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Name of Principal Author and all other author(s):

Brock Webb

Principal Author's Organization and address:

5695 King Centre Drive
Suite 300
Kingstowne, VA 22315

Phone: 703-924-3050 x5126
Fax: 703-924-3070
Email: Brock.Webb@cubic.com
brockwebb@cox.net

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BIOLOGICAL DEFENSE:

EVALUATING SENSOR ARRAY QUANTITY AND QUALITY VERSUS DETECTION CAPABILITY

Brock Webb
Cubic Defense Applications
brockwebb@cox.net

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CUBIC DEFENSE APPLICATIONS

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AGENDA

- Part 1 Background
- Part 2 Design of Experiment
- Part 3 Data Analysis
- Part 4 Results & Conclusions
- Part 5 Questions

PART 1 BACKGROUND

- Project History
- Project Objectives
- Basic Definitions

Project History

- Began as a project for SYST 798 at GMU
  - Investigating quality versus detection capability of different sensor arrays using a fixed number of sensors to detect an Anthrax attack
  - Project sponsored by the Defense Threat Reduction Agency (DTRA) through the Weapons of Mass Destruction Assessment and Analysis Center (WMDAAC) OR Cell
- Study modeled the release of Anthrax from 8 different release points
  - Used HPAC to generate plume data

Project History Cont.

- Sought to understand the effectiveness of four different notional sensor types in a fixed sensor array
  - Study the effects of agent amount (1 & 2 kg), wind speed (4,8,12 knots)
  - Used *perfect* sensors (no false detections)
- Time constraints required a definitive scope of the project
  - Future studies were recommended
  - This new study was designed to further the research and answer questions left unanswered

Project Objectives

- Model the release of a biological agent (Anthrax) into a protected area surrounded by notional sensors
  - Determine the effect of sensor sensitivity on detection capability
  - Determine the effects of using more or less sensors
  - Understand the cost vs. performance tradeoff
  - Use *perfect* (no false detections) and *non-perfect* sensors (require multiple detections to rule out false positives)

Basic Definitions

ACPLA
- Agent Containing Particles Per Liter of Air (ACPLA), for Anthrax, 1 ACPLA = 1 X 10^-11 kg/m^3
- Measure of a sensor's sensitivity level; the lower the number, the better the sensor

Battle Space
- A 16x19 km rectangular area that contains the total geographical region that the release of agent is modeled within

Defense Area
- Found inside the Battle Space, this 10x13 km rectangular area surrounded by sensors and contains the population/valuable assets to protect

Detection/Hit
- When the concentration of agent around the sensor is above the threshold of detection

HPAC
- Hazardous Prediction and Assessment Capability — models the propagation of the agent's plume across the Battle Space

PART 2 DESIGN OF EXPERIMENT

- Hypothesis
- Scenario Design
- Defining the Battle Space
- Sensor Model

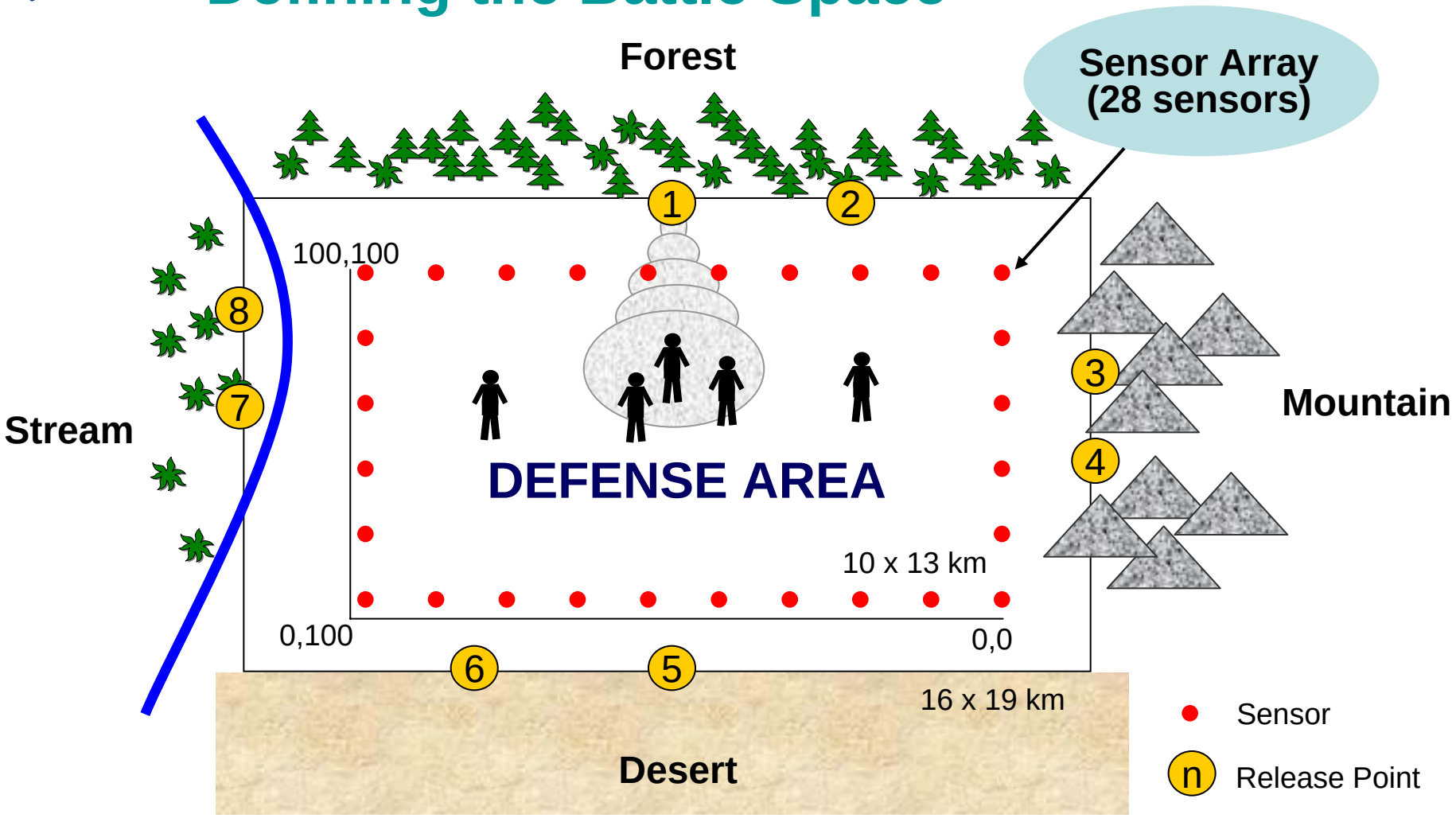
Hypothesis

- An increased quantity of cheaper, notional sensors will provide equivalent or better detection capability for less cost
  - Using more sensors reduces the space between sensors and reduces the likelihood of an agent's plume slipping through undetected
  - Instead of buying more sensitive sensors, spend less money, buy more cheaper sensors for the equivalent detection capability at a reduced cost

Scenario Design

- Scenarios Modeled in HPAC
  - 0.5, 1 and 2 kg anthrax releases
    - 8 release points
    - Release height at 2 m, over .08 km distance
    - 90% purity with 60% dissemination efficiency
    - Atmospheric conditions constant for all releases
      - Scattered clouds, ambient temperature
  - Wind speed at 4, 8, and 12 knots
    - Wind direction toward center of defense area from the release point (worse case)
  - Two releases from four different terrain conditions
    - Mountain, Desert, Forest, and Stream
    - 3 km from sensor array

Defining the Battle Space



During model runs, wind blows from Release Point to center of Defense Area

Biological Defense: Evaluating Sensor Array Quality Versus Detection Capability Webb, et al. GMU SYST 798, Fall 2004

Sensor Model

- Four generic types of notional sensors used based on their threshold of detection
  - 1, 10, 20, 30 ACPLA
    - Theoretical 1 ACPLA sensor used as basis for best possible detection capability
- Sensor Configuration
  - Rectangular perimeter defense
  - Tested 16, 28, 42, 65 and 129 sensors
    - Equally distributed around the perimeter of a 10x13 km rectangle

PART 3 DATA ANALYSIS

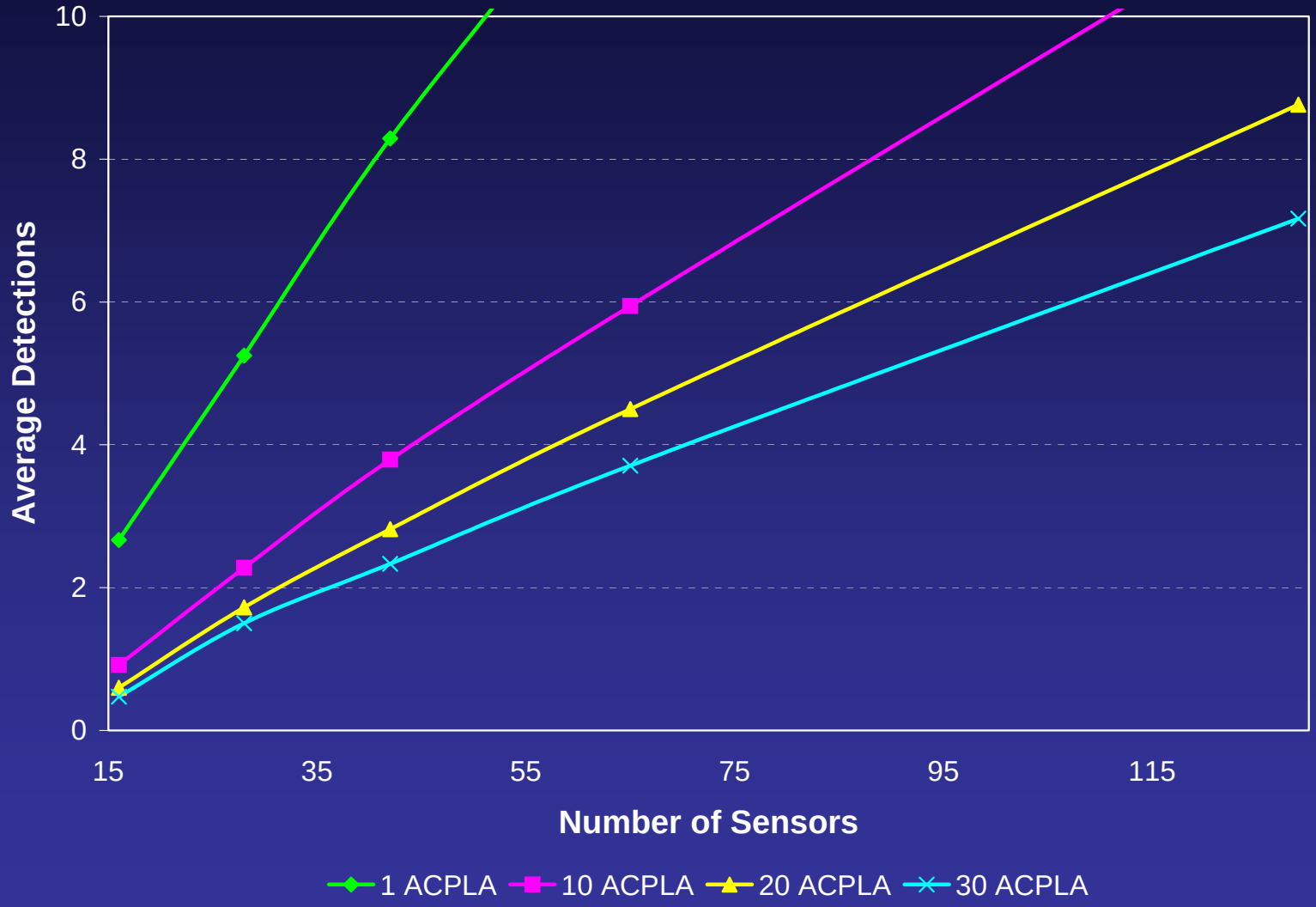
- Technical Methodology
- Average Detections
- Defining a Better Performance Metric
- Cost vs. Performance

Technical Methodology

- Simulated release of agent using HPAC
  - Captured concentration at every point in 100 X 100 matrix representing the Battle Space in 2 minute time steps over a 4 hour period
  - Imported data into Access Database
- Determined if, at any time, a concentration in the location of a sensor exceeded the sensor's threshold of detection

Hazard Prediction and Assessment Capability (HPAC) — government off-the-shelf software for use in modeling chemical and biological agents

Average Detections



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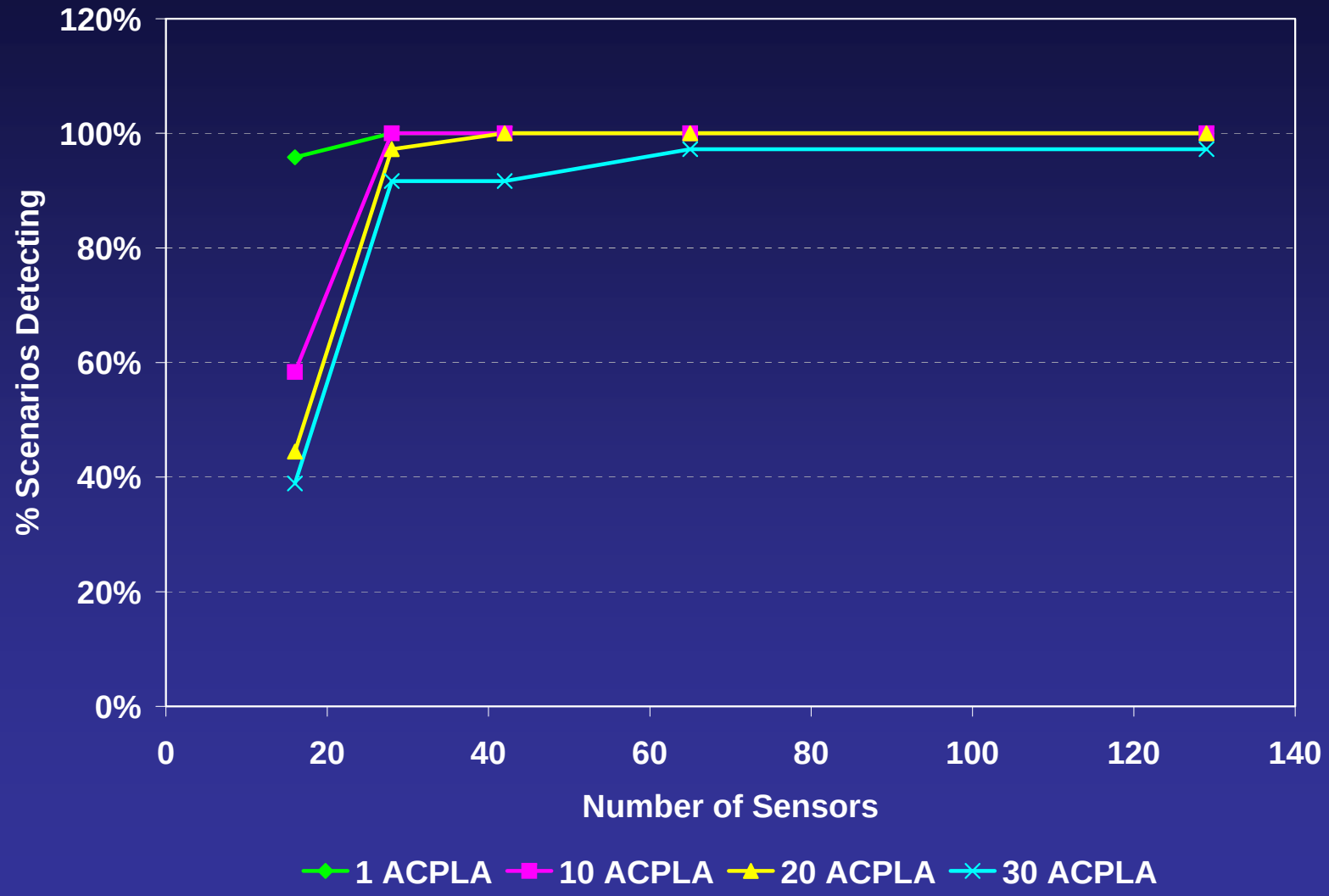
Defining a Better Performance Metric

- Averaging the detections does not provide any useful information
  - Result is an average and does not let one know if one or zero detections occurred with any scenario
    - More true of lesser agent amounts (0.5 kg case)
    - Zero detection results in casualties!
  - Difficult to account for *non-perfect* sensors

- Better performance metric is counting the number of releases where our detection criteria is met
  - >0 for *perfect*
  - >1 (at least 2 detections) or
    >2 (at least 3 detections) for *non-perfect*

Detection — *Perfect* Sensors



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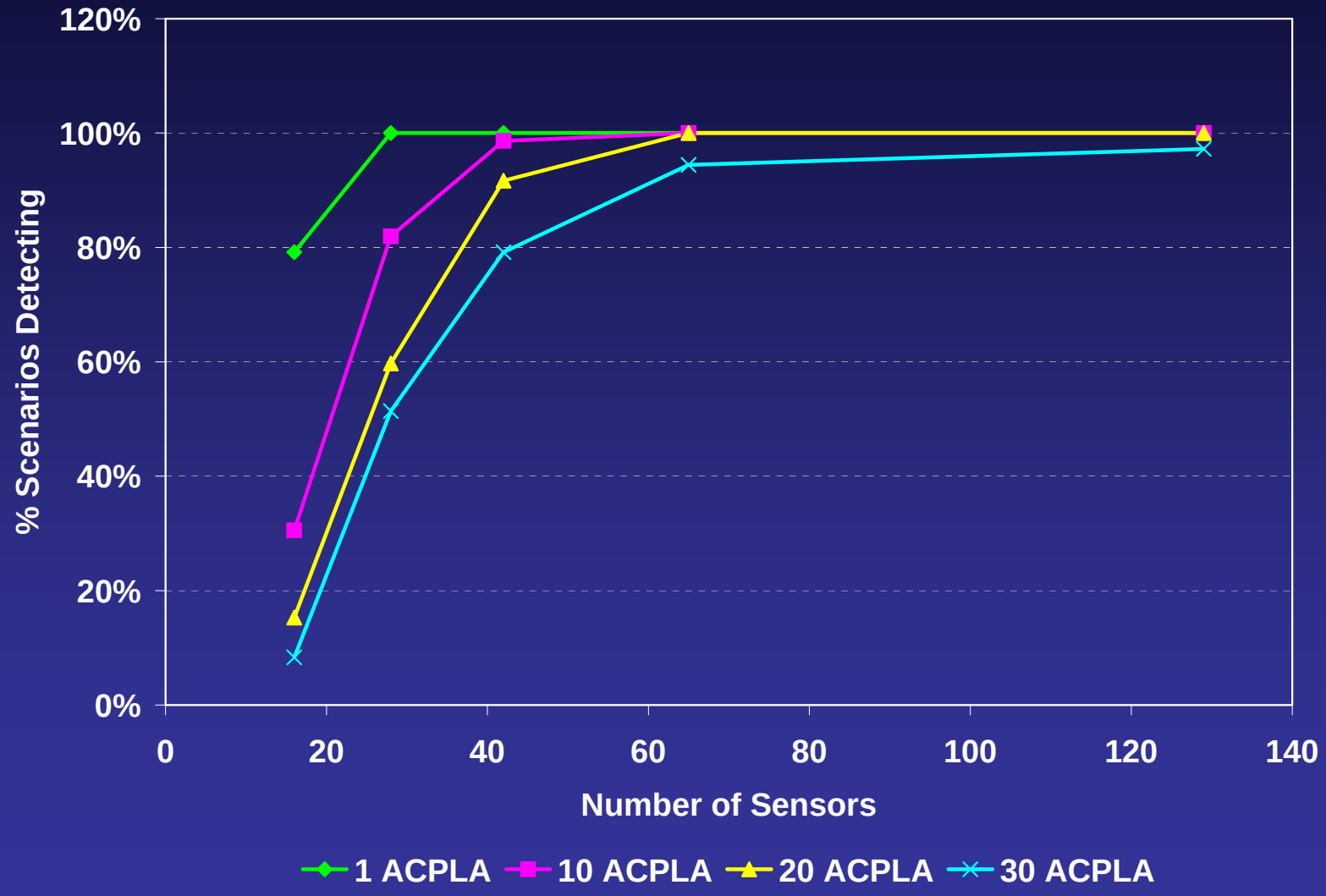
Detection — >1 Required



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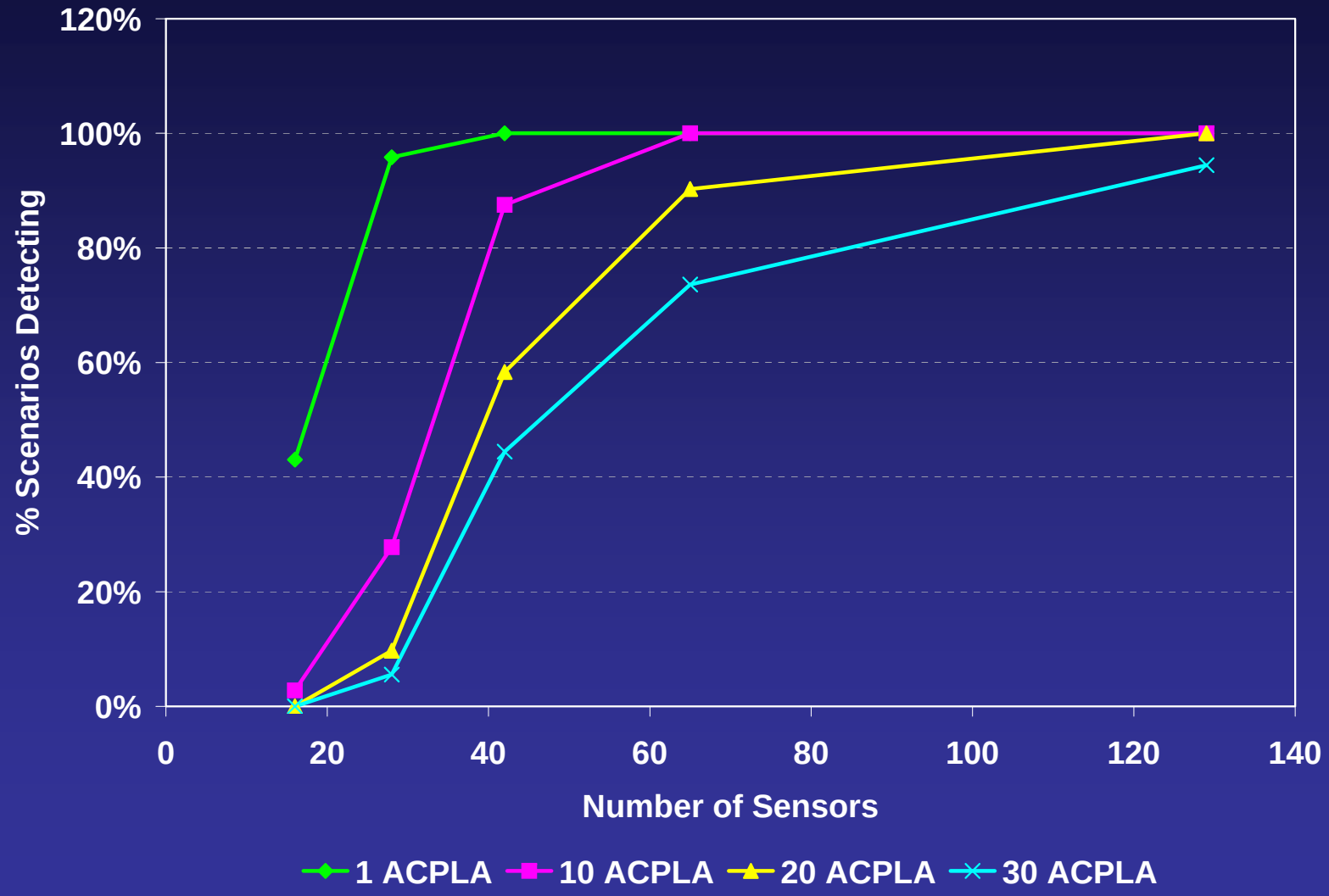
Detection — >2 Required



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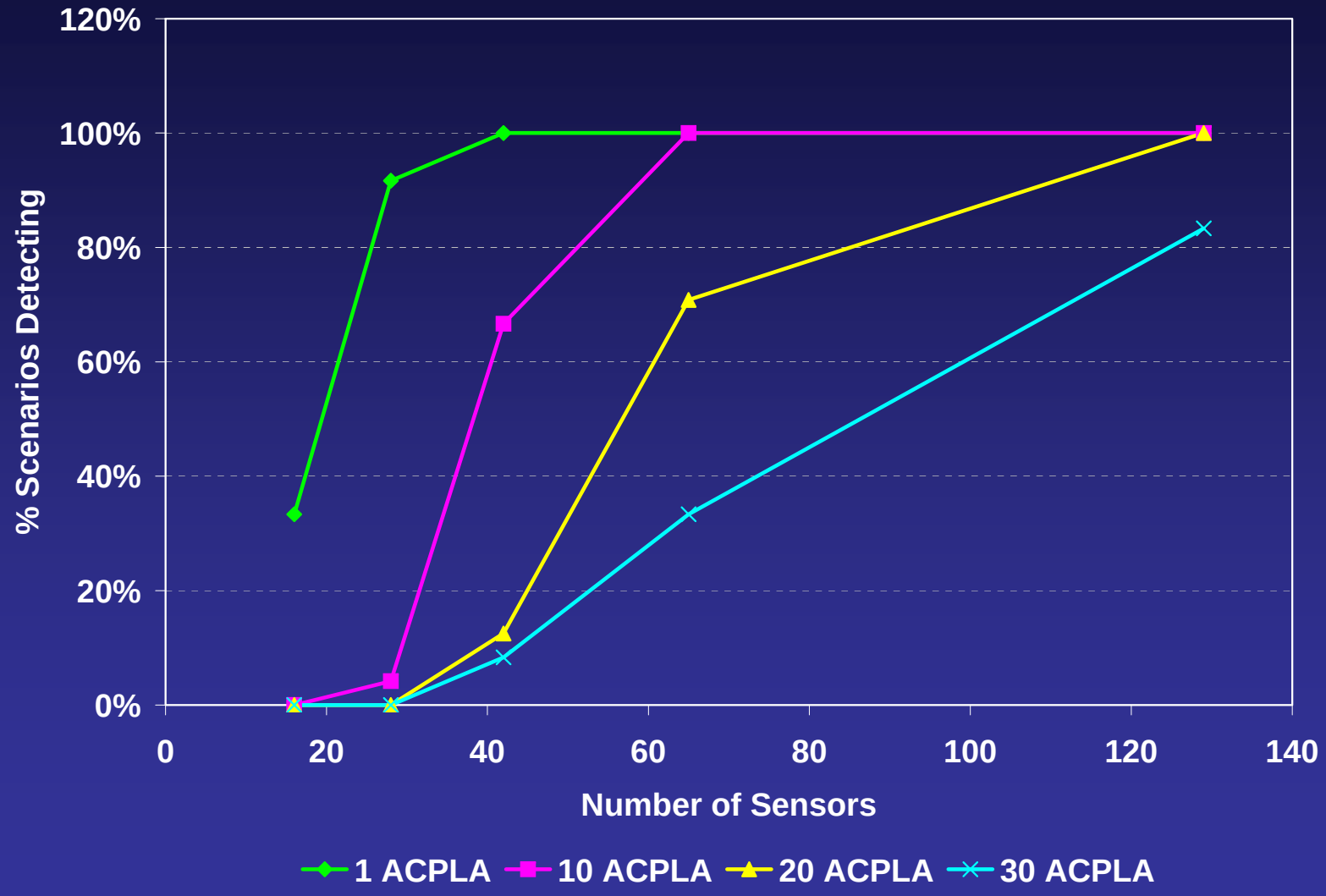
0.5 kg Case Detection — >2 Required



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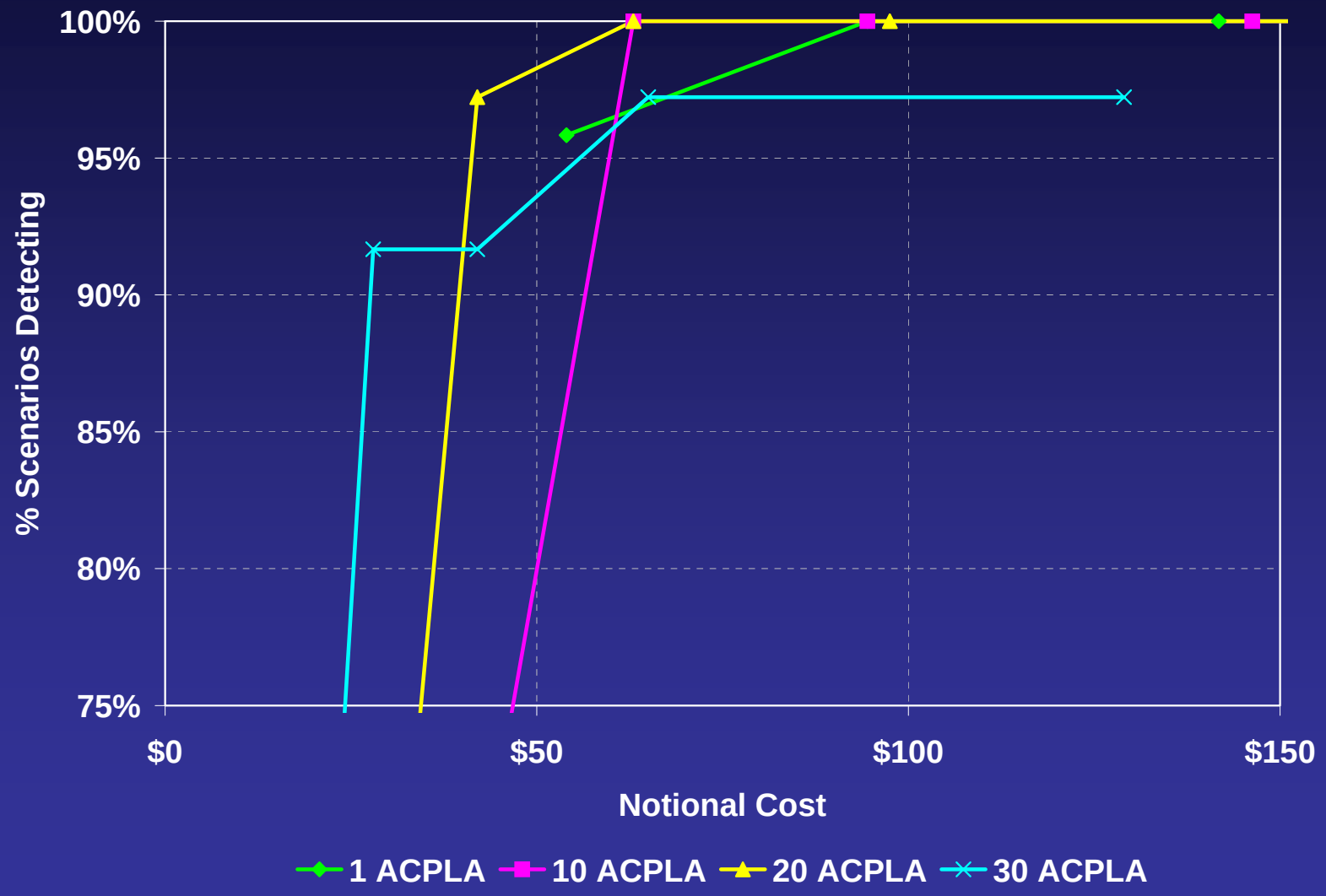
Cost vs. Performance

- Cost of a notional sensor was estimated using the following formula:
  - Better Sensor = 1.5 * Cost Worse Sensor
  - 20 ACPLA = 1.5 * Cost 30 ACPLA;
    10 ACPLA = 1.5 * Cost 20 ACPLA; etc.
- Notional cost estimates used to examine the general behavior of the system in order to observe trends
- Cost analysis does not include:
  - Deployment cost/sensor
  - Normal cost of everyday sensor usage
  - Cyclical maintenance cost/sensor/unit time

Perfect Sensor Cost



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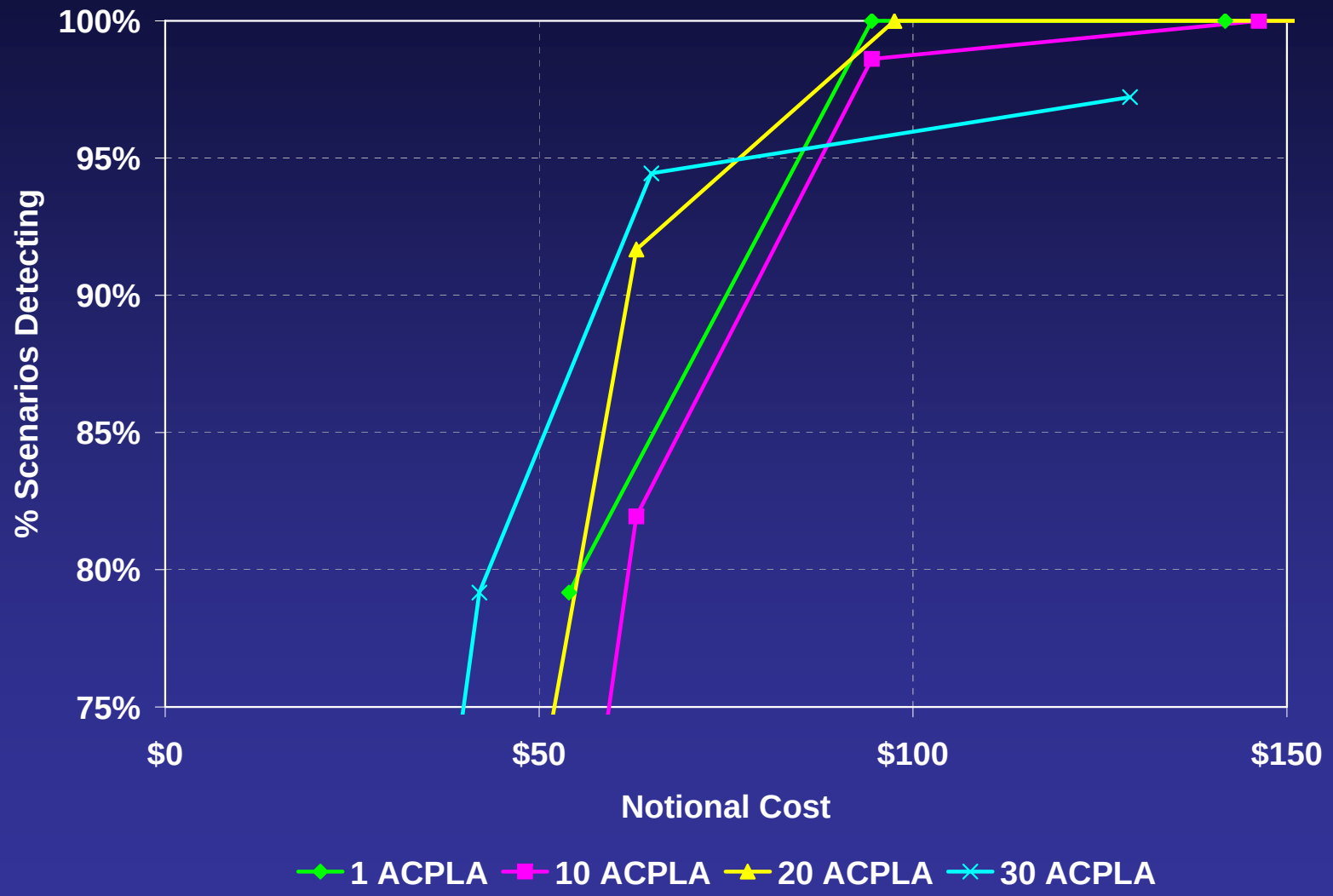
>1 Detection Cost



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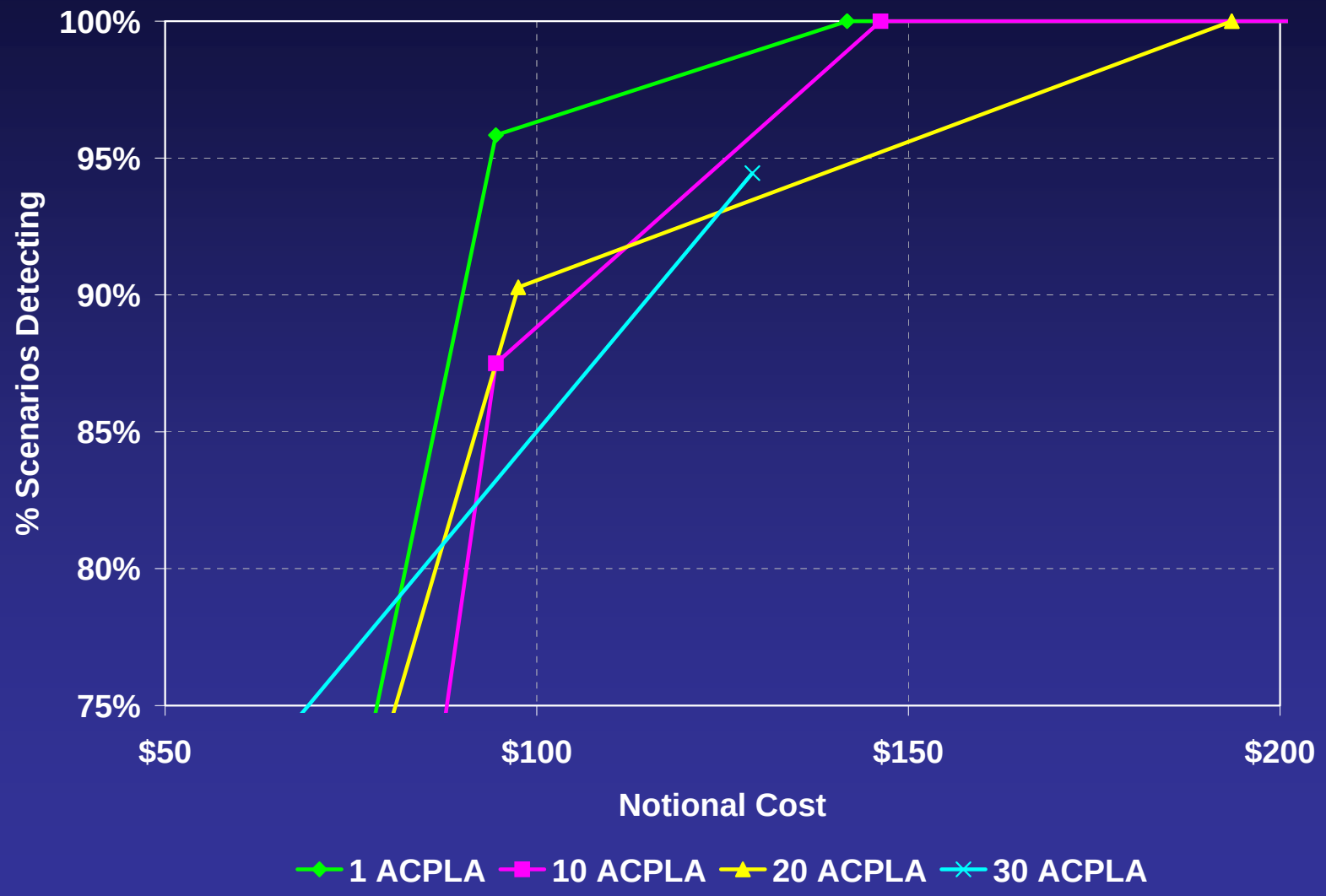
>2 Detection Cost



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PART 4 RESULTS & CONCLUSIONS

Results & Conclusions

- Total count of releases meeting detection criteria is a much better metric for evaluating the notional sensor array performance
  - Total counts of successful detection reveal the cases where little or no detections occur, while averaging the counts can be misleading
  - 30 ACPLA sensors could not achieve 100% performance, even with 129 sensors (360 m spacing between sensors)
- 0.5 kg scenarios were the main driver for reduced performance
  - This is a more realistic amount to manufacture than 2 kg
  - Consider using 0.25 kg to improve understanding of smaller scale attacks

Results & Conclusions

- 1 ACPLA sensors outperform all other sensors and cost less for 100% detection when considering *non-perfect* sensors
  - 10 ACPLA sensors perform very well and are also a good alternative, especially when 3 or more detections are required
  - 20 ACPLA sensors had more difficulty with the 0.5 kg cases, and might perform even worse for smaller attacks
- Based on the results, reject the hypothesis that an increased quantity of cheaper sensors provides an equivalent or better detection capability for less cost
  - Increased sensitivity performs better with smaller releases
  - Recommend less quantity with more quality

PART 5 QUESTIONS