Developing an Integrated Mission Simulation to Evaluate Technology Impact on Military Scenarios

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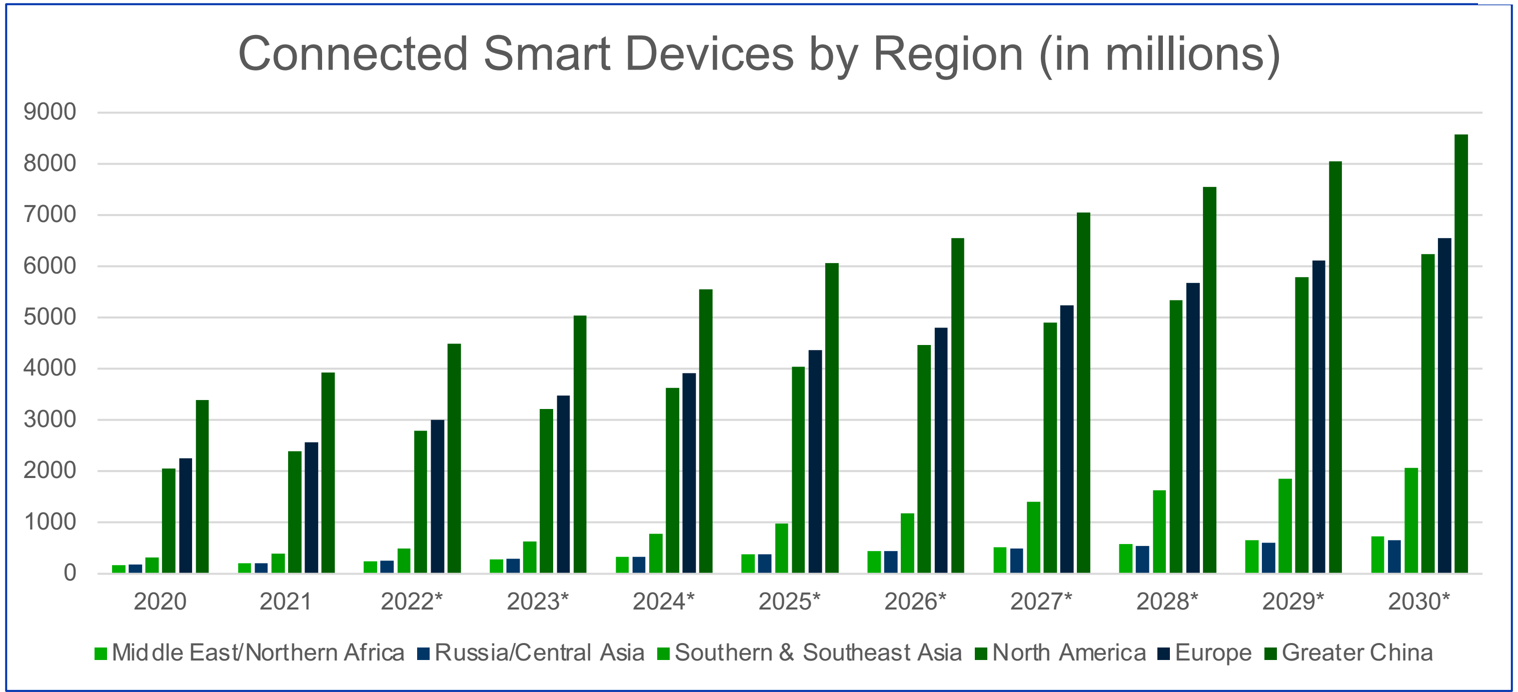
Outline

- Introduction
- Example Scenario 1: Istanbul Bombing 2022
- Example Scenario 2: Mumbai Bombing 2008
- Summary

Smart Devices in the Commercial Sector

Example Smart Devices



Connected devices compared to population (2022)

Middle East/N. Africa	0.35x
Russia/Central Asia	1.14x
Southern & Southeast Asia	0.2x
North America	4.82x
Europe	4.02x
Greater China	3.18x

* Denotes projected values

Smart Devices have and continue to experience rapid and widespread growth in the commercial sector

Effects of Smart Devices in the Battlefield: Strava Leak

- **In 2018, data from wearable fitness devices gives away locations of forward operating bases via routine running routes of U.S. and allied personnel in deployed locations.**

- **Because of instances like this, it is becoming increasingly important for the military to understand how a changing technological landscape will impact missions**

How do we use modeling and simulation to predict technology impact on missions?

Integrated Mission Simulation (IMS) Framework

Technology System Performance Data

- Device Capabilities
- Key Performance Parameters

Technology System Geographical Proliferation Data

- Number of Devices Available
- Geographical Density

Mission Context Models

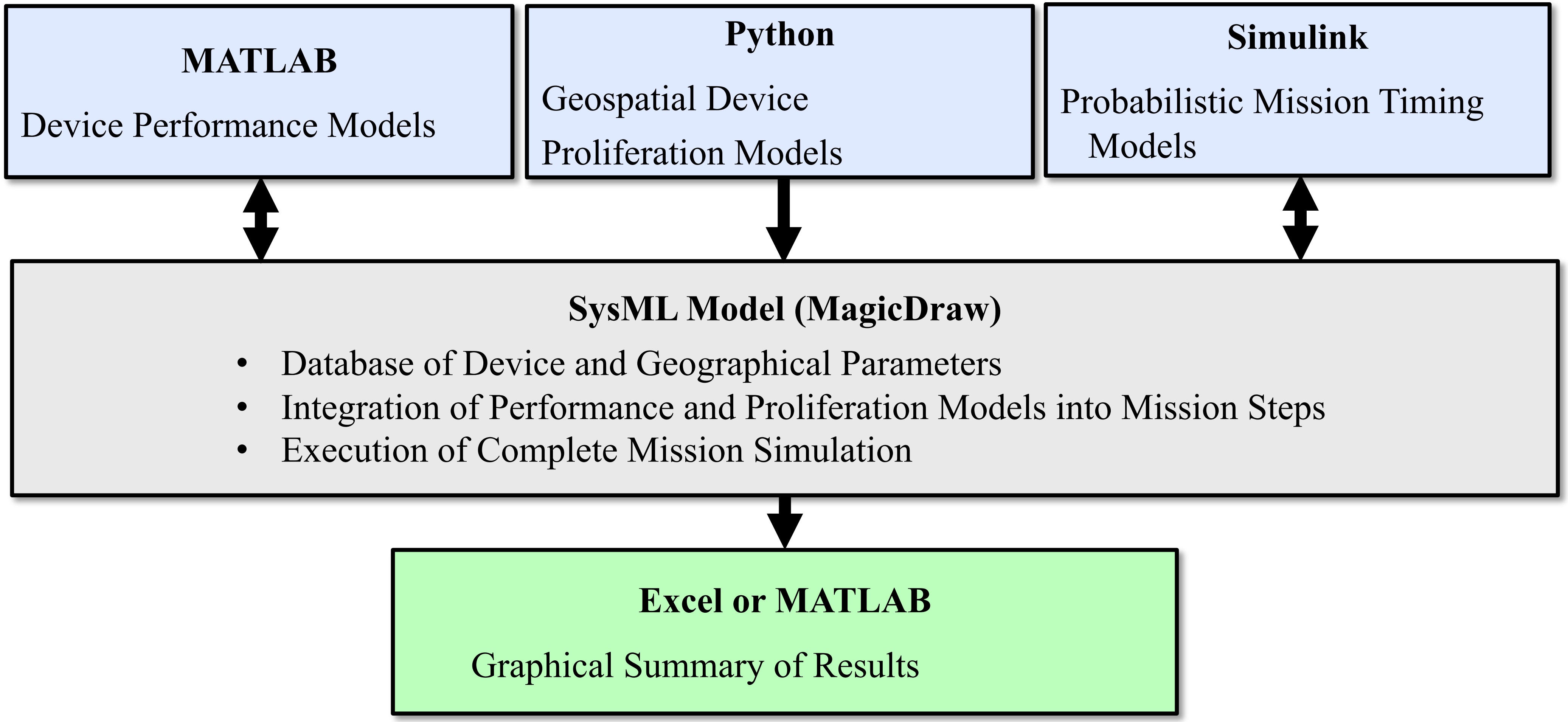
- Convert Device Performance and Proliferation Data into Action
- Convert Action into Simulated Mission

Technology Impact

- Impact on Key Mission Outcome Parameters
- Opportunities and Vulnerabilities

This generic, reusable framework enables users to analytically examine how devices that already exist in an area impact a mission

Implementation of the Integrated Mission Simulation Framework



Output from one model is automatically linked to the input of another model, allowing for a seamless, automated mission simulation

Rationale for Using SysML as the Hub of the IMS

Rationale		Benefits to User
• Reuse existing library elements to create and simulate different mission scenarios	→	• No need to create a new model for each mission
• Link together mission steps, actors, and external models which simulate each mission steps	→	• Enables better understanding of which variables have an impact on which parties at which stage of the mission
• Captures and links key mission success criteria to the final simulation outputs	→	• Easily visualize if the result of the mission simulation meets the success criteria

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Example Scenario 1: 2022 Istanbul Bombing

Mission Objective: identify, track and capture the suspect of a bombing in Istanbul

Use of Cameras in Real Scenario

- ~1200 cameras used to determine the suspect's ID and escape route

Mission Outcome: Success

- Suspect found and captured ~24 hrs after the bombing

Preliminary Analysis

- Use camera area covered as proxy for probability of detection

Camera Performance and Proliferation Parameters

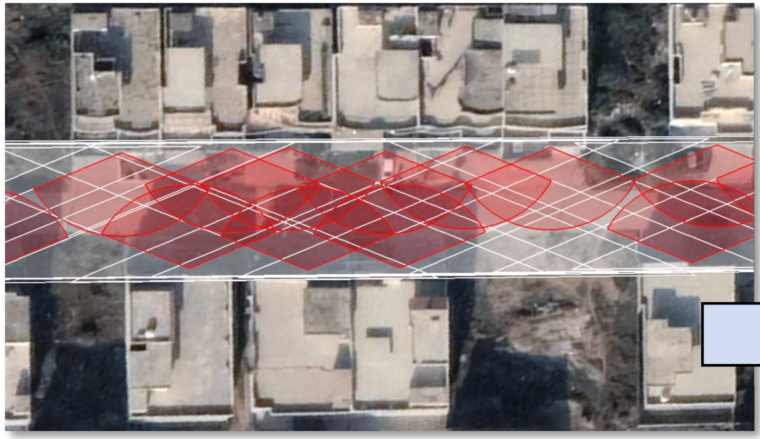
1. 2k resolution cameras, low proliferation rate
2. 4k and 8k cameras, low proliferation rate
3. 2k resolution cameras, higher proliferation rates

With higher resolution cameras (performance) and better camera coverage (proliferation), could suspect capture time be shortened?

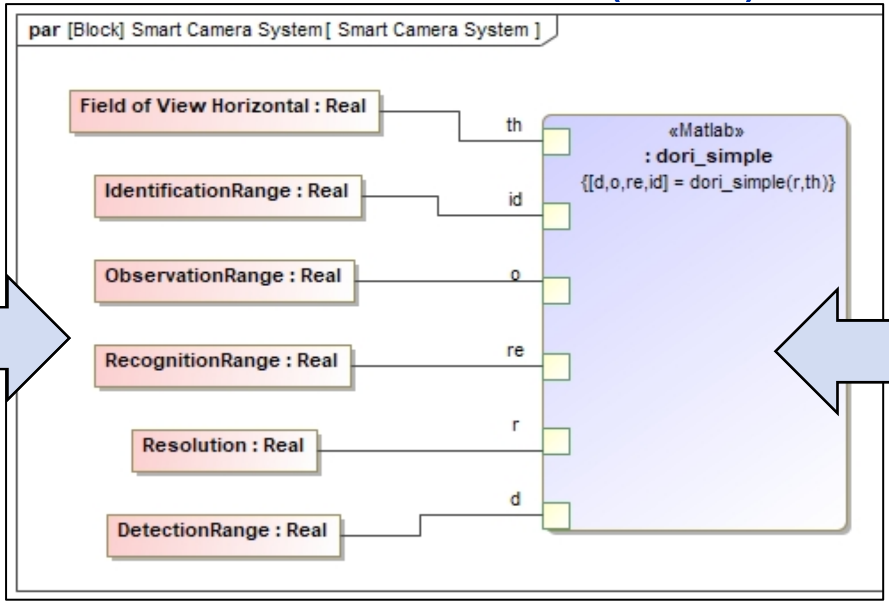
Sources: https://www.cnn.com/2022/11/14/world/istanbul-turkey-attack-suspect-syria-intl/index.html

Overview of IMS for Istanbul Bombing

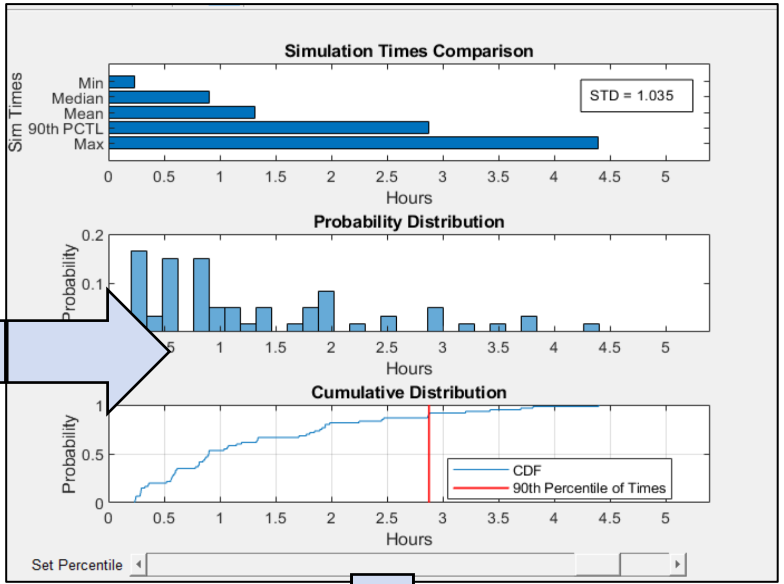
Camera Performance and Proliferation Models (MATLAB and Python)



Mission Context Model (MBSE)



Probabilistic Timing Model (Simulink)



Library of Camera Parameters (MBSE)

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Simulation Results (MBSE, then exported to Excel)

#	Name	percentroadcoverage : Real	GatherIntelligenceTime : Real
1	Istanbul 2k	0.0162	19.4207
2	Istanbul 4k	0.0649	4.9382
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- Denotes reusable elements

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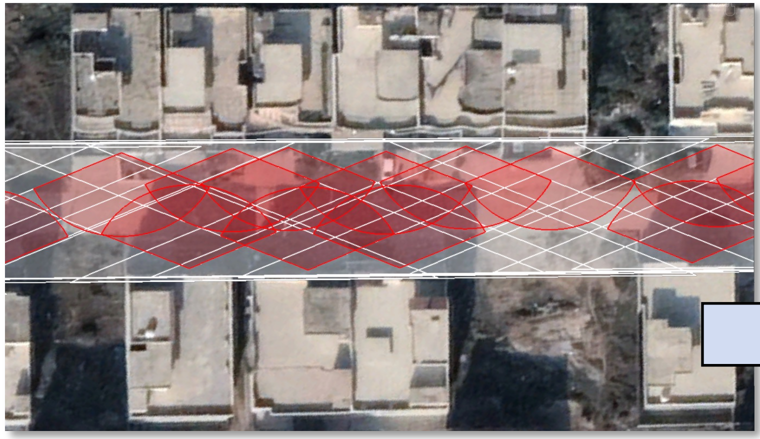

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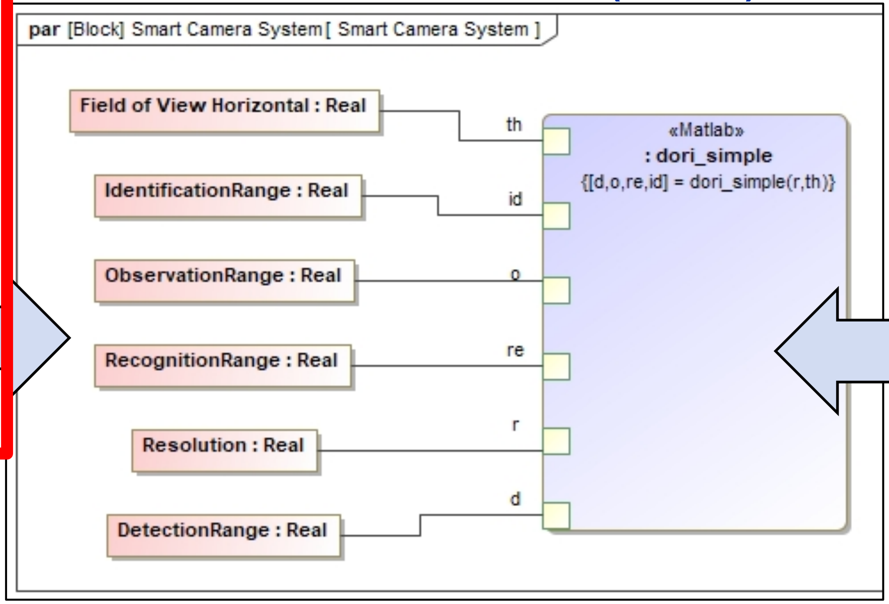

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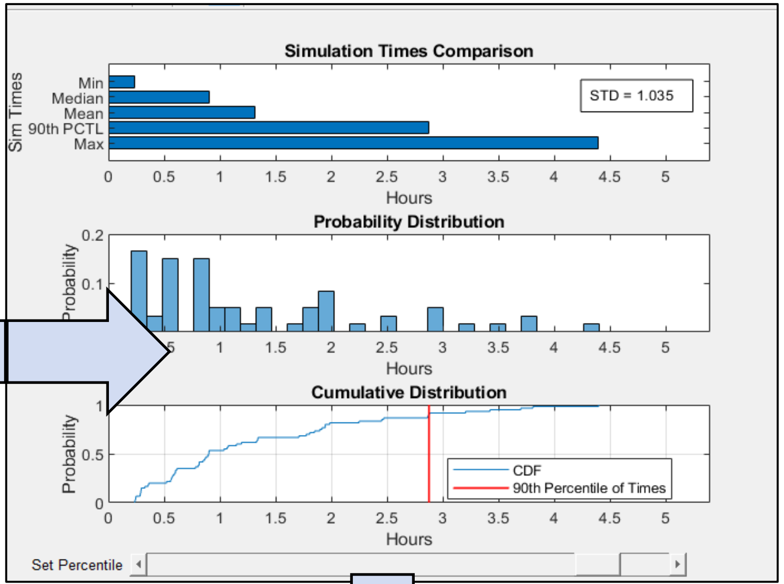

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Camera Performance: The DORI Standard

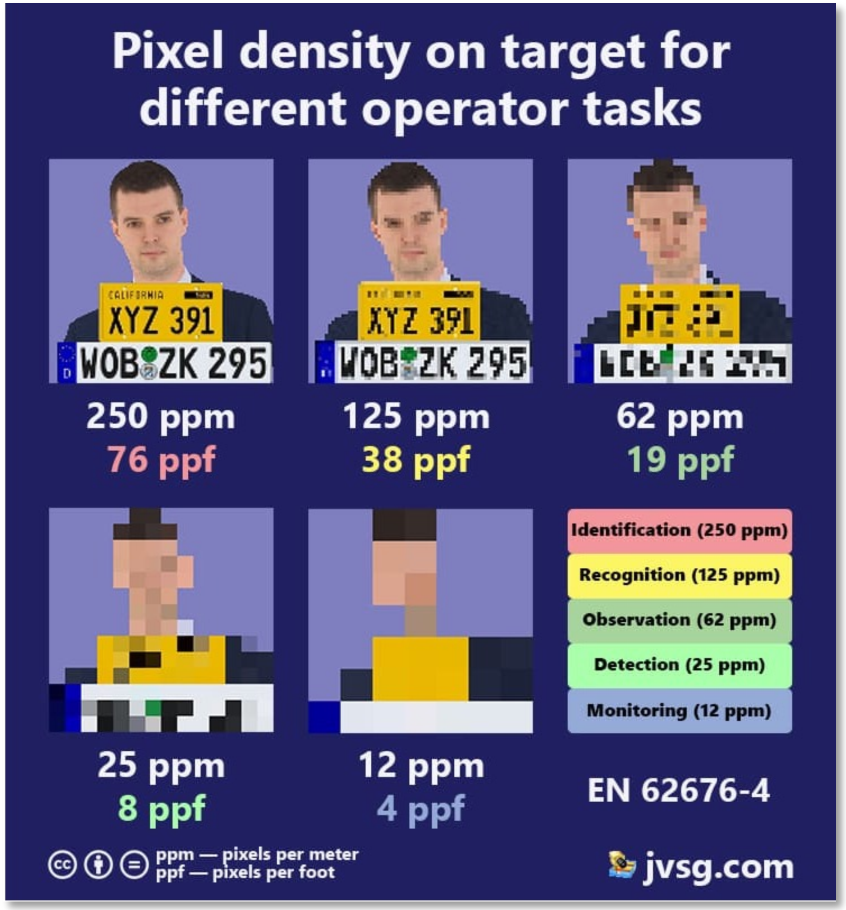
Detect — **O**bserve — **R**ecognize — **I**dentify

Background

- **Defines security-related functions performed by humans with imagery**
- **Specifies minimum *pixel density* required for each task**
  - **Pixel density: pixels per unit length (foot, meter, etc.) on a subject**
- **International standard captured in IEC Document 62676-4:2015**
- **Widely adopted by video security and surveillance firms**

Four Primary Functions

- **Detection (8 ppf):** notice a subject's presence
- **Observation (19 ppf):** notice characteristics of subject, such as distinctive clothing
- **Recognition (38 ppf):** recognize already-known subject (e.g., a familiar person)
- **Identification (76 ppf):** identify subject beyond a reasonable doubt



The DORI Standards enables translation of camera performance into mission-supporting functionality.

- **IEC:** International Electrotechnical Commission
- **ppf:** pixels per foot

Source: https://www.jvsg.com/pixel-density/

Camera Performance: The DORI Standard

Maximum Distance for Each Function

- **For a given camera, each DORI function will have a maximum distance (D) and an area covered (A)**
- **Determined by three parameters:**
  - **Camera resolution (r, pixels)**
  - **Camera field of view (θ, angle)**
  - **Required pixel density (p, pixels per unit length)**

Camera resolution

Function's maximum distance → $$D = \frac{r}{p \cdot \theta}$$

Required pixel density

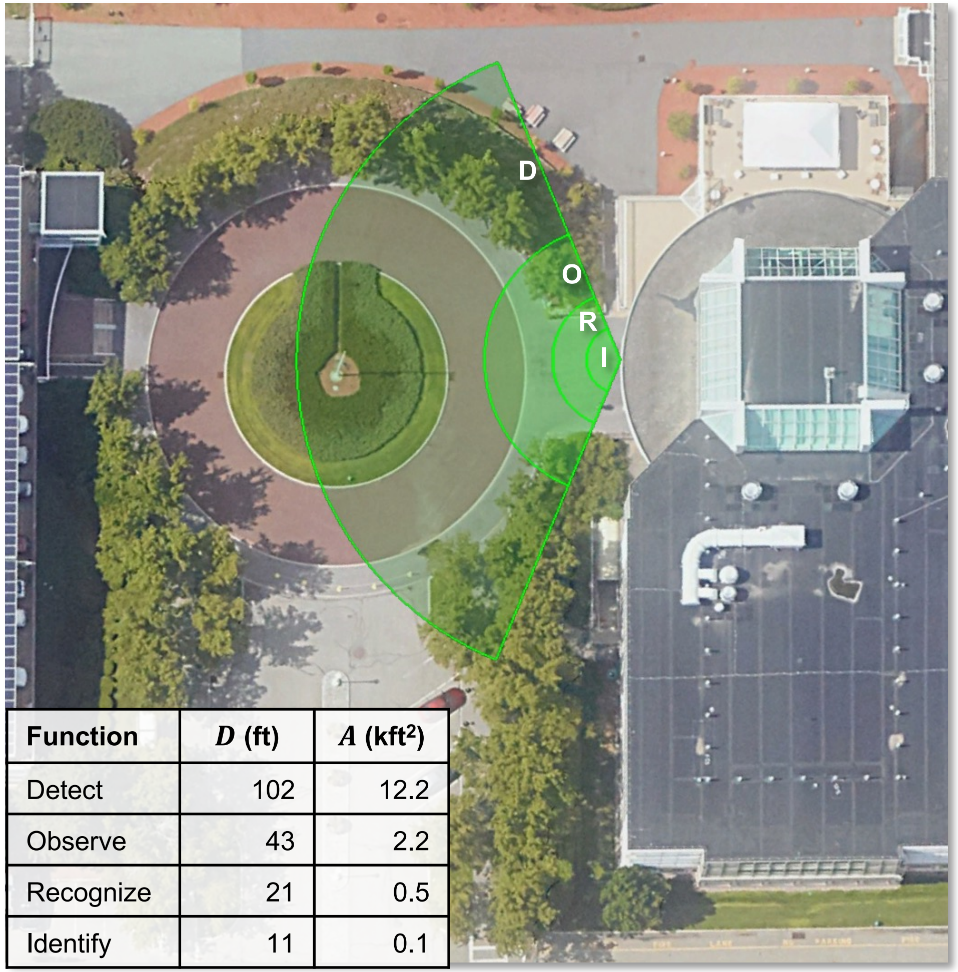
Camera FOV (radians)

Camera FOV (radians)

$$A = \frac{1}{2}\theta D^2$$

Function's area covered

Function's maximum distance



Function	D (ft)	A (kft^2)
Detect	102	12.2
Observe	43	2.2
Recognize	21	0.5
Identify	11	0.1

DORI extents and areas of coverage for camera with 1920 pixels horizontal resolution and 135 deg field of view

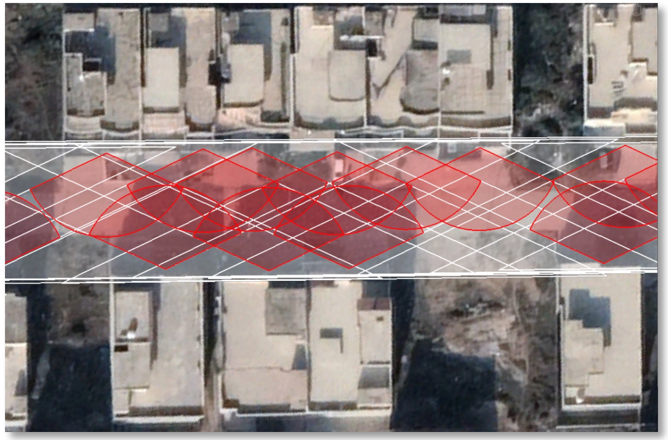
DORI: Detect, Observe, Recognize, Identify

Effects of Camera Performance and Proliferation

- White region: camera field of view
- Red region: facial recognition zone

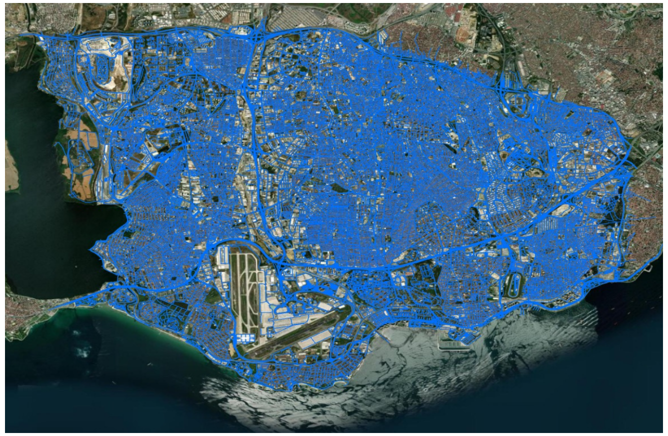
Proliferation rate of cameras as well as camera performance influences probability of detection

Camera Proliferation Model



Max Coverage Example

Real World Street: 30ft wide



City Scale Road Area: 567,669,700 ft^2

Percent Road Area Covered With Video Capture= $\frac{\text{NumberCameras} * \text{CameraCoverage Area}}{\text{Road Area for AOI}}$

Number of Cameras = Number of Buildings * Proliferation Rate

CameraCoverageArea = $\frac{FOV}{360}(\pi DetectionDistance^2)$

Example: Percent of roads in Istanbul with a 10% camera proliferation rate

Variables For Video Detection:

- Number of Buildings = 80,644
- Proliferation Rate = 10%
- FOV = 145
- Detection Distance = 30ft
- Road Area = 567,599,700ft^2

Percent Road Area Covered With Cameras = $\frac{(80{,}644 \ * \ 0.10) * \frac{145}{360}(\pi 30^2)}{567{,}599{,}700}$ = 1.6%

Python and OpenStreetMaps Data enables the creation of a camera proliferation model

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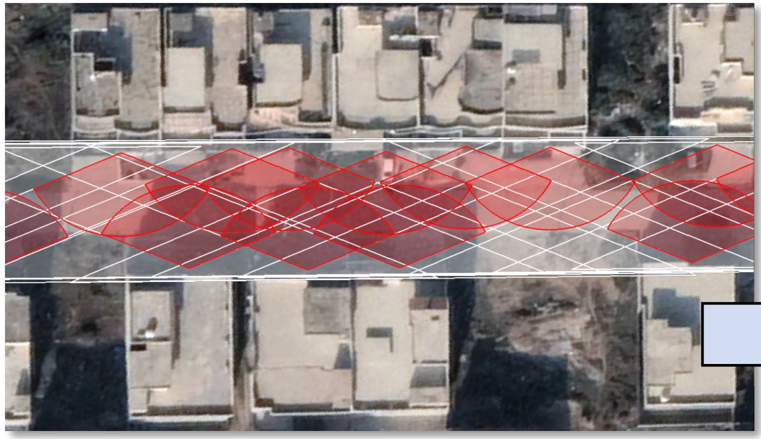

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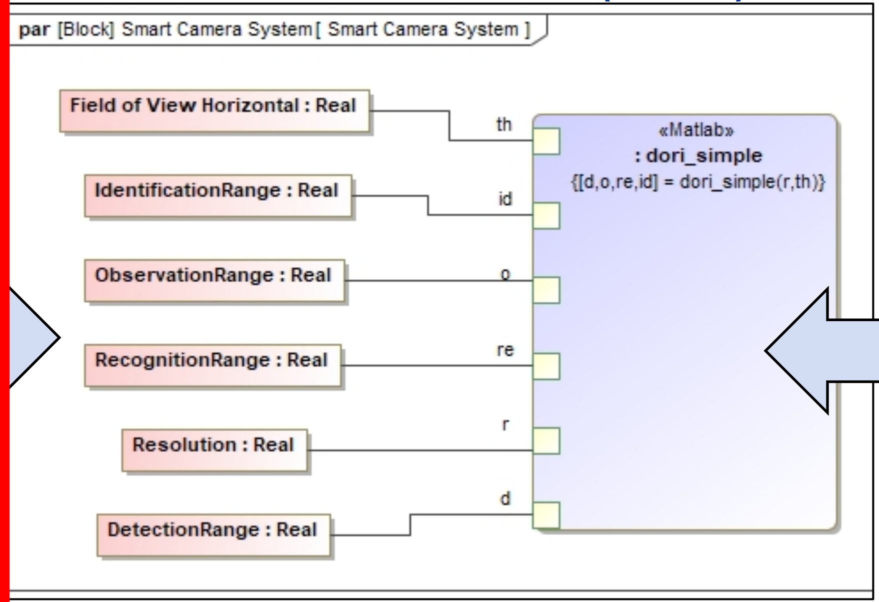

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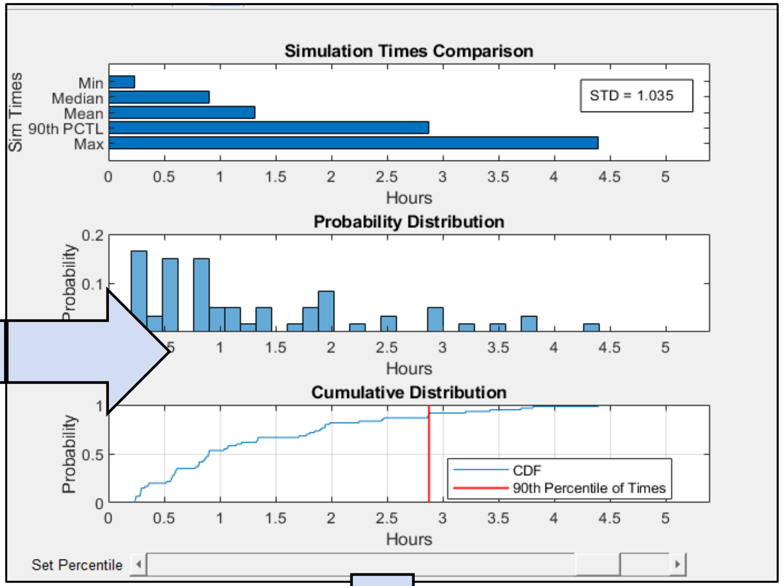

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Mission Context Model: Instance Library

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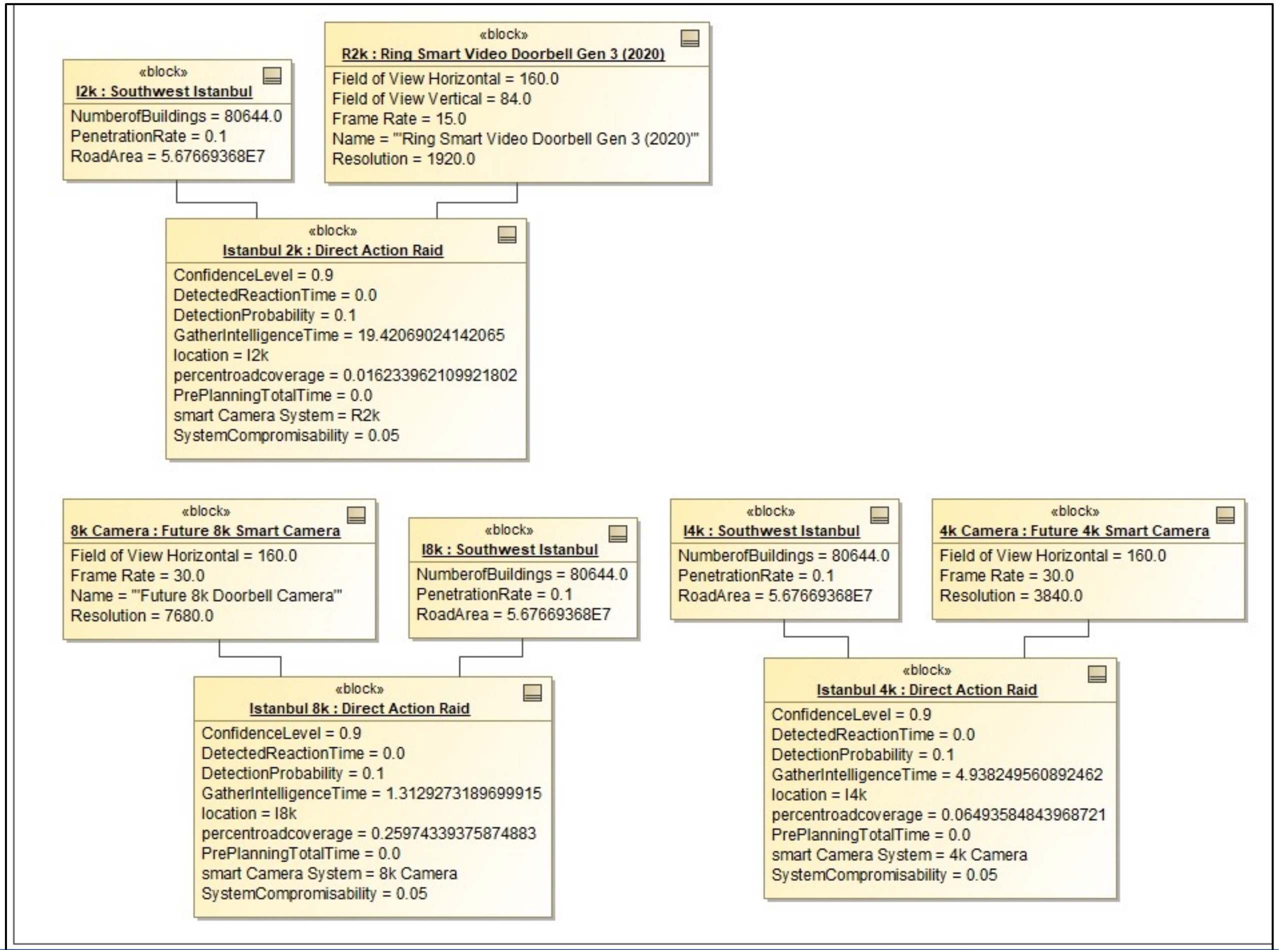
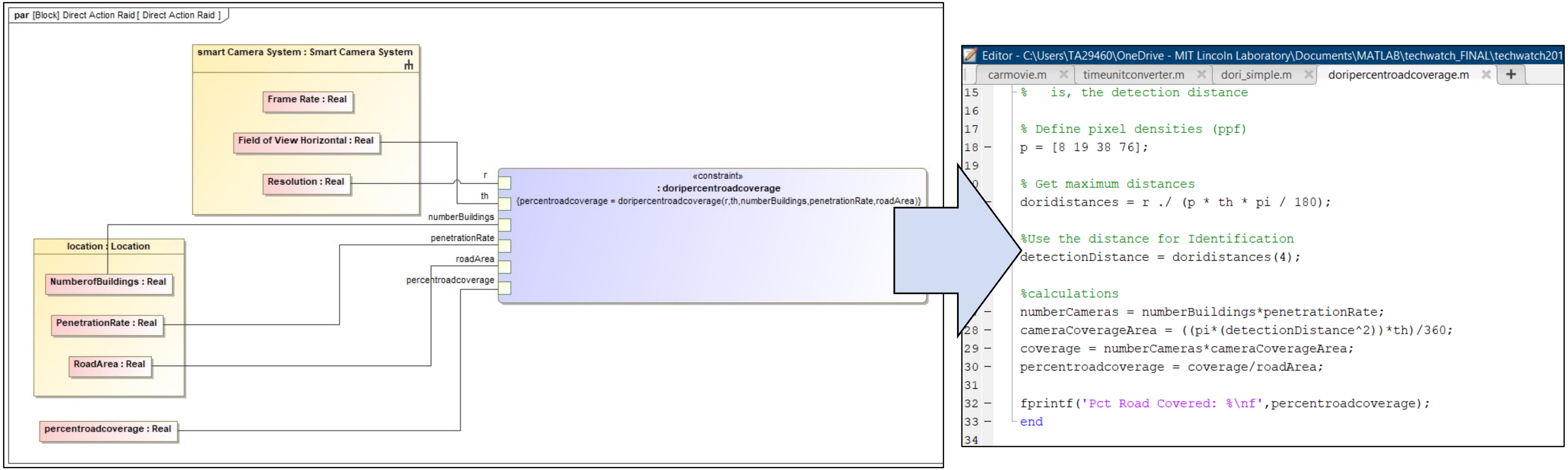


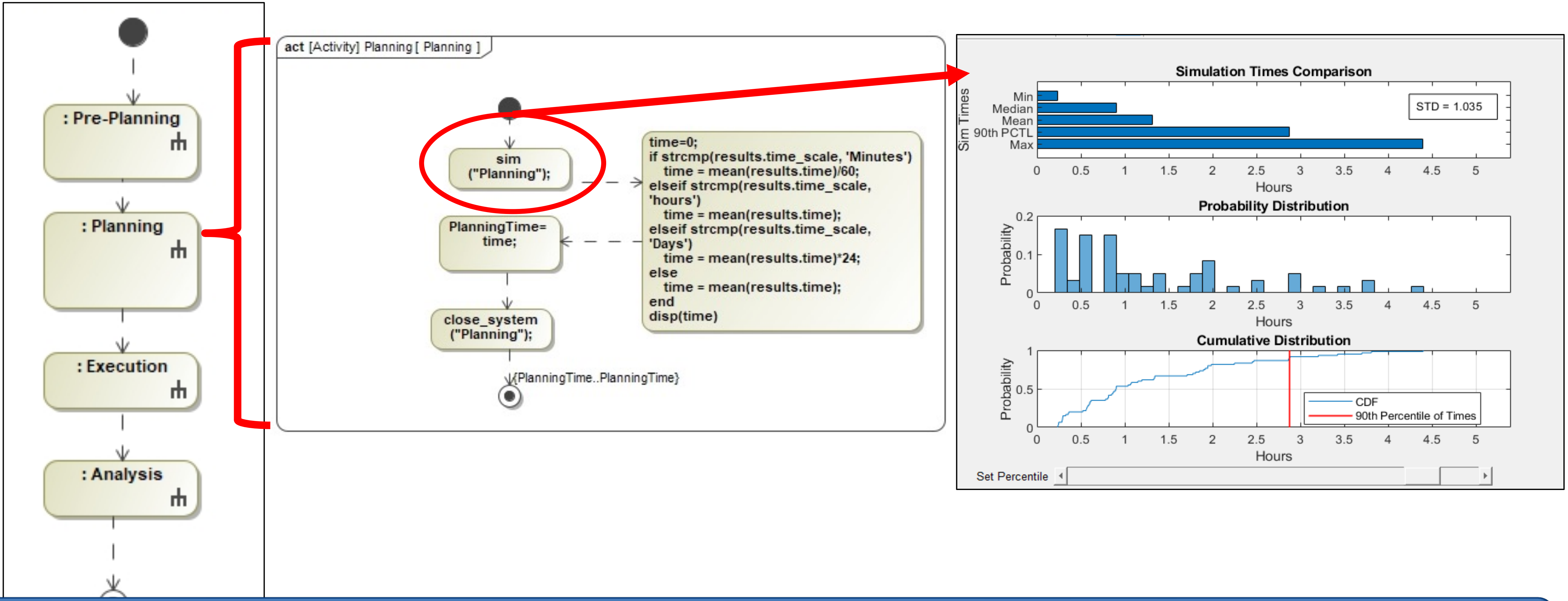
Instance Library enables users to easily define the cameras and the city to be used in the simulation, and to reuse the data for other missions

Mission Context Model: Parametric Diagram and MATLAB



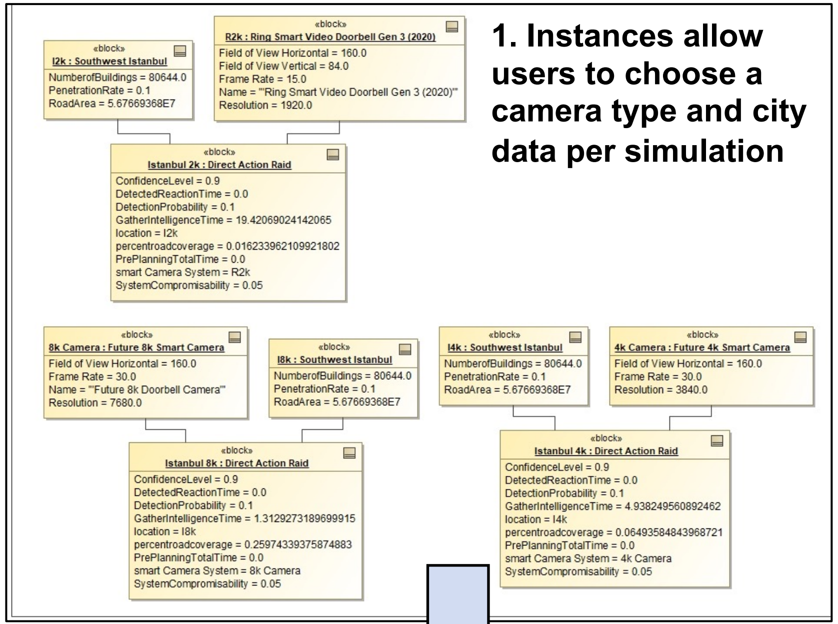
Upon execution, parameters specified from the Instances are automatically inputted into a Parametric Diagram, which then calls MATLAB to calculate percent road covered

Mission Context Model: Activity Diagrams and Simulink

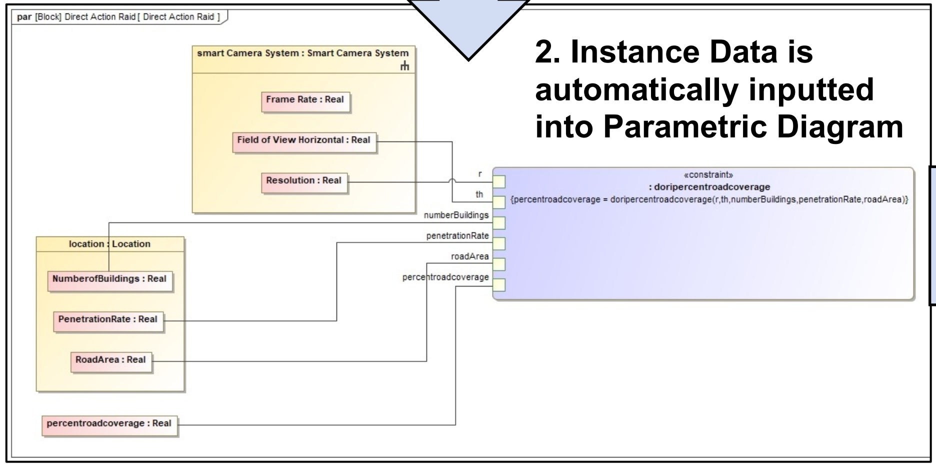


Activity Diagrams define the sequence of events for the scenario, and the connected Simulink model calculates the probabilistic timing for each step

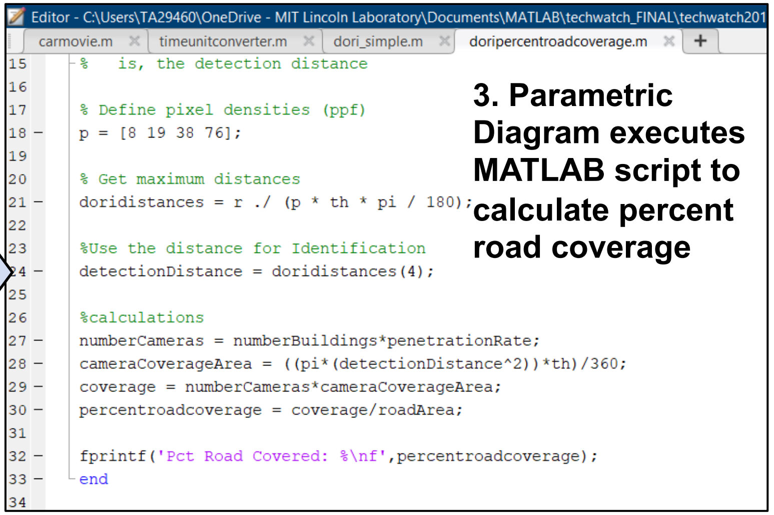
Summary of the Mission Context Model



1. Instances allow users to choose a camera type and city data per simulation

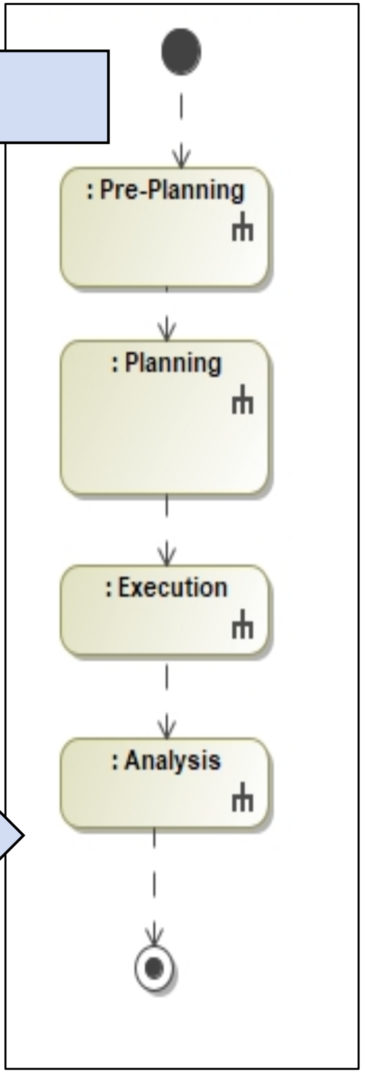


2. Instance Data is automatically inputted into Parametric Diagram



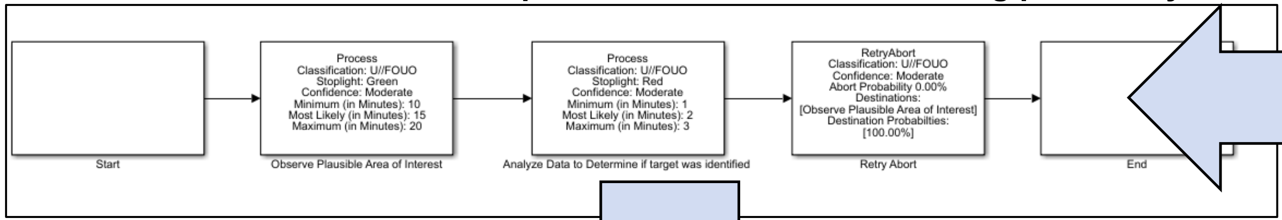

```
%   is, the detection distance

% Define pixel densities (ppf)
p = [8 19 38 76];

% Get maximum distances
doridistances = r ./ (p * th * pi / 180);

%Use the distance for Identification
detectionDistance = doridistances(4);

%calculations
numberCameras = numberBuildings*penetrationRate;
cameraCoverageArea = ((pi*(detectionDistance^2))*th)/360;
coverage = numberCameras*cameraCoverageArea;
percentroadcoverage = coverage/roadArea;

fprintf('Pct Road Covered: %\nf',percentroadcoverage);
end
```

3. Parametric Diagram executes MATLAB script to calculate percent road coverage



4. Activity Diagram executes scenario

5. Simulink model runs over multiple iterations to calculate timing probability



6. Timing data is input back into MBSE to finish the simulation and summarize results

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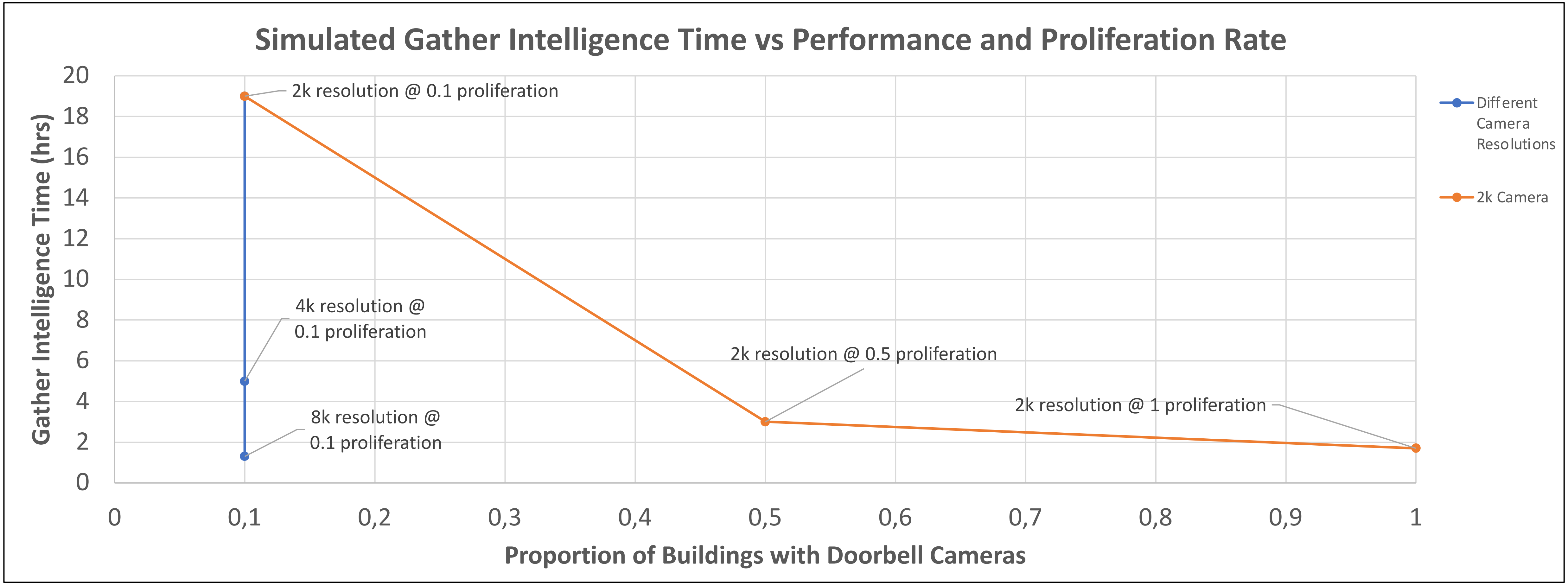
Simulation Results



Increased camera proliferation had similar effects on intelligence gathering as improved performance

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- Example Scenario 2: Mumbai Bombing 2008
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Example Scenario 2: 2008 Siege of Taj Mahal Hotel in Mumbai

Mission Objective: To capture the terrorists involved in laying siege to the Taj Hotel in Mumbai

Mission Details

- After arriving by boat, the terrorists **drove through the city** and attacked several locations, the Taj Mahal Hotel being one of them
- Once at the hotel, the terrorists **walked the halls with the intent of killing as many people as possible**, and **constantly moved** in order to confuse and delay any government forces
- It took **four hours for special government forces to arrive** and respond to the attack. In the meantime, civilians and under-trained local forces were left to address the attack themselves

Mission Outcome

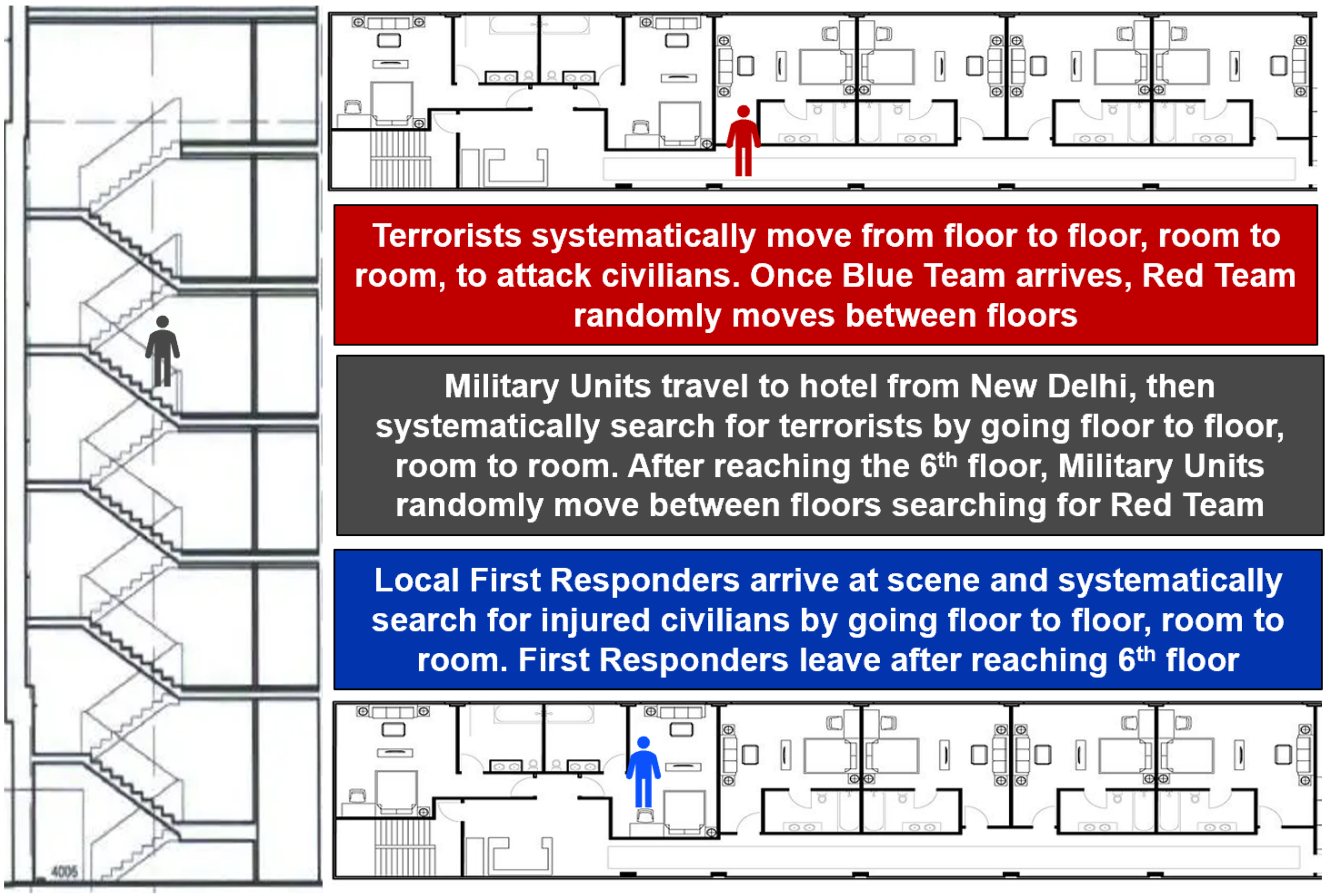
- After 60 hours, the two terrorists laying siege to the hotel were finally captured

If this scenario took place in a hotel filled with smart devices, could access to those devices impact scenario timing and casualties?

Sources: https://www.rand.org/content/dam/rand/pubs/occasional_papers/2009/RAND_OP249.pdf

Key Modeling Differences Between Scenarios 1 and 2

- **Examining the impact different sensor and actuator technologies has on the mission**
- **Modeling the actions of three different actors:**
  - **Terrorists**
  - **Military Units**
  - **Local First Responders**
- **Integrating two different mathematical models into the mission context:**
  - **Movement Model**
  - **Casualty Model**
- **Tracking two different outcome variables**
  - **Active Threat Time**
  - **Number of Civilian Casualties**



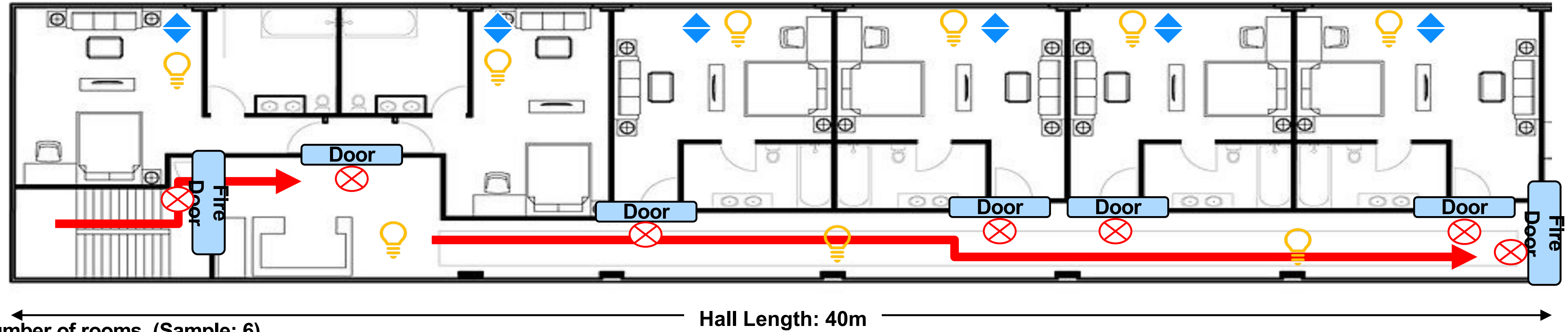
Conceptual Impact of Smart Devices on Simulated Mission

Device	Role	Impact on Scenario
Smart Hotel Door Locks	Enable/Disable access to civilians	Active Threat Time, Civilian Casualties
Room Occupancy Sensors	Enable knowledge of civilian location	Active Threat Time, Civilian Casualties
Indoor Security Cameras	Enable location knowledge	Active Threat Time
Smart Lights	Slow down speed of movement throughout building	Active Threat Time
Civilian Wearable Devices	Enable knowledge of who is injured and where	Civilian Casualties

- **Sensor Technology**
- **Actuator Technology**

Hotel Single Floor Movement Model: Room Occupancy Unknown

- To attack as many civilians as possible, the terrorists would need to walk to a guest room, breach the door, conduct an attack if there were civilians in the room, and move on to the next room on the same floor
- Same model can be applied to military units looking for the terrorists, and first responders looking for injured civilians

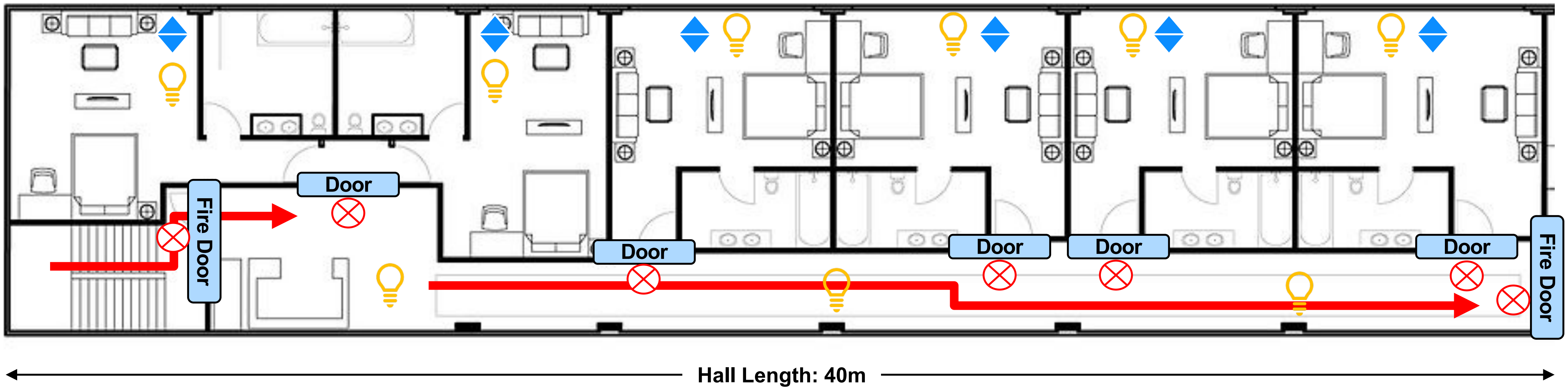


- R = number of rooms (Sample: 6)
- O = % rooms to enter: Informed by *IoT occupancy sensor access*
- B = Breach door time: Dictated by *IoT door lock access*
- S = Movement speed: Dictated by *IoT light control access*
- P = people per room (Sample: 2)
- L = hallway length (Sample: 40m)
- K = room action time (Sample: 30 seconds)

Time to enter each room and perform action $= (R * B) + (R * O) * K + \left(\frac{L}{S}\right)$

Hotel Single Floor Movement Model: Room Occupancy Known

- **If the room occupancy is known, then the terrorists, military units and first responders will not waste time entering a room that is unoccupied**



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Time to enter each room and perform action = $(R * O) * (B + K) + \left(\frac{L}{S}\right)$

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Attacked Civilians and Casualty Model

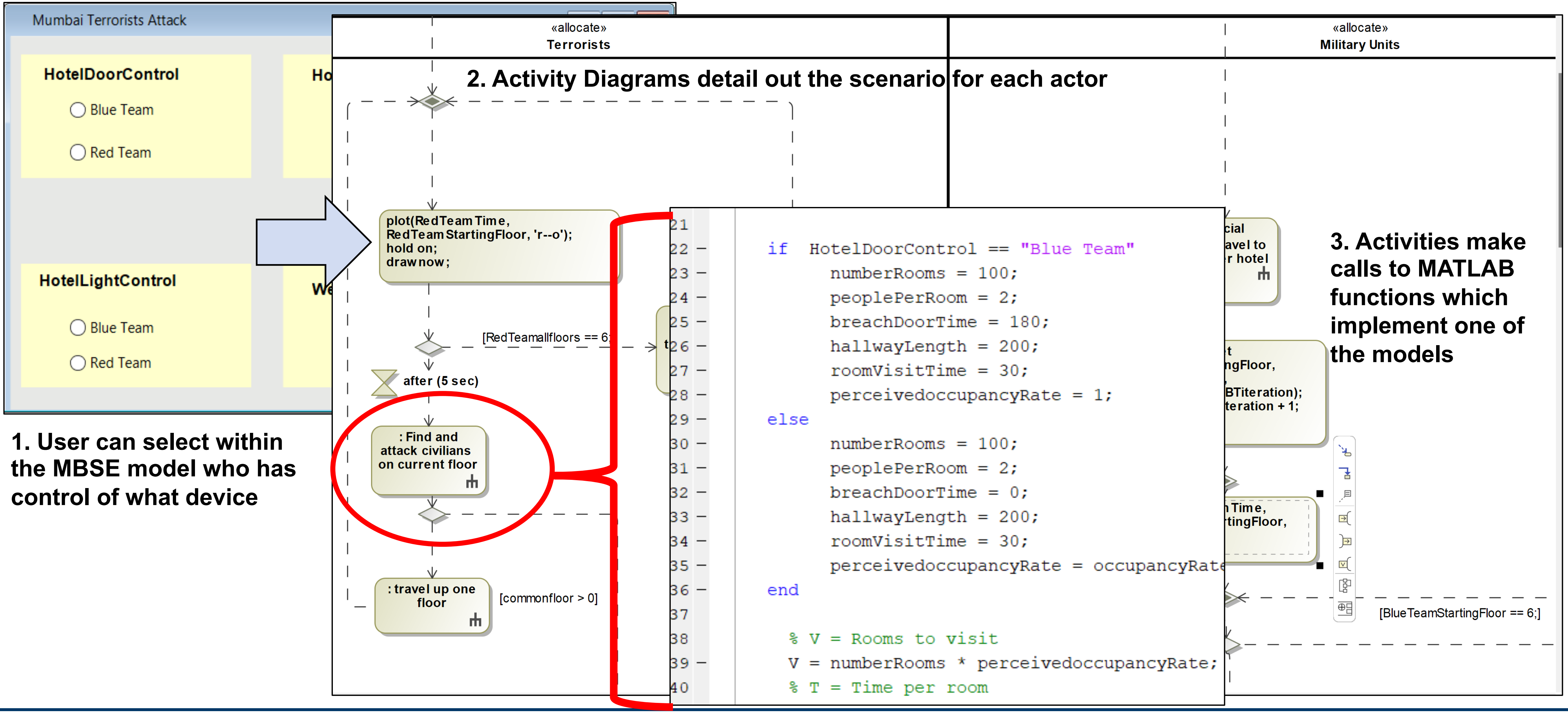
- **Injured civilians have ~30 min until the chance of mortality significantly increases**
- **Single Floor Movement Model can be used to calculate when First Responders arrive**

	Number of Civilians Attacked per Floor	**Time until casualty**
Room Occupancy Unknown	$C = \left(\frac{T - \frac{L}{S}}{B + (O * K)}\right) * O * P$	$(R * B) + (R * O) * K + \left(\frac{L}{S}\right) < 30$
Room Occupancy Known	$C = \left(\frac{T - \frac{L}{S}}{(B + K)}\right) * P$	$(R * O) * (B + K) + \left(\frac{L}{S}\right) < 30$

- **R = number of rooms**
- **O = % rooms to enter: Informed by *Wearable Device***
- **B = Breach door time: Dictated by *IoT door lock access***
- **S = Movement speed: Dictated by *IoT light control access***
- **P = people per room**
- **L = hallway length**
- **K = triage time**
- **C = Number of Civilians**

Source: https://litfl.com/trauma-mortality-and-the-golden-hour/

Integrated Mission Simulation for Mumbai Bombing Scenario



2. Activity Diagrams detail out the scenario for each actor

1. User can select within the MBSE model who has control of what device

3. Activities make calls to MATLAB functions which implement one of the models

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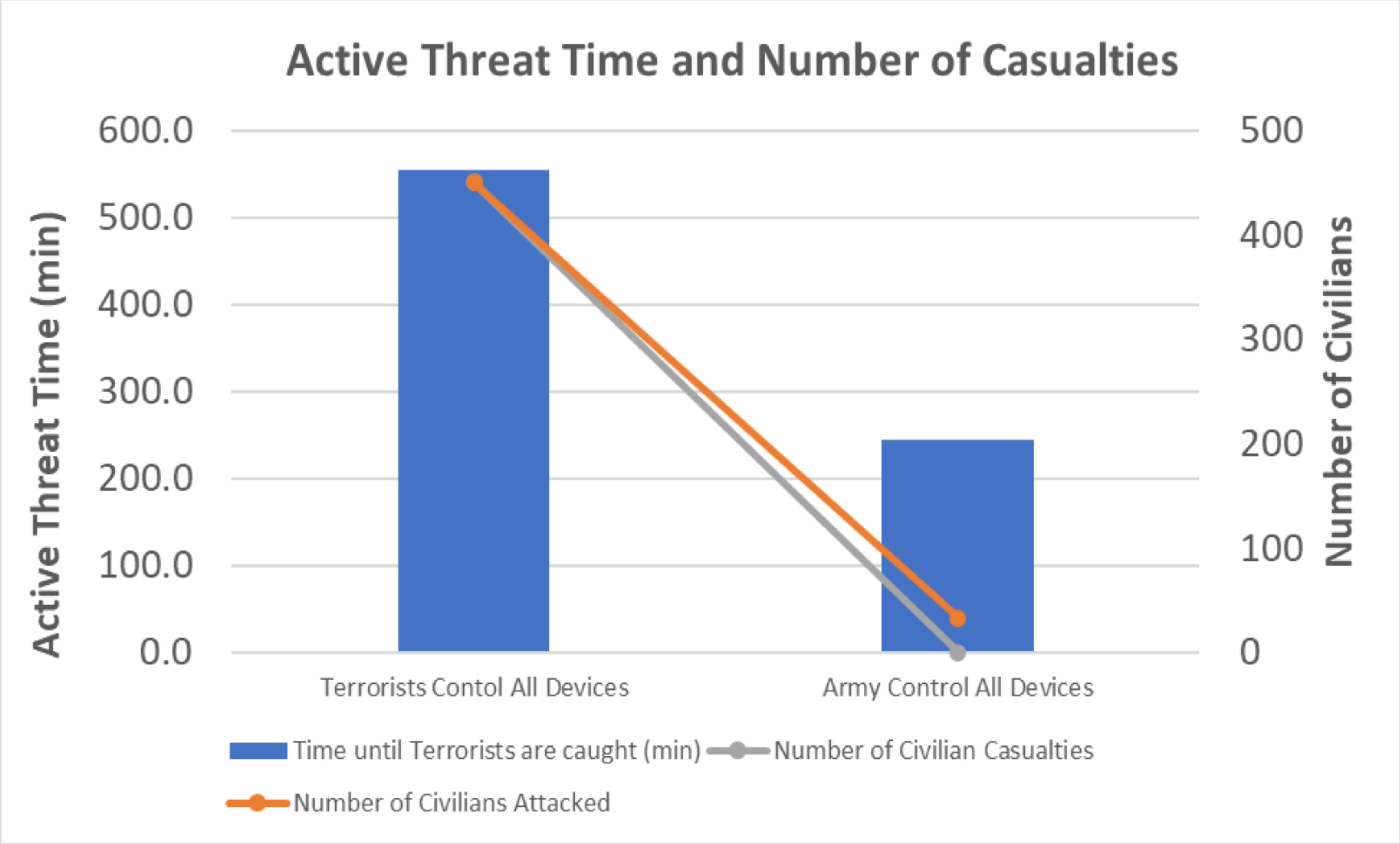
Simulation Results

- ~ 46% difference in active threat time between if the terrorists' or the military control all devices
- ~13x increase in casualties if terrorists control all devices instead of the military
- Wearable devices have impact on the number of casualties, but only if local first responders have access to smart door locks and occupancy sensors.



Outline

- Introduction
- Example Scenario 1: Istanbul Bombing 2022
- Example Scenario 2: Mumbai Bombing 2008
- Summary

Summary

- **Becoming critical for the military to understand how changing technology landscape will impact missions**

- **Demonstrated an Integrated Mission Simulation to understand impact by simulating different what-if scenarios for a mission**