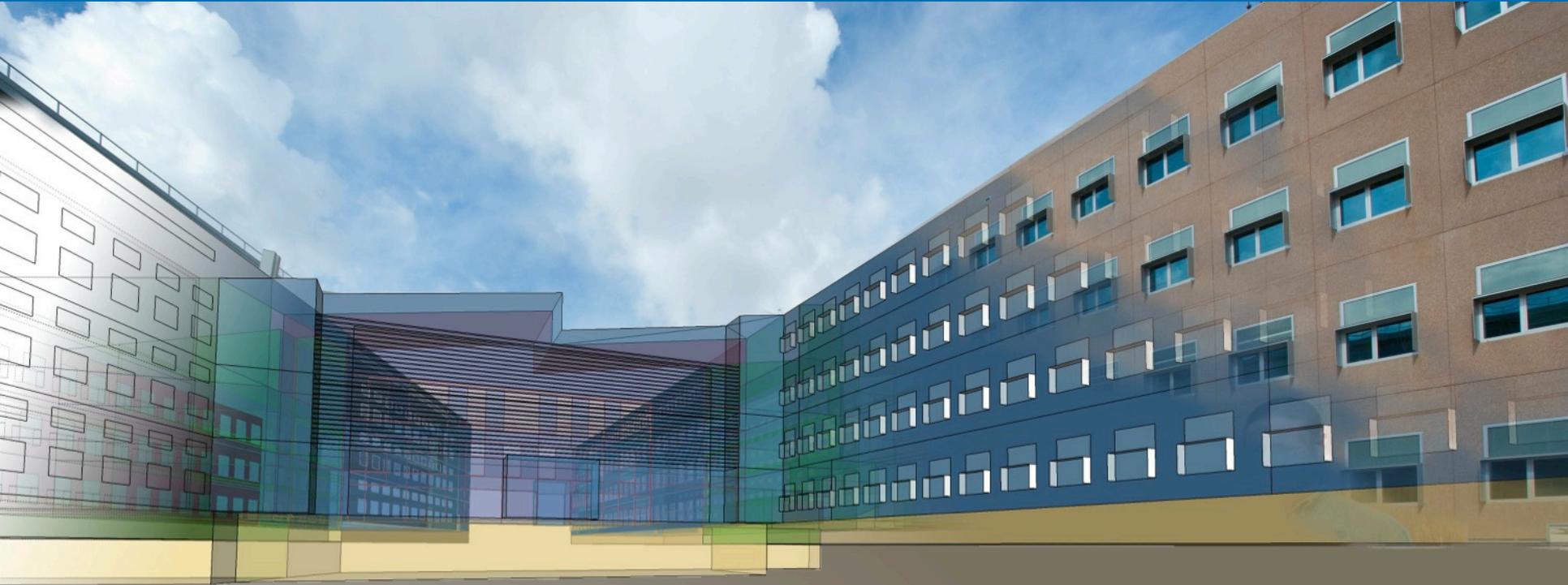


Image Processing Occupancy Sensing



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The Occupancy Sensing Problem

- **Problem:**

- Current occupancy detection technologies* **infer** occupancy via motion
- False negatives result in occupant discomfort, false positives in energy waste
- Sensors are undertuned or even defeated, trading off energy savings
- Sensors have very limited range
- Sensors perform a single function

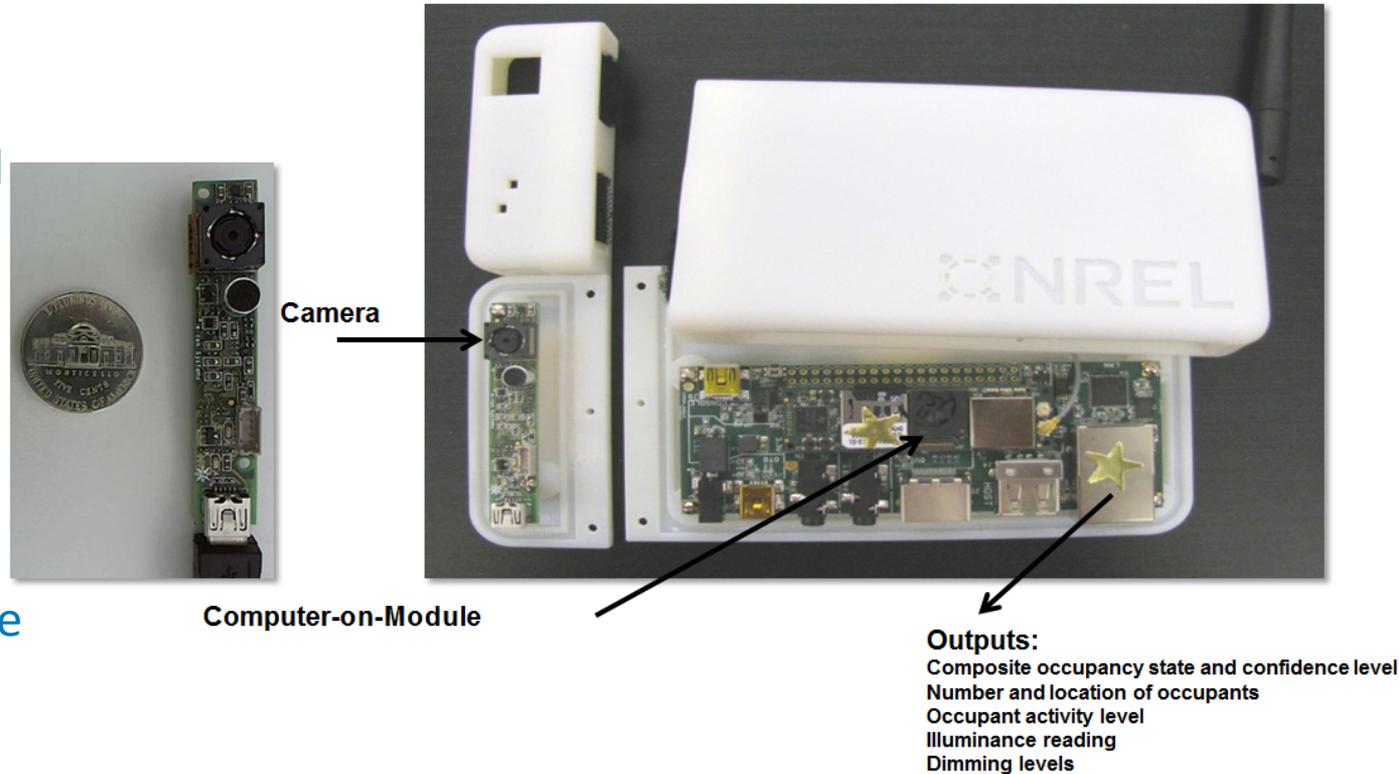
- **Objectives:**

- Produce a low-cost occupancy sensor with greater accuracy and range
- Provide a richer set of outputs with a single device that enables a larger number of building automation use cases and applications

* Passive Infrared (PIR) sensors are a prevalent technology

Image Processing Occupancy Sensing (IPOS)

- IPOS uses image processing to identify occupancy
- Uses commodity hardware produced for the cell phone industry
 - Small form factor
 - Low cost
 - Low power consumption
- Built on open source software
 - OpenCV computer vision library
 - Open BACnet

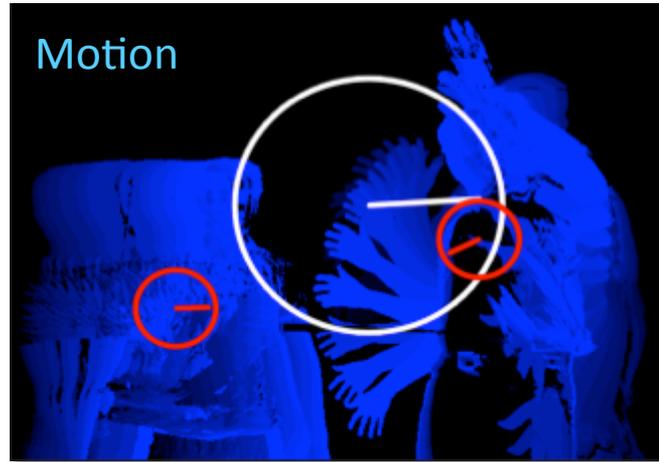


Quarter Shown for Scale

Image Processing Occupancy Sensing (IPOS)

- Image processing can provide a more robust solution and a richer set of feedback

- Multiple detection methods
- Number of occupants
- Location estimation
- Activity level
- Luminance



- Single sensor

- Provides multiple functions
- Covers a larger area than current technologies



Occupant Location and Luminance Estimation



- IPOS can extract a richer set of information from digital images
- In this example the embedded system estimates occupant location

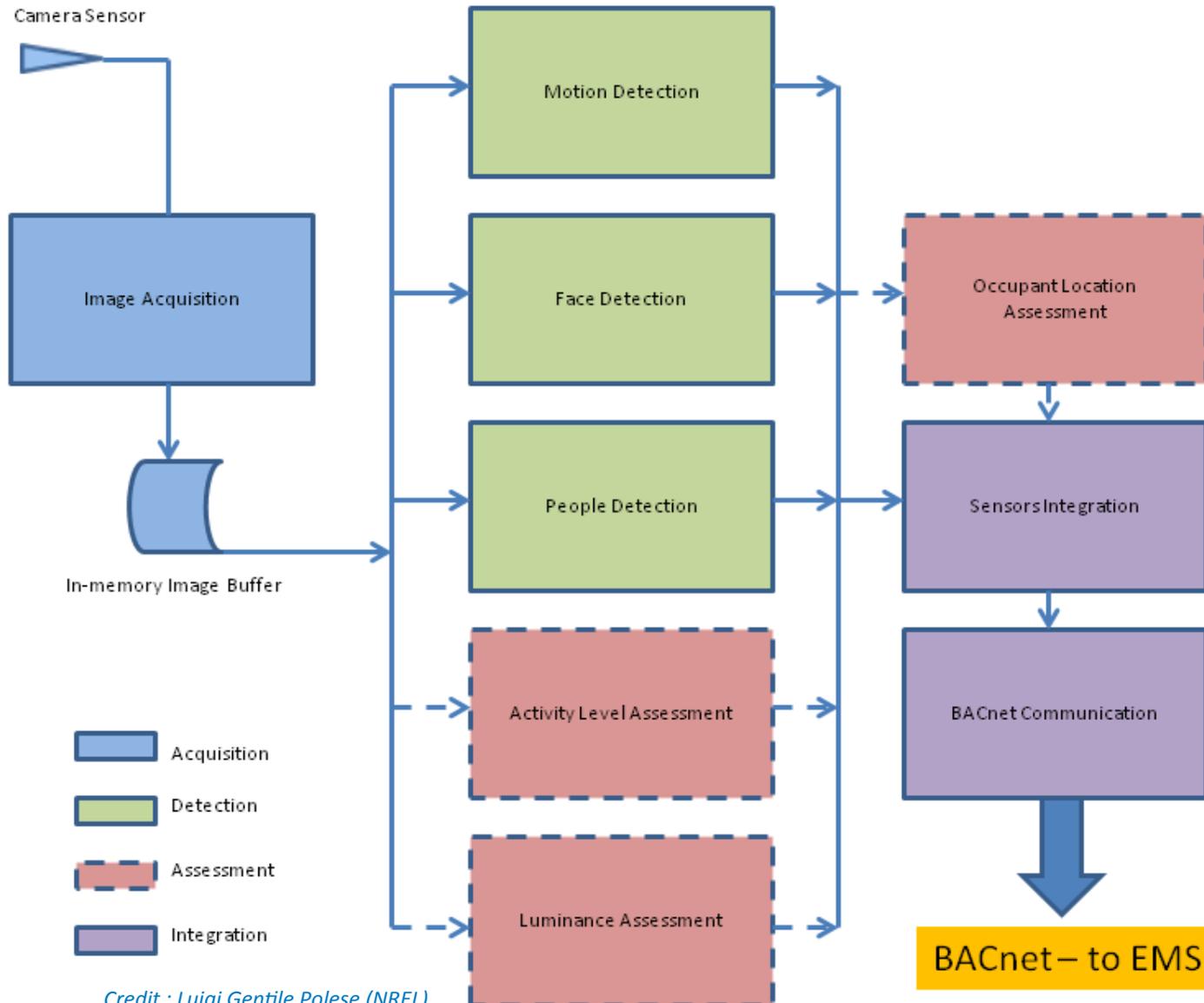
Occupants	Frame Size (pixels)	Source	Area (pixels ²)	Estimated Distance (ft)	Angle (degrees)
1	320 × 240	PDM	6,272	10.3	100.0

- The data can be used to localize lighting for increased energy savings



- A single sensor can also estimate scene luminance for daylighting control
- Luminance estimation improved through software-controlled exposure

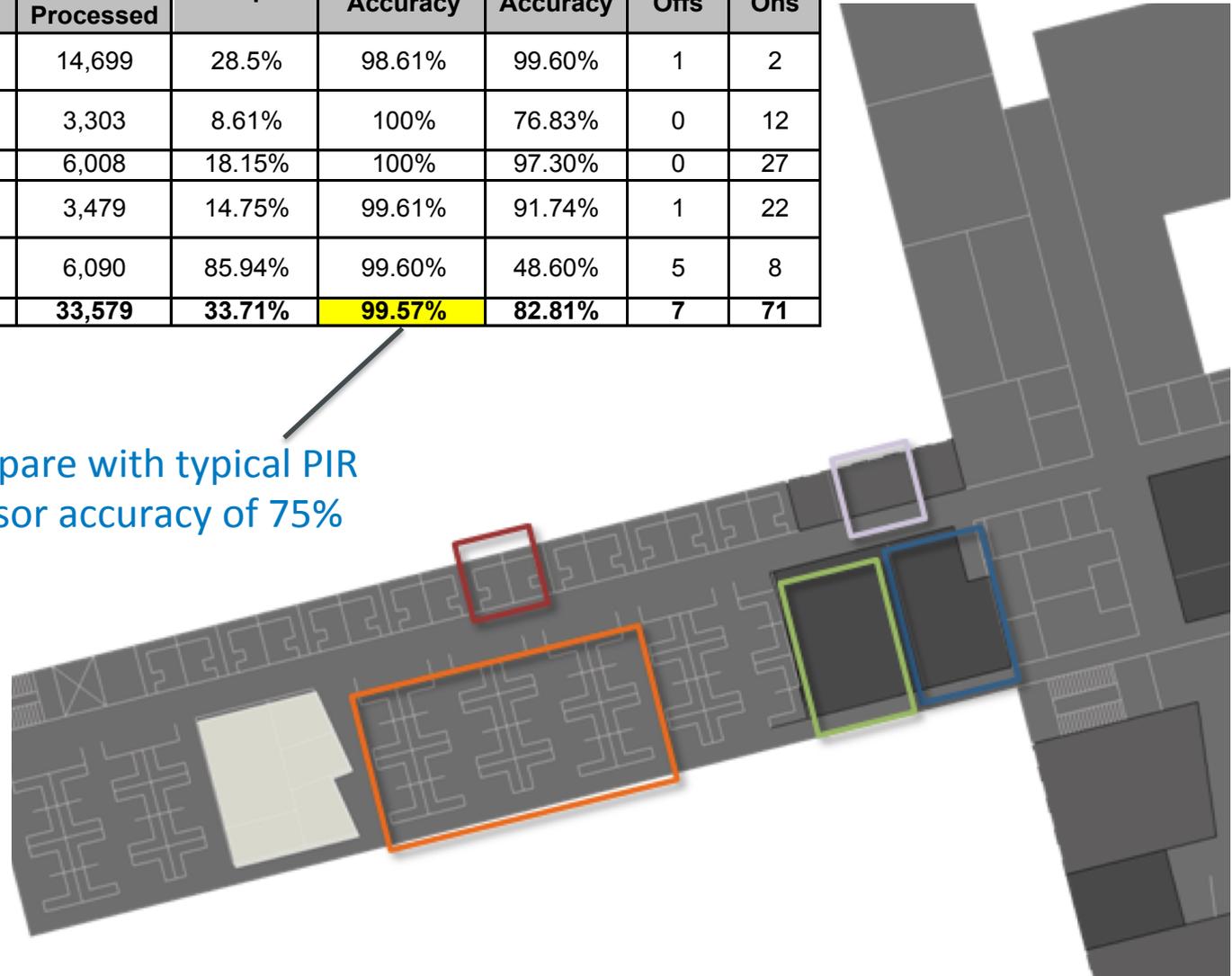
IPOS Software Architecture



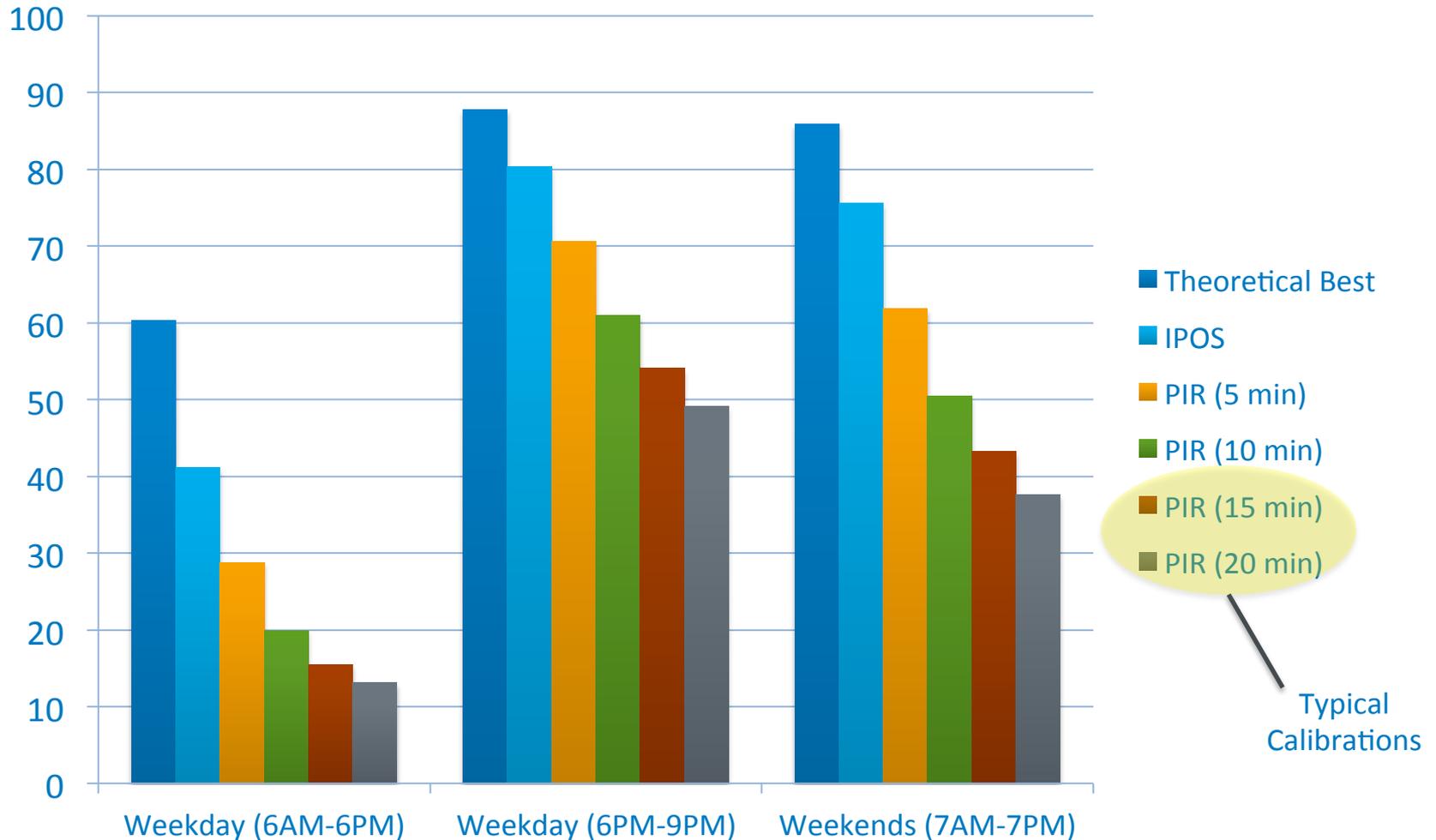
Preliminary Test Results at NREL's RSF

Zone Evaluated	Test Duration (s)	Image Frames Processed	Occupied	Occupancy Accuracy	Vacancy Accuracy	False Offs	False Ons
Conference Room	27,881	14,699	28.5%	98.61%	99.60%	1	2
Enclosed Office	17,106	3,303	8.61%	100%	76.83%	0	12
Kitchen	8,824	6,008	18.15%	100%	97.30%	0	27
Print/Copy Room	4,467	3,479	14.75%	99.61%	91.74%	1	22
Open Office	11,022	6,090	85.94%	99.60%	48.60%	5	8
All Zones	69,300	33,579	33.71%	99.57%	82.81%	7	71

Compare with typical PIR sensor accuracy of 75%



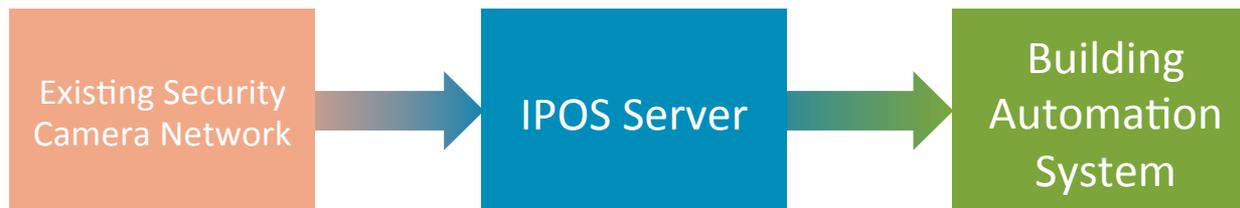
Potential Percentage Energy Savings



Comparison of potential energy savings in RSF spaces with perfect occupancy knowledge, IPOS performance, and PIR sensors using varying sensor timeout calibrations to avoid complaints

A Broader Value Proposition

- As a physical sensor, IPOS can replace multiple PIR, daylight harvesting, and CO₂ sensors for lower first cost, improved comfort, and greater energy savings.
- These same algorithms may be applied to any digital imagery.
- Why not turn a building security network into a system that can save energy as well?



IPOS Is a Leap Forward

- Substantial improvement in occupancy detection accuracy that leads to increased energy savings
- Ability to provide a rich set of feedback from a single device for multiple control applications
 - Lighting
 - Daylighting
 - Demand controlled ventilation
 - Temperature management
- Potential to integrate with building security systems for even greater capital savings

Image Processing Occupancy Sensing

Thank You!

Questions?

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