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# National Institute of Building Sciences

Provider Number: G168

## Smart Buildings Can't Exist Without Machine Learning

Course Number

Dr. Filip Ponulak

January 8, 2019





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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.





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## Course Description

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Machine learning has taken residence at our cities' cores and now we can finally have "smart cities." Cities are a collection of buildings made to provide the structure and safety necessary for people to function, create and survive. Buildings are a pool of ever-changing performance data from large automated systems such as heating and cooling to the people that live and work within them. Through machine learning, buildings can optimize performance, reduce costs, and improve occupant comfort by sharing information within the building and with outside city infrastructure via real time shared cloud capabilities.





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# Learning Objectives

At the end of the this course, participants will be able to:

1. Understand all the sources of data within a building.
2. Know how machine learning can take data points into increased building performance and efficiency, including predictive maintenance.
3. Understand the importance of personal preference on inhabitants' productivity, comfort and mood.
4. Recognize the value of buildings as the core of smart cities





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# SMART BUILDINGS CAN'T EXIST WITHOUT MACHINE LEARNING

Filip Ponulak, PhD

Director of Data Science, Site 1001

[www.site1001.com](http://www.site1001.com)





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# SMART DEVICES

By now, we are used to many IoT devices...



Smart thermostats



Smart lighting



Smart cameras



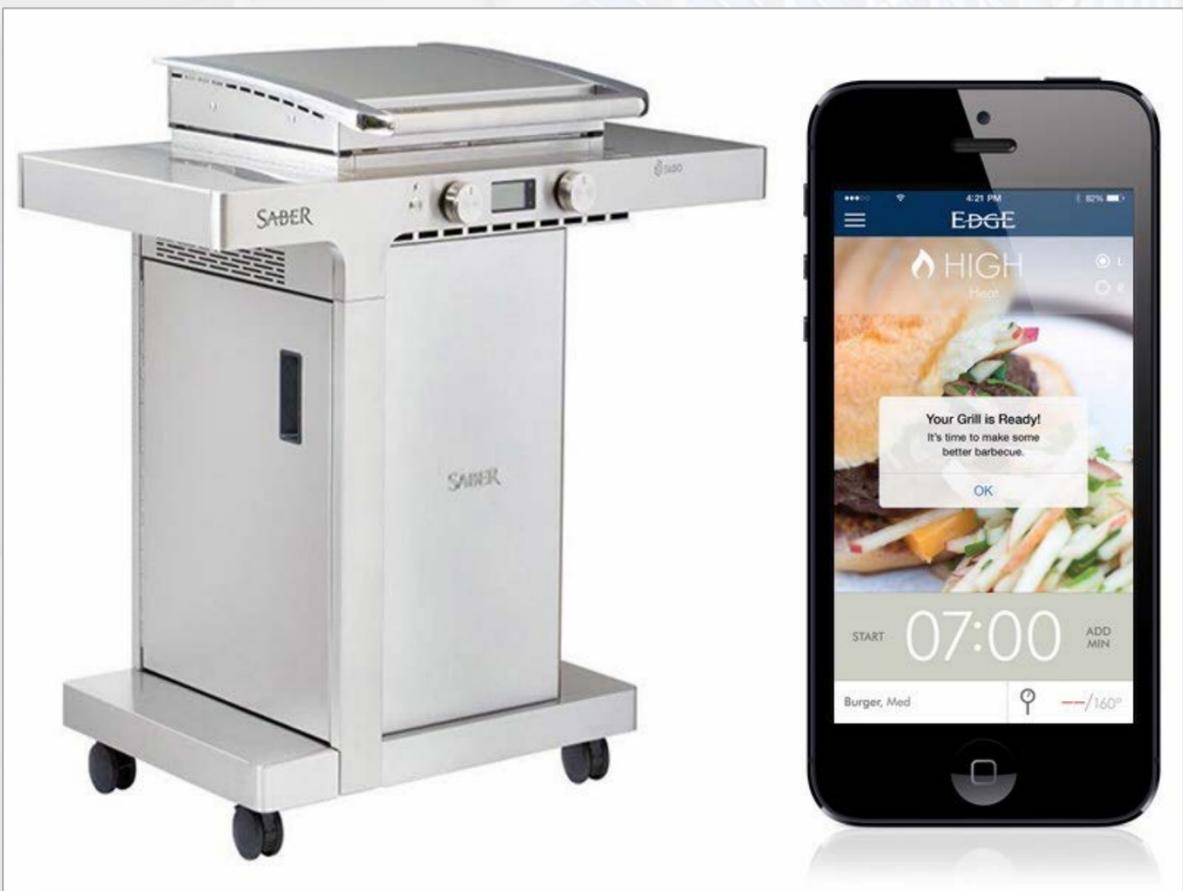
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# SMART DEVICES

But, apparently, everything needs to be smart today ...



Smart BBQ



Smart shower



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# SMART DEVICES

But, apparently, everything needs to be smart today ...



Smart BBQ



Smart shower



Smart fork



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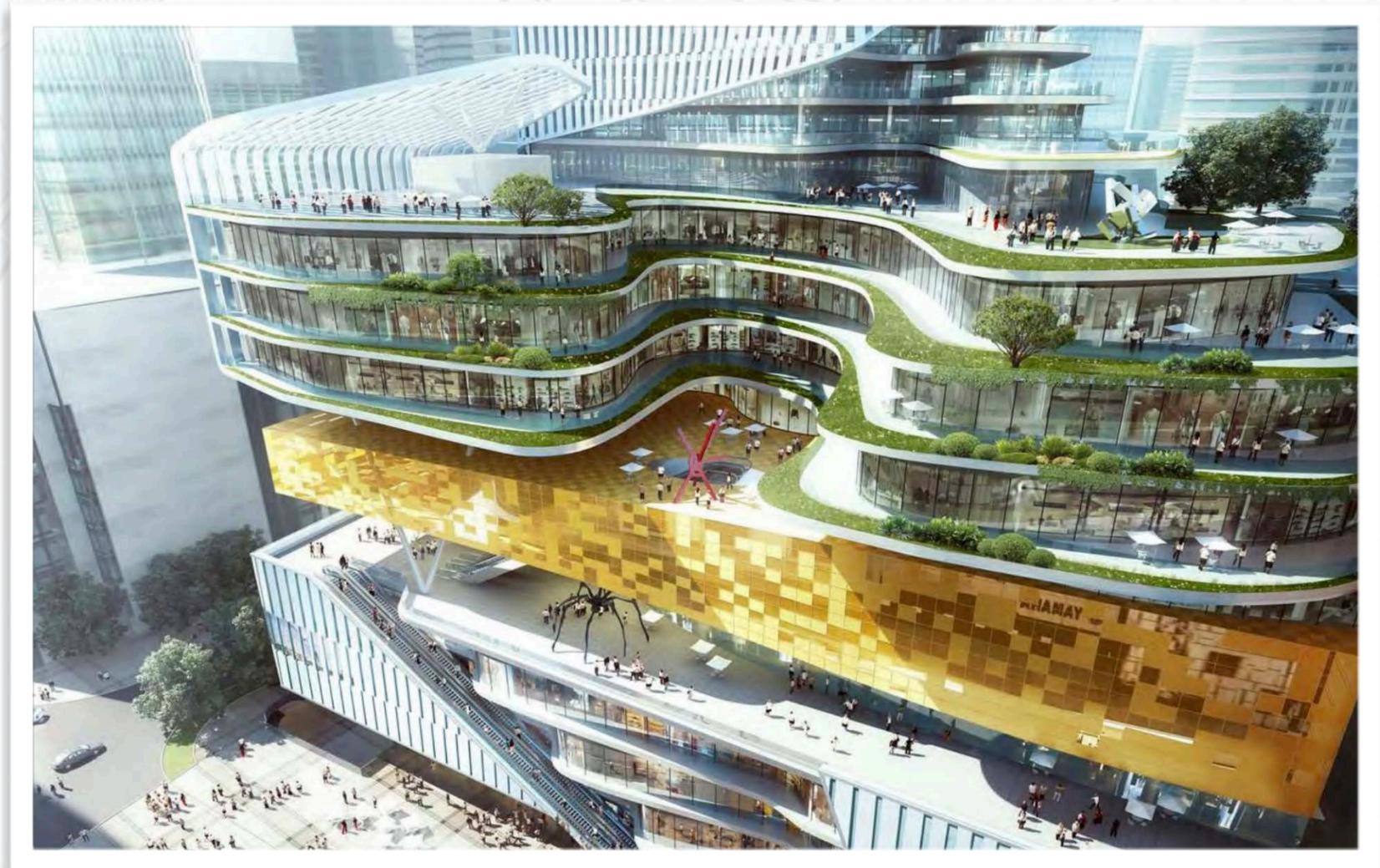
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# SMART CITY

Is this just yet another buzzword?

The term has been overused, but  
the objectives are real and tangible ...





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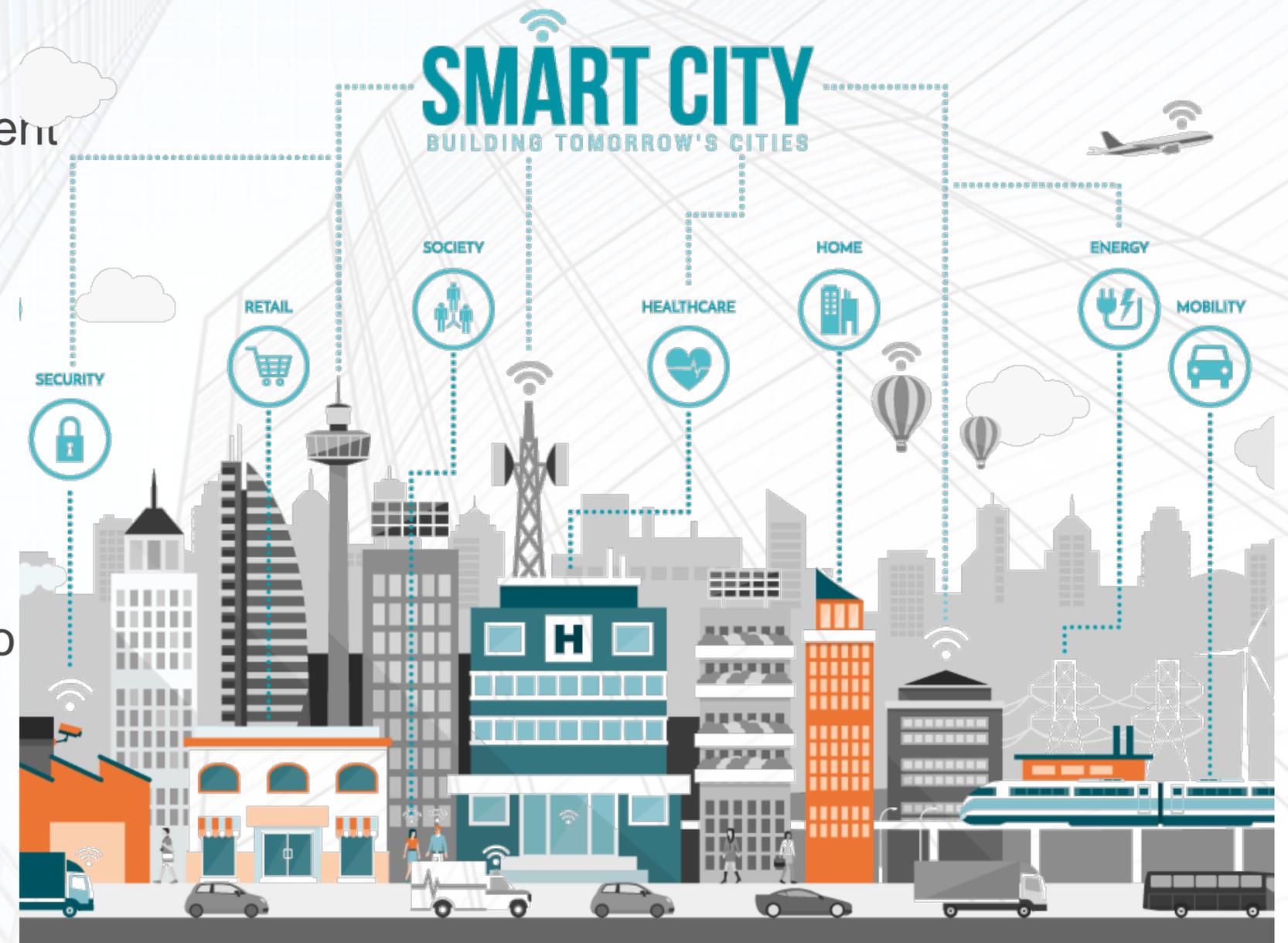
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# SMART CITIES

## Value Proposition

- Cities equipped with **technology** and processes used to create an environment that is:
  - **safe,**
  - **healthy,**
  - **comfortable,**
  - **enables productivity**
  - **and well-being for its citizens.**
- The technology and processes are also used to:
  - **optimize city operations,**
  - **reduce costs / waste and improve sustainability**



# SMART BUILDINGS

(Personal) vision of a smart building of the 'near-term' future:

- **Personalized environment:**
  - thermal comfort
  - noise level control
  - individual lighting preferences
- **Healthier environment:**
  - air quality control, sickness identification / containment
- **Convenience & time-efficiency:**
  - availability of local amenities (restaurants, gym),
  - available ground transportation/timing, traffic monitoring, etc.

Would anyone care to live in such a building or work in such an office?



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# ABOUT THE SPEAKER

Dr. Filip Ponulak, Director of Data Science, Site 1001

### Academic Experience:

- M.Sc. in Robotics, Automation and Control, PUT Poland
- Ph.D in Artificial Intelligence, PUT Poland
- Postdoctoral Researcher, Freiburg University, Germany
- Postdoctoral Researcher, Princeton University, USA

### Industrial Experience:

- Data Analytics | Smart buildings | AI & Robotics | IoT



**SITE 1001™**  
Your building is talking. Are you listening?

'id:analytics.



**LifeLock**  **Symantec**

brain CORPORATION 

**QUALCOMM®**



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# ABOUT SITE 1001

## PLATFORM



## OBJECTIVES:

- Create building environments that are:
  - safe,
  - healthy,
  - comfortable,
  - enable productivity and
  - well-being for its occupants.
- Use analytics & AI to:
  - optimize building operations,
  - reduce costs and improve the ROI.



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# SMART BUILDINGS

Using technology to provide the following:





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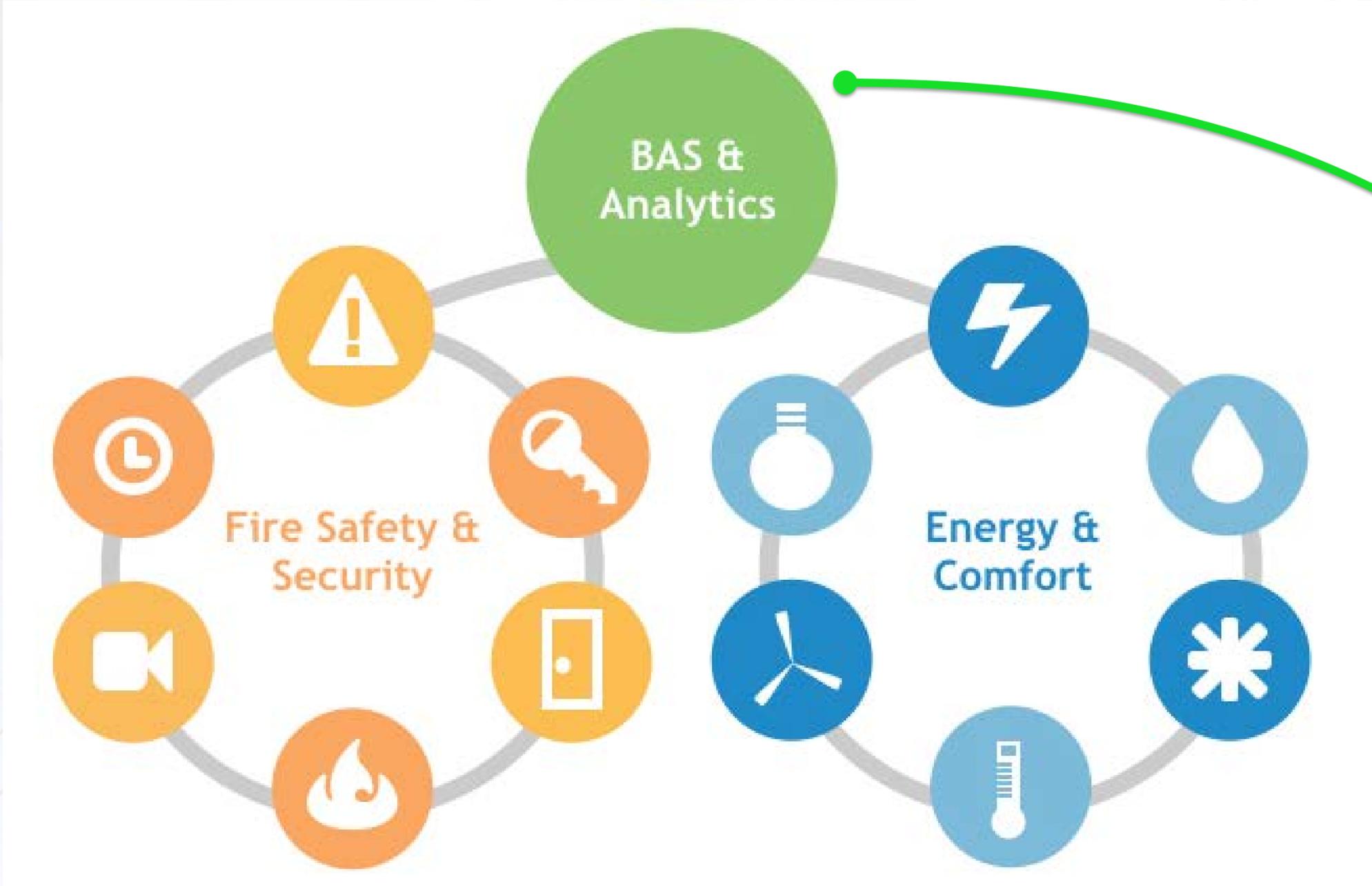
# SMART HOMES

Multiple, disparate systems



# COMMERCIAL SMART BUILDINGS

Integration through Building Automation System (BAS)



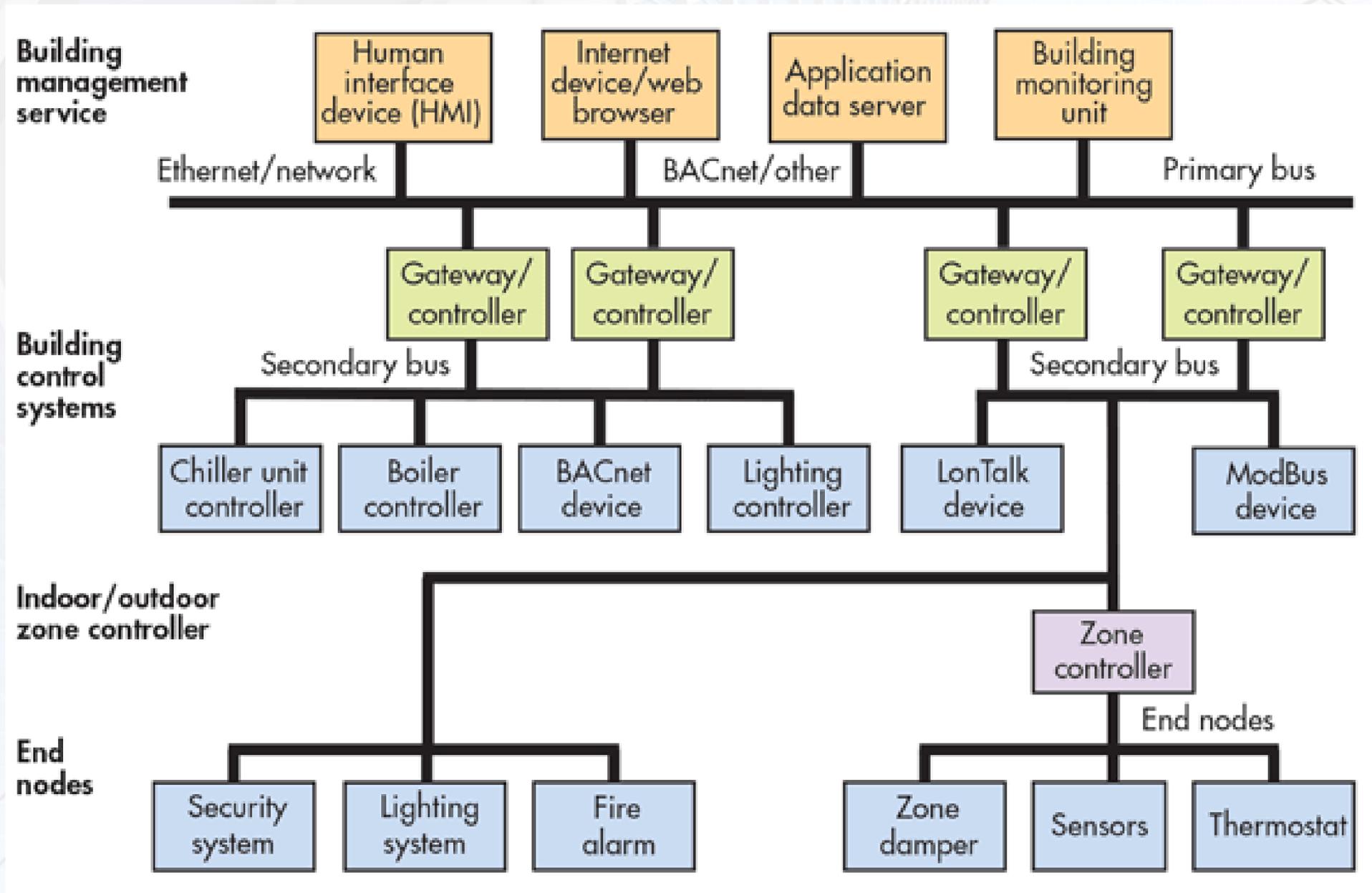
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# WHAT IS BAS?

## Computerized control system



- (5) human interface
- (4) coordinated control
- (3) cross-system comm.
- (2) local controllers
- (1) data collection / monit.



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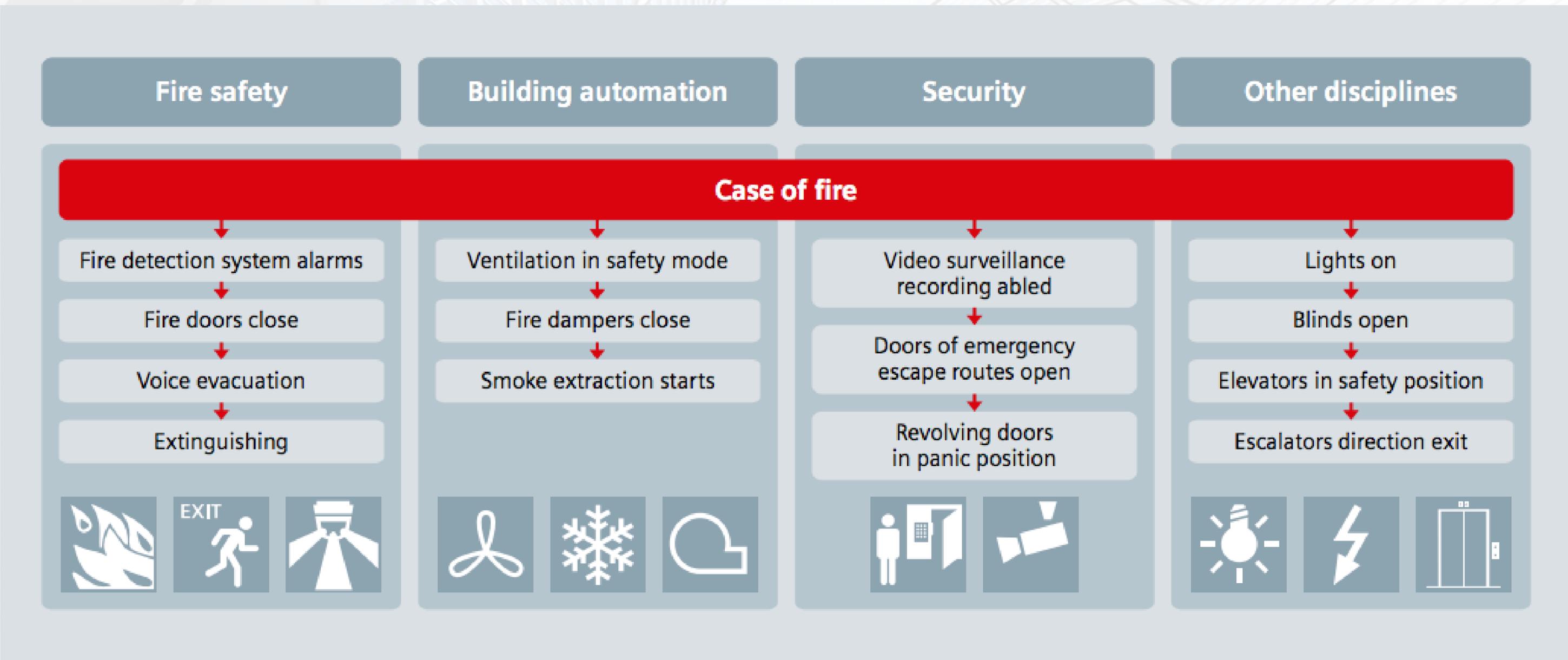
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# SYSTEM COORDINATION

## Sample scenario: fire emergency

Disciplines that work together in case of fire





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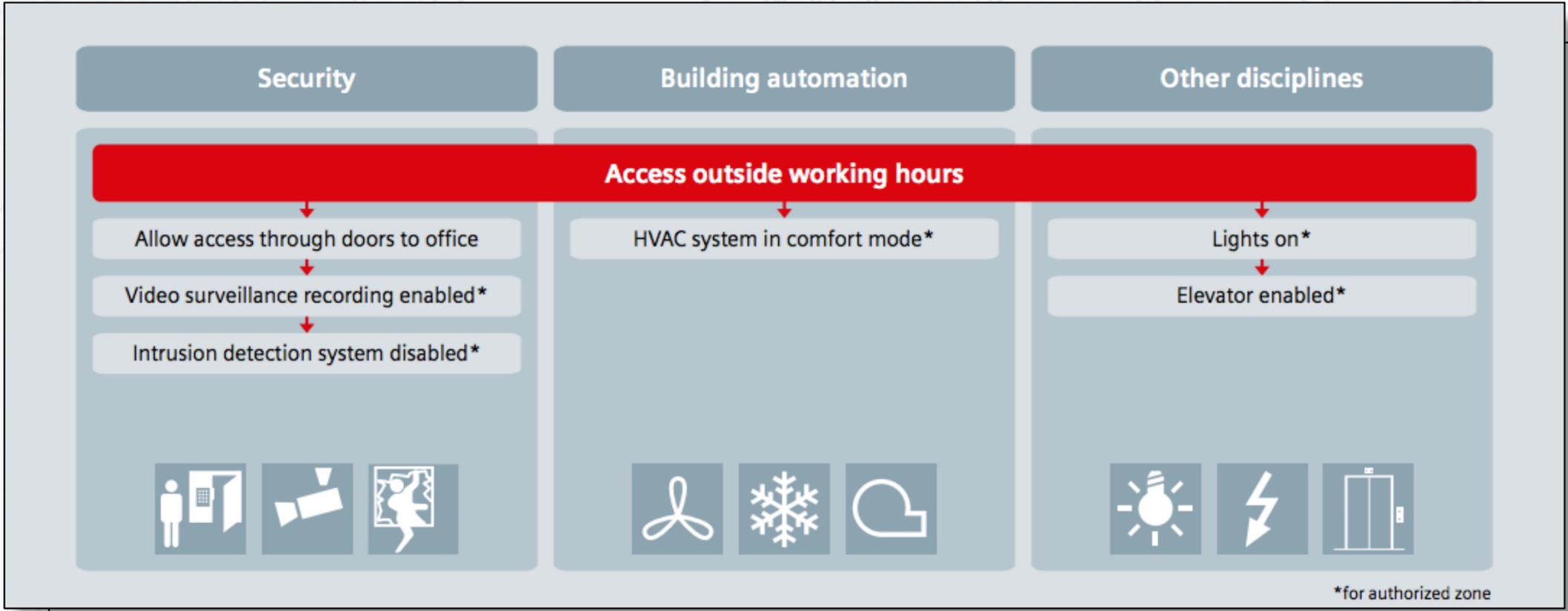
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# SYSTEM COORDINATION

## Other scenarios

- An employee entering the building outside of working hours
- Water leak or structural risks detected
- Other emergencies (active shooter, tornado, ...)





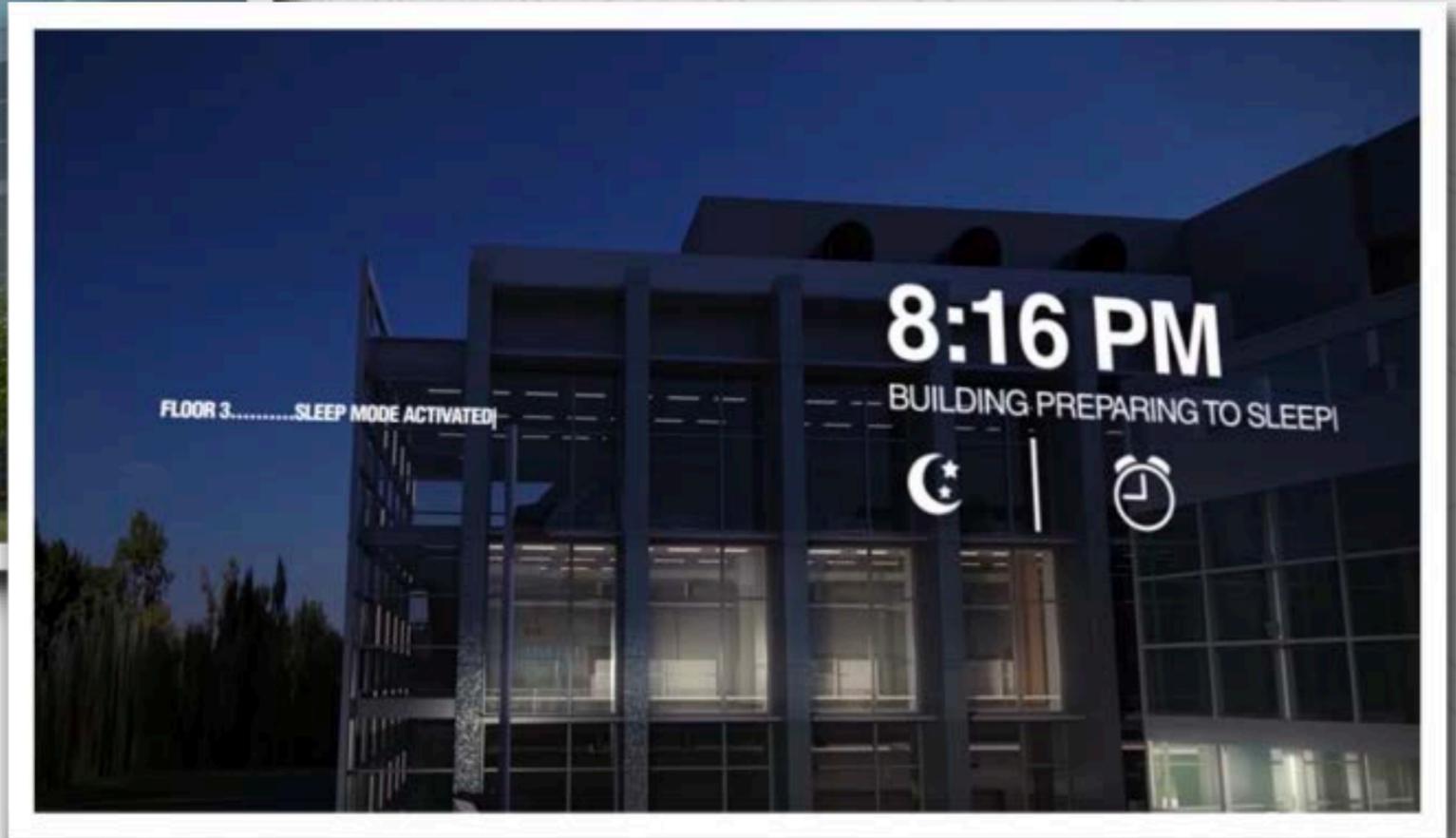
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# SYSTEM COORDINATION

Illustration





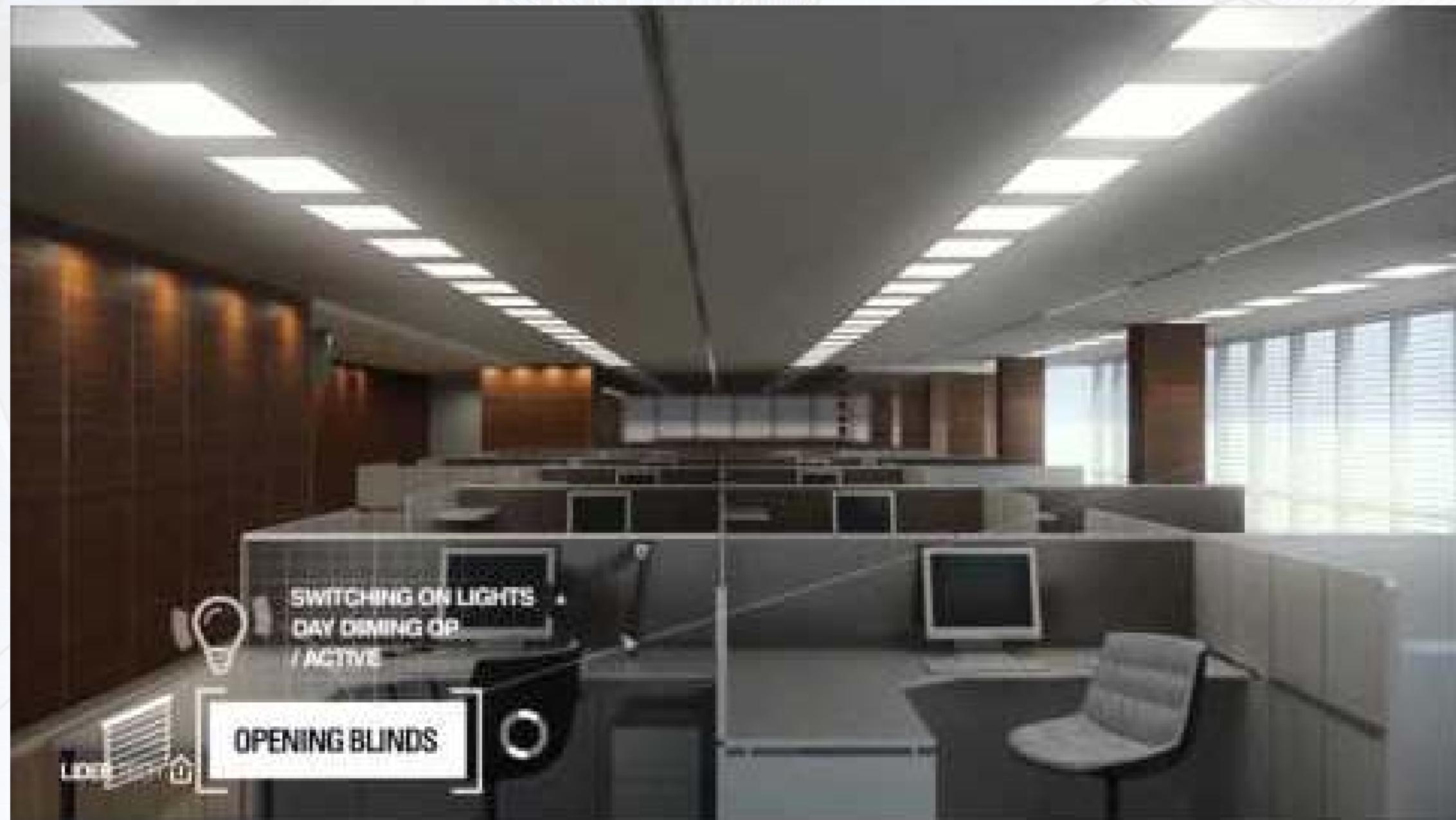
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# SYSTEM COORDINATION

Illustration





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SO, WHERE IS  
**MACHINE LEARNING?**



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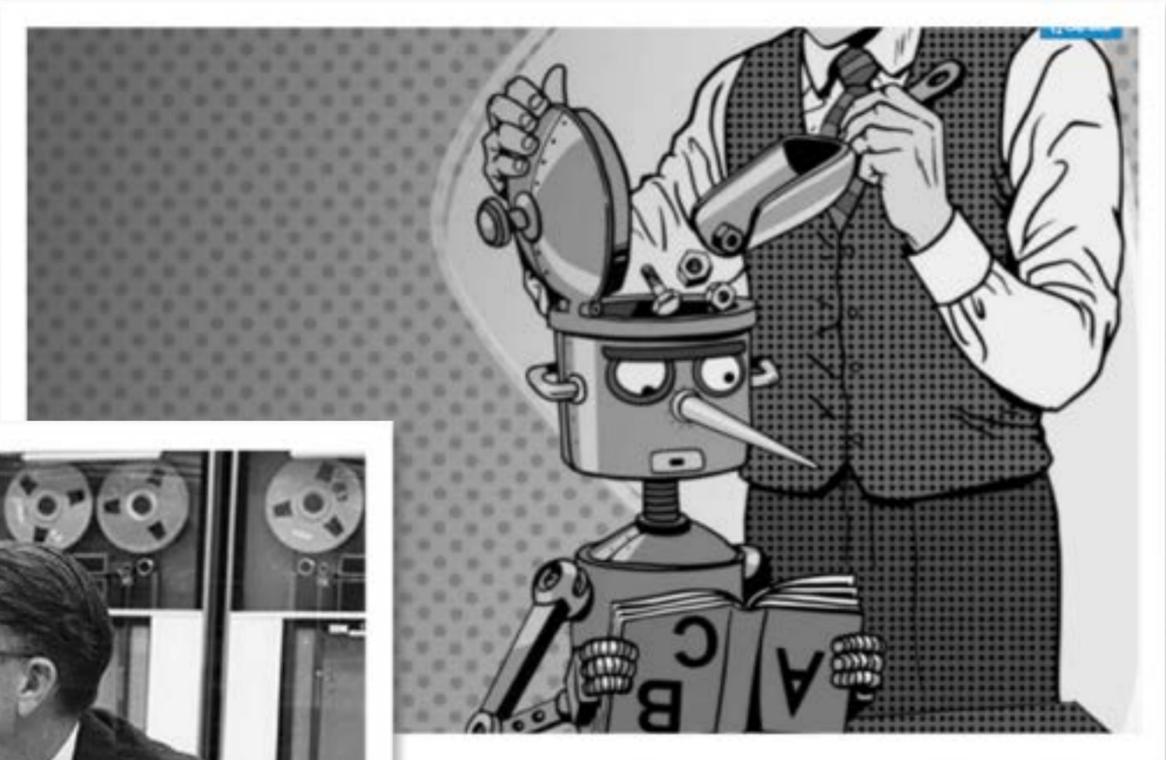
# WHAT IS MACHINE LEARNING?

"Machine Learning is a field of study that gives computers the ability to learn without being explicitly programmed"  
[for a given task]

- Prof. Arthur Samuel (1959)



Prof. Samuel and his famous checkers program (IBM)





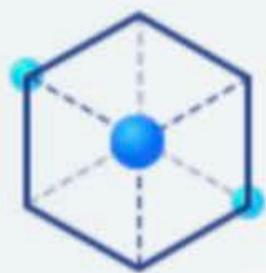
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# MACHINE LEARNING

## Selected application scenarios



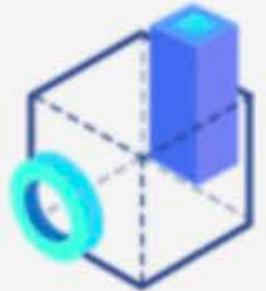
### Image Recognition

- Scene Recognition
- Image Marking
- Image Diagnosis
- Image Recognition



### Text Recognition

- Card Identification
- Document Text Recognition
- Video Text Recognition
- Identification



### Natural Language Processing

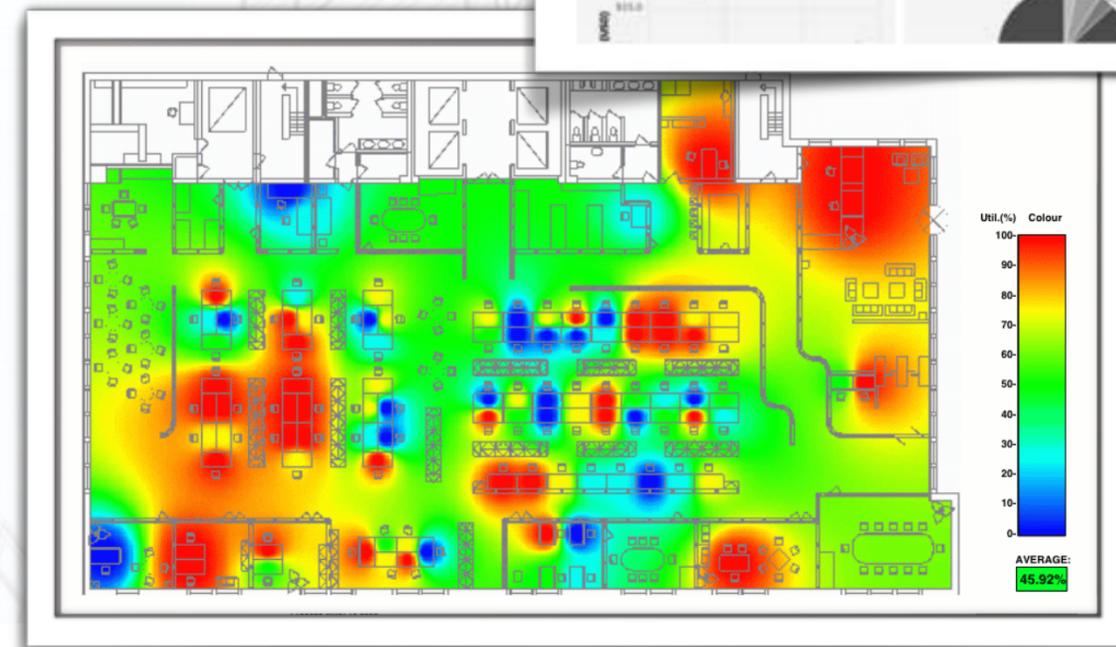
- Word Segmentation
- Speech Tagging
- Translation
- Recommendation Feeds
- Product Evaluation
- Emotional Analysis
- Entity Recognition

# SPACE

## Occupancy / Space utilization

Recent studies show that:

- Mobility is becoming more important
- More need for technology (online conf.)
- The way we use space is changing

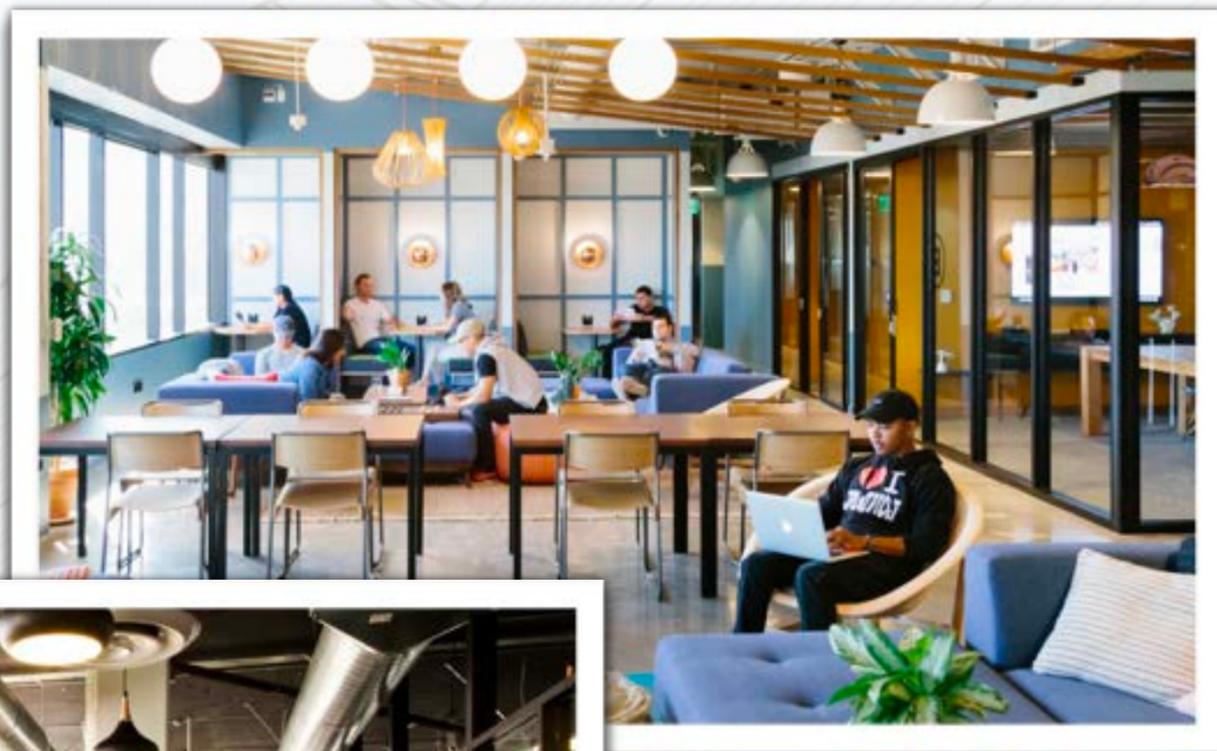
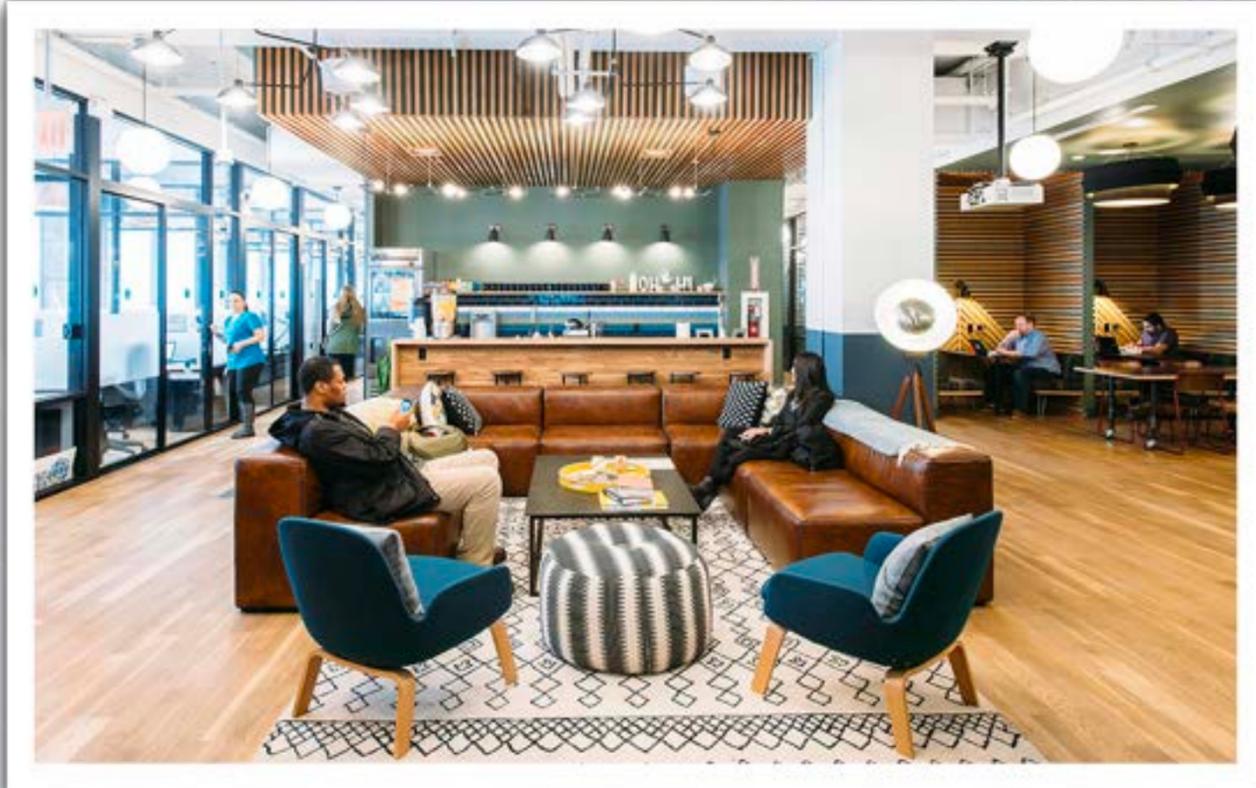




# SPACE UTILIZATION

WeWork shared workspace example

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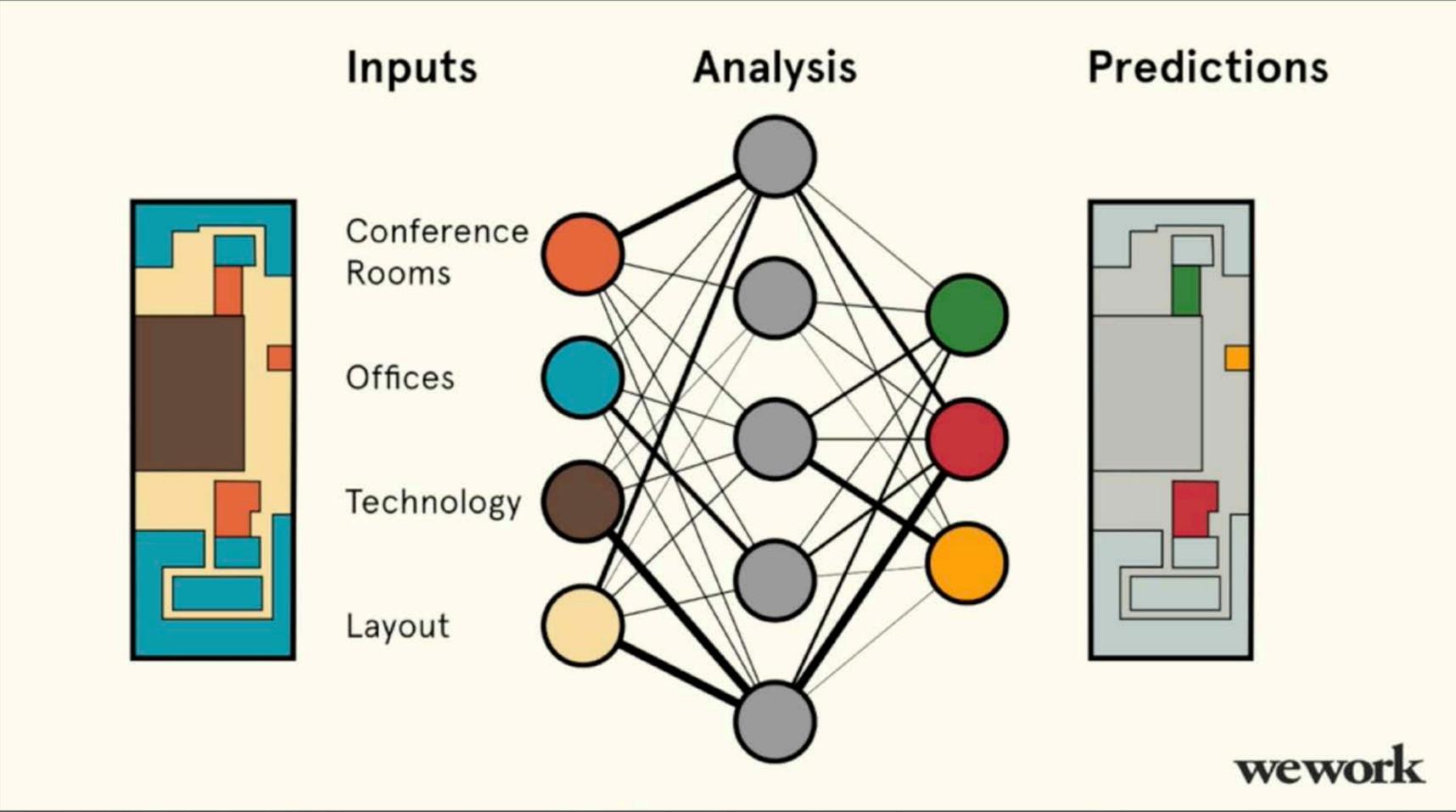
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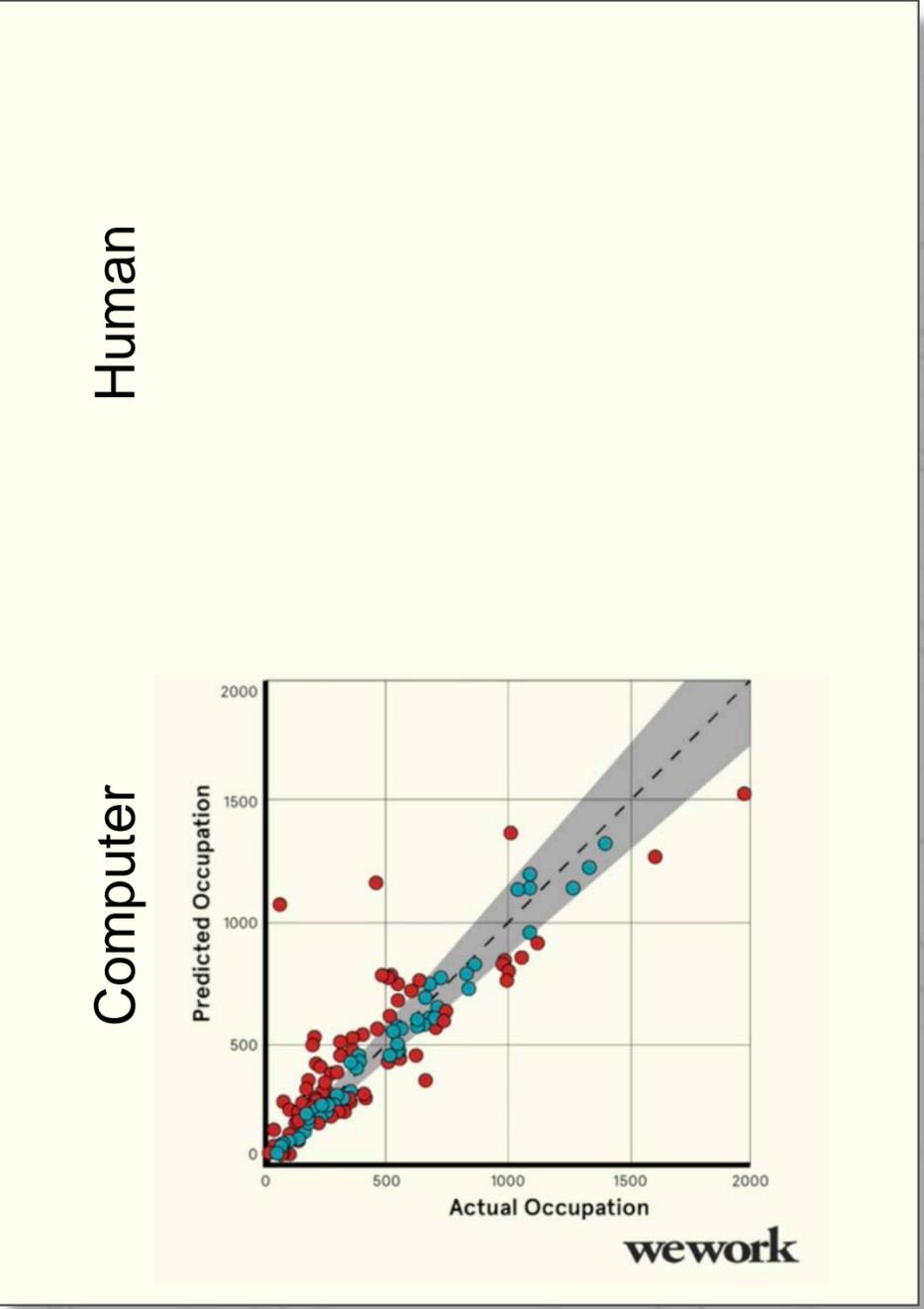
# SPACE UTILIZATION

Using ML to evaluate designs for the optimal use of space



Based on the talk by Daniel Davis, PhD, Director of Product Research at WeWork,  
Accelerate Live Conference, Chicago, 2017

source: <https://www.bdcnetwork.com/accelerate-live-talk-applying-machine-learning-building-design-daniel-davis-wework>





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# SPACE UTILIZATION

Real-time occupancy data collection & analysis

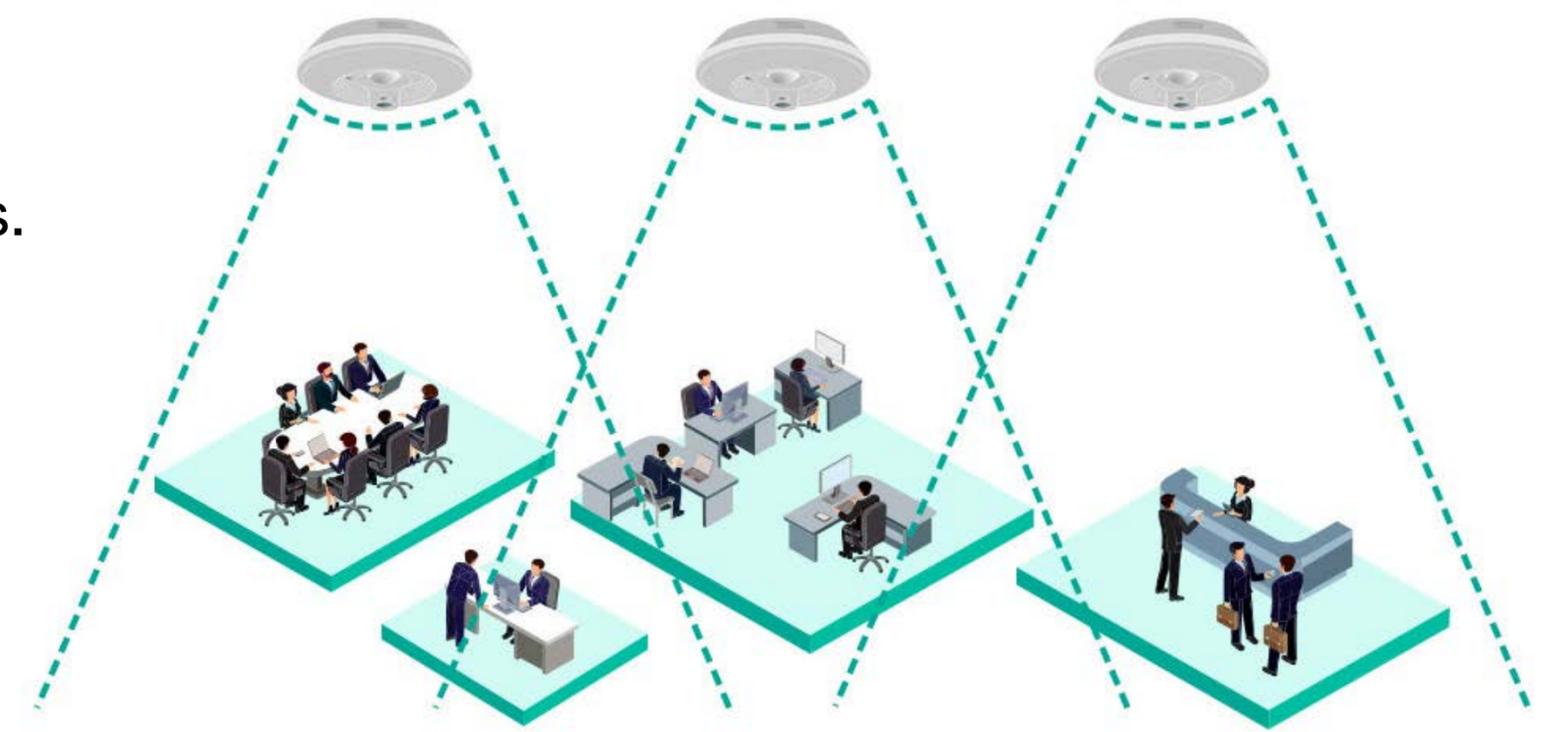


CogniPoint (by Pointgrab):

- Optical sensor with edge analytics
- Embedded deep learning technology
- Detects occupants': loc., count, movements.

Benefits:

- improving energy efficiency,
- optimizing use of space
- improving safety and security.





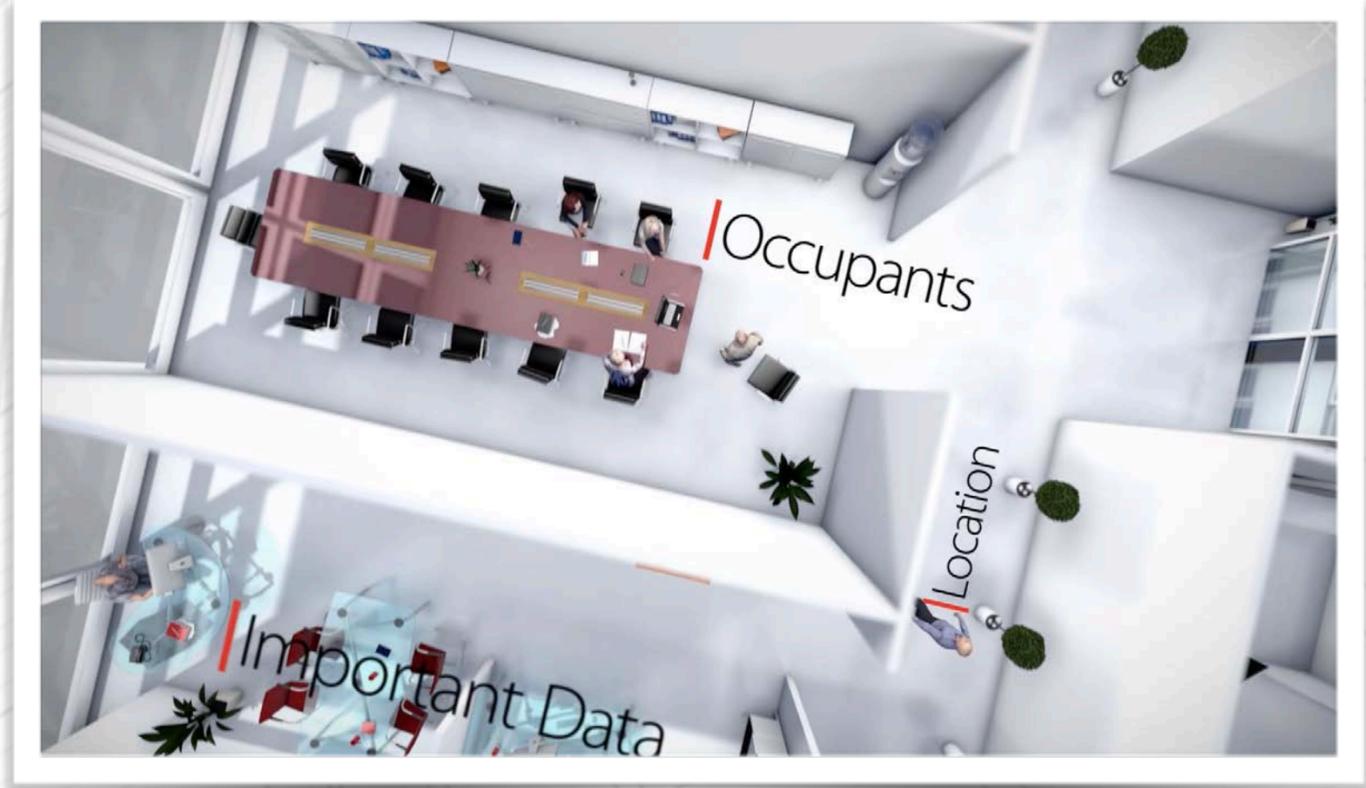
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# SPACE UTILIZATION

Real-time occupancy data collection & analysis





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# SPACE UTILIZATION

Real-time occupancy data collection & analysis





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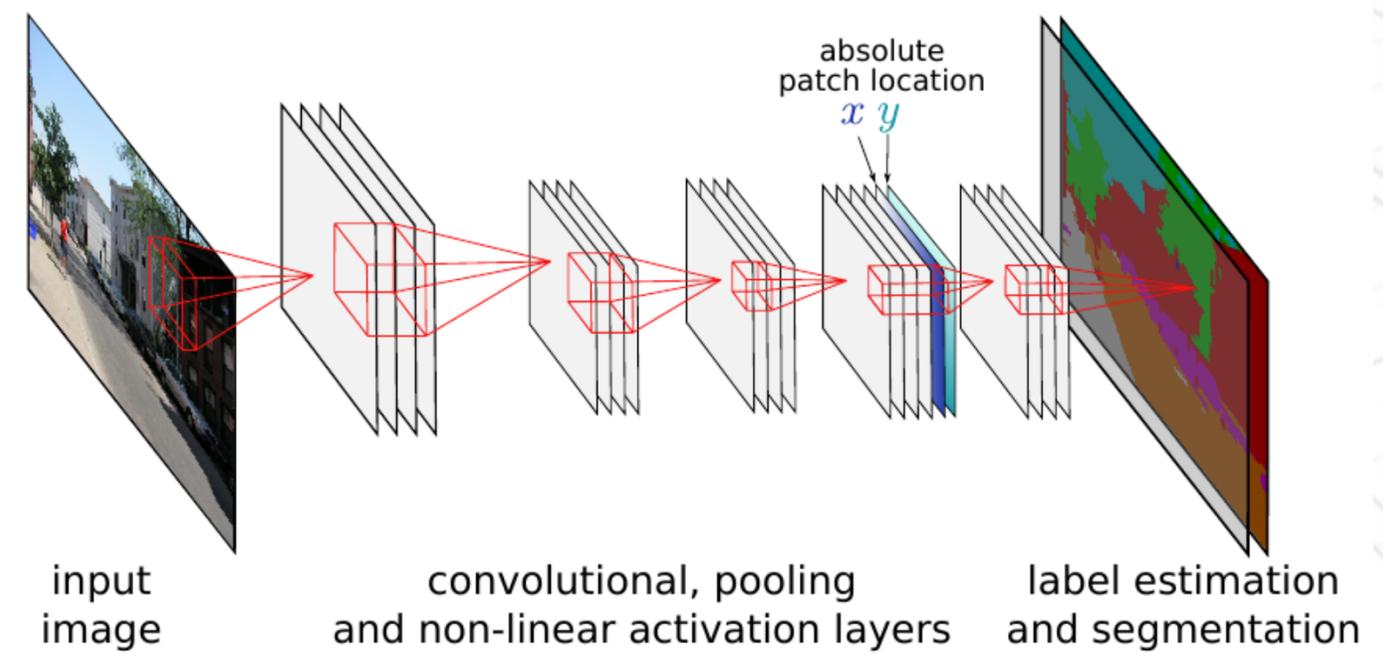
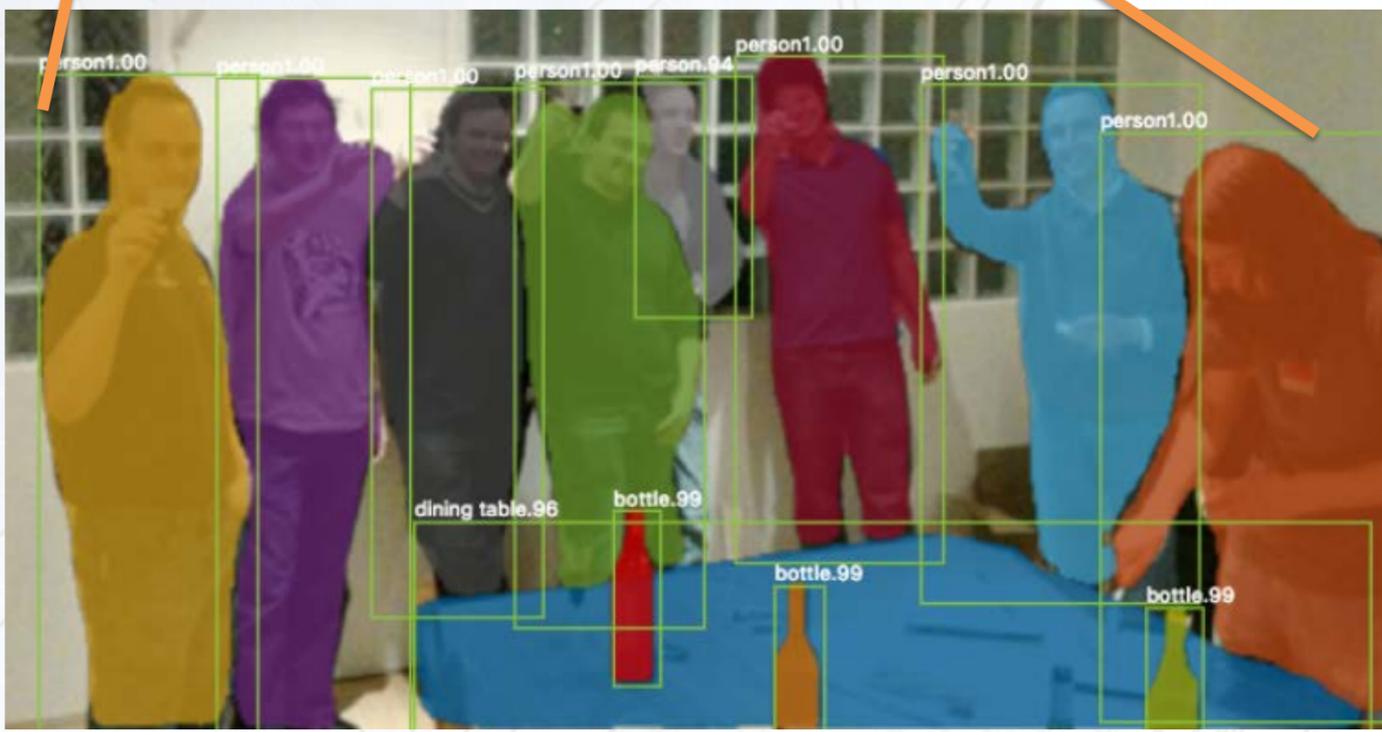
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# SPACE UTILIZATION



No details provided, but:

- Likely using a convolutional neural network (CNN)
- With human- & movement detection & posture identification





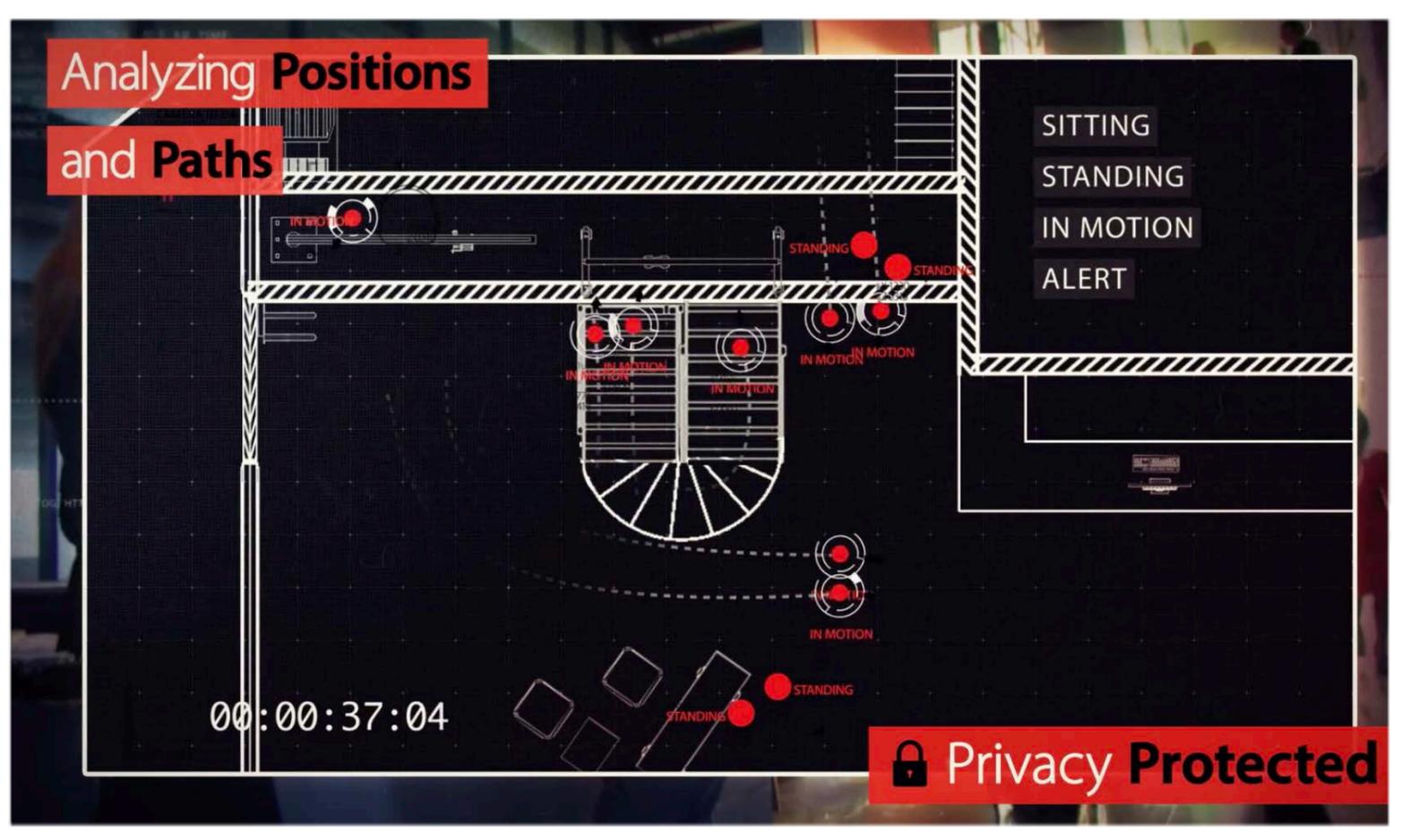
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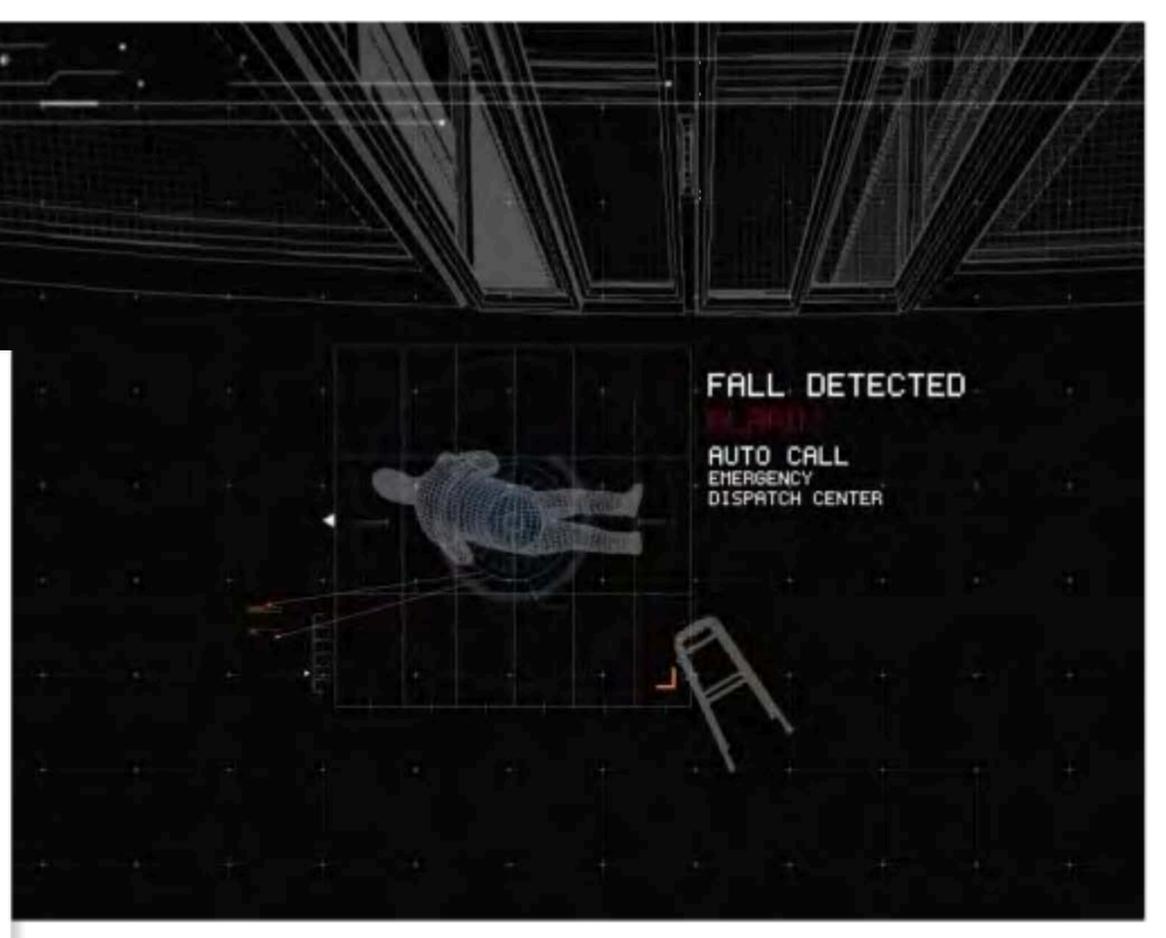
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# SPACE UTILIZATION

Real-time occupancy data collection & analysis



- SITTING
- STANDING
- IN MOTION
- ALERT



Safety: fall detection



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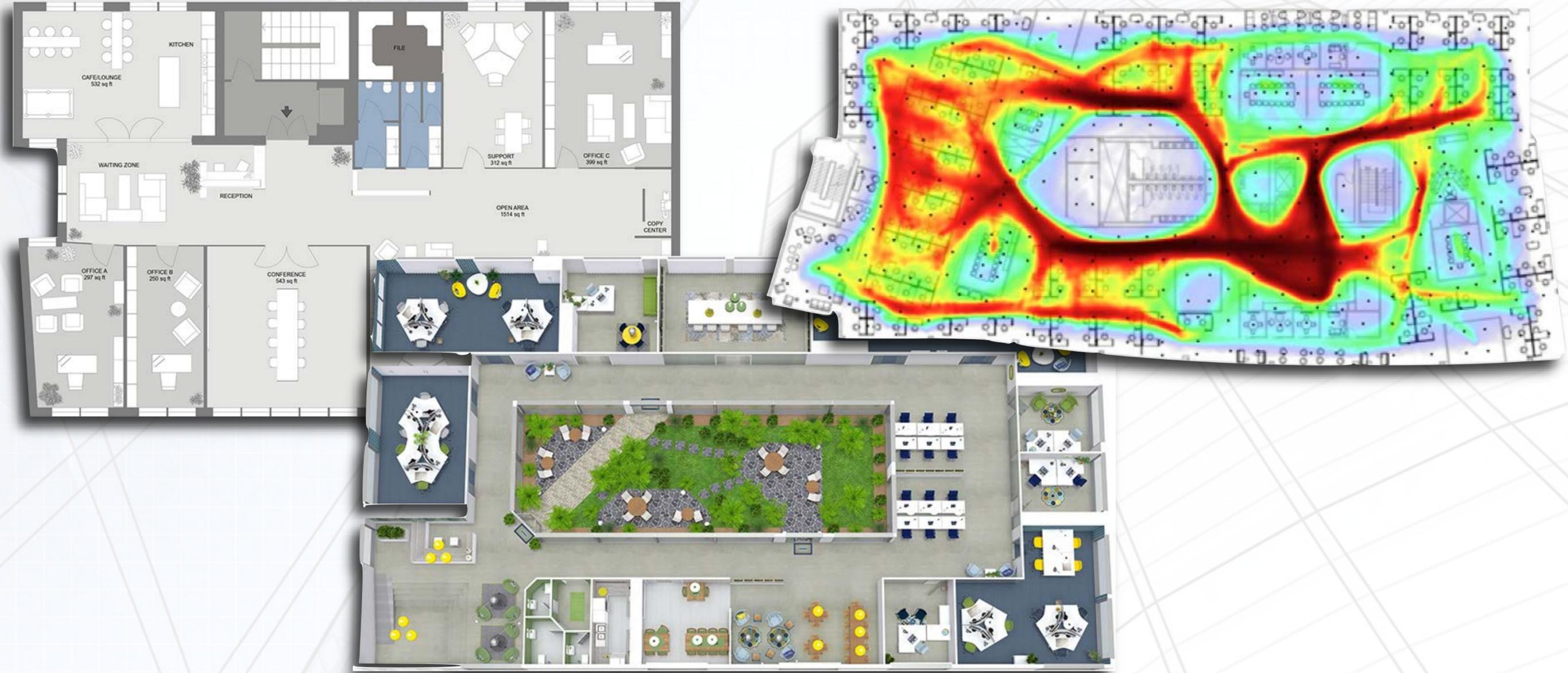
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# SPACE / FLOOR PLANS

## Reality check

How / where from do we get all these interactive floor plans?







# BUILDING INFORMATION MODELING

## PlanGrid ABBYY® FineReader®

**2012 As-Built Site Plan Location**  
Utica Square Shopping Center  
21st and Utica Avenue, Tulsa, Oklahoma

**History**  
Utica Square is a historic modern shopping center in south Tulsa, Oklahoma, on the corner of 21st Street and Utica Avenue. It was first conceived by developers as a way to accommodate suburban customers, so they did not have to travel downtown to shop. At first, the developers had difficulty gaining financial backing to support the novel idea of building the retail center on the outskirts of the city.

After months of consideration and design, construction of Utica Square finally began in 1951 and the shopping center formally opened 15 months later, on May 22, 1952. Utica Square was not only Tulsa's first and finest suburban shopping center, it's also been one of the country's first. Throughout the original development of Utica Square (Dr. Dale Carter) had the community in mind. The center was built in a series of small blocks, a village or community. This design was most inviting to customers without alienating nearby residents. Today, the surrounding residential area is now considered midtown Tulsa, and some of the city.

The architectural style of Utica Square varies from Georgian, to Country French and Colonial. Although incorporating a mixture of styles, regulations on store front designs were created to create cohesiveness throughout the shopping center. These stores and restaurants reflect a diverse mix of retailers, ranging from local to national.

**Acquisition of Utica Square**  
Helmerich & Payne, Inc.  
Throughout the years, Helmerich and Payne Tulsa company, observed the continual growth of the shopping center and wanted for its chance to purchase the property. Originally, Walter Helmerich tried to acquire Utica Square from the leading developer, but the contract was being drafted, the developer died. The developer, however, did soon sell the building to a prominent independent oil and gas company. Six months later, a sudden attack on the company, and the company was purchased by the property from his widow, in 1951.

After acquiring Utica Square, Helmerich and Payne continued the community oriented philosophy of the original developer. The firm successfully achieved its concept by keeping one third of the merchandise. Also, they held musical and holiday events for the community, and still do to this day.

**Design Data**  
2000 ADT = 11,000  
2020 ADT = 25,000  
Min Design Speed = 55 MPH  
except for horizontal curve of PI Sta. 693+79.45 which is 45 MPH

**MIDPOINT OF PROJECT**  
NAD 83 Modified Central Zone  
State Plane Coordinates  
X=1,296,000  
Y= 713,000

**INDEX OF SHEETS**

Sheet No.	Sheet Type
1	Face Sheet
1A-1D	ADOT Standard Drawings
2 - 18	Design Sheets
19 - 21	Barrier Summary Sheets
22 - 35	Pipe Summary Sheets
36	Box Culvert Summary Sheets
37	Pipe Sleeve Summary Sheet
38 - 56	Detail Sheets
57 - 86	Drainage Detail Sheets
87 - 101	Geometric Sheets
102 - 130	Existing Condition Sheets
131 - 320	Profile and Plan Sheets
321 - 349	Storm Drain Plan and Profile Sheets
350 - 412	Traffic Control Sheets
413 - 443	Lighting and Signal Sheets
444 - 512	Signing and Marking Sheets
513 - 649	Structure Sheets
650 - 681	Grading and Landscape Sheets
682 - 715	Erosion Control Sheets
716 - 730	Utility Sheets
731 - 793	Camp Verde Sanitary District Sheets

**LENGTH OF PROJECT**  
Gross Length Sta. 495+94.01 to 757+50.00 = 27,055.19 Feet = 5.12 Miles  
Bridge Exception (Camp Verde T.L.I) Sta. 530+57.15 to 533+54.85 = 297.70 Feet  
Bridge Exception (Verde River Bridge) Sta. 700+43.40 to 706+93.50 = 650.50 Feet  
Net Length = 26,106.59 Feet = 4.94 Miles  
MP 210.06 to 223.18 = 5.12 Miles

**EARTHWORK QUANTITIES**

Roadway Excavation	622,820 CY
Shrink	223,870 CY
Drainage Excavation	325 CY
Shrink	28 CY
Pipe Excavation	5,458 CY
Shrink	3,301 CY
Pipe Backfill	5,458 CY
Trench Backfill	11,090 CY
Structural Excavation	5,289 CY
Shrink	793 CY
Structural Excavation (Retaining Wall)	4,776 CY
Shrink (Retaining Wall)	716 CY
Waste	393,424 CY
No Shrink or Small Applied	
Structural Backfill	2,178 CY
Structural Backfill (Retaining Wall)	2,180 CY
Embankment (Trench and Comp)	1,093,690 CY

**EARTHWORK FACTORS**

Station	Shrink/Swell	Ground Compaction
495+94.00 to 547+00	15% Shrink	0.3 *
547+00 to 581+00	25% Shrink	0.3 *
581+00 to 587+50, 0'-3"	25% Shrink	0.3 *
581+00 to 587+50, 3'-6"	15% Shrink	0.3 *
587+50 to 598+00	15% Shrink	0.3 *
598+00 to 622+00, 0'-3"	30% Shrink	0.3 *
598+00 to 622+00, 3'-6"	15% Shrink	0.3 *
622+00 to 663+00	20% Shrink	0.3 *
663+00 to 679+00, 0'-15"	15% Shrink	0.3 *
663+00 to 679+00, 15'-6"	25% Shrink	0.3 *
679+00 to 769+33	15% Shrink	0.3 *

**pH AND RESISTIVITY**

Station	Offset	pH	Resistivity (ohm-cm)
520+57	60' RI	7.9	1577
525+00	300' LI	7.6	1365
542+00	1675' RI	8.2	1725
557+40	E	7.9	2160
572+48	E	8.0	1672
610+35	E	7.9	1889
624+35	25' LI	8.4	3141
628+00	10' LI	8.2	4922
666+15	60' RI	8.4	3480
718+20	10' LI	7.7	3399
724+80	E	8.0	4042

**SLOPE EXCEPTIONS**

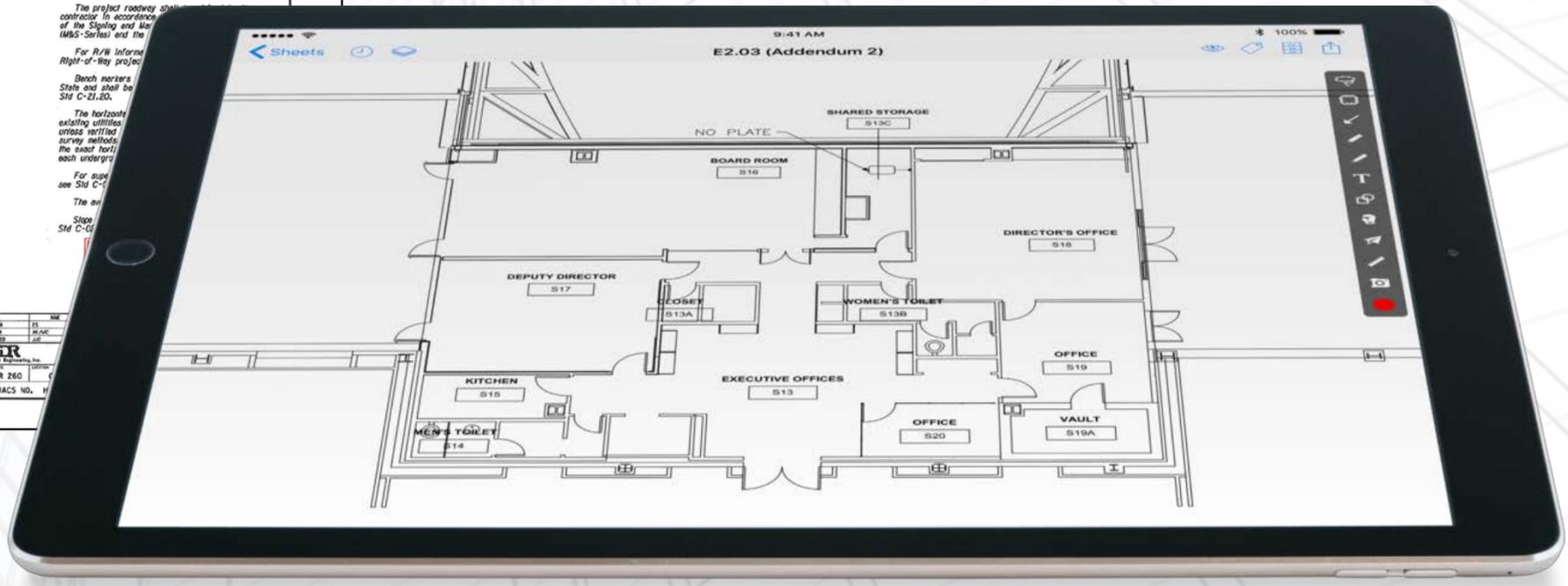
Station to Station	Cut/Fill	Side	Slope
503+62 to 507+35	Fill	LI	4:1
507+90 to 519+30	Cut	RI	Special Grading *
523+50 to 528+00	Fill	LI & RI	4:1
537+80 to 541+65	Fill	RI	4.5:1
545+50 to 547+00	Cut	RI	Well
577+00 to 581+65	Cut	RI	Ditch **
599+75 to 618+20	Fill	RI	4:1
600+75 to 624+00	Fill	LI	4:1
645+30 to 651+70	Cut	LI	Special Grading *
651+70 to 659+00	Cut	LI	Well
654+04 to 655+70	Fill	RI	Well
659+75 to 675+00	Cut	LI	Special Grading *
686+90 to 693+50	Cut & Fill	LI & RI	2:1
693+45 to 700+10	Fill	LI	Well
706+10 to 712+50	Cut & Fill	LI	Access Rd. * **
714+15 to 719+50	Cut	LI	3:1
715+00 to 723+95	Cut	LI	Ditch **

**VIEW A FOG COAT APPLICATION**

**Revisions and Change order modifications are recorded along the left side of the plan's border. This table can be shown inside the page where it records the who, what and when of the revision, as shown.**

**GENERAL NOTES**  
The roadway plans have been designed utilizing the 2000 Construction Standard Drawings (C-Series), and current revisions.  
R/W Markers shall be furnished and placed by the contractor, as directed by the Engineer, Std C-21.10.  
The project roadway shall be constructed by the contractor in accordance with the Signing and Marking (M&S-Series) and the Right-of-Way (RW) project.  
Bench markers shall be established and shall be Std C-21.20.  
The horizontal existing utilities unless verified survey methods, the exact horizontal location of each utility.  
For sign see Std C-21.10.  
The on Slope Std C-21.10.

- Image processing
- OCR - text extraction)





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# 3D SCANNING & RECONSTRUCTION





# 3D SCANNING & RECONSTRUCTION



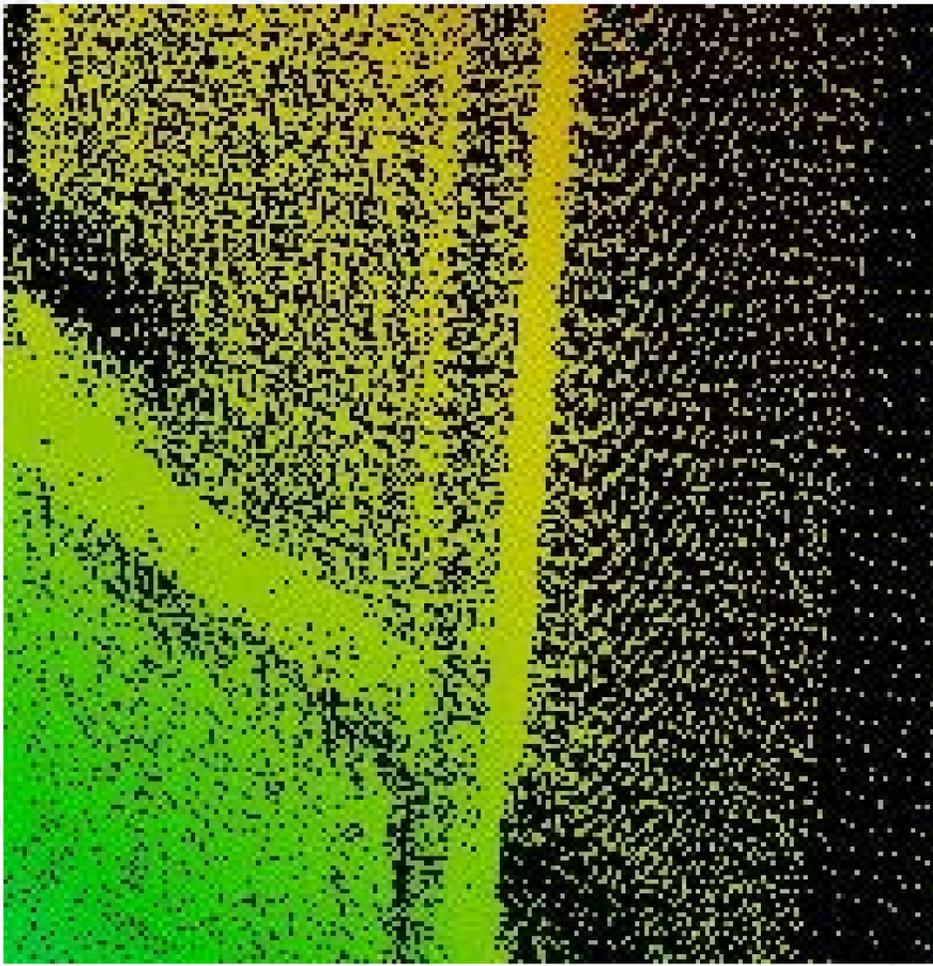
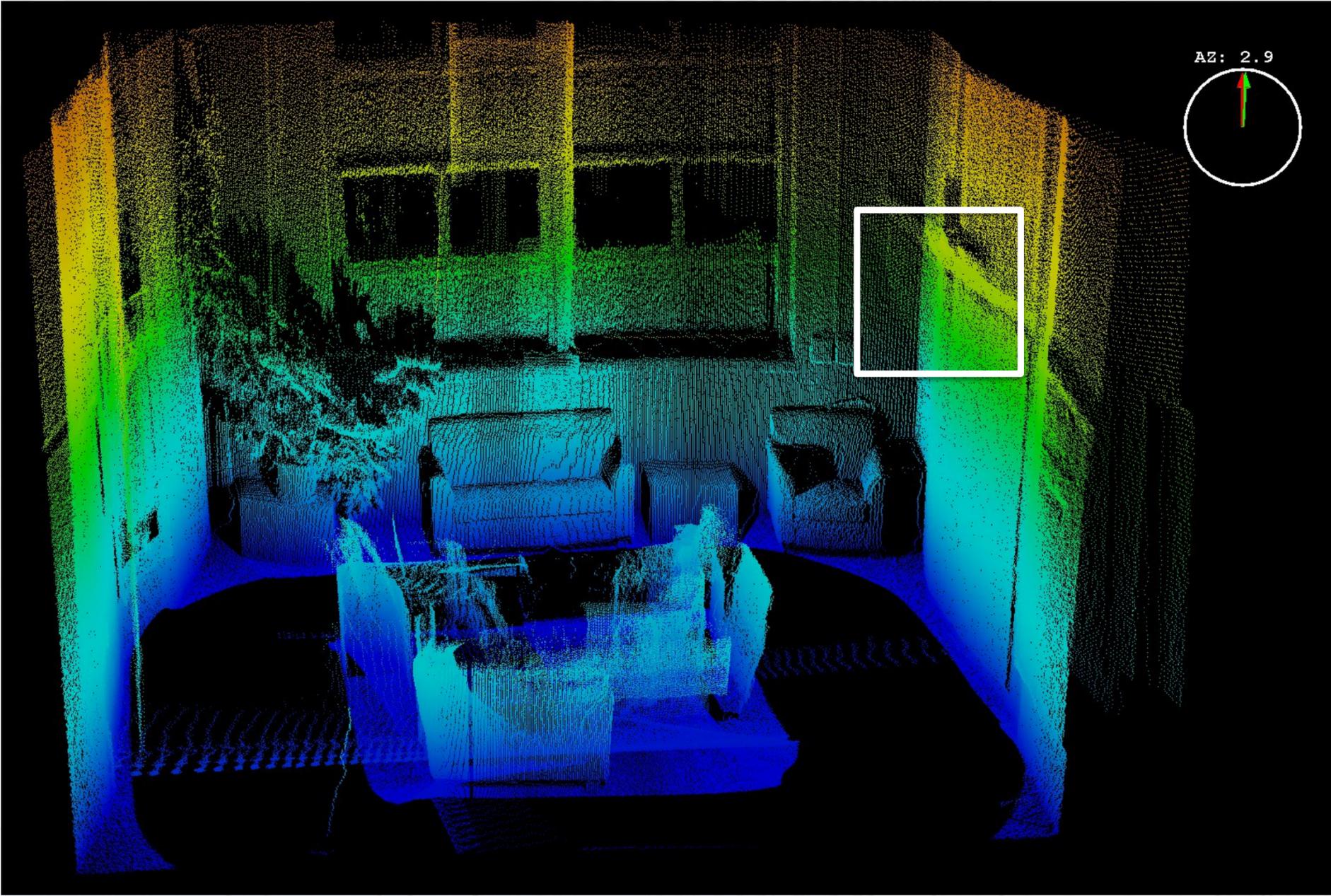


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# 3D SCANNING & RECONSTRUCTION







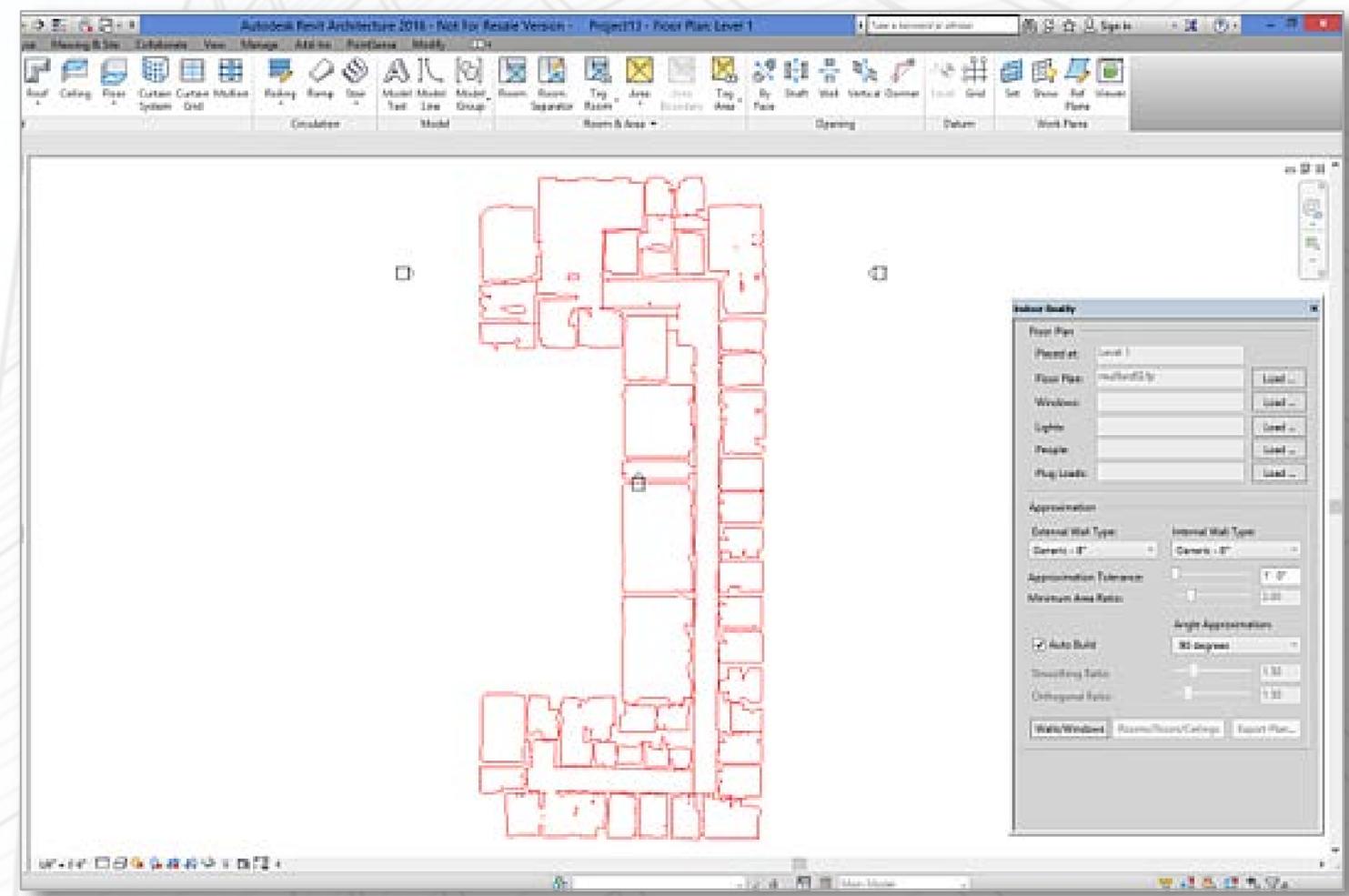
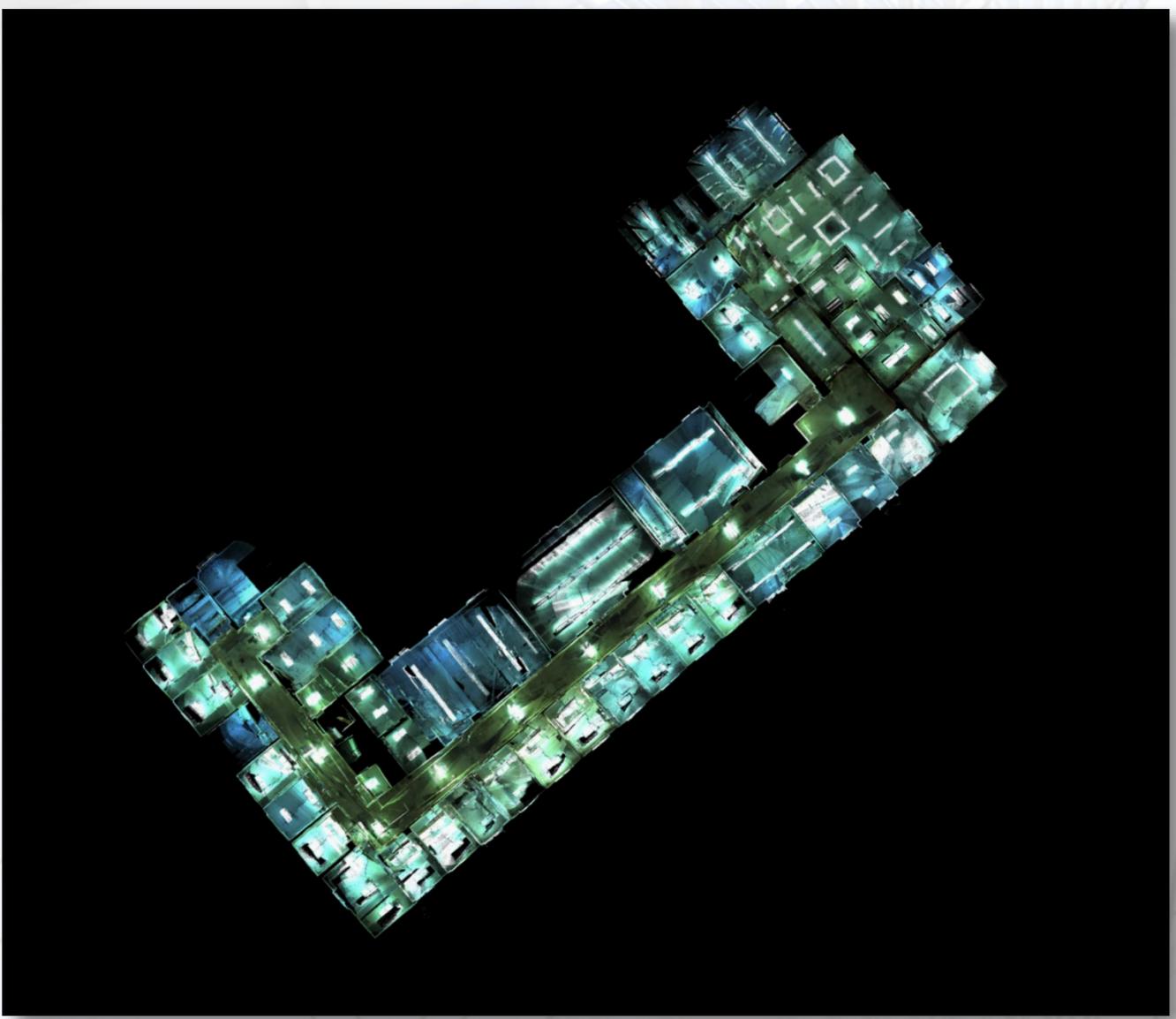
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# 3D SCANNING & RECONSTRUCTION

## Floor-plan reconstruction from 3D models





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# Data Integration and Analytics

Home BMS Locations Assets Work Orders Inventory Reports Admin System Search

### Room: 029 MECHANICAL / CHILLERS

Actions

Details  
Floor  
MEP



Room Code	029	Construction Code	029
Name	029 MECHANICAL / CHILLERS	Square Footage	1,500
Location	Building J.E. Dunn World HQ	Navigation Code	
	Area LOWER LEVEL		

Home BMS Locations Assets Work Orders Inventory Reports Admin System Search

### Room: 029 MECHANICAL / CHILLERS

Actions

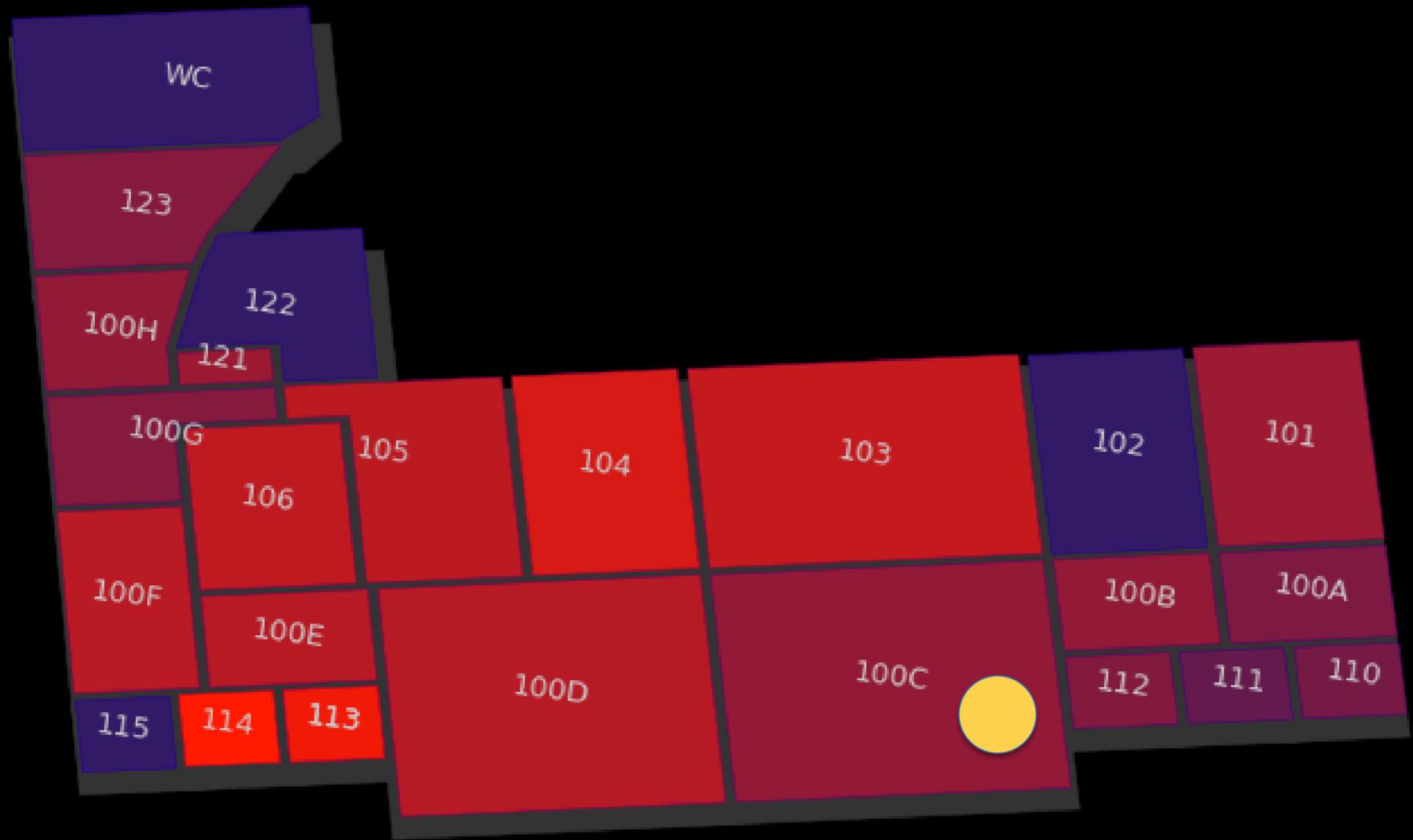
Details  
Floor  
MEP  
Electrical  
Piping  
Panorama  
Finishes 4  
Assets 19  
Custom 0  
Work Orders 8  
Monitors 0



**AHU-3**  
Category Air Handler  
Code AHU-B  
Make Carrier  
Model 36-39/MN



# OCCUPANT COMFORT & PRODUCTIVITY



## SENSORS

- TEMPERATURE & HUMIDITY
- INDOOR AIR QUALITY
- WATER LEAK DETECTION
- WATERBORNE PATHOGENS



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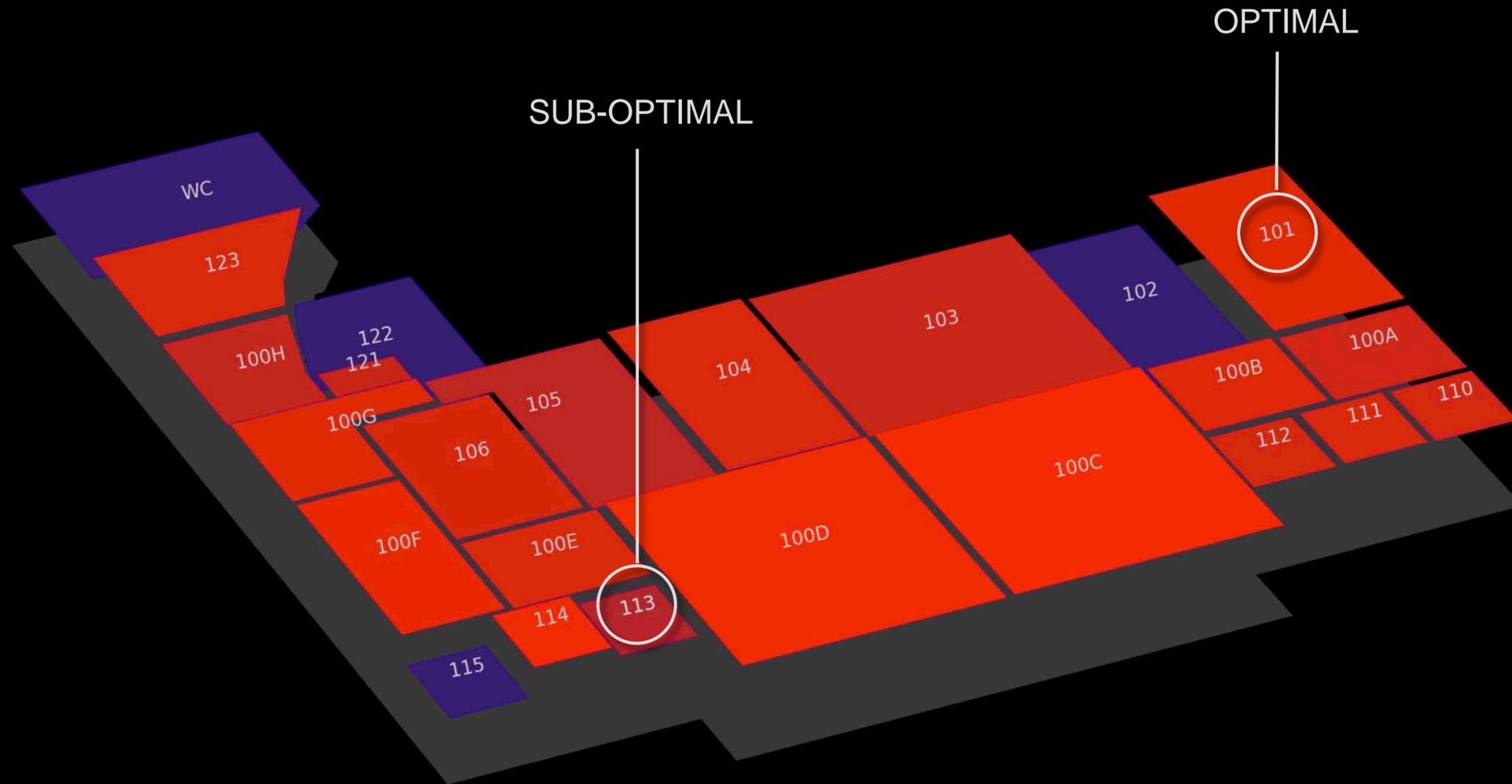
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# OCCUPANT COMFORT & PRODUCTIVITY

## HEAT INDEX (PERCEIVED COMFORT LEVEL)



# INDOOR ENVIRONMENT QUALITY



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# INDOOR ENVIRONMENT QUALITY

## MATERIAL CORROSION/DECAY RISK



SUB-OPTIMAL

OPTIMAL





# Occupant Experience

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# Occupant Experience



# VIRTUAL ASSISTANTS

Personal vs. for business

Potential benefits for businesses:

- Boosting productivity
- Automating meetings
- Improved communication
- Accessibility



alexa for business



**Google AI**  
Google Duplex



Hi, how can I help?  
Google Assistant



**Skylight**  
from Site 1001



voicera

# The important of a virtual assistant for smart buildings

---

- Facilitating communication with building management teams
  - Building / indoor environment monitoring / alert generation
  - Predictions & user sentiment analysis
  - Reporting issues / work orders
  - And more ...
- 



## Skylight

BUILDING PERFORMANCE  
& OPERATIONS PLATFORM



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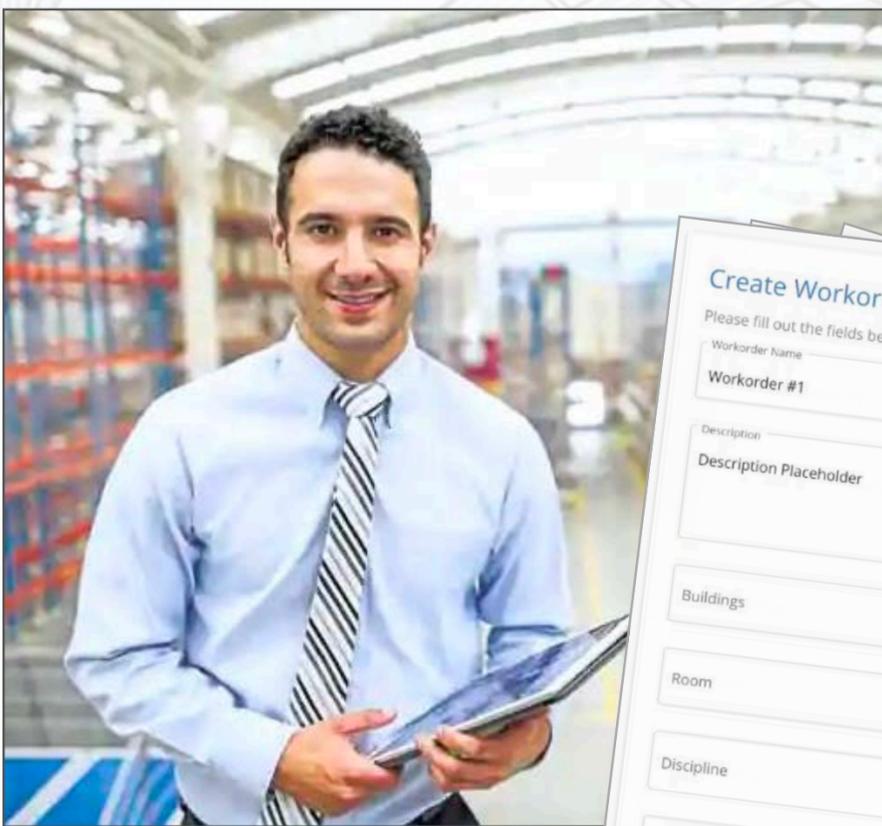
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# A VIRTUAL ASSISTANT FOR SMART BUILDINGS

## Use case 1:

- Work Order Management systems used in every commercial building
- Work order ("*workorder*") is a task or a job that can be scheduled or assigned to someone (technician, contractor, cleaning crew, ...)
- **Challenge:** creating work orders and reporting the work done is typically tedious (multiple fields to fill in);
- Problems get unreported / inefficiencies / loses / risk



**Create Workorder**  
Please fill out the fields below to create an workorder.

Workorder Name  
Workorder #1

Description  
Description Placeholder

Buildings

Room

Discipline

Name

Notes  
Test notes

Upload Image



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# A VIRTUAL ASSISTANT FOR SMART BUILDINGS

Use case 1: Easily communicate with facility staff / report issues

Facility manager



Technician



Tenants





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- What if you have just the data for the system fields for
- Ideally the user understands
- What if the user also learns from prediction to make the model complete





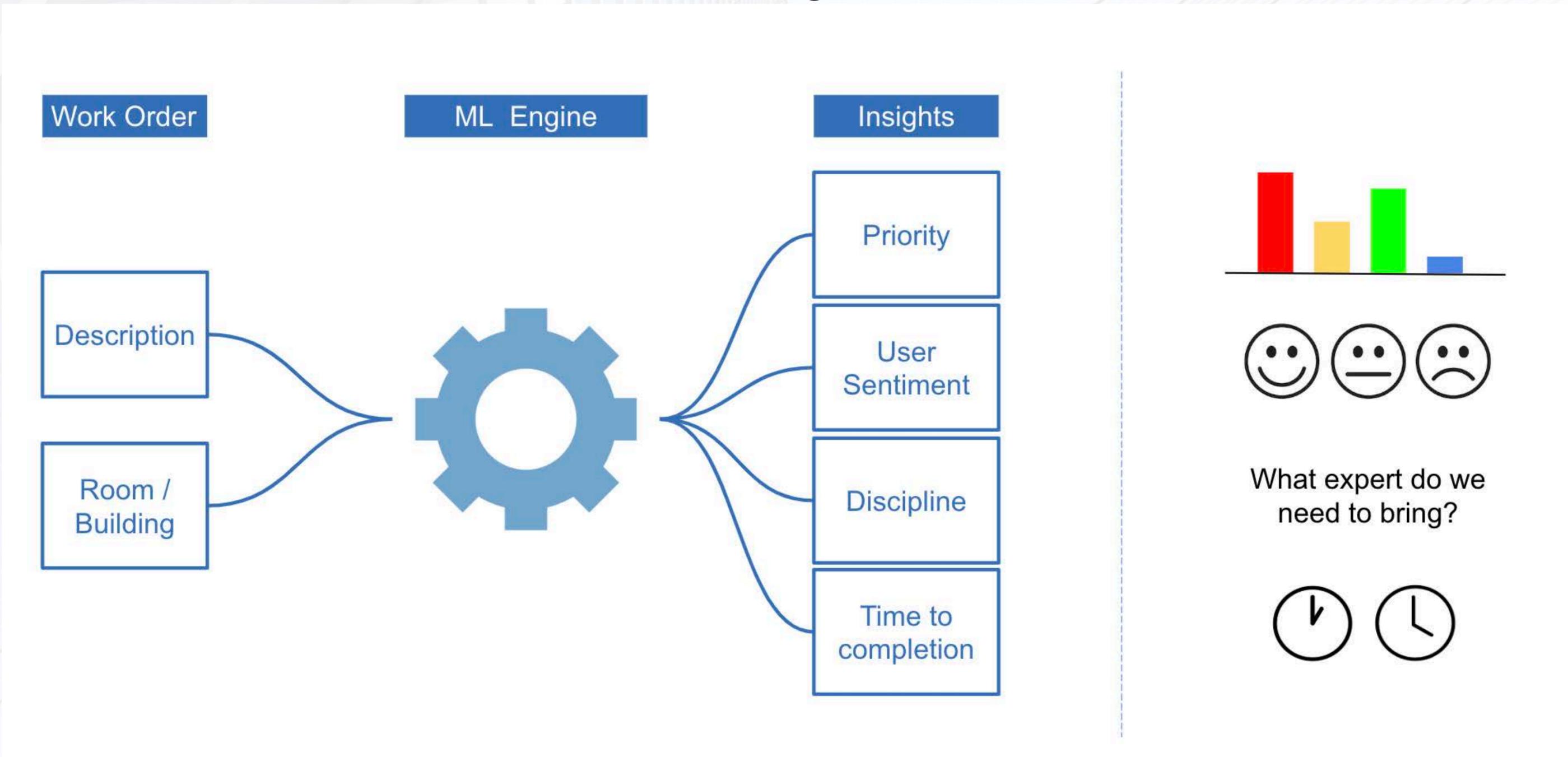
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# A VIRTUAL ASSISTANT FOR SMART BUILDINGS

## Predictive engine



# A VIRTUAL ASSISTANT FOR SMART BUILDINGS

Text-messaging-based communication



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- Listing all work orders assigned to a person.
- A quick way to create a new work order.



# A VIRTUAL ASSISTANT FOR SMART BUILDINGS

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# SUMMARY

1. We've seen here some interesting applications of ML in smart buildings
2. There is definitely more to cover (predictive analytics, robots in buildings, etc.)
3. All of this is still the advent of the broader use of ML in this space
4. Multiple exciting opportunities (and challenges) ahead of us! :)



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This concludes The American Institute of Architects  
Continuing Education Systems Course

# THANK YOU.

Filip Ponulak, PhD

[Filip.Ponulak@site1001.com](mailto:Filip.Ponulak@site1001.com)

[www.site1001.com](http://www.site1001.com)



Your building is talking. Are you listening?

# ADDENDUM

# ROBOTS IN SMART BUILDINGS

EMMA by BrainCorporation



<https://www.youtube.com/watch?v=vVtedeNztLk>

Relay - delivery robot by Savioke



<https://vimeo.com/210686178>