Volume Sensor – Multi-sensor, Multi-criteria Event Detection

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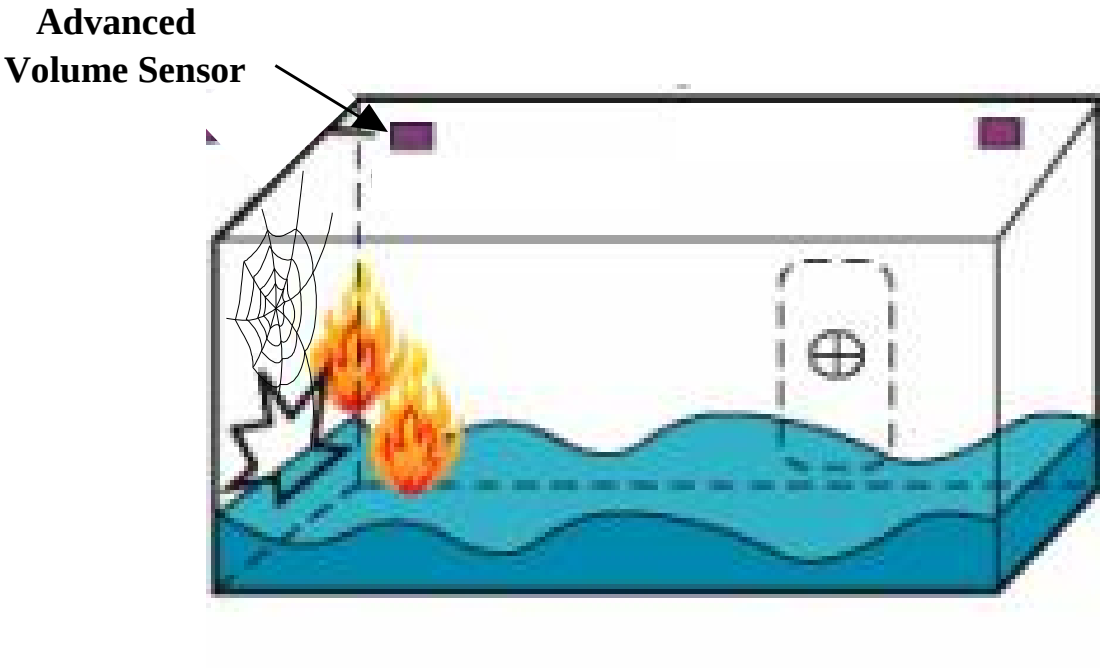
Advanced Damage Countermeasures
Volume Sensor

Objective: Develop an affordable, real-time volume sensor for identification of shipboard conditions such as fire, explosions, pipe ruptures, and flooding level.



Increased Situational Awareness

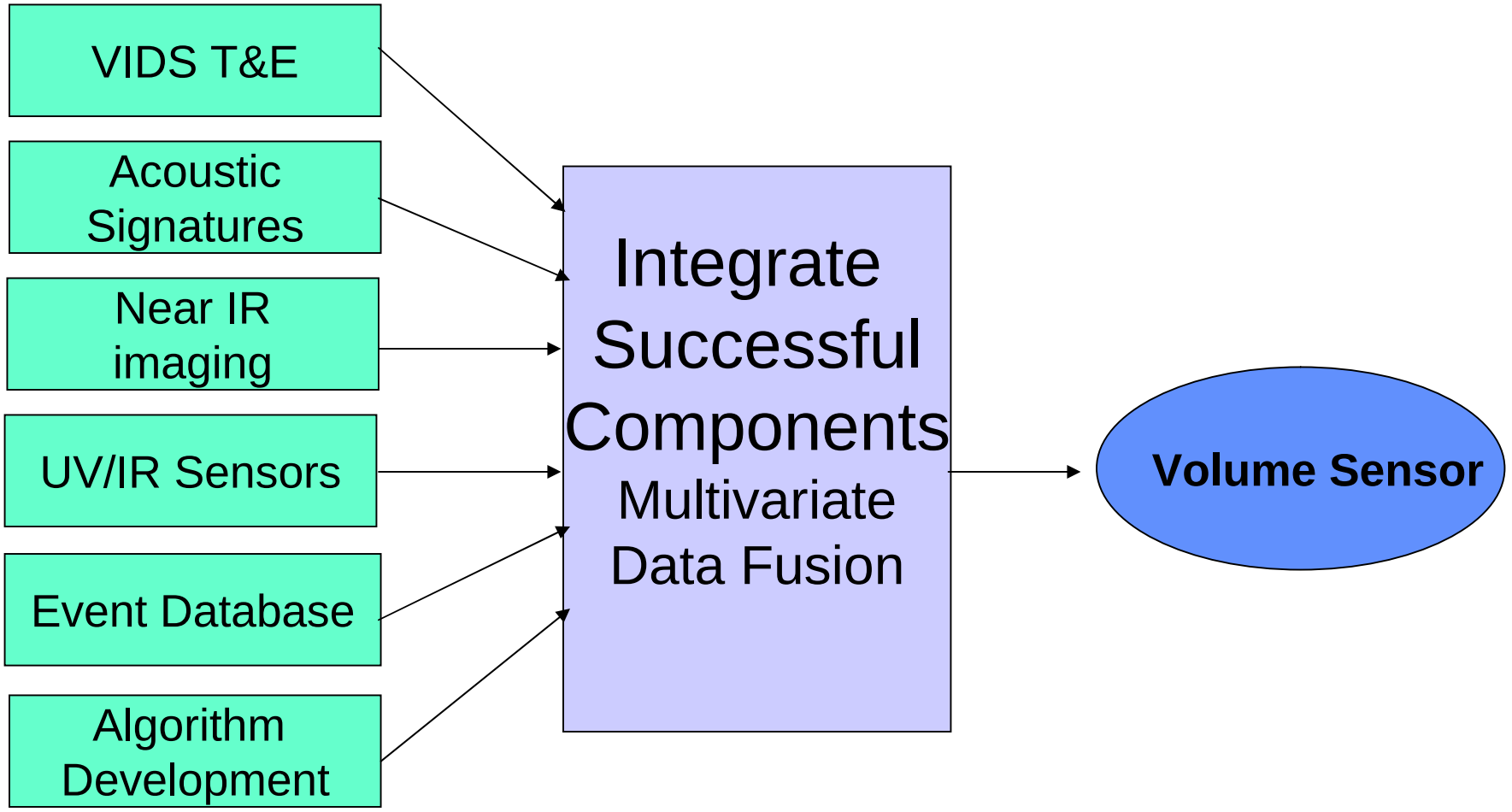
Volume Sensor Suite

DC Central with intelligent supervisory control system aboard ex-USS Shadwell

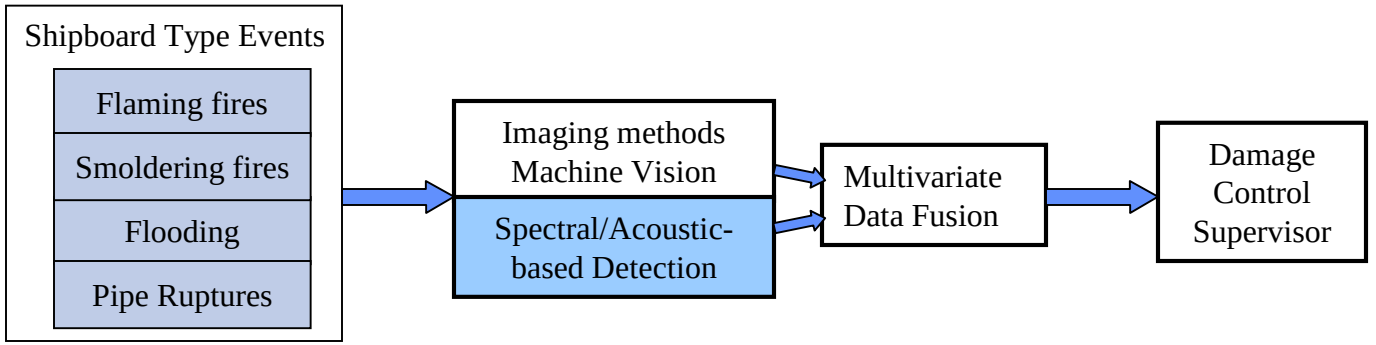
Volume Sensor

- Continuously monitors ships environment
- Automatically notifies damage control personnel
  - Alarm indicators
  - Pop-up video
  - Event classifications

Volume Sensor Concept



Volume Sensor Approach

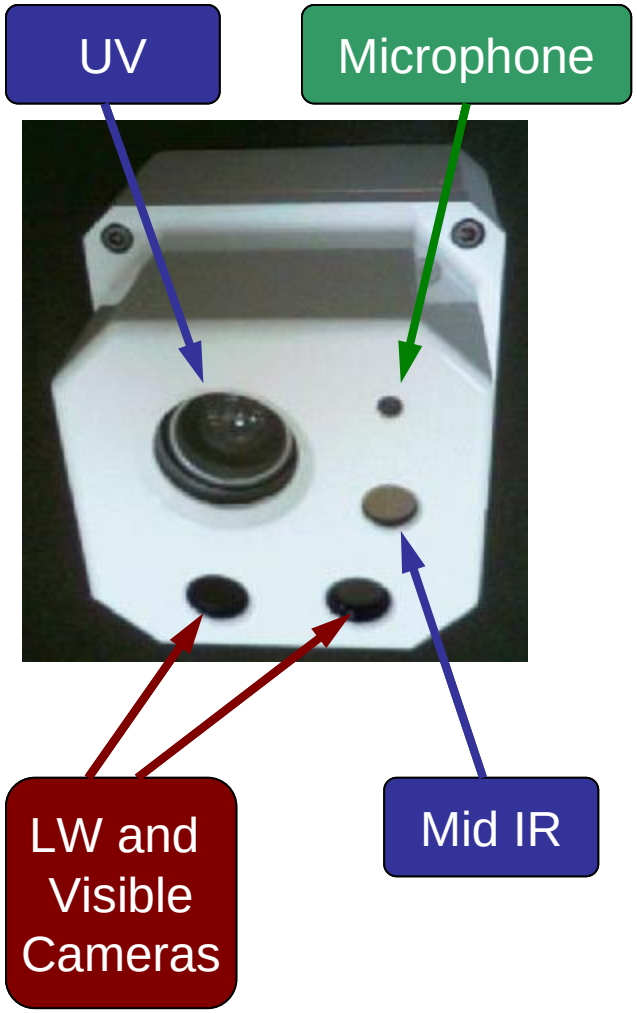


- Investigate commercial video image detection (VID) methods to determine limitations in Navy environment
- Interact with commercial companies to adapt current VID systems for Navy application
- Expand event detection to include flaming and smoldering fires, flooding, pipe ruptures, gas releases and identification of nuisance sources
- Investigate spectral and acoustic signatures to enhance detection
- Develop advanced machine vision and data fusion algorithms
- Develop Volume Sensor Prototype
- Demonstrate Volume Sensor Prototype

FY05 Tasks

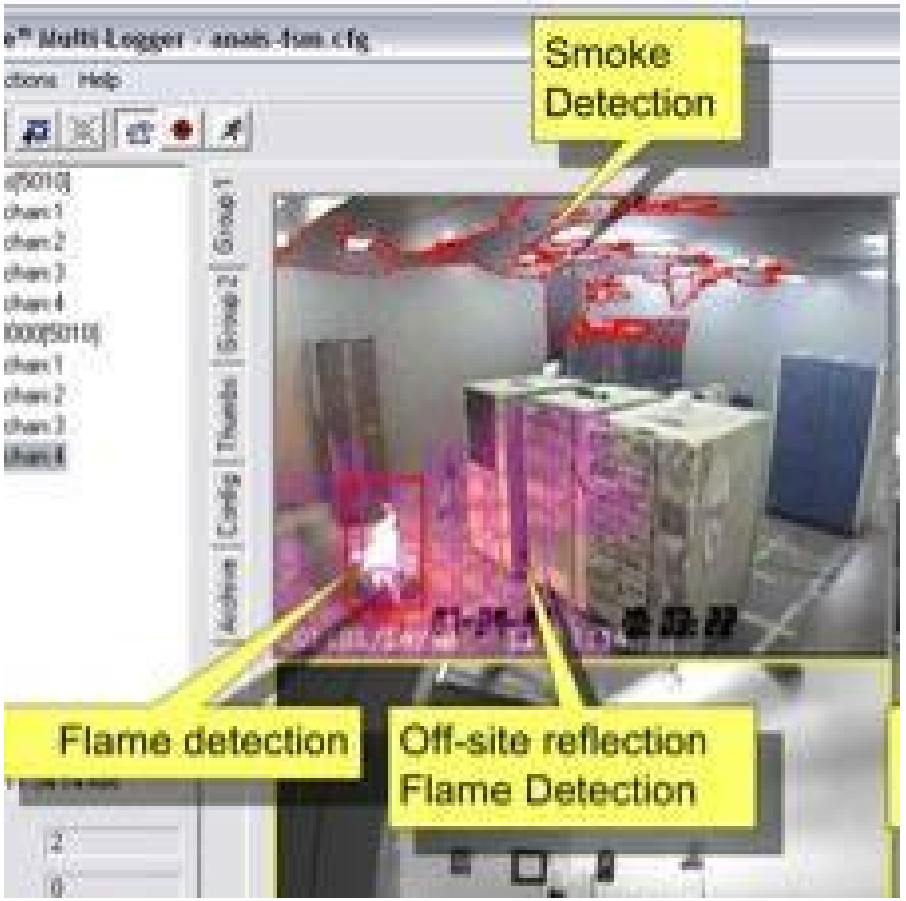
- Improving and refining algorithms
- Integration with Supervisory Control System
- Test series 5 (July 25-Aug 5)
  - Scale up to 6 compartments and 8 VS suites
  - Continued evolution/improvement of algorithms
- Damage Control System Demonstration planned for 15 September (postponed due to Katrina)

Volume Sensor Prototype



Video Image Detection (VID)

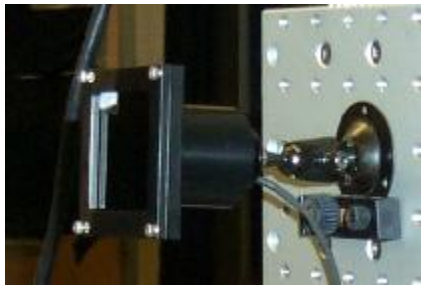
- Video-based Artificial Intelligence algorithms that integrate standard CCTV cameras into an advanced fire, smoke, and motion detection system.
- Some vendors only detect smoke, while others can detect flame, smoke, motion, and even reflected fire light
- Various stages of listings/approvals
- Extensive evaluations by NAVY/HAI
- Comparable and better performance than spot smoke detection
- Systems with smoke and flame algorithms not very sensitive to camera settings – need reasonable video image



Long Wavelength Video Detection

Long wavelength video detection (LWVD):

- Inexpensive
- Augment visible cameras
- Use extended red/NIR sensitivity of standard CCDs
- Long wavelength filter suppresses visible image for higher contrast
- Detect reflected, bright & hot objects
  - Modest thermal imaging
  - Minimum temperature for hot object detection ~ 400ºC
  - NRL luminosity algorithm



LWVD – Reflected Emission

Regular Video

NIR Video

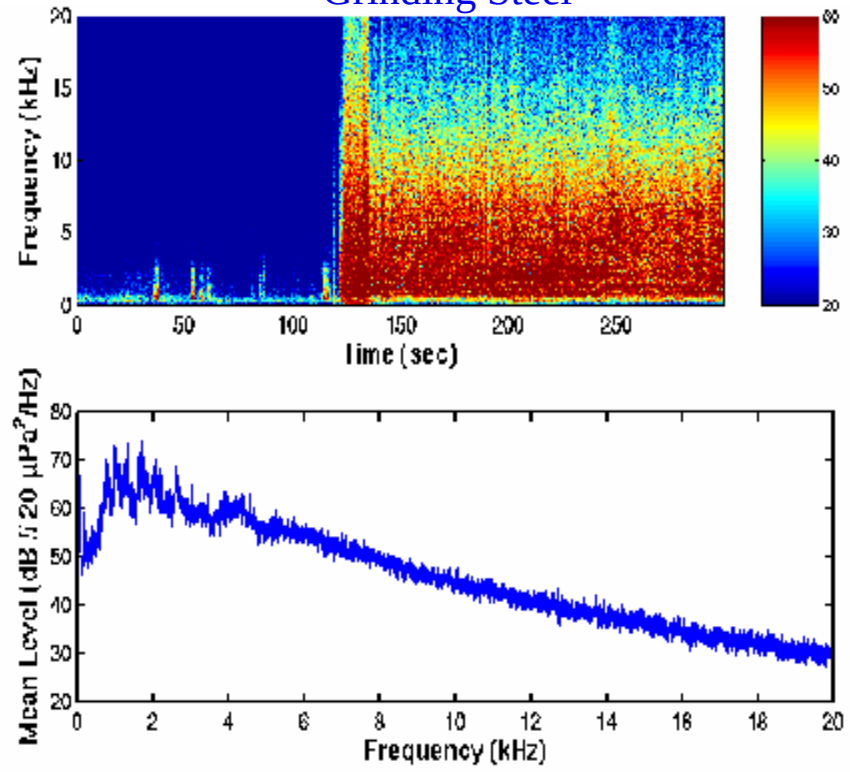
Acoustic Signatures

Objectives

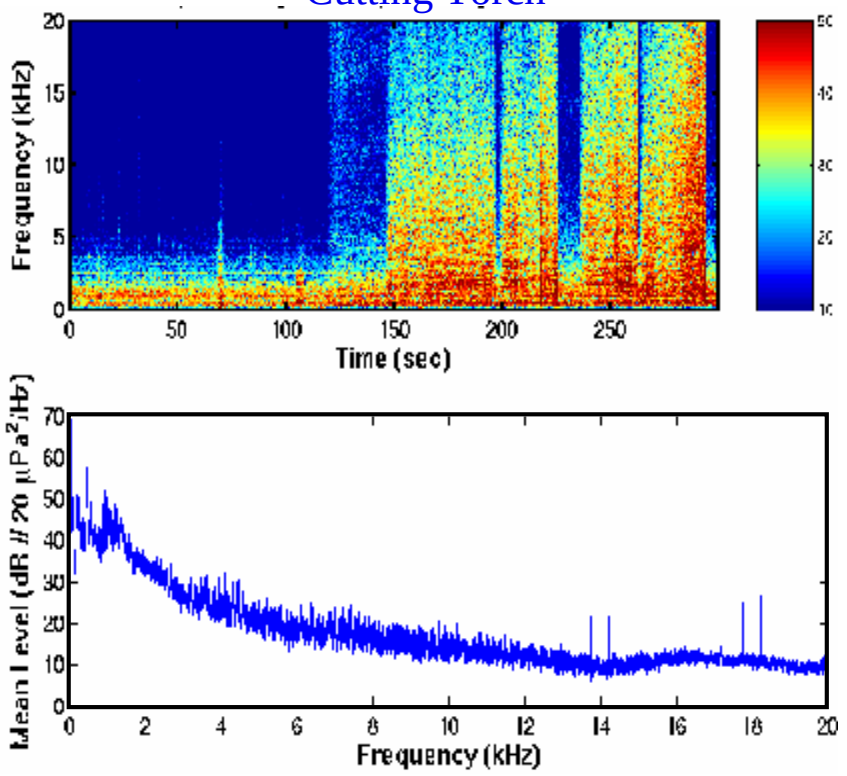
- Determine if acoustic signals generated during a fire are of practical use either alone or in support of a video system
- Develop techniques to identify nuisance events to reduce false alarms for Volume Sensor Prototype
- Detect the acoustic signals for pipe ruptures (liquid fluid flow), gas releases and flooding
  - Identify type of event and severity

Nuisance Events

Grinding Steel



Cutting Torch



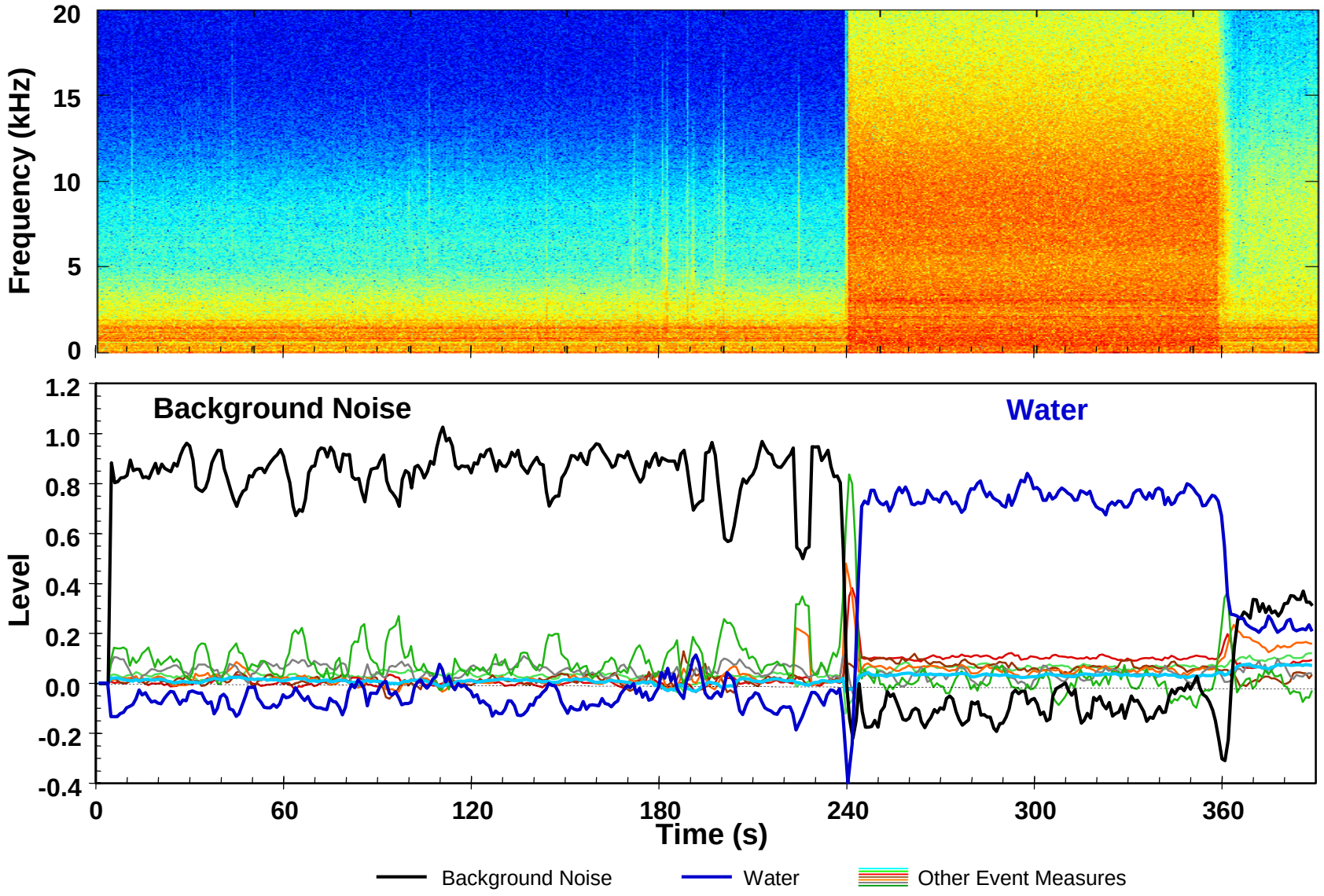
- Grinding Steel
  - –Low low frequency levels
  - –Level varies 5-10 dB with time

  Cutting Torch

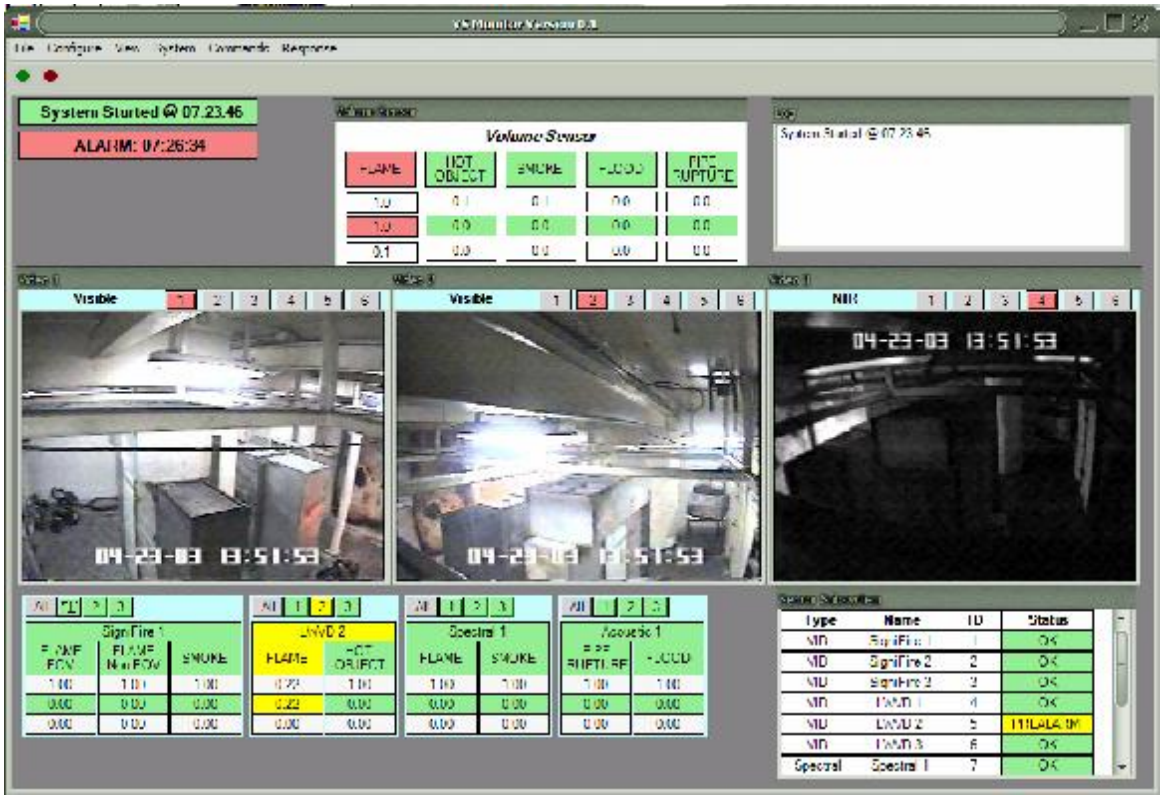
  Irregular spectra, occasional HF hump

  On-off nature of event
- Many nuisances are acoustically loud with a unique time-frequency character.
- Both examples above also show evidence of people working prior to the event.
- Algorithms developed for common nuisance sources (e.g., grinding and welding)

Detection Example - Water from Pipe Slit



Volume Sensor Prototype (VSP)

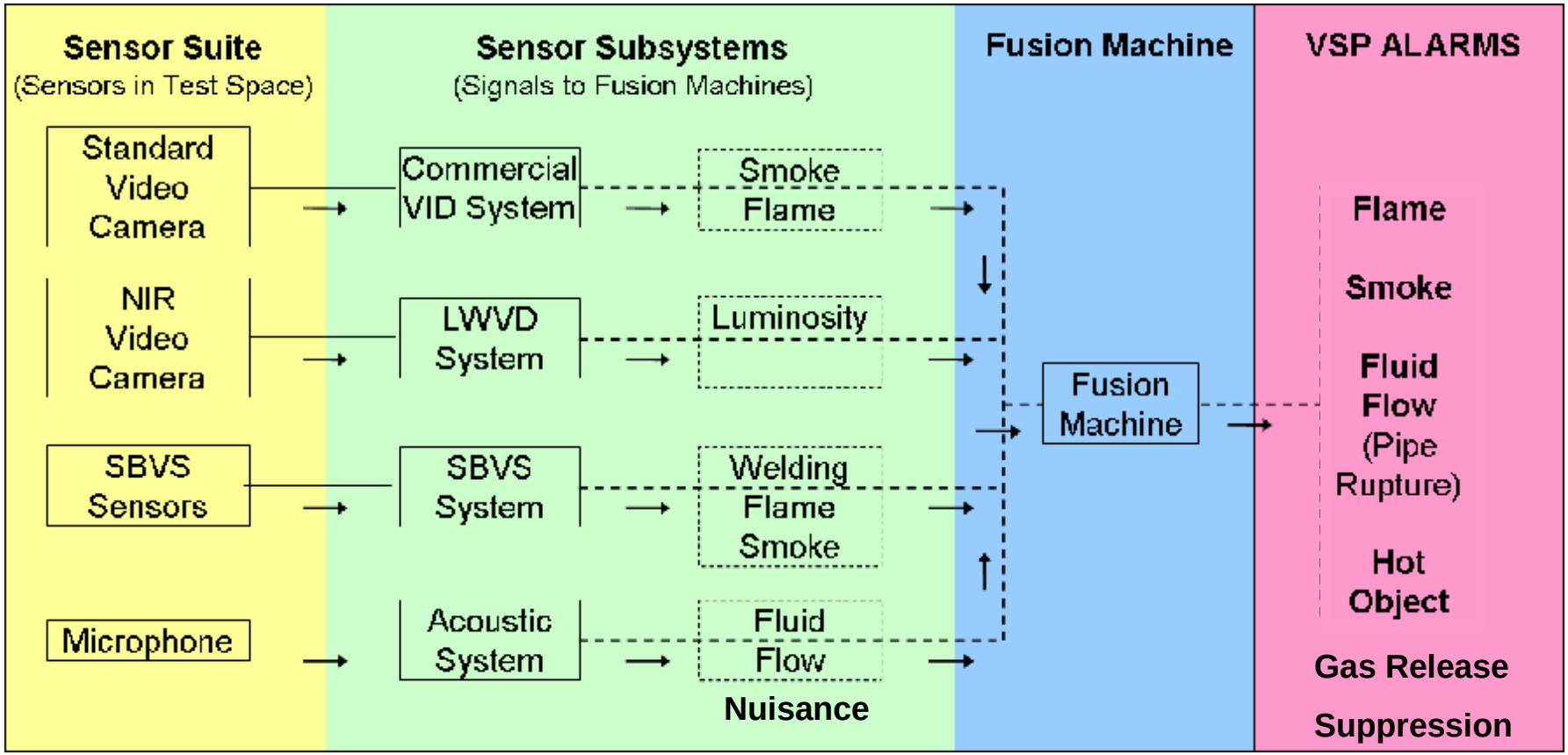


Captures strengths of sensor systems while minimizing their weaknesses

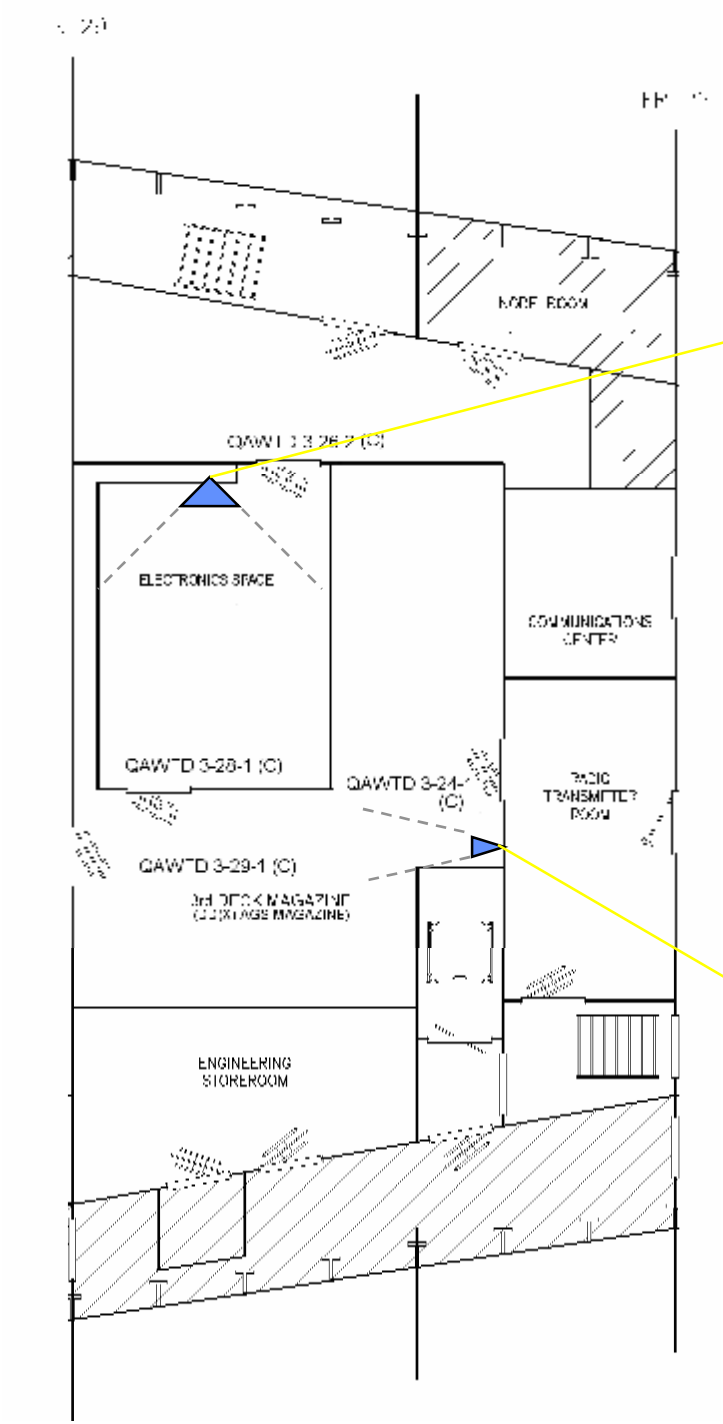
Incorporates event detection capabilities of individual sensors

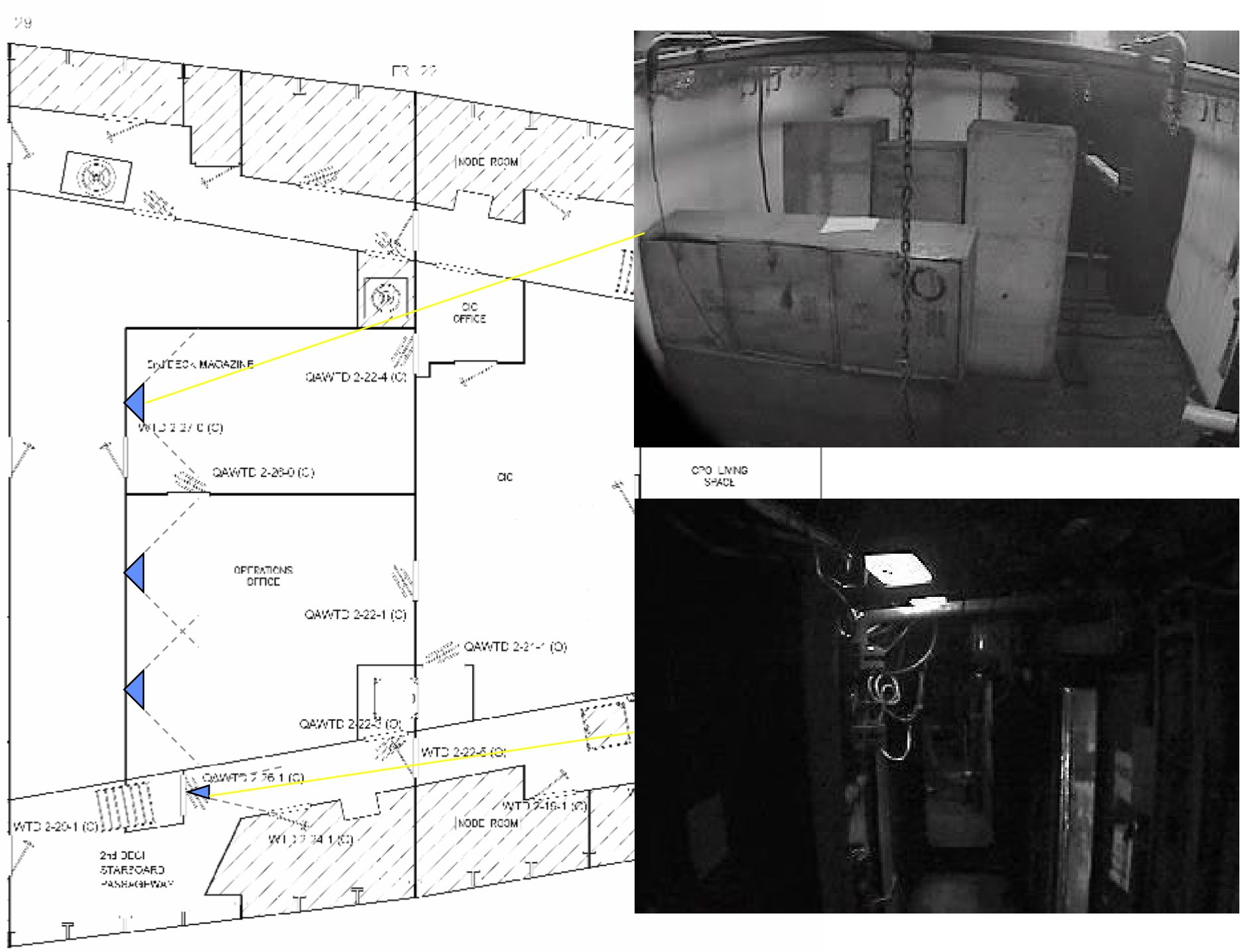
Data fusion uses multivariate analysis methods and Bayesian-based decision network

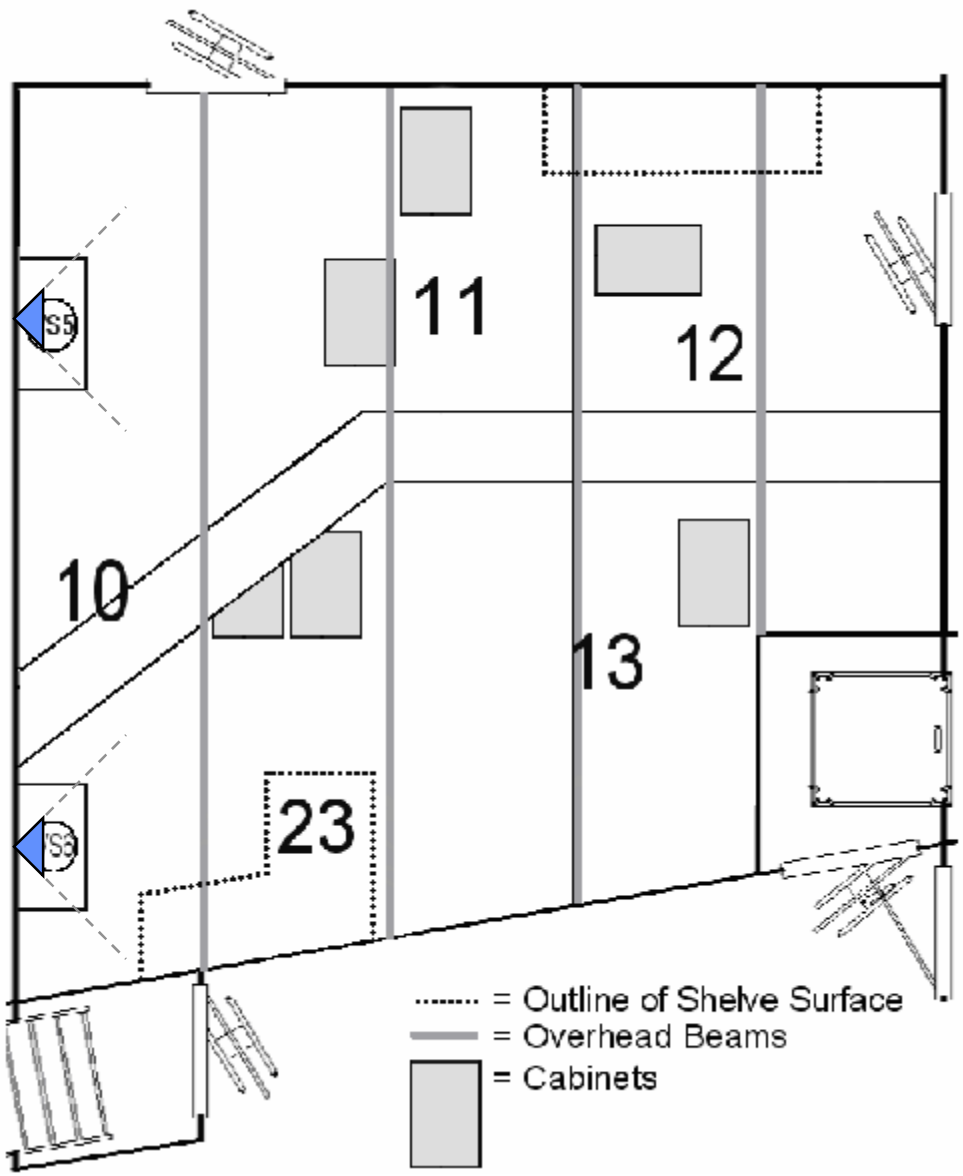
Volume Sensor Prototype Tested



Summary of Test and Evaluation


ELECTRONICS SPACE
QAWTD 3-28-1 (C)
QAWTD 3-29-1 (C)
ENGINEERING
STOREROOM


NODE ROOM
CIC OFFICE
QAWTD 2-22-4 (C)
CIC
CPO LIVING SPACE
OPERATIONS OFFICE
QAWTD 2-22-1 (C)
WTD 2-22-5 (C)
WTD 2-20-1 (C)
NODE ROOM

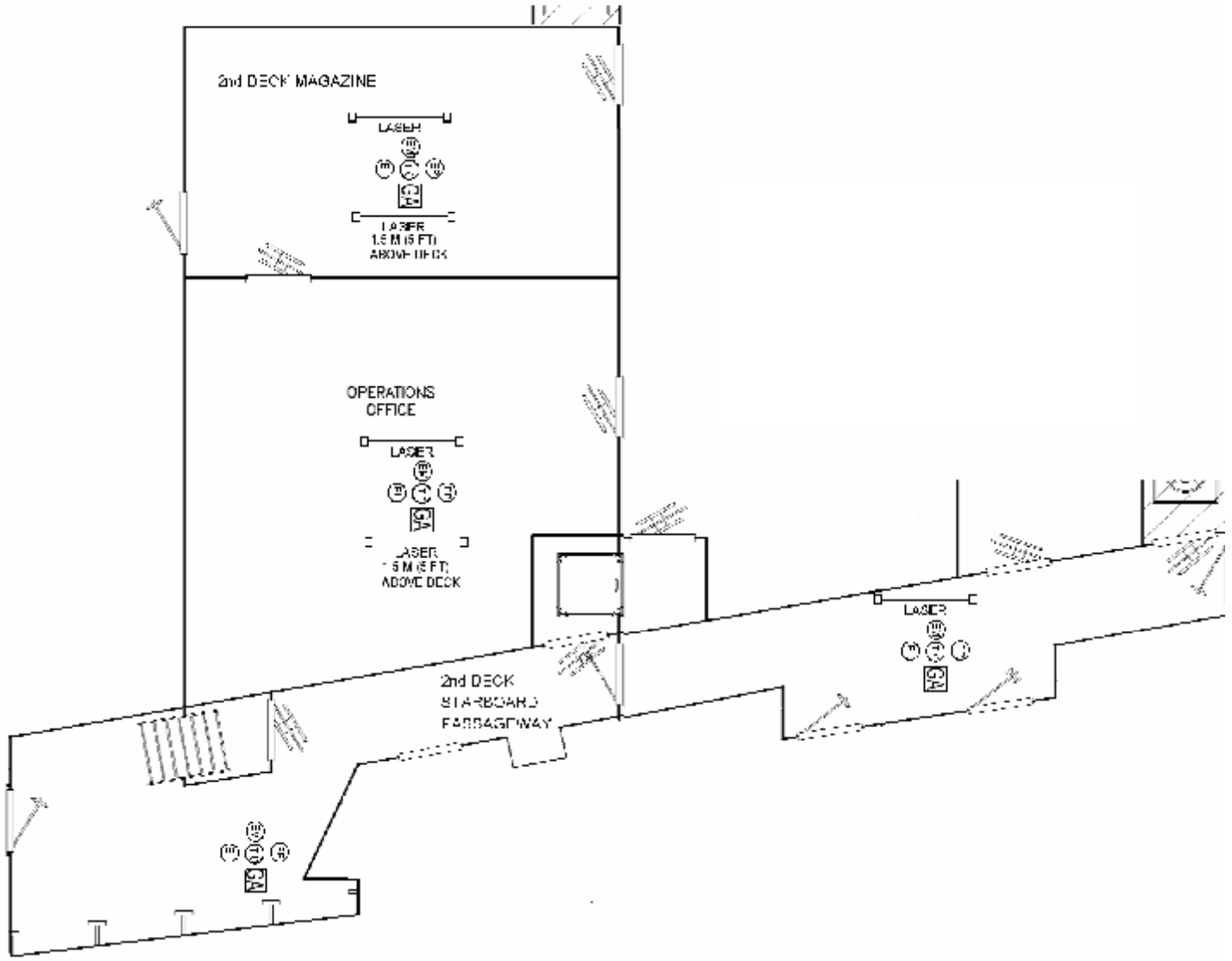

11
12
10
13
23
S5
S3
..... = Outline of Shelve Surface
= Overhead Beams
= Cabinets

Measures of Performance

- Ability to operate in multiple compartments with multiple simultaneous sources.
- Ability to discriminate sources in compartments varying in size, shape, and content (obstructions).
- Ability to successfully integrate with the AFSS control system

- The percent correct classification of sources vs spot-type and VID systems.
- The speed of response to fire sources compared spot-type and VID systems.

Smoke Detectors



Fire Sources

- Flaming cardboard boxes with polystyrene pellets
- Flaming trash can
- Flaming shipping supplies
- Flaming IPA spill fire
- Smoldering mattress and bedding
- Smoldering cable bundle
- Smoldering laundry
- Smoldering oily rags
- Painted bulkhead heating
- Shielded IPA pan fire

Nuisance Sources

- Torch cut steel
- Welding
- Grinding painted steel
- Toaster:normal toasting
- Engine exhaust
- People working in space
- Waving materials
- Spray aerosol
- Spilling metal bolts
- Space heater
- Heat gun
- Flash photography
- AM/FM radio
- VHF radio
- TV

Water Flow Sources

- Water aerosol (mist)
- Pipe rupture (gash)
- Pipe rupture (open pipe)
- Pipe rupture (sprinkler)
- Water mist system
- Pipe rupture (9 holes)
- Pipe rupture (small gash)

Gas Release Sources

- Air and Nitrogen
- Various orifice sizes
- Various pressures

Comparison of Detection Capability

Event Type	VSP1	VSP2	SFA	SigniFire	Ionization	Photoelectric	Multi-criteria
Flaming[1]	**95% (38)**	**97% (38)**	91% (33)	95% (37)	88% (32)	75% (32)	88% (32)
Smoldering[2]	71% (28)	75% (28)	65% (26)	89% (27)	63% (27)	**93% (27)**	78% (27)
Fire Sources	85% (66)	88% (66)	80% (59)	**92% (64)**	76% (59)	83% (59)	83% (59)
Nuisance	80% (40)	85% (40)	49% (43)	57% (45)	71% (38)	**92% (32)**	83% (36)
Pipe Rupture[3]	**88% (16)**	**88% (16)**	NA[4]	NA	NA	NA	NA
Gas Release	**53% (17)**	**53% (17)**	NA	NA	NA	NA	NA

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Pipe Rupture[3]	**88% (16)**	**88% (16)**	NA[4]	NA	NA	NA	NA
Gas Release	**53% (17)**	**53% (17)**	NA	NA	NA	NA	NA

Speed of Response Evaluation

Flaming (33 events)						Flaming (33 events)				
	VSP1	EST Ion	EST Photo	EST Multi			VSP2	EST Ion	EST Photo	EST Multi
First	82%	12%	3%	6%		First	82%	12%	3%	6%
30 sec	82%	12%	3%	6%		30 sec	82%	12%	3%	6%
120 sec	88%	21%	9%	15%		120 sec	85%	18%	9%	12%
Smoldering (27 events)						**Smoldering (27 events)**				
	VSP1	EST Ion	EST Photo	EST Multi			VSP2	EST Ion	EST Photo	EST Multi
First	74%	7%	11%	0%		First	67%	14%	4%	4%
30 sec	74%	7%	11%	0%		30 sec	74%	14%	4%	7%
120 sec	74%	11%	14%	4%		120 sec	78%	18%	18%	18%

Speed of Response Evaluation

Flaming (33 events)									
	VSP1	EST Ion	EST Photo	EST Multi		VSP2	EST Ion	EST Photo	EST Multi
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	VSP1	EST Ion	EST Photo	EST Multi		VSP2	EST Ion	EST Photo	EST Multi
First	74%	7%	11%	0%	First	67%	14%	4%	4%
30 sec	74%	7%	11%	0%	30 sec	74%	14%	4%	7%
120 sec	74%	11%	14%	4%	120 sec	78%	18%	18%	18%

Speed of Response Evaluation

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	VSP1	EST Ion	EST Photo	EST Multi		VSP2	EST Ion	EST Photo	EST Multi
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120 sec	**88%**	**21%**	**9%**	**15%**	120 sec	85%	18%	9%	12%
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30 sec	74%	7%	11%	0%	30 sec	74%	14%	4%	7%
120 sec	**74%**	**11%**	**14%**	**4%**	120 sec	78%	18%	18%	18%

Conclusions

- The VSP systems demonstrated the ability to function in multiple compartments, specifically discriminating between multiple types of events in multiple compartments.
- The VSP systems demonstrated the ability to discriminate between source types by detecting flaming and smoldering fire sources, water releases, and gas releases while rejecting nuisance sources.
- The VSP systems generally performed better than VID and spot-type smoke detection systems relative to the range of detection capabilities, ability to detect fires, ability to reject nuisance sources, and speed of response.

Volume Sensor Team

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