Applications of AI in Government and Industry:

A workshop organized by the National Academies Innovation Policy Forum

Applying Artificial Intelligence to Built Environments

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- A global leader in buildings, energy and security market
- Invented the first electric thermostat (Warren Johnson, 1883)
- We create innovative, integrated solutions to make cities more connected, buildings more intelligent and environment safer.
- We manufacture, sell and service building HVACR, control system and energy equipment around the world
  - Chillers, boilers, air handling unit, rooftop unit, refrigeration units, energy storage system, security systems, fire detection systems, BMS, BAS, EMS,…
- More and more our equipment are being equipped with sensors and collect data in real time and AI/ML creates values with the data
  - → Digital Solutions business

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AI Solutions for Connected Equipment in Buildings

- Optimal control: optimal temperature, comfort, cost, energy source at multiple levels (room, floor, building, campus)
- Equipment operating at maximum efficiency and uptime and dispatched for minimum cost
- Improved, cost-effective security: better understanding of risk, faster response, higher efficiency and reduced cost
- Risk modeling and prediction
- Advanced cybersecurity risk management
- When, what, how to repair—even before customer realizes a problem exists
- Wayfinding, space utilization metrics, space efficiency
- Natural user interactions with building systems
- Common data models across all JCI devices and Equipment (HVAC, Fire, Security) unify the system
- Seamlessly connected to the Digital Vault for advanced offerings and analytics
- A logical building taxonomy scheme (BRICK) organizes and interconnects the building

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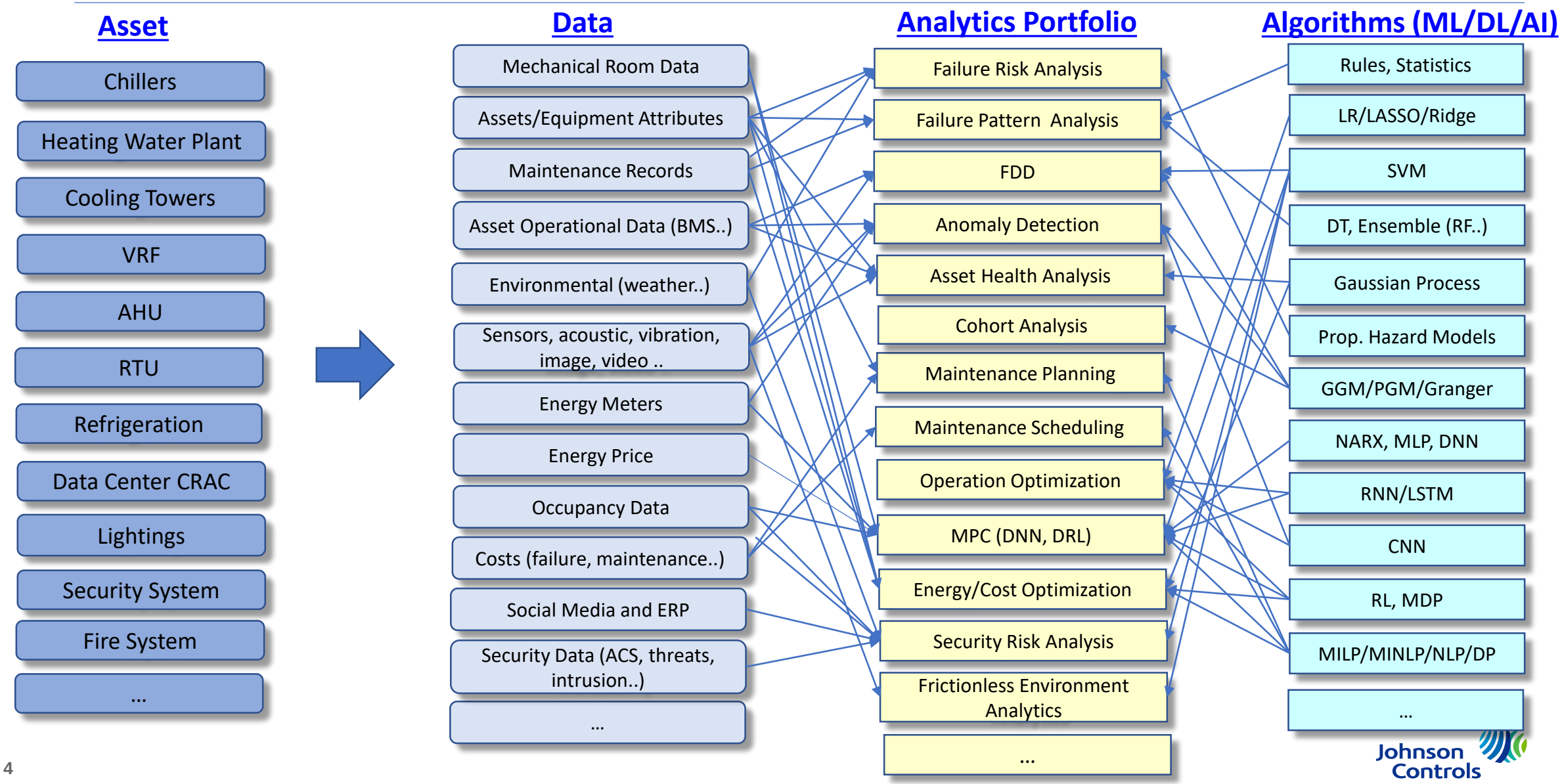
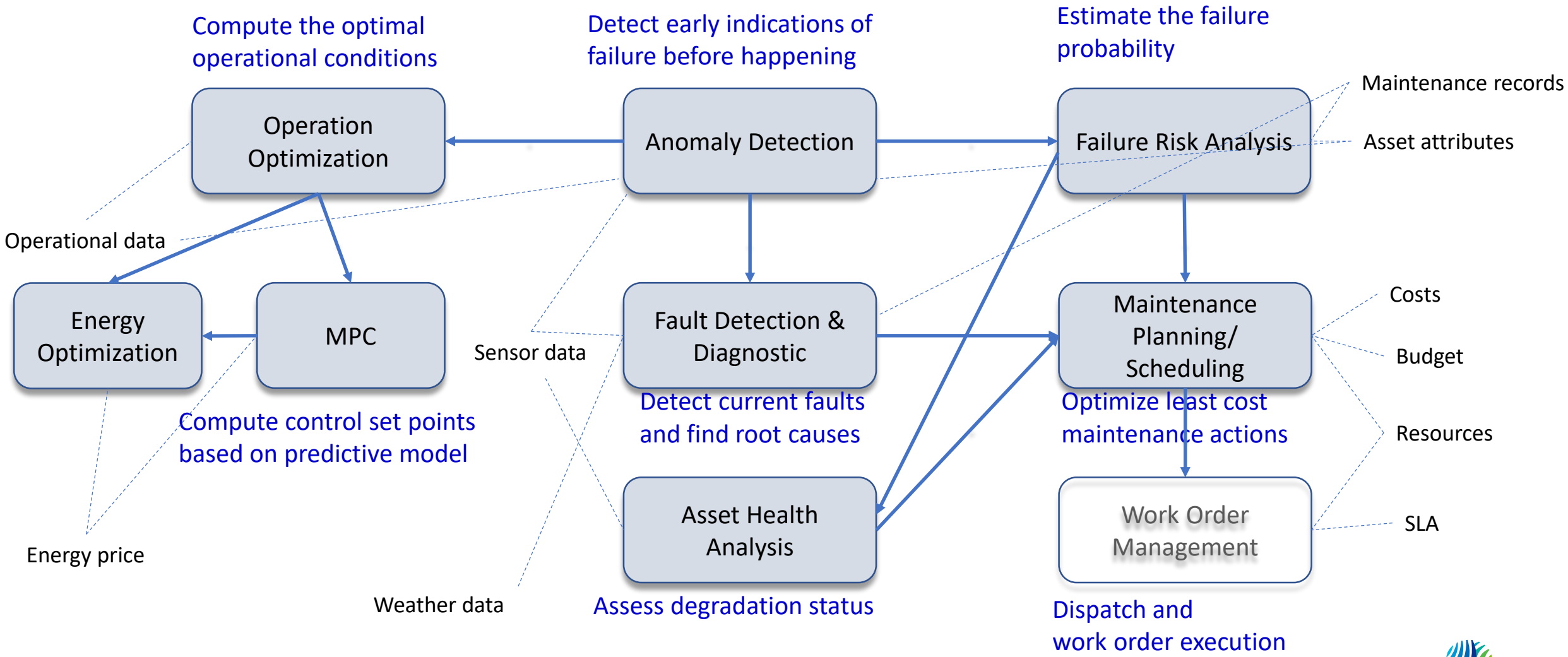
Smart Built Environment AI Solution Landscape at JCI



Integrated AI Solutions for Assets & Operations: Examples



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Connected AI Solutions: Vision

ML/DL/AI Science:

AI Technology:

Continuous Influx of new advancement of AI Science/Technology

Network of integrated cyber models

Autonomous configuration of cyber models (AI/ML/DL)

Compute the optimal operational conditions

Detect early indications of failure before happening

Estimate the failure probability

Operation Optimization

Anomaly Detection

Failure Risk Analysis

Asset attributes

Operational data

Energy Optimization

MPC

Sensor data

Fault Detection & Diagnostic

Maintenance Planning/ Scheduling

Costs

Budget

Resources

SLA

Compute control set points based on predictive model

Detect current faults and find root causes

Optimize least cost Maintenance actions

Energy price

Asset Health Analysis

Work Order Management

Weather data

Assess degradation status

Dispatch and work order execution

Continuously Optimized Client value

Fully connected assets

Heating Water Plant

Chillers

RTU

VRF

Refrigeration

Fire Panel

Data Center CRAC

AHU

Cooling Towers

Security System

...

Lightings

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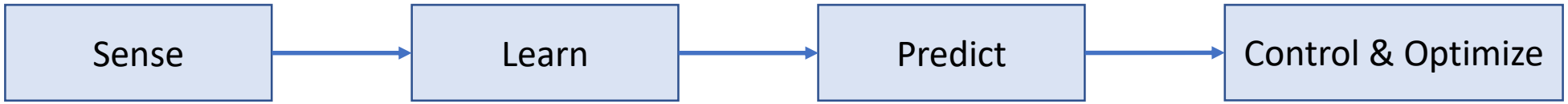
Our AI Solution Capabilities

- Four key AI capabilities that work together to make the building smart and make building occupants comfortable and productive



  - Sense
    - Accessing, collecting and cleaning data from all the building systems, subsystems, equipment, occupants, assets and sensors
  - Learn
    - Learning the evolution and patterns of different states in the buildings and what influences the change of states. (Supervised Learning, Unsupervised Learning, Reinforcement Learning)
  - Predict
    - Prediction of various states in the future and enabling intelligent decisions of changing controllable actions
  - Control & Optimize
    - Making changes or determining control actions to make building energy efficient, productive, safe and value-added

Our future AI solutions will be autonomously configured, installed, commissioned and provisioned

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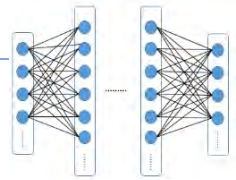
Artificial Intelligence Solutions for Prediction and Control of States

(1) Develop AI model of states using past data → Build Digital Twins $x_{t+1} = f(x_t, u_t)$

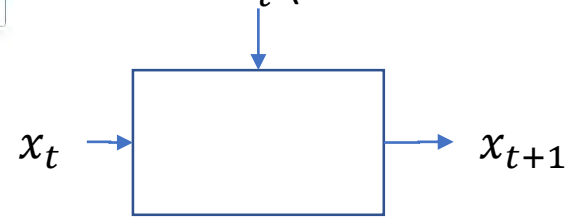


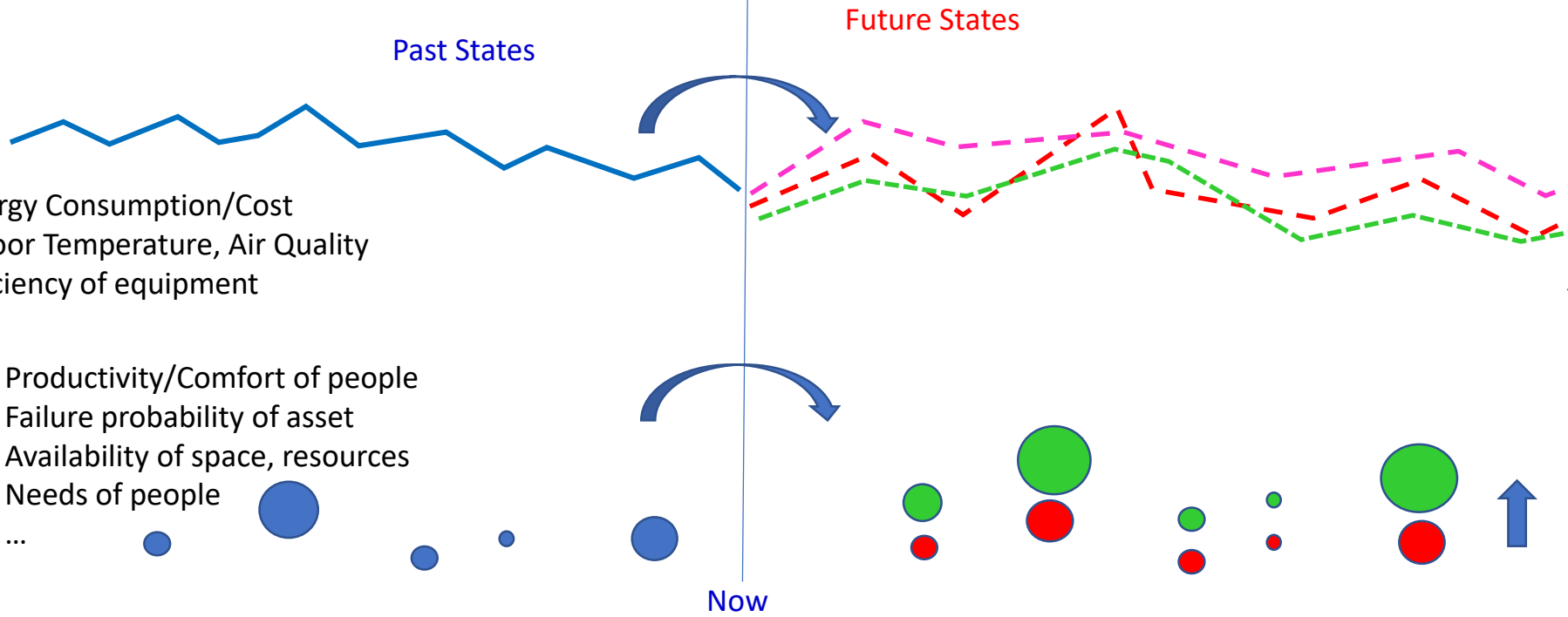
(2) Predict future states → fault prediction, energy consumption prediction, productivity..

(3) Simulate future states with different control variables → what-if analysis

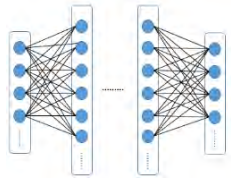
(4) Determine control actions that improve a value in the future → optimal control

u_t (control action, planning)





- Energy Consumption/Cost
- Indoor Temperature, Air Quality
- Efficiency of equipment
- ..
  - Productivity/Comfort of people
  - Failure probability of asset
  - Availability of space, resources
  - Needs of people
  - …



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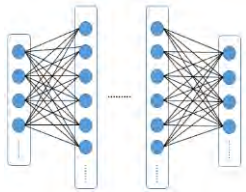
Use Case: Sensor Based FDD: Chiller Shutdown Prediction Model

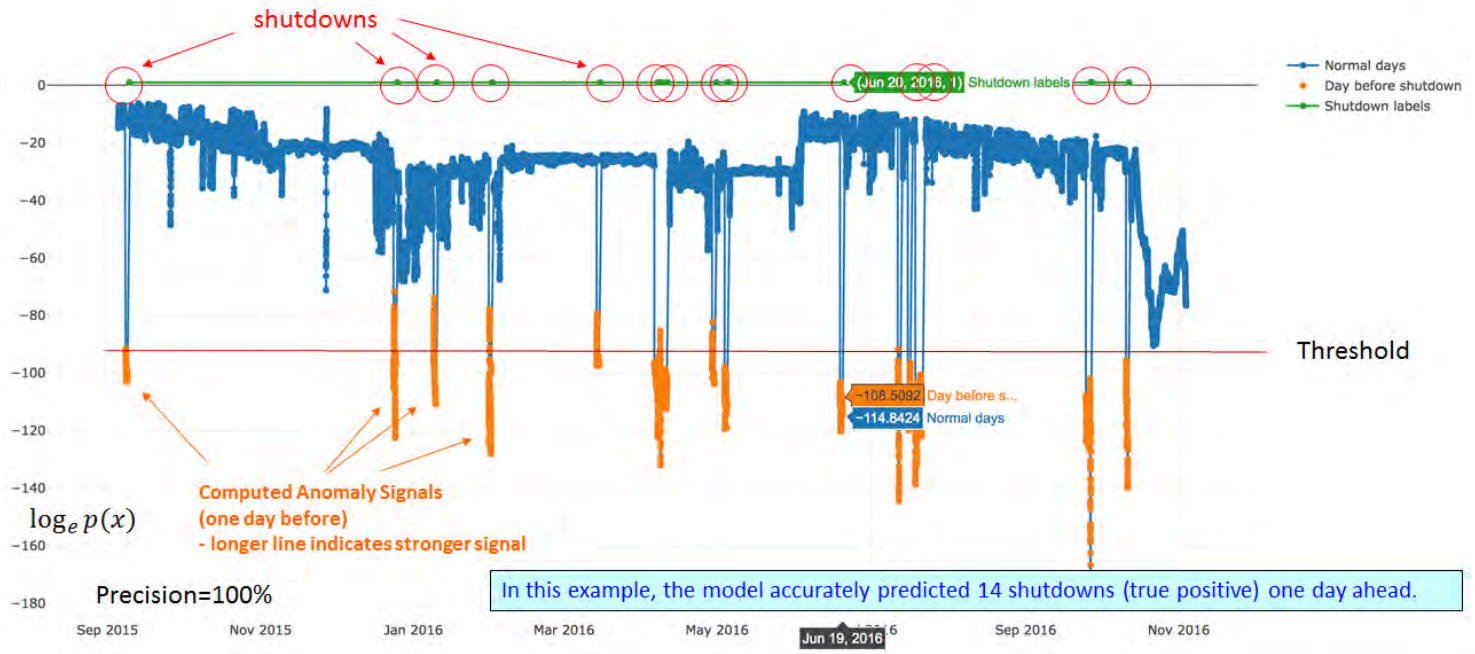
- Using connected chiller data, predict safety shutdown of chillers before they happen so that appropriate maintenance action is taken
- Prediction Performance (for a group of YK chillers)
  - Recall: 73%, Precision=81%, F1-Score=0.77 (for one-day ahead prediction)
- Reduce repair costs (typically 15%), improve customer service, extend the operational life of chillers and components



Operational Data

AL Model

Anomaly Signal (a day ahead)



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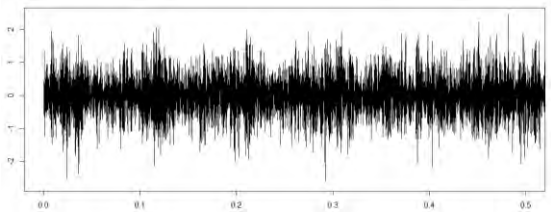
Use Case: Chiller Vibrational Analysis with AI (CNN)

- Automated analysis of chiller vibration data for overall machine health and component health assessment
- Analyze more equipment (from 20,000 to 45,000) with same number of analysts
- Reduce maintenance costs, extend the operational life of chillers and components

Use **machine learning** (ML) to filter out “normal” machines

Vibration Data



ML (CNN) Model

Domain expertise
Historical data

Abnormal or unsure

Normal

Generate report for technician & customer

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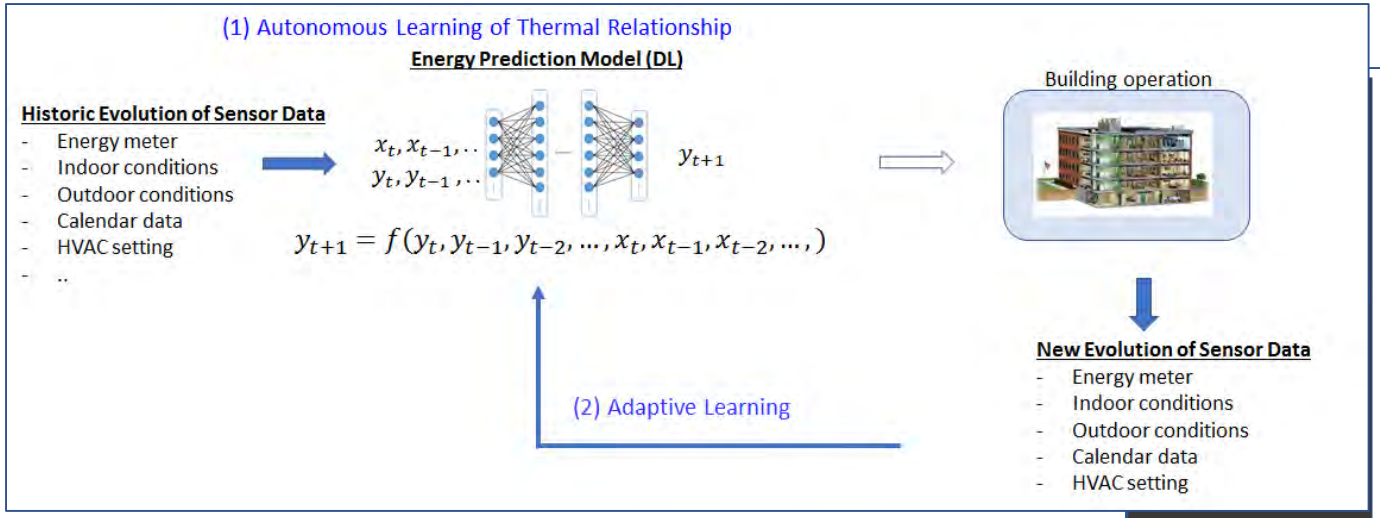
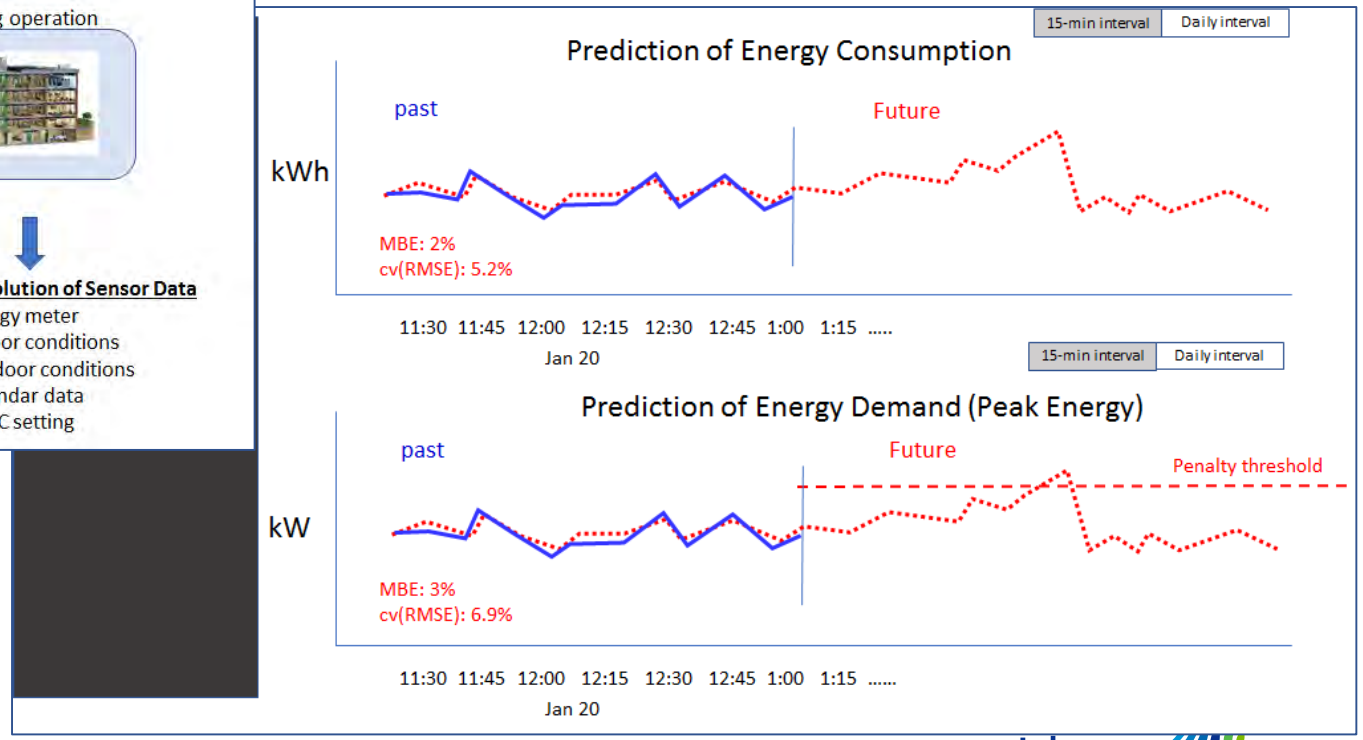
Use Case: Energy Prediction Model (EPM)

- Predicts energy consumption of a whole building, or equipment level or energy consuming component level for various external (e.g., weather) and indoor conditions using Deep Learning (S2S LSTM technique)
- Allows peak shaving, load shifting, demand response, sourcing decision
- Reduce energy consumption, energy costs (typically 10%)





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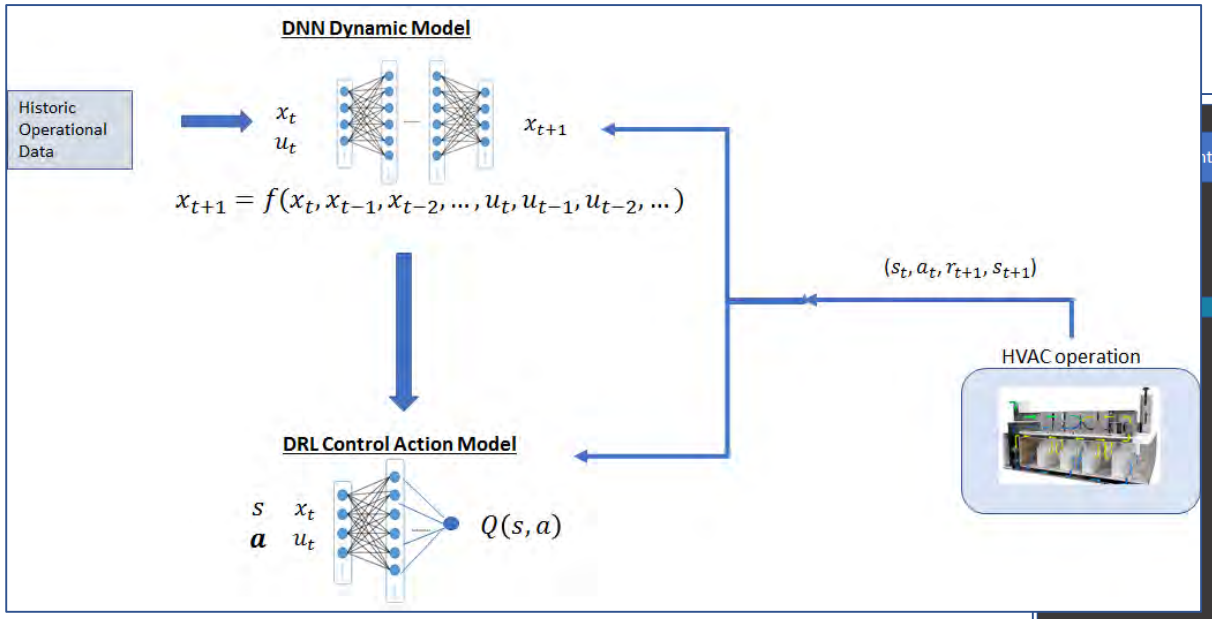
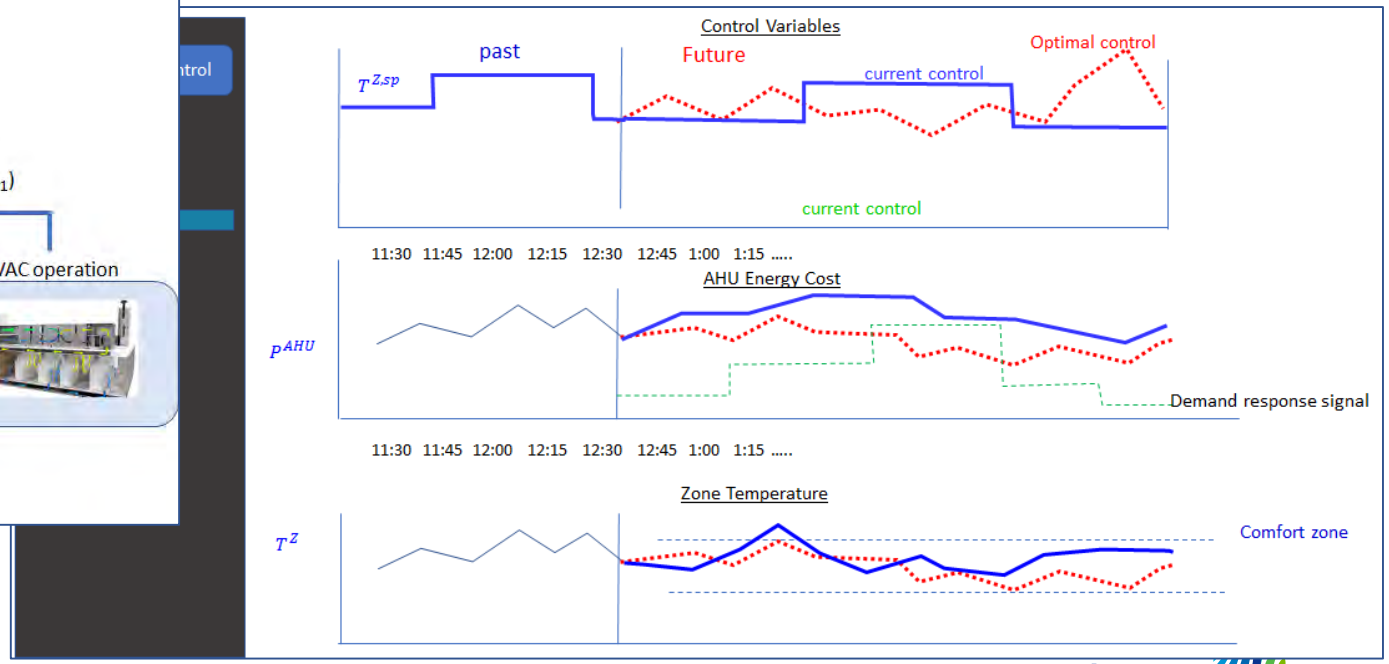
Use Case: Optimal Control of HVAC System with DNN and DRL

- Computes optimal operational set-point for the airside of HVAC system by taking into consideration
  - Thermal mass of the building as thermal storage, predicted energy load, electricity rate structure, occupant comfort level
- Reduce energy cost (typically 20%), improve the comfort and wellness of building occupants, improve the productivity of building occupants





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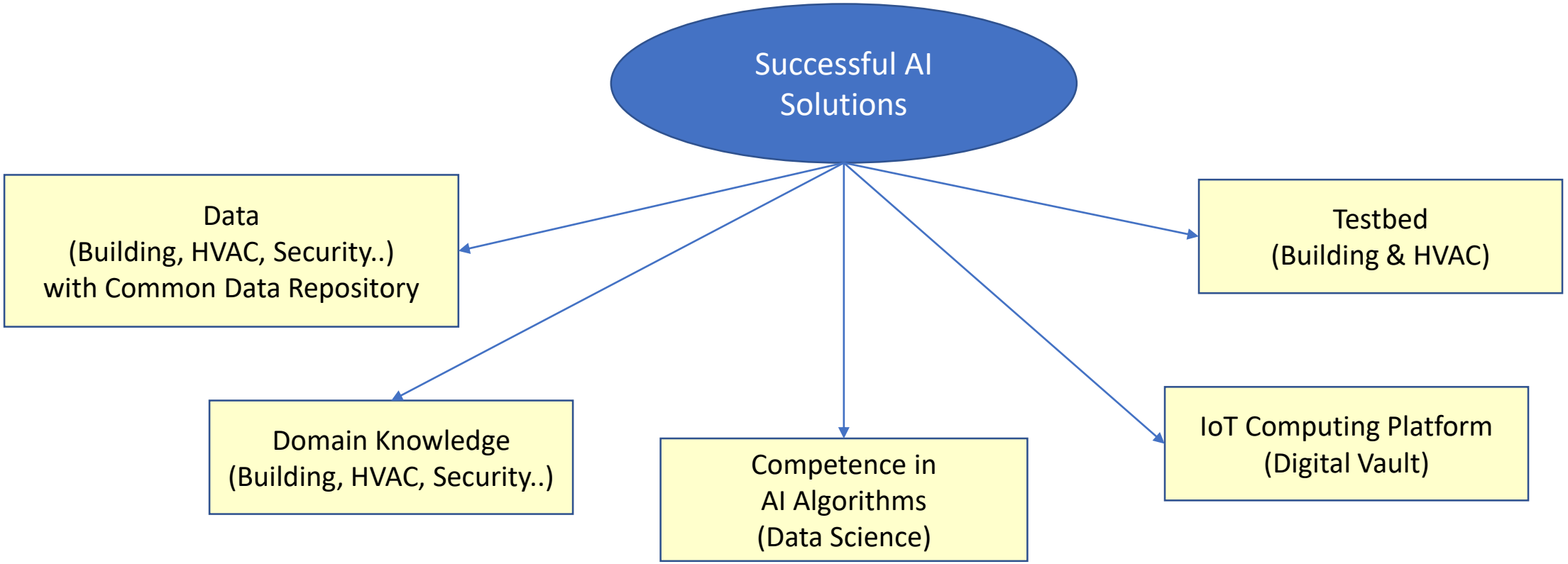
Key Elements for Successful AI Solutions in Building and Energy Management

There is no magic in AI



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