An End-to-End Approach to Developing Biological and Chemical Detector Requirements
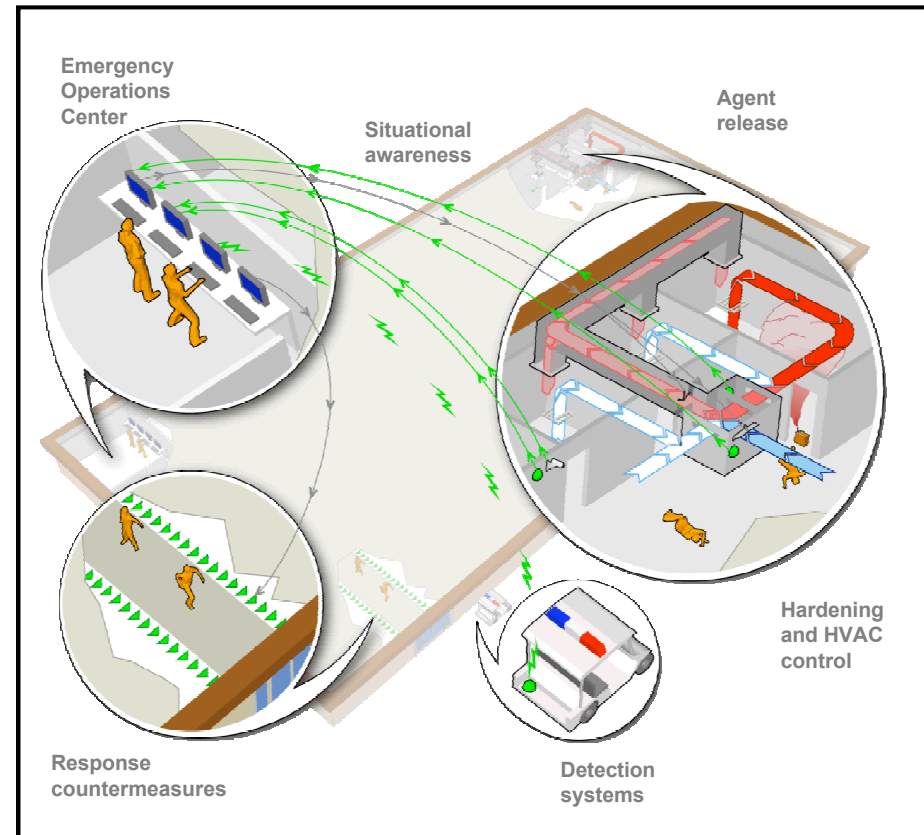
Nerayo P. Teclemariam, Liston K. Purvis, Greg W. Foltz, Todd West, Donna M. Edwards, Julia A. Fruetel, and Nathaniel J. Gleason
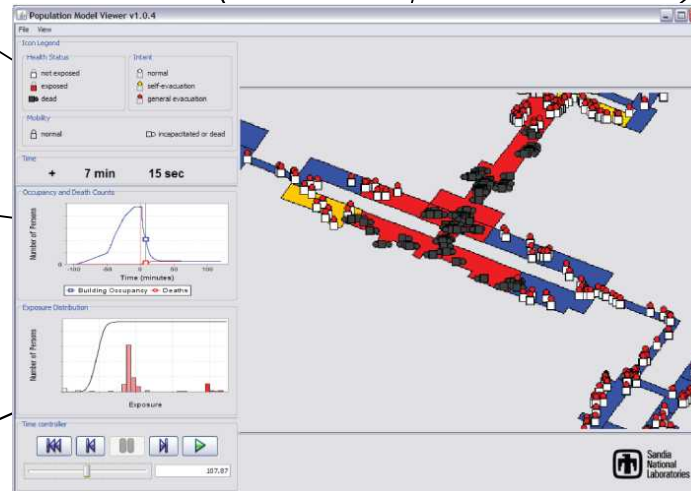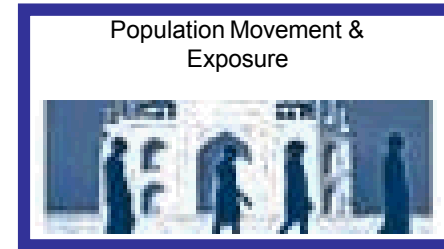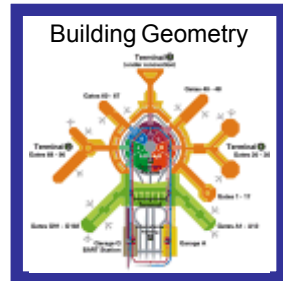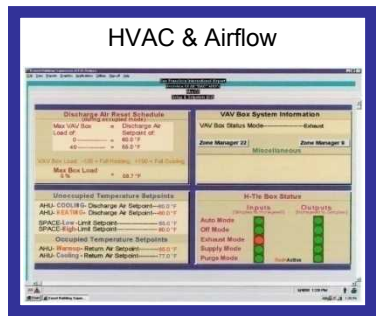
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Effective defense against chemical and biological threats requires an "end-to-end" strategy
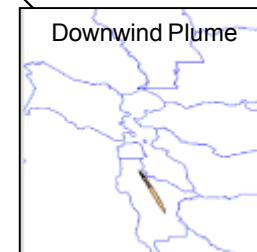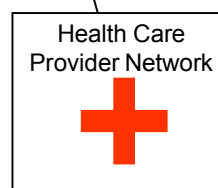
- **Threat assessment**
  - *What is the problem / threat?*

- **Attack prevention / hardening**
  - *What measures can be implemented to reduce the likelihood or impact of an attack*

- **Countermeasures evaluation**
  - *How can we effectively respond to an attack?*

- **System requirements**
  - *What support / information is needed to implement effective actions?*

- **System architecture design and deployment**
  - *How do we best deploy available assets?*

- **Signal interpretation / decision support**
  - *How do we use available information to make the best operational decisions during an event?*

- **Restoration and recovery**
  - *How do we get back to normal operations after an attack?*

Emergency Operations Center

Situational awareness

Agent release

Hardening and HVAC control

Response countermeasures

Detection systems

Facilities Weapons of Mass Destruction Decision Analysis Center (FacDAC)

HVAC & Airflow

Building Geometry

Simulated Attack

Population Movement & Exposure

Detection Systems

Signal interpretation / post-event sampling

Response Options

Public Health

Health Care Provider Network

Downwind Plume

Disease Models

- **Analysis**
  – Detection systems analysis
  – Risk / vulnerability assessment
  – Response evaluation
  – Event reconstruction
- **Exercise support**
- **Operational / decision support**
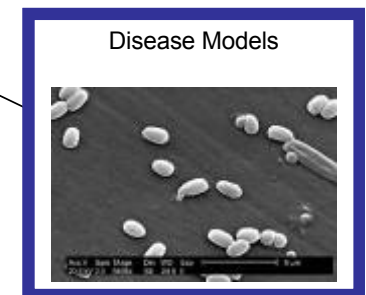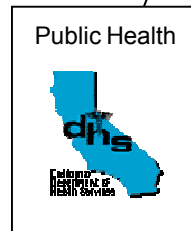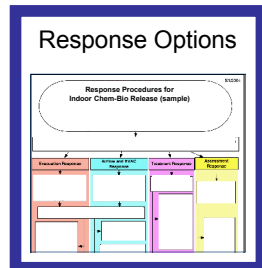
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Process to determine requirements to support technology development

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Algorithm to rigorously develop detector requirements for a given application

- **Develop a library of potential attack scenarios**

- Build a database of response effectiveness

- Optimize detector architecture

- Examine value of detection system as a function of detector performance parameters

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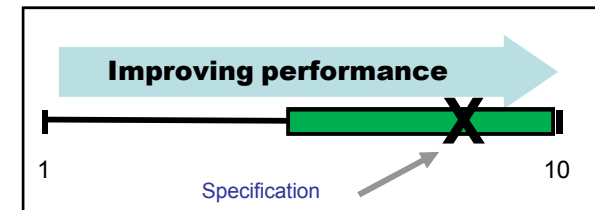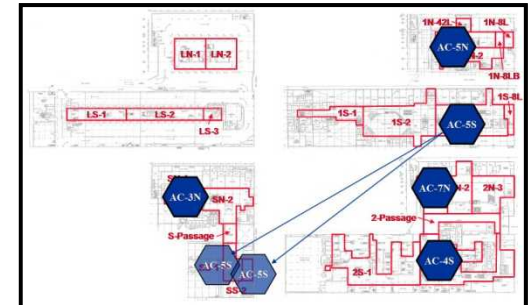
Algorithm to rigorously develop detector requirements for a given application

- **Develop a library of potential attack scenarios**

- **Build a database of response effectiveness**

- **Optimize detector architecture**

- **Examine value of detection system as a function of detector performance parameters**

Build a database of response effectiveness:
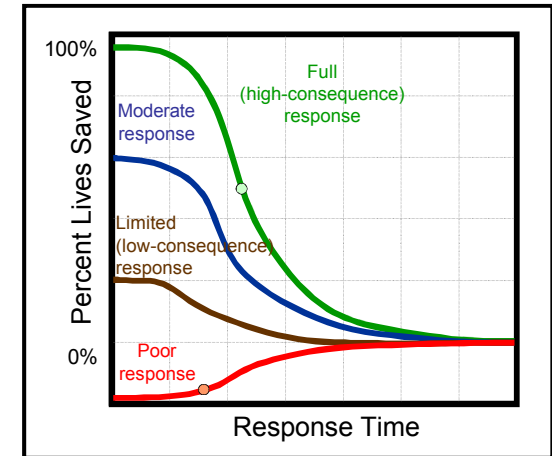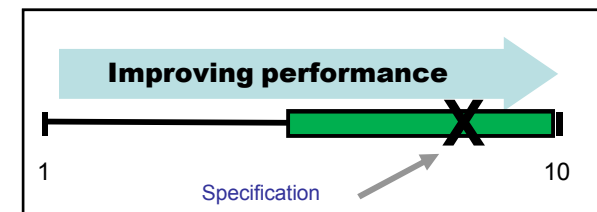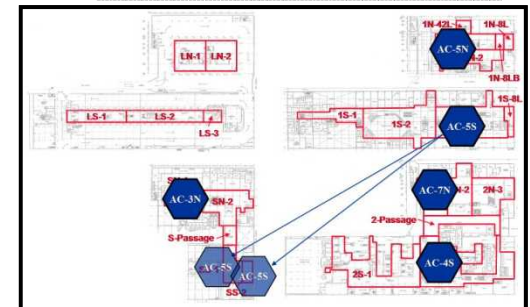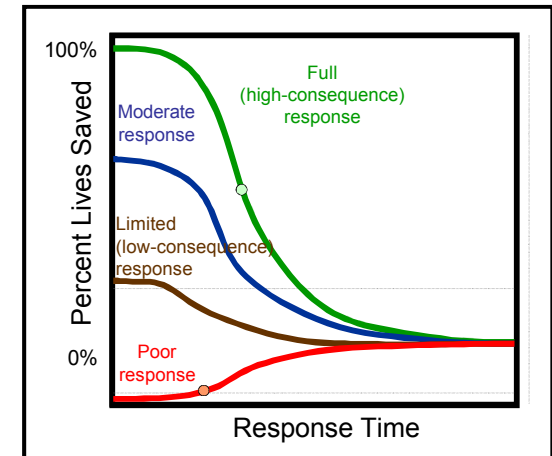## *Countermeasures effectiveness*

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Algorithm to rigorously develop detector requirements for a given application

- Develop a library of potential attack scenarios

- Build a database of response effectiveness

- **Optimize detector architecture**

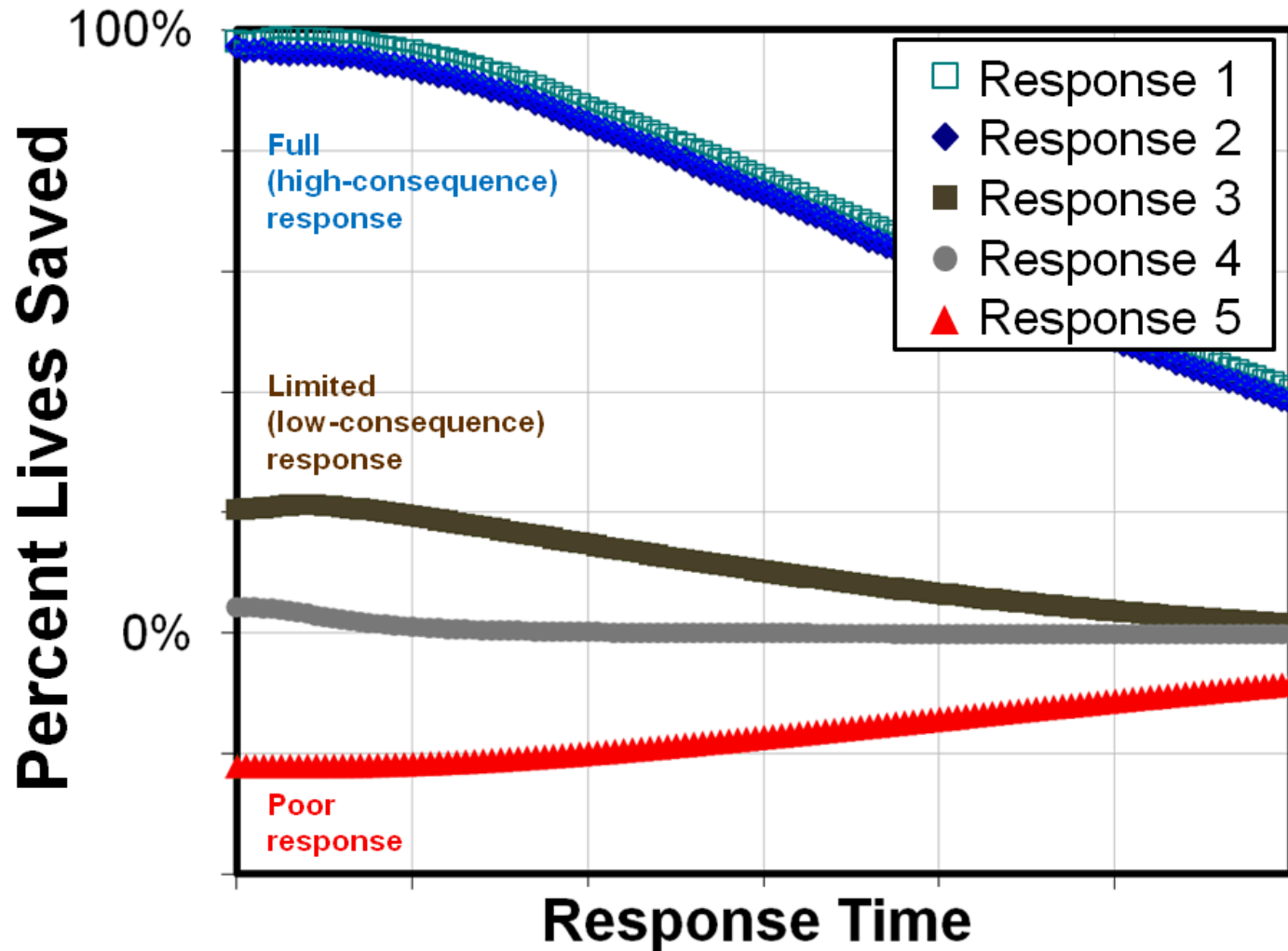- Examine value of detection system as a function of detector performance parameters

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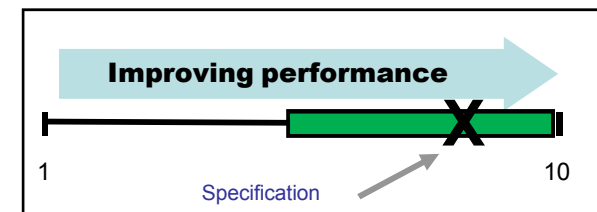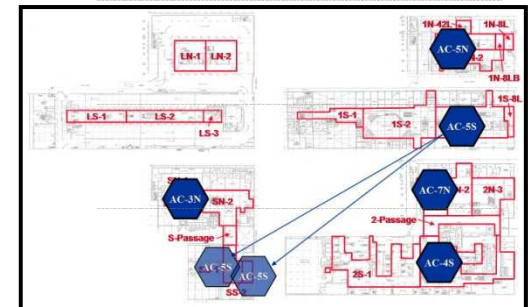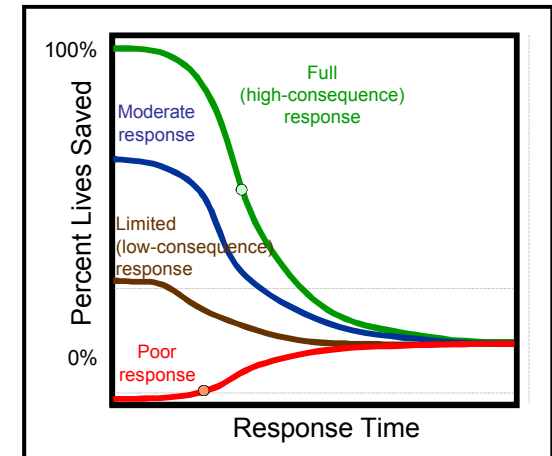
Optimize detector architecture

Candidate Architecture
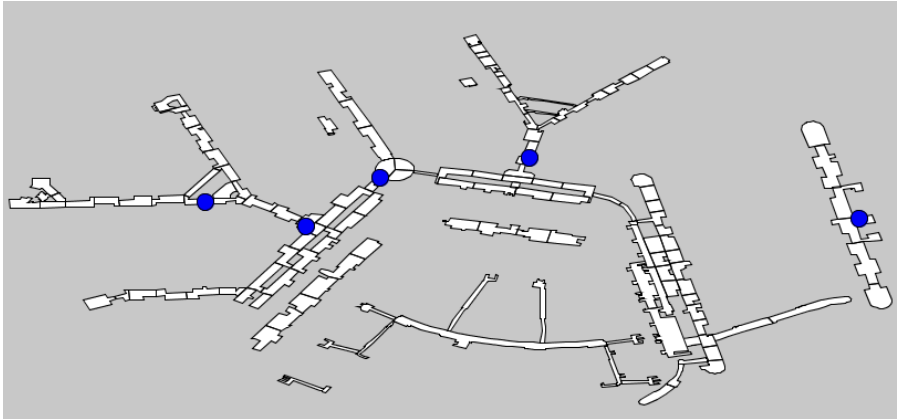
Select candidate architecture

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Optimize detector architecture

Candidate Architecture
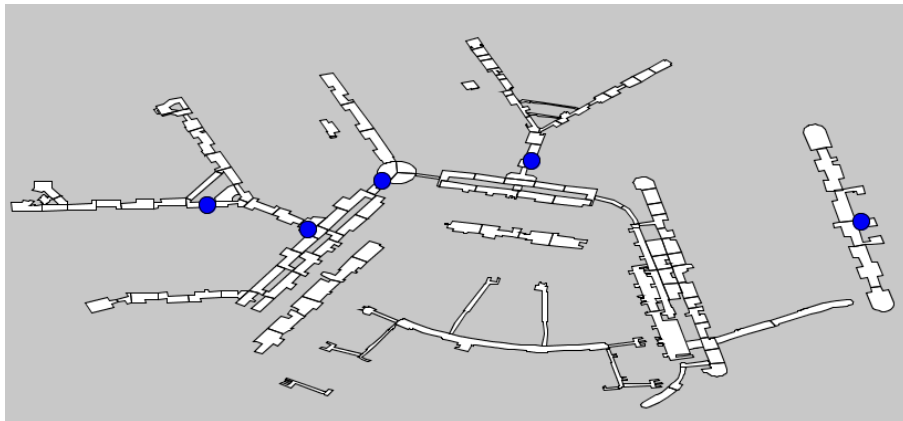
Candidate Architecture Evaluation

Scenario	Detected	Detection Time
1	Yes	1 min
2	Yes	5 min
3	No	--
…	…	…
n	Yes	3 min

Determine which scenarios are detected and when
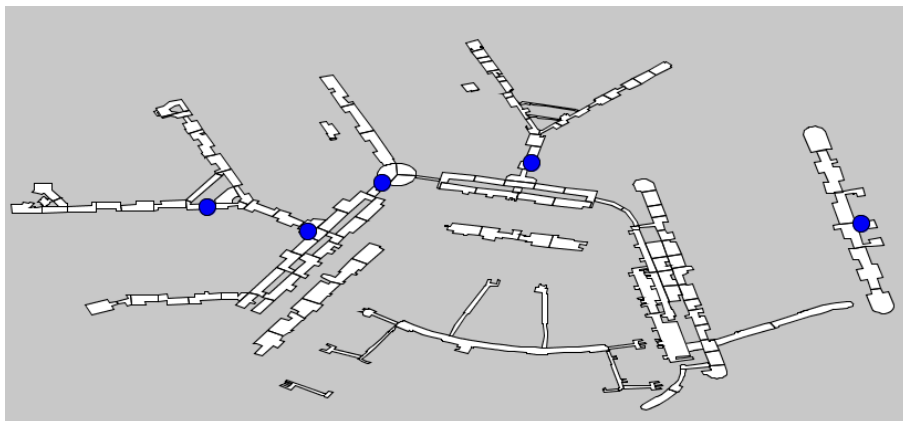
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Optimize detector architecture

Candidate Architecture

Response Effectiveness

Percent Lives Saved vs. Response Time (min)

Legend:
- Scenario 1
- Scenario 2
- Scenario 3
- Scenario 4
- Scenario 5

Casualties with no response

Candidate Architecture Evaluation

Scenario	Detected	Detection Time	Casualties without Detection	Casualties with Detection	Lives Saved
1	Yes	1 min	10,000		
2	Yes	5 min			
3	No	--			
…	…	…			
n	Yes	3 min			

Determine benefit of detection for each scenario

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Optimize detector architecture

Candidate Architecture

Candidate Architecture Evaluation

Scenario	Detected	Detection Time	Casualties without Detection	Casualties with Detection	Lives Saved
1	Yes	1 min	10,000	1,000	
2	Yes	5 min			
3	No	--			
…	…	…			
n	Yes	3 min			

Response Effectiveness

Determine benefit of detection for each scenario

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Optimize detector architecture

Candidate Architecture

Response Effectiveness

Casualties with triggered response

Percent Lives Saved (y-axis, 0% to 100%)

Lives Saved

- Scenario 1
- Scenario 2
- Scenario 3
- Scenario 4
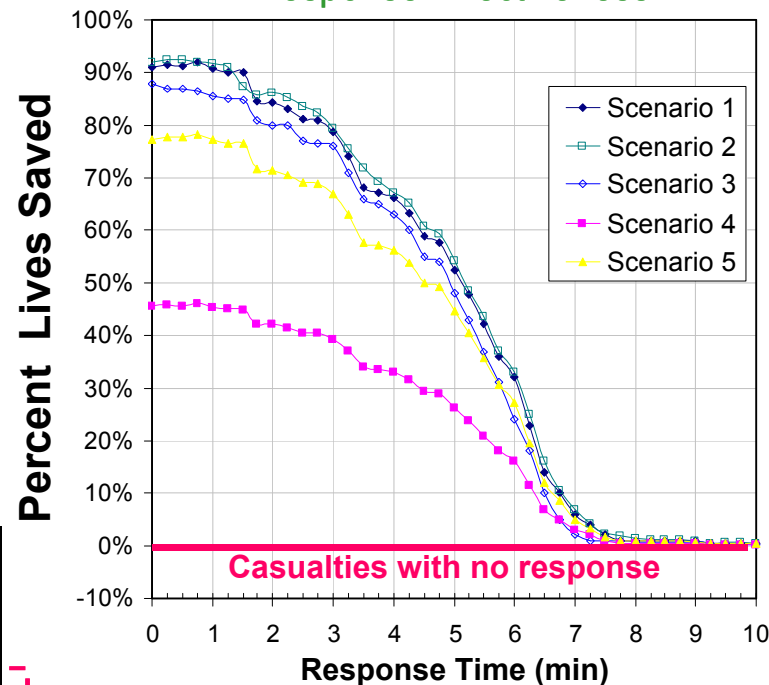- Scenario 5

Casualties with no response

Response Time (min)

Candidate Architecture Evaluation

Scenario	Detected	Detection Time	Casualties without Detection	Casualties with Detection	Lives Saved
1	Yes	1 min	10,000	1,000	9,000
2	Yes	5 min			
3	No	--			
…	…	…			
n	Yes	3 min			

Determine benefit of detection for each scenario

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Optimize detector architecture

Candidate Architecture

Response Effectiveness
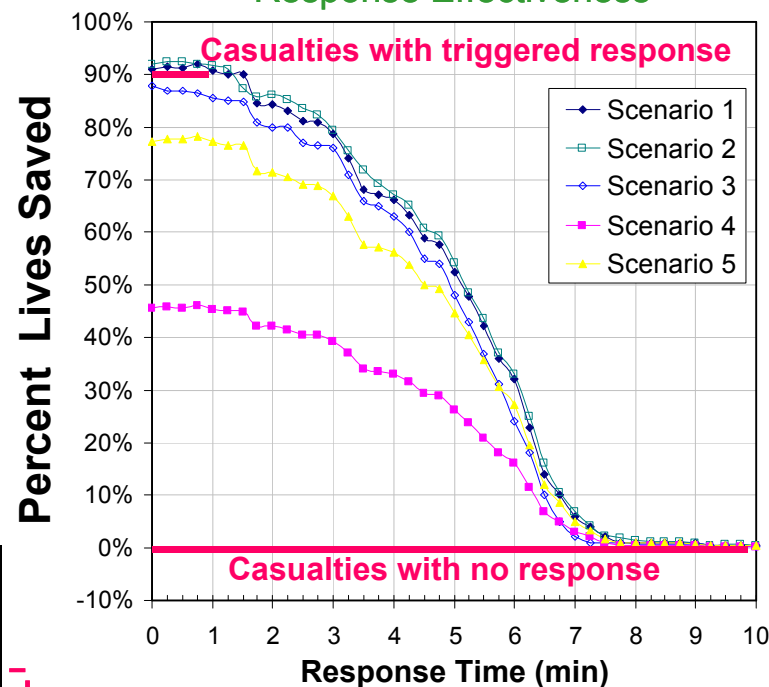

Candidate Architecture Evaluation

Scenario	Detected	Detection Time	Casualties without Detection	Casualties with Detection	Lives Saved
1	**Yes**	**1 min**	**10,000**	**1,000**	**9,000**
2	**Yes**	**5 min**	**8,000**	**4,200**	**3,800**
3	**No**	**--**			
…	**…**	**…**			
n	**Yes**	**3 min**			

Determine benefit of detection for each scenario

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Optimize detector architecture

Candidate Architecture

Response Effectiveness

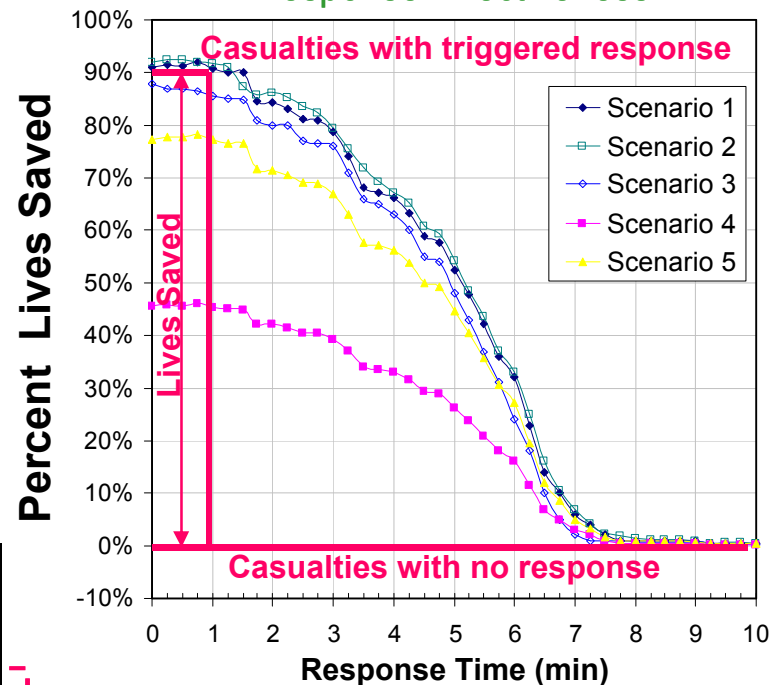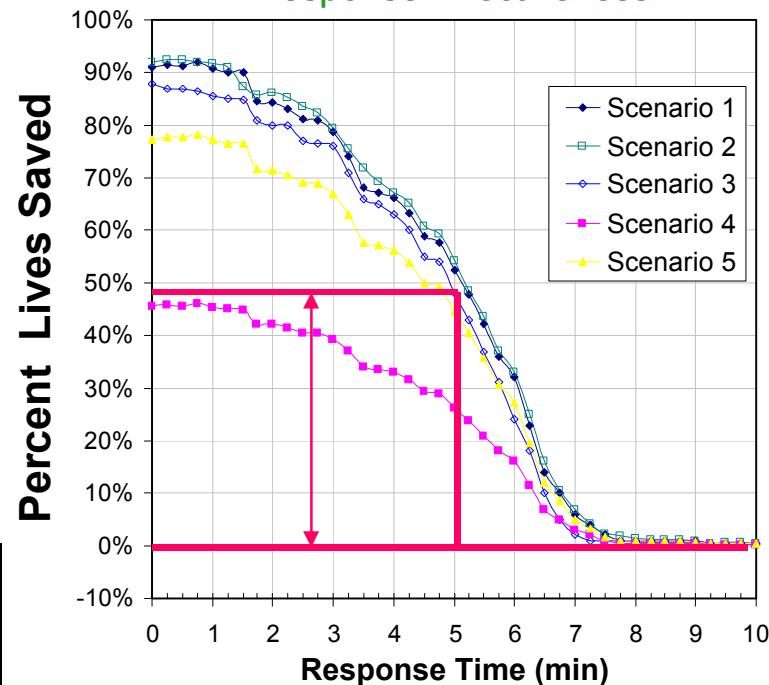### Candidate Architecture Evaluation

Scenario	Detected	Detection Time	Casualties without Detection	Casualties with Detection	Lives Saved
1	**Yes**	**1 min**	**10,000**	**1,000**	**9,000**
2	**Yes**	**5 min**	**8,000**	**4,200**	**3,800**
3	**No**	**--**	**9,500**	**9,500**	**0**
…	**…**	**…**			
n	**Yes**	**3 min**			

Determine benefit of detection for each scenario

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Optimize detector architecture
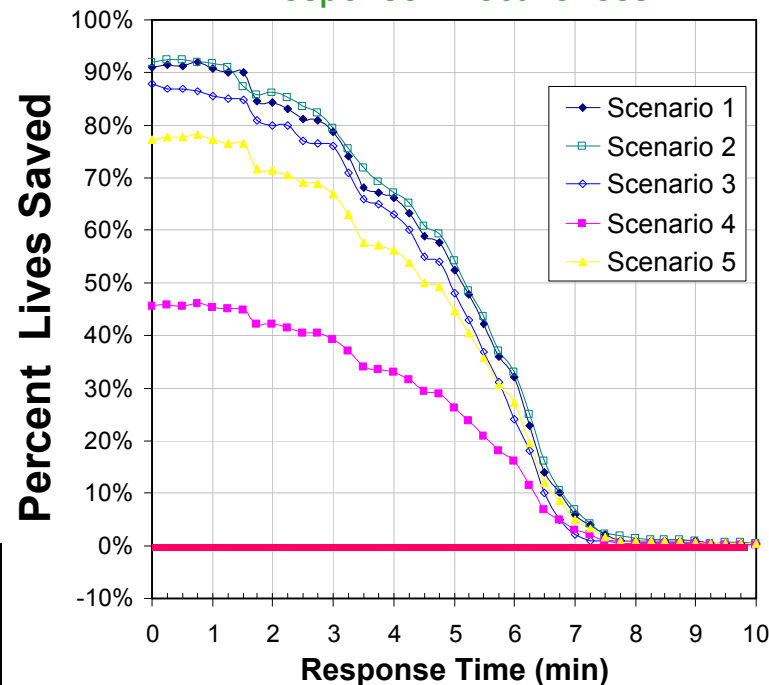
Candidate Architecture

Response Effectiveness

Candidate Architecture Evaluation

Scenario	Detected	Detection Time	Casualties without Detection	Casualties with Detection	Lives Saved
1	Yes	1 min	10,000	1,000	9,000
2	Yes	5 min	8,000	4,200	3,800
3	No	--	9,500	9,500	0
…	…	…	…	…	…
n	Yes	3 min	12,300	9,400	2,900

Mean Lives Saved = 5,400

Determine "Lives Saved" for candidate architecture
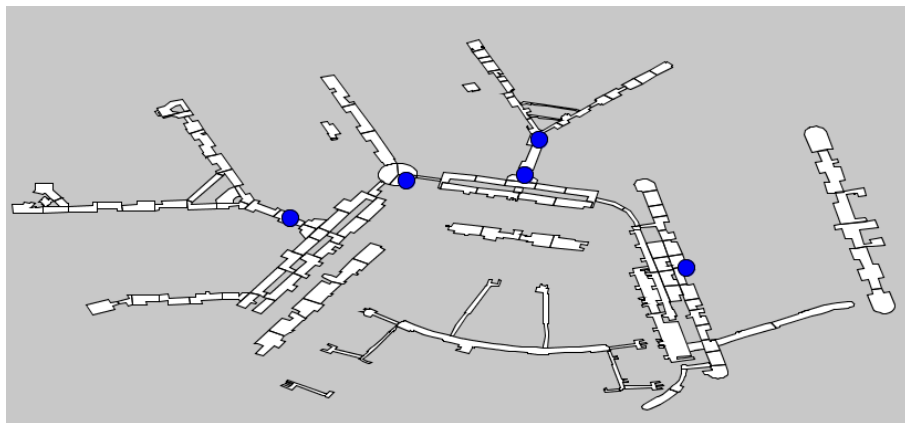
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Optimize detector architecture

Candidate Architecture

Response Effectiveness

Percent Lives Saved vs **Response Time (min)**

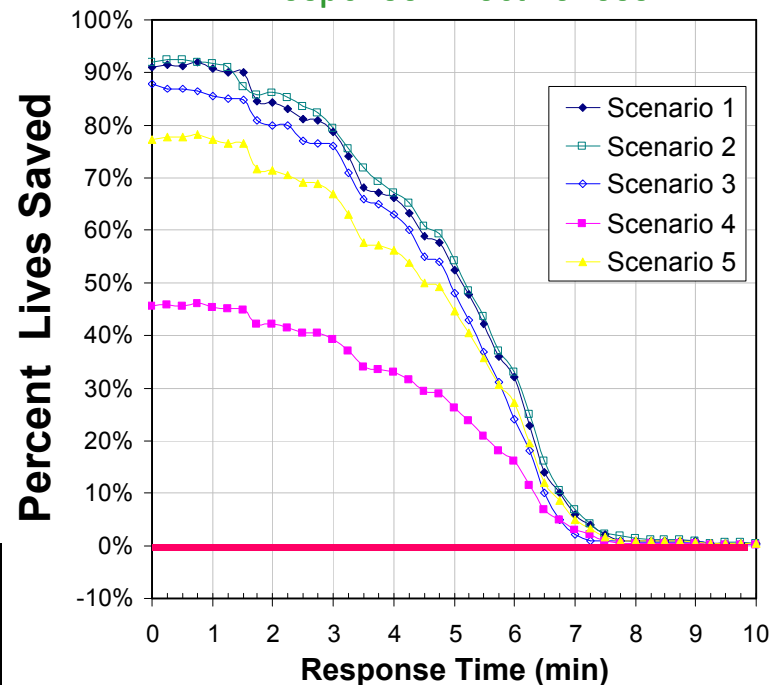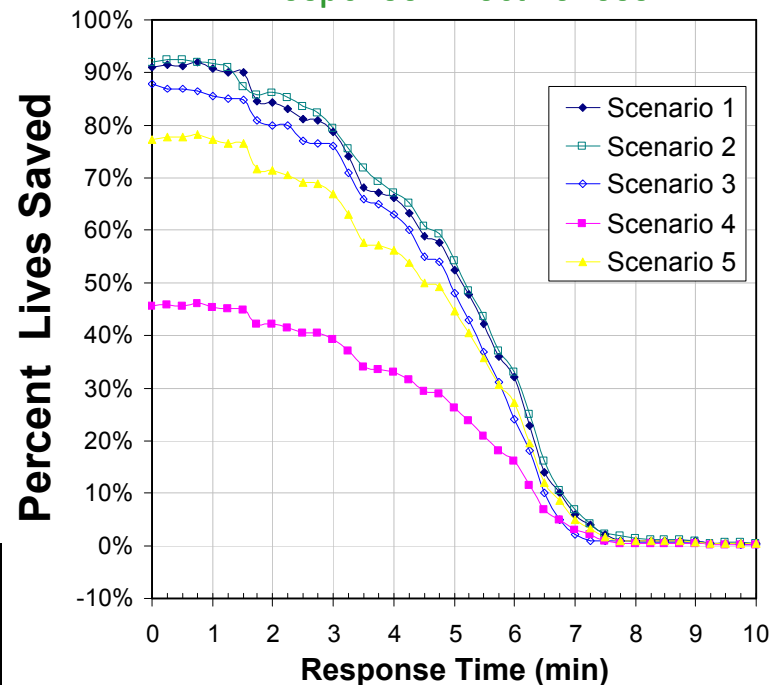- Scenario 1
- Scenario 2
- Scenario 3
- Scenario 4
- Scenario 5

Candidate Architecture Evaluation

Scenario	Detected	Detection Time	Casualties without Detection	Casualties with Detection	Lives Saved
1	Yes	1.5 min	10,000	1,500	8,500
2	No	--	8,000	8,000	0
3	Yes	3 min	9,500	2,200	7,300
…	…	…	…	…	…
n	Yes	1 min	12,300	1,400	9,900

➡ **Mean Lives Saved = 8,600**

Optimize architecture according to metric

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Algorithm to rigorously develop detector requirements for a given application

- Develop a library of potential attack scenarios

- Build a database of response effectiveness

- Optimize detector architecture

- **Examine value of detection system as a function of detector performance parameters**

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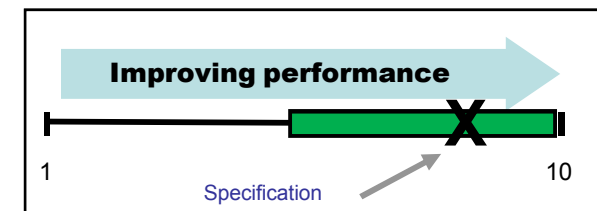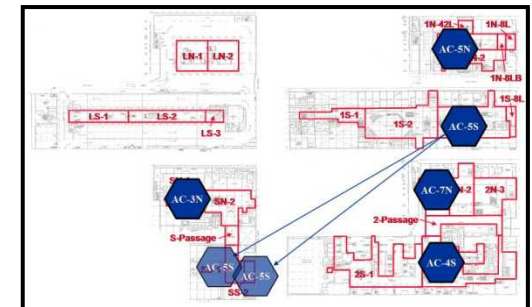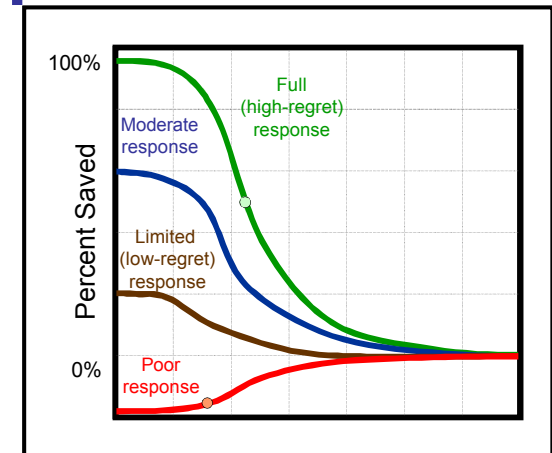
Process supports multiple stages of detection system development

- **Technology development**
  - Determine which technologies are candidates

- **Detection system requirements**
  - Set system performance targets for developing a system

- **Evaluation of specific systems**
  - Decide which or whether to field a specific system

- **Deploy architectures**
  - Develop protection metrics for facilities and optimize architectures for deployment

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Develop requirements for detectors
Approach to developing requirements

Improving performance

Requirement

1   10

Minimum value[*]
If a detector does not perform at least this well in this single parameter, it is extremely unlikely that a system of these detectors will be useful

"Reasonable" range[*]
Parameter must be in this range for system to give moderate-to-good performance assuming moderate values for other parameters

Point of diminishing returns
Improving parameter beyond this value does not produce a significant benefit in terms of system performance

[*] All parameters being within this range is a *necessary* but *not sufficient* condition to meet the performance criteria

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Develop requirements for detectors
Requirements guide selection of technologies for development

Lives saved ~ 1,500 - 2000

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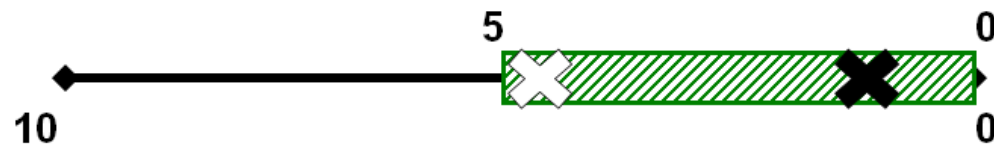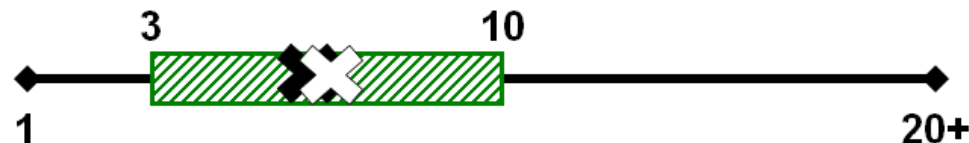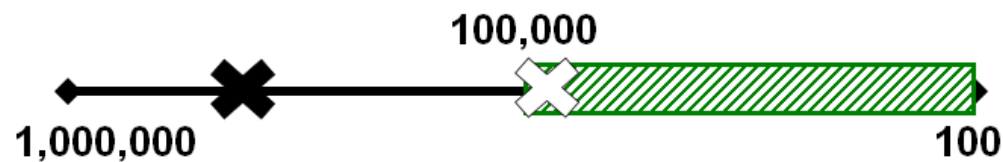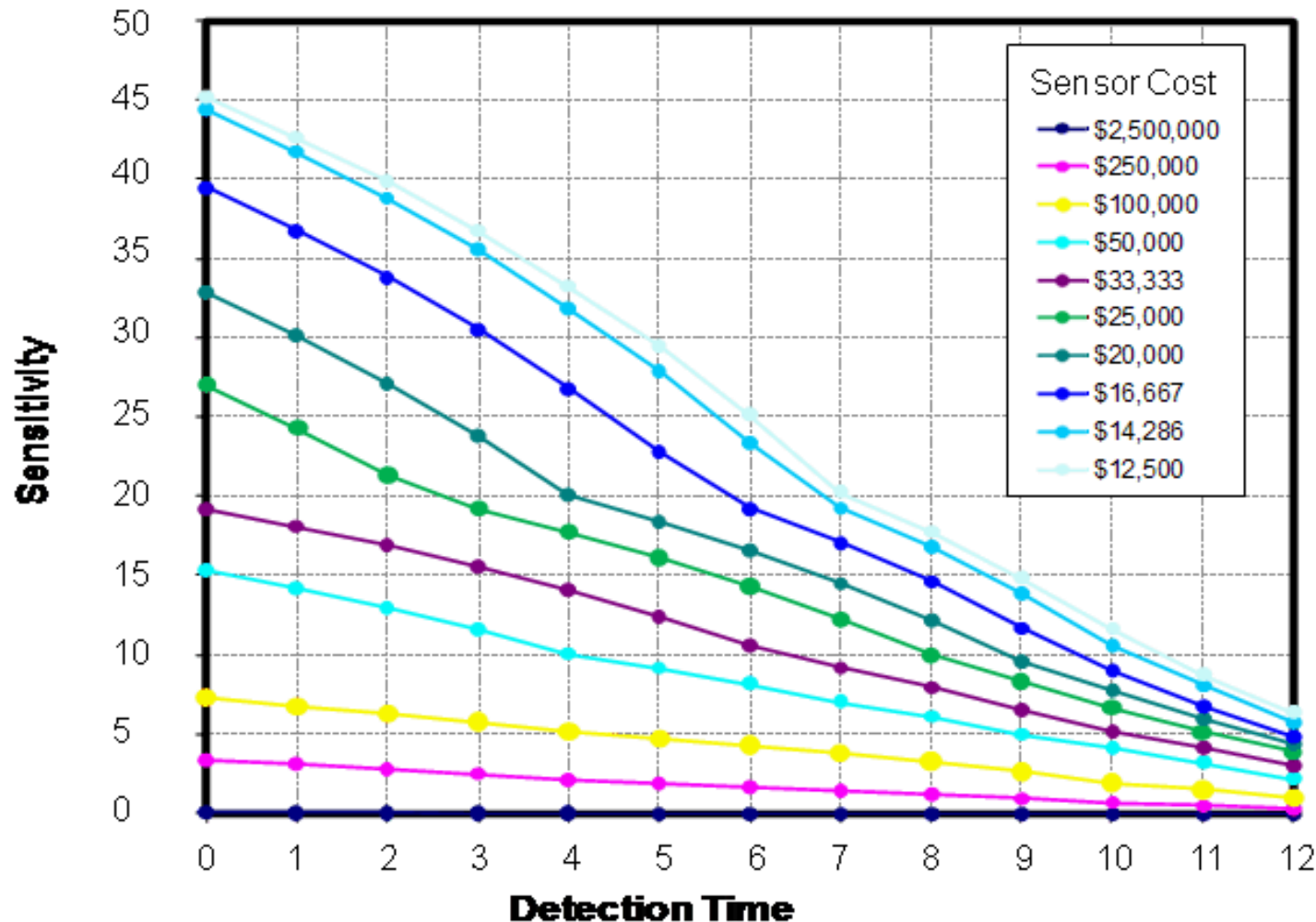
Iso-performance charts used for evaluation of specific detection systems

All points on this chart provide identical *system* performance

Conclusions

- **Algorithm provides a rigorous method for generating defensible requirements for applications**

- **Iso-performance charts and performance trade-offs graphs can be employed to evaluate technologies and show requirements' interdependency**

- **FacDAC, the facility analysis toolset, enables requirements determination and technology evaluation across multiple detector development stages**