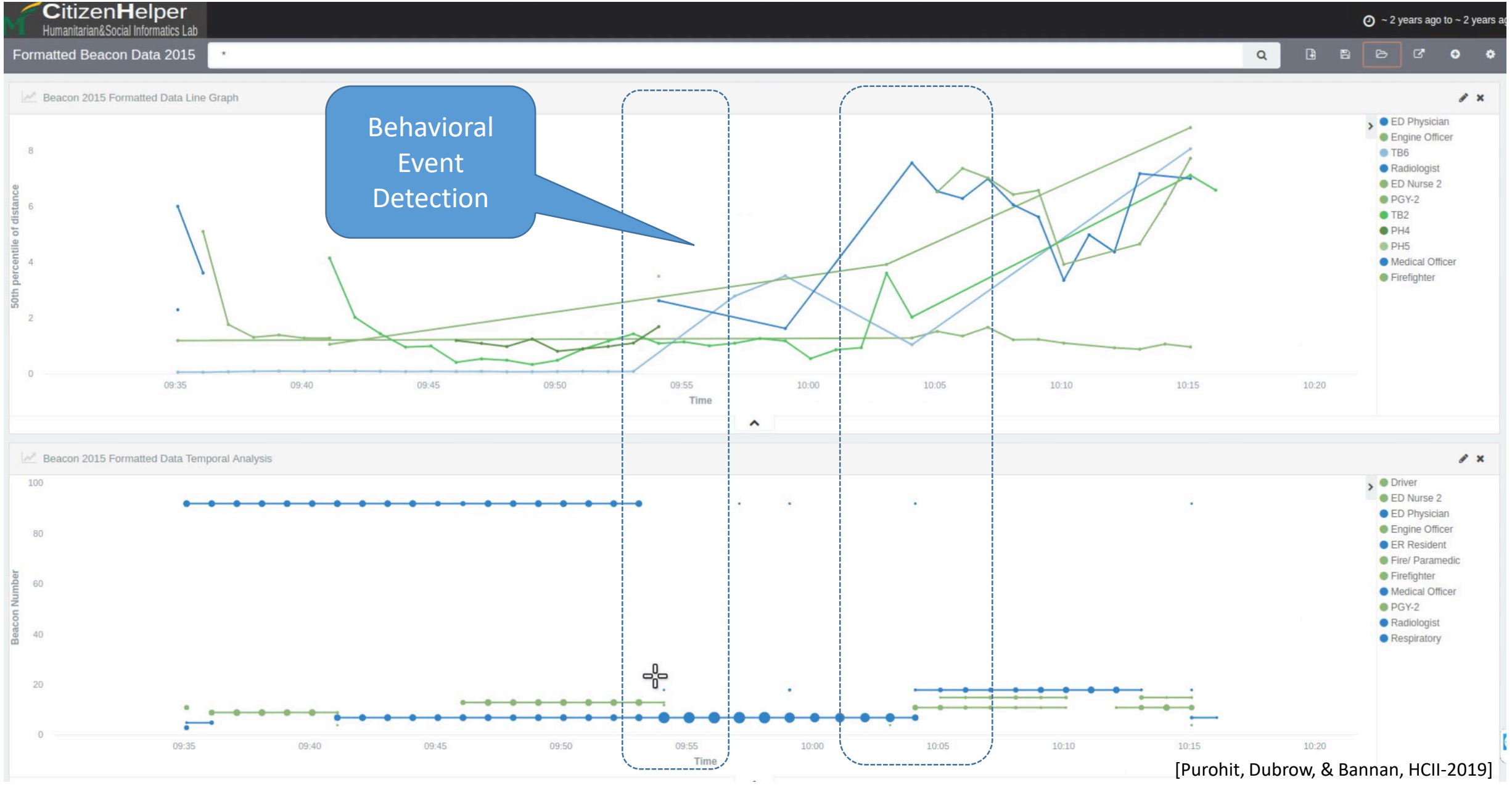
CitizenHelper System: Extensible Stream Processing Architecture

- Supports in-memory and web service-driven multimodal data processing



[Karuna, Rana, & Purohit (2017). CitizenHelper: A Streaming Analytics System to Mine Citizen and Web Data for Humanitarian Organizations. In The 11th International AAAI Conference on Web and Social Media]

CitizenHelper Prototype: IoT Sensor Analytics



[Purohit, Dubrow, & Bannan, HCII-2019]

Scene – Patient Handoffs

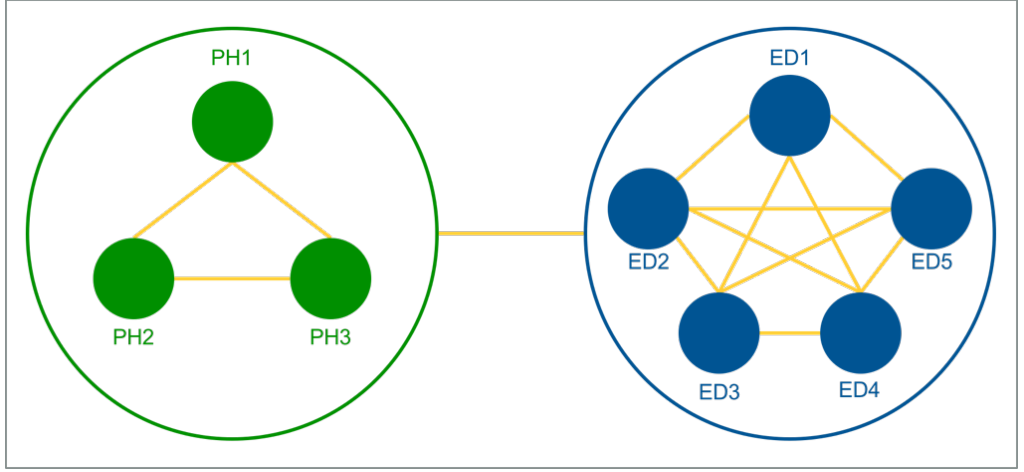


Figure 1. Healthcare MTS Example

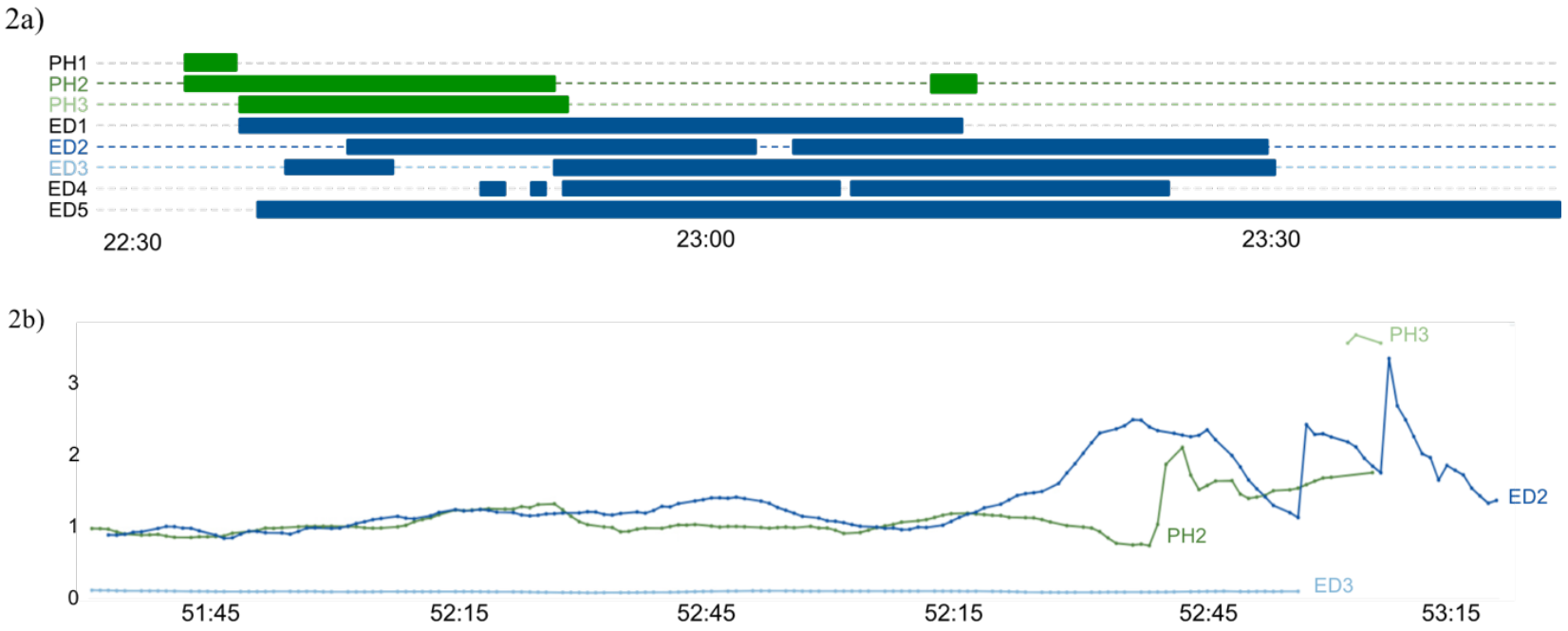


Figure 2. Timeline: MTS Member Physical Contact with and Proximity to Simulated Patient.

PH = Pre-Hospital Team (Green). ED = Emergency Department Team (Blue). PH1 = Paramedic. PH2 = Firefighter. PH3 = Driver. ED1 = Respiratory. ED2 = Radiology. ED3 = Surgery Junior Resident. ED4 = Surgery Senior Resident. ED5 = ED Doc.

Toward actionable Insights for First Responders

Table 1.1 Transformation from tradition-based fire fighting to Smart Fire Fighting.

Current State	Future State
Tradition-based tactics	Data-driven science-based tactics
Local information	Global information
Data-poor decision making	Information-rich decision making
Lack of awareness	Situational awareness
Untapped or unavailable data	Comprehensive data collection, analysis, and communication
Isolated equipment and building elements	Interconnected equipment and building monitoring, data, and control systems
Human operations	Human controlled, collaborative, and automated operations with inanimate objects (buildings, machines, etc.)

Source: https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1191.pdf

Toward Data-driven Science Insights

- Deeper dive into theoretical constructs informing data collection/analysis
  - Interactive team cognition/tactics

    ITC theory proposes that team cognition exists in the **dynamic flow of team member interaction**, and retrospective accounts
  - How to support reflection-on-action and transfer in a pro-active and offensive manner through live simulation training
  - To achieve the ultimate goal – improve performance to save lives
  - How teams work together as a system
  - Focus on explicitly revealing intrateam and interteam behavior
    - Toward shared mental models and improved coordination by the team
    - Learning as an MTS system – interdependent teams
    - Tacit knowledge and explicit knowledge – making the tacit explicit
    - Uncover patterns of behavior and communication
    - Analyze quality or totality of communication
    - Interaction among people, processes, components – in a socio-technical system

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Thank You!

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