Artificial Intelligence + *Industrial Control Systems*

Adopting AI to Protect ICS: Assessing Challenges and Opportunities

From the operators' perspective!

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Carnegie Mellon University

S3D

CyLab Carnegie Mellon University
Security and Privacy Institute

What are industrial control systems (ICS)?

- ICS are systems that control processes in critical infrastructure

[1] https://www.cisa.gov/topics/critical-infrastructure-security-and-resilience/critical-infrastructure-sectors

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Energy

Water Treatment

Manufacturing

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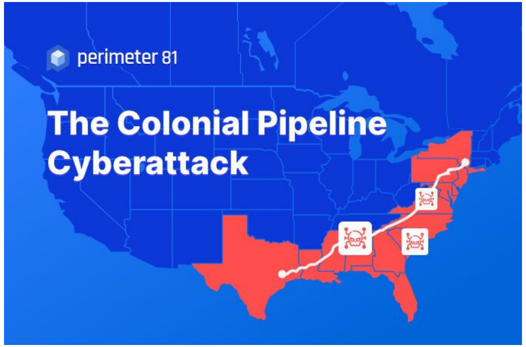

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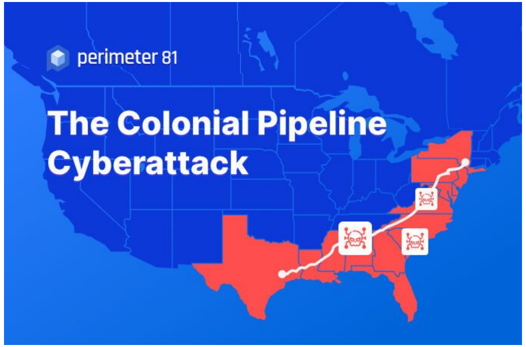

Aliquippa Water Plant (2023)

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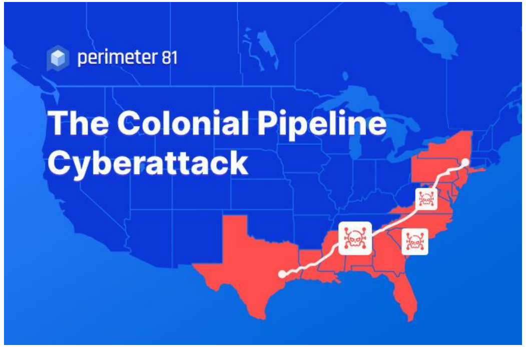

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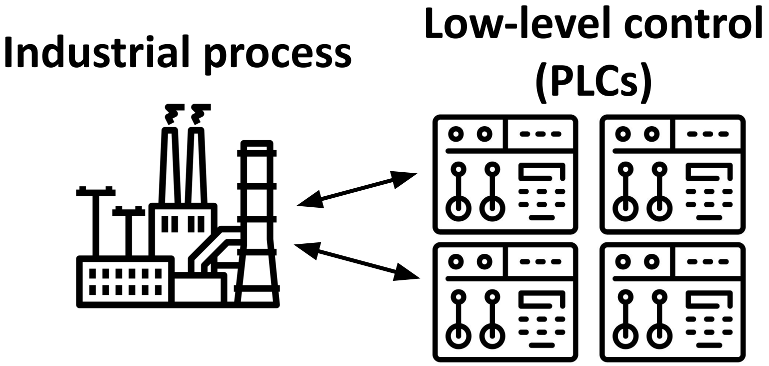
- July 2021: US President issues National Security Memorandum
  - "Improving Cybersecurity for Critical Infrastructure Control Systems"

Protecting ICS: current practice

Industrial process

Protecting ICS: current practice



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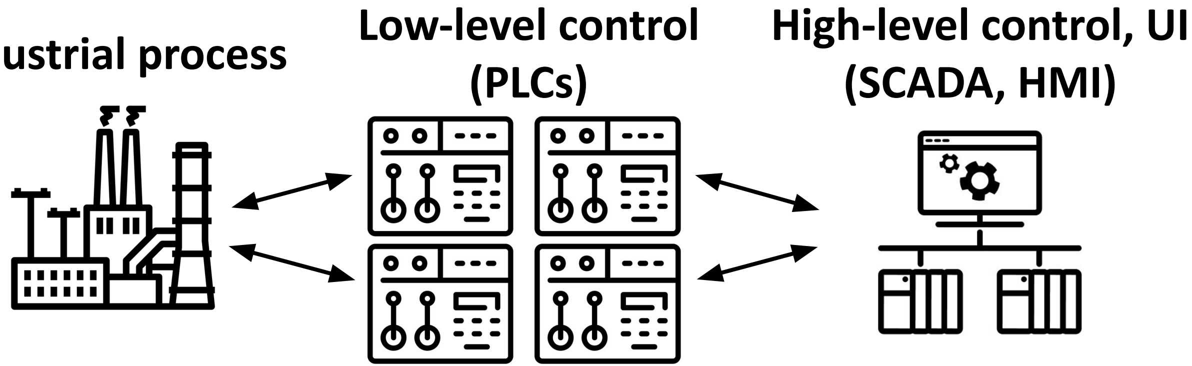

Industrial process

Low-level control (PLCs)

High-level control, UI (SCADA, HMI)

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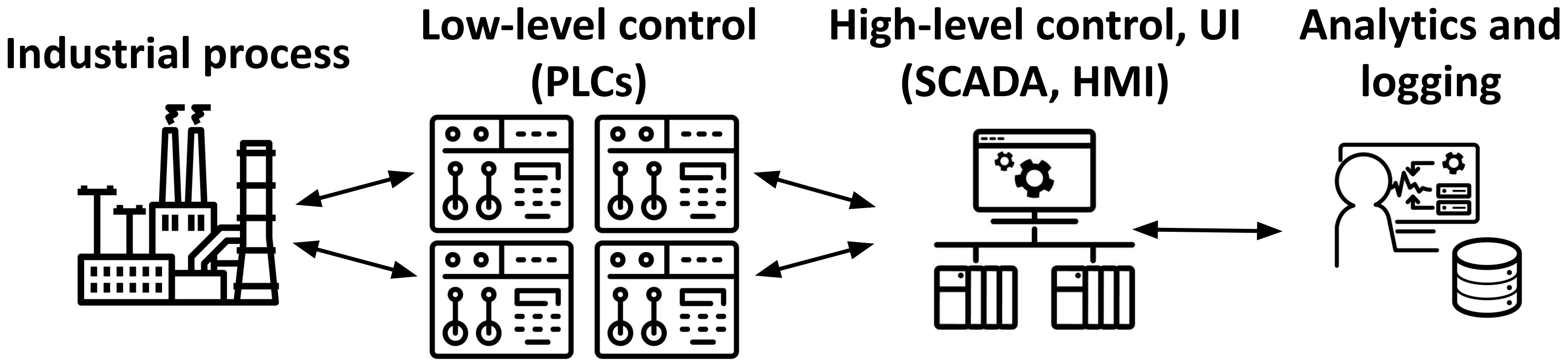

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Analytics and logging

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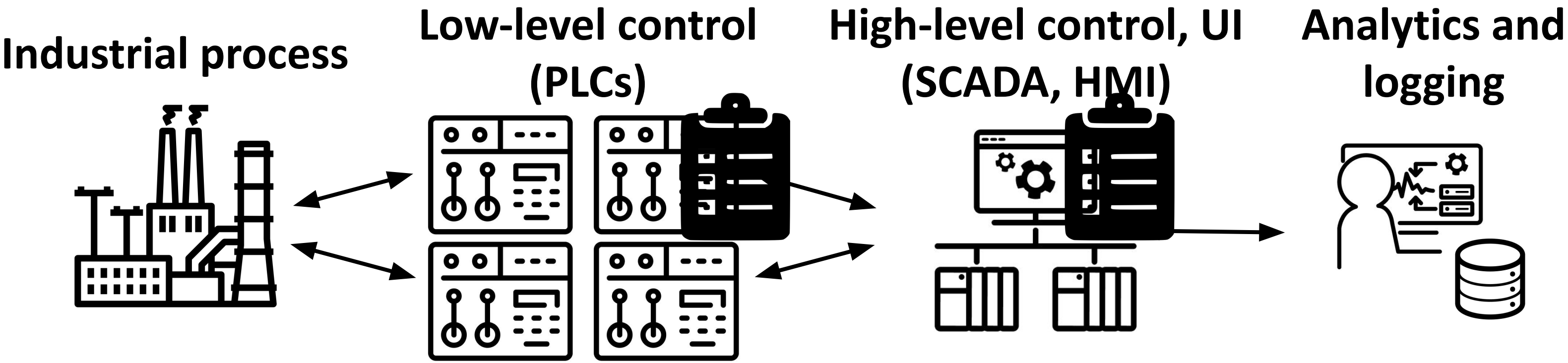

ICS security in practice:

- Manually write detection rules

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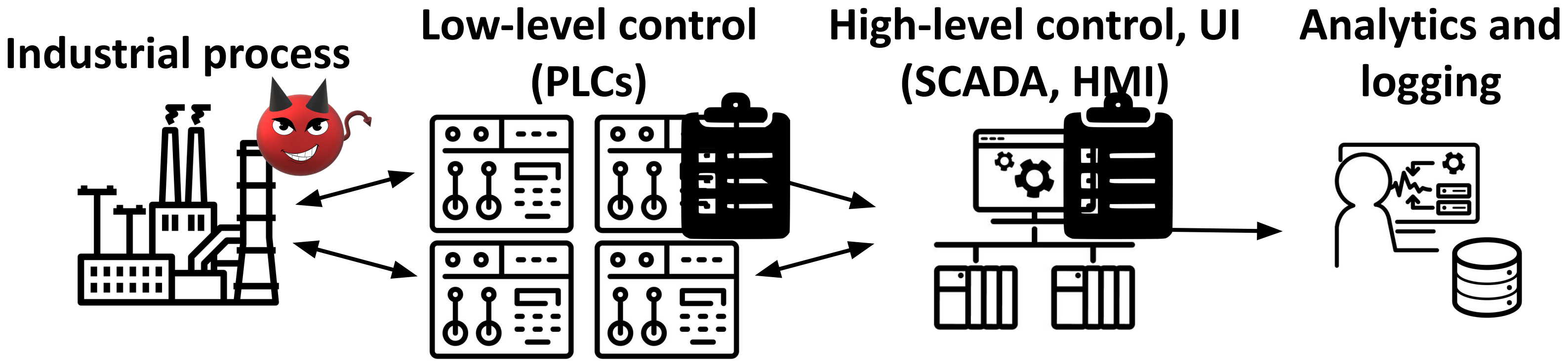

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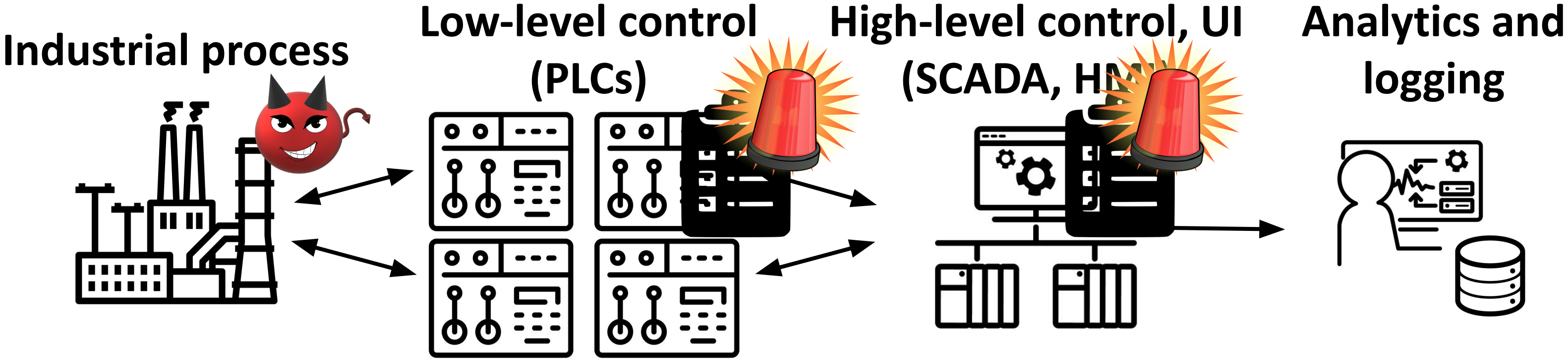

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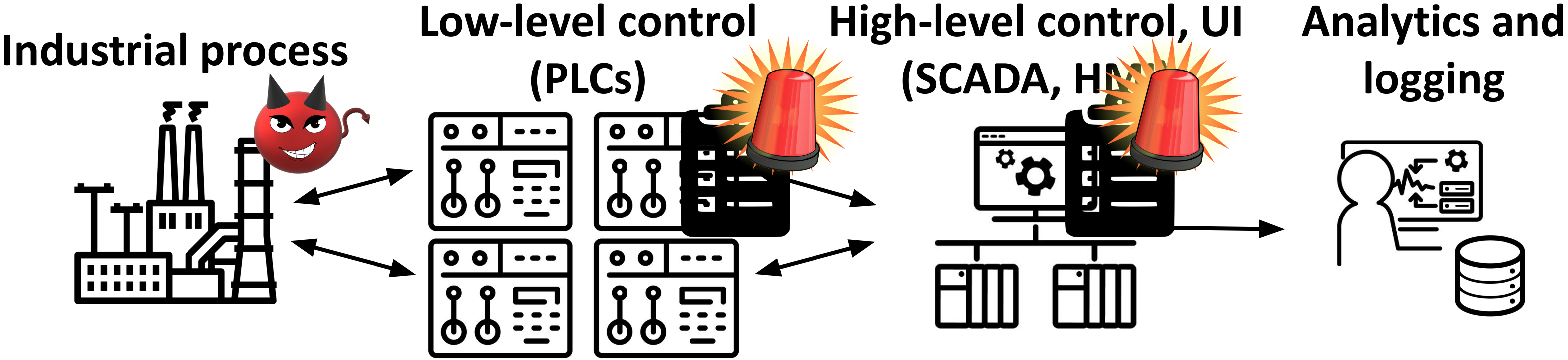
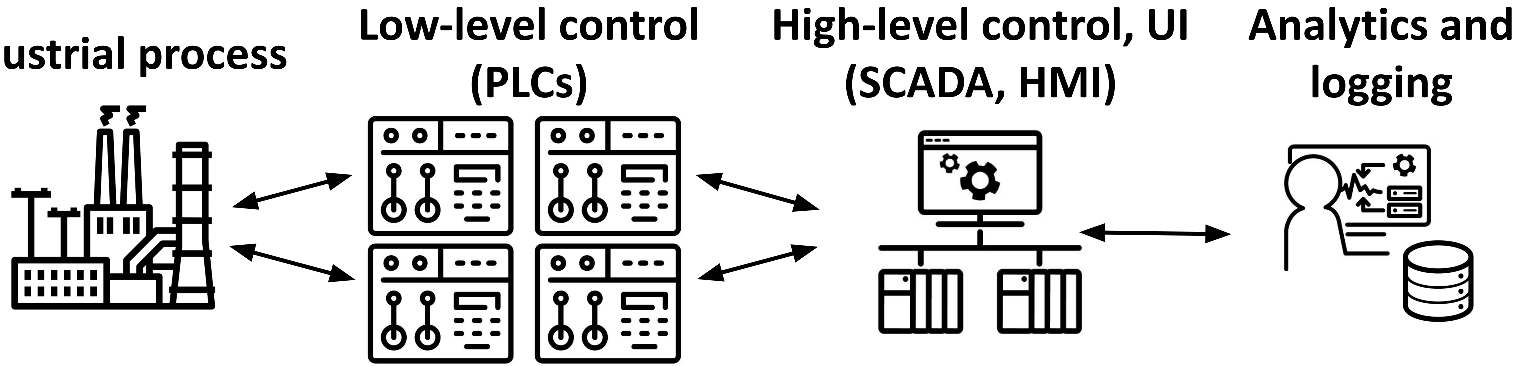


ICS security in practice:

- Manually write detection rules
- **Imperfect** and **labor-intensive**

Protecting ICS: in research, using AI



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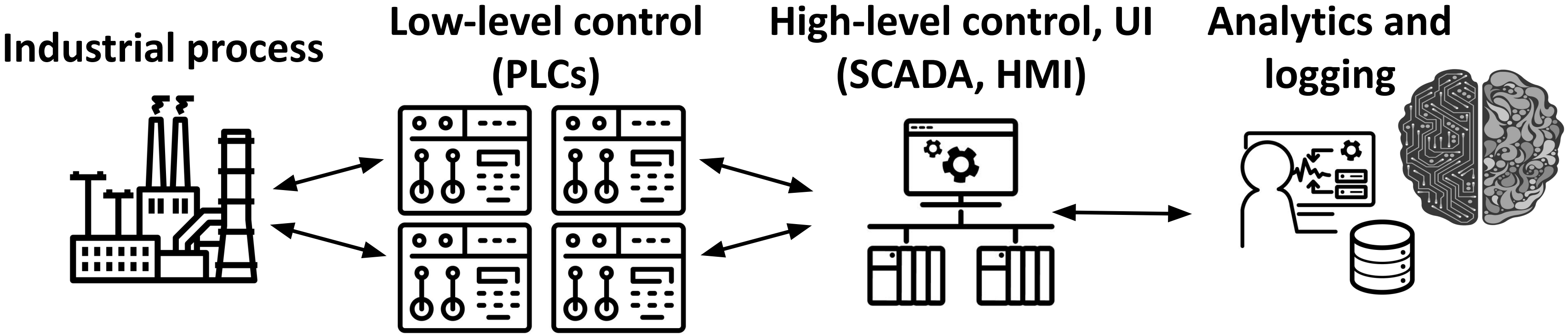

AI for ICS security in **research papers**:

- Train an AI model on ICS data

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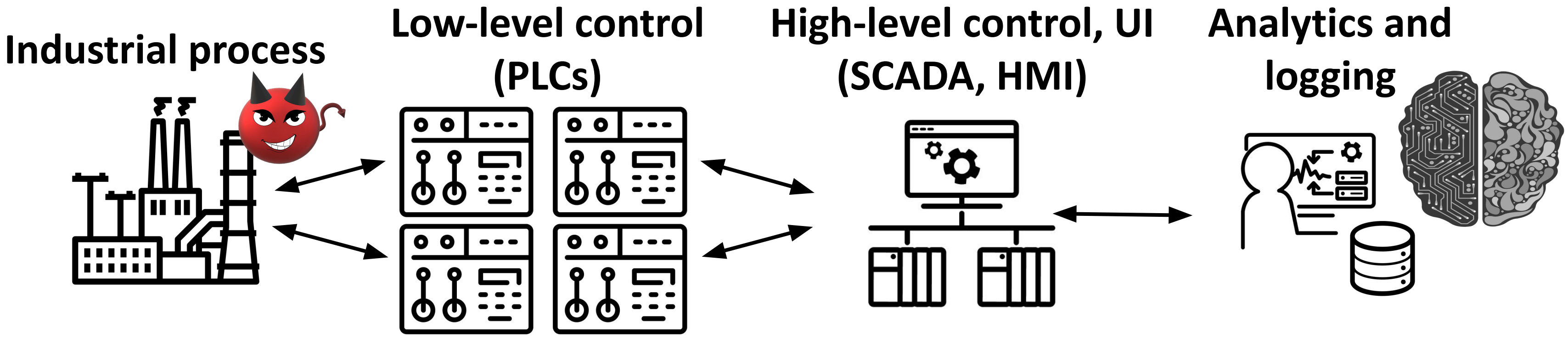

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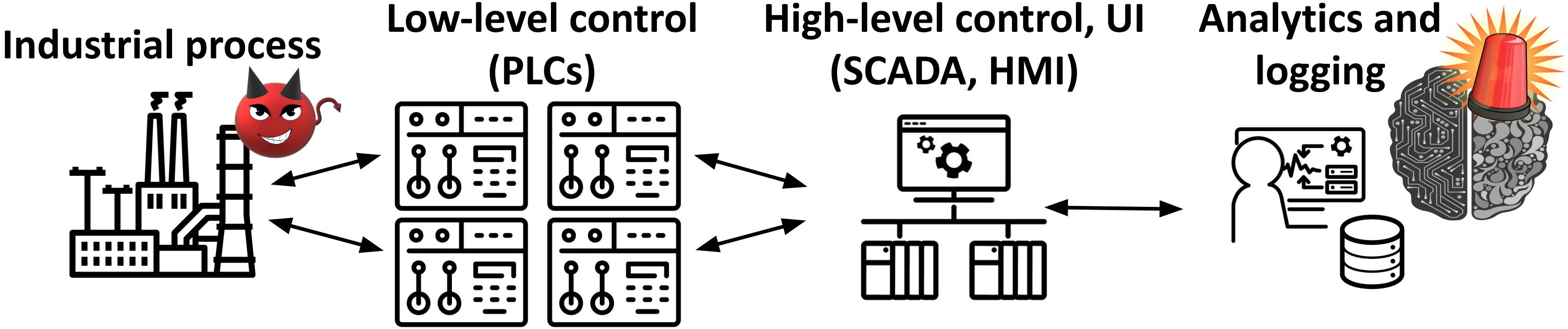
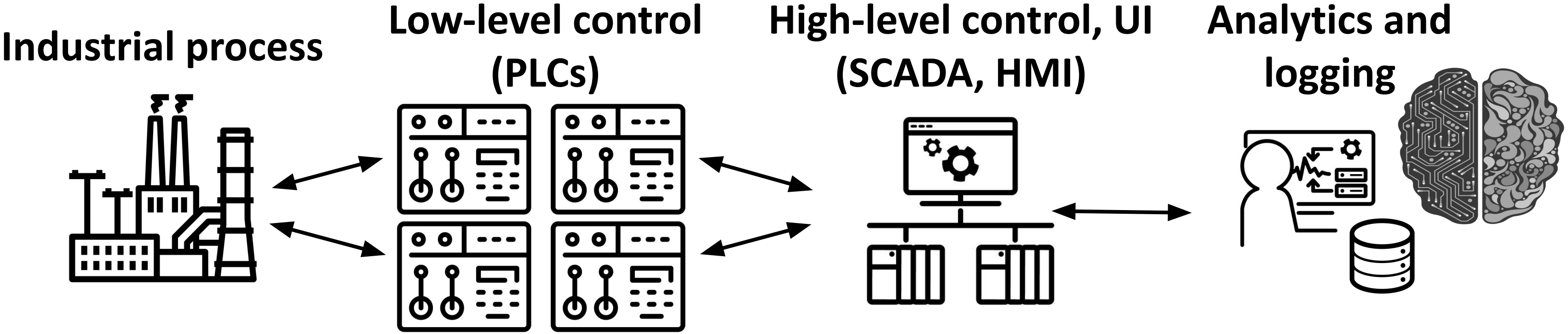


AI for ICS security in **research papers**:

- Train an AI model on ICS data
- Detect attacks with high accuracy

Protecting ICS: in research, using AI



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AI for ICS security **in practice** (2024):

2024 ICS/OT Survey

The State of ICS/OT Cybersecurity

Survey Author:
Jason Christopher

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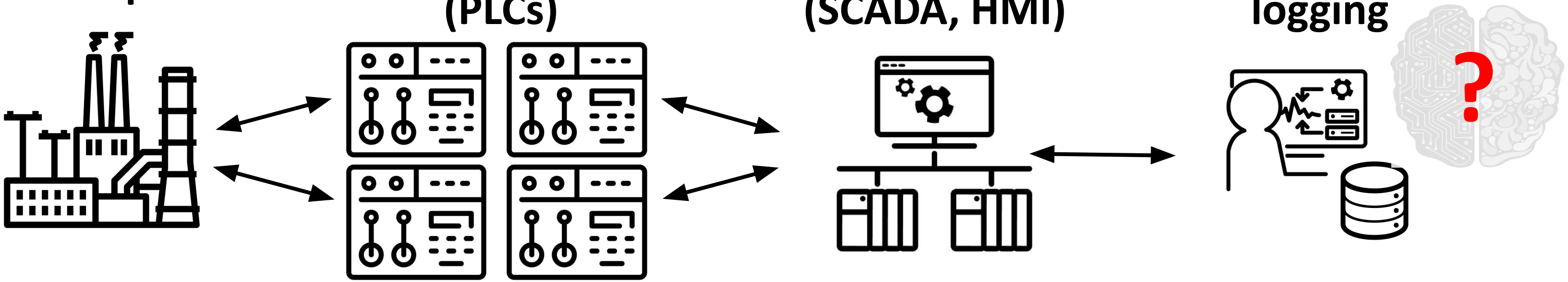

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AI for ICS security **in practice** (2024):

- 10% are using AI in ICS networks
- 19% are experimenting with AI

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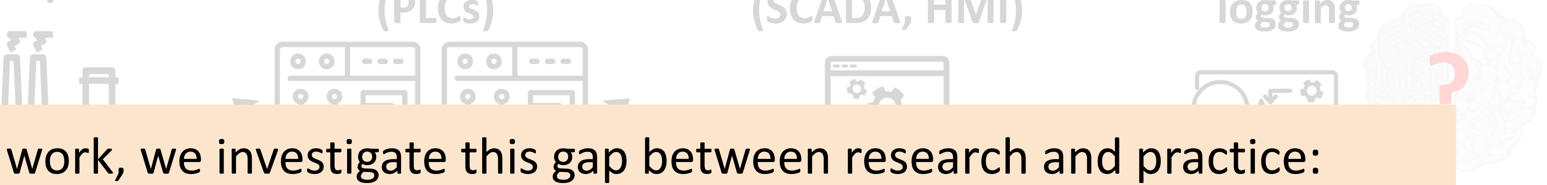

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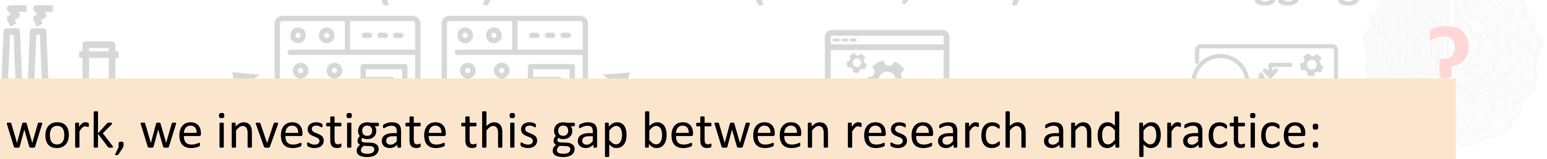

In this work, we investigate this gap between research and practice:

We **interview practitioners who work on protecting ICS** to understand their practices, pain points, and requirements

- 10% are using AI in ICS networks
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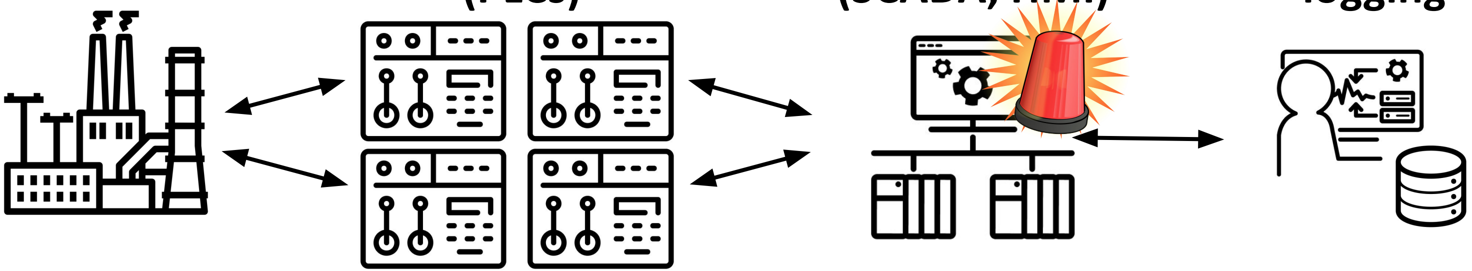
Who is involved with protecting ICS?



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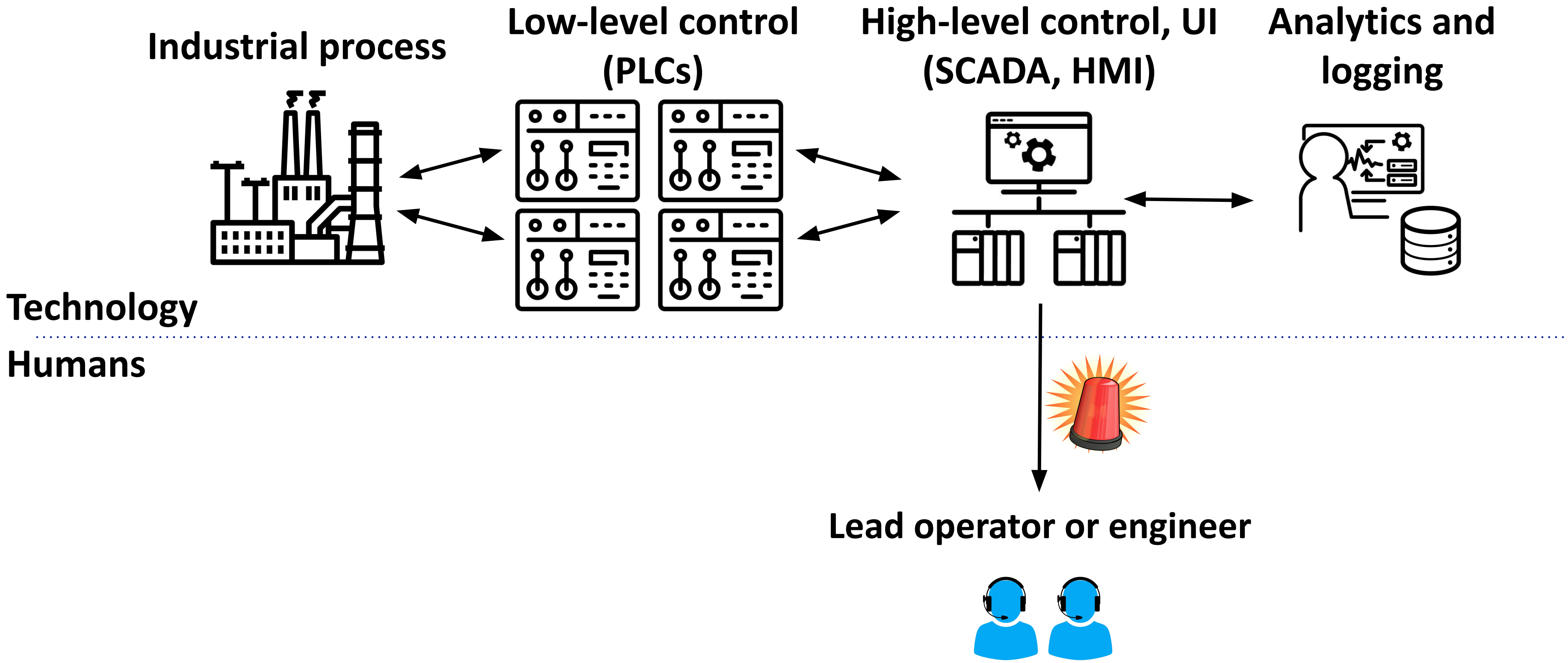

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Technology

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Lead operator or engineer

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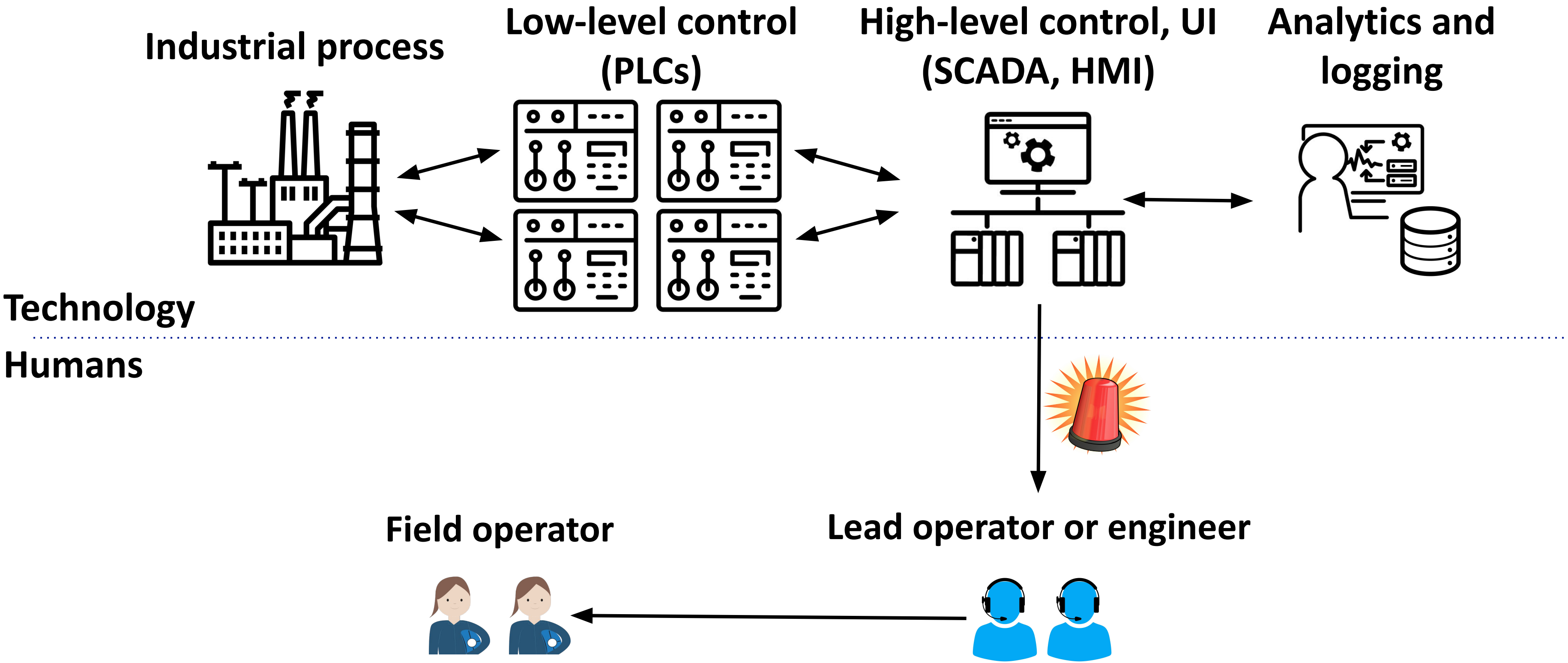

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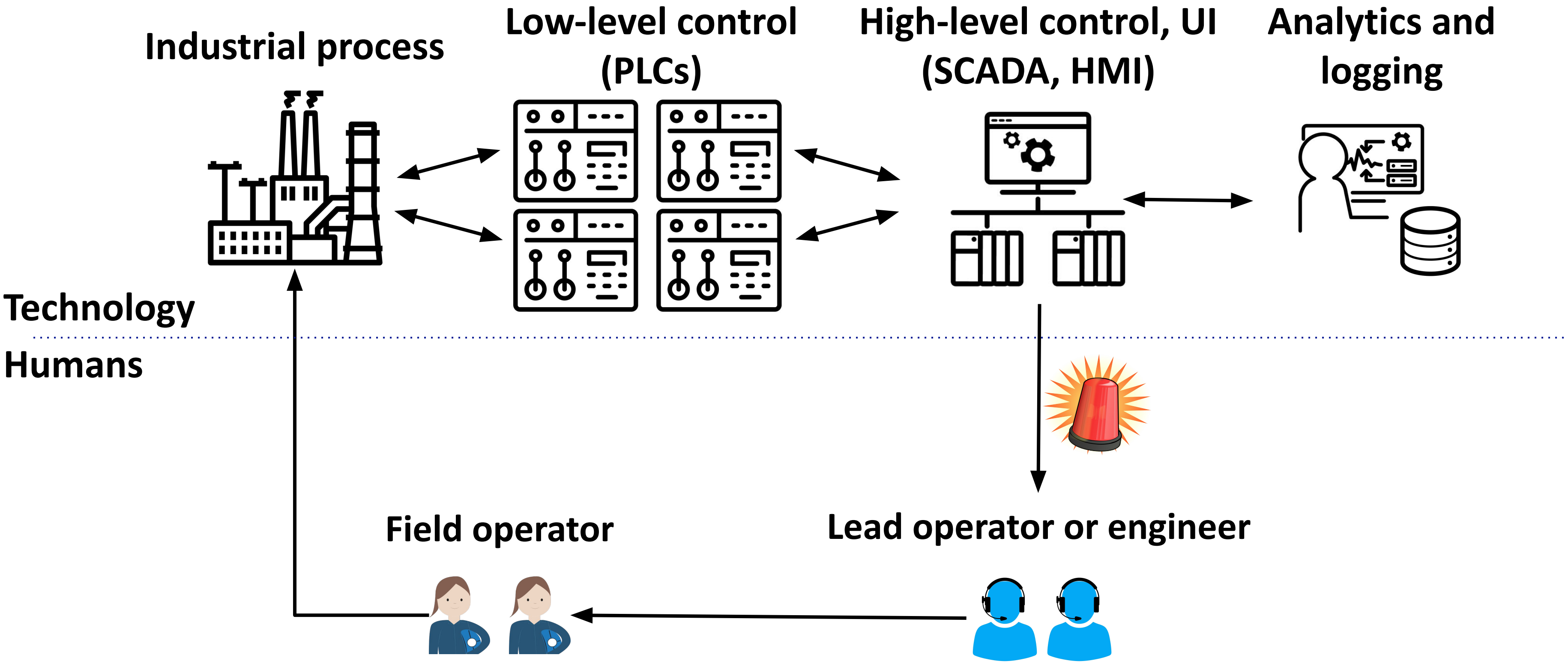

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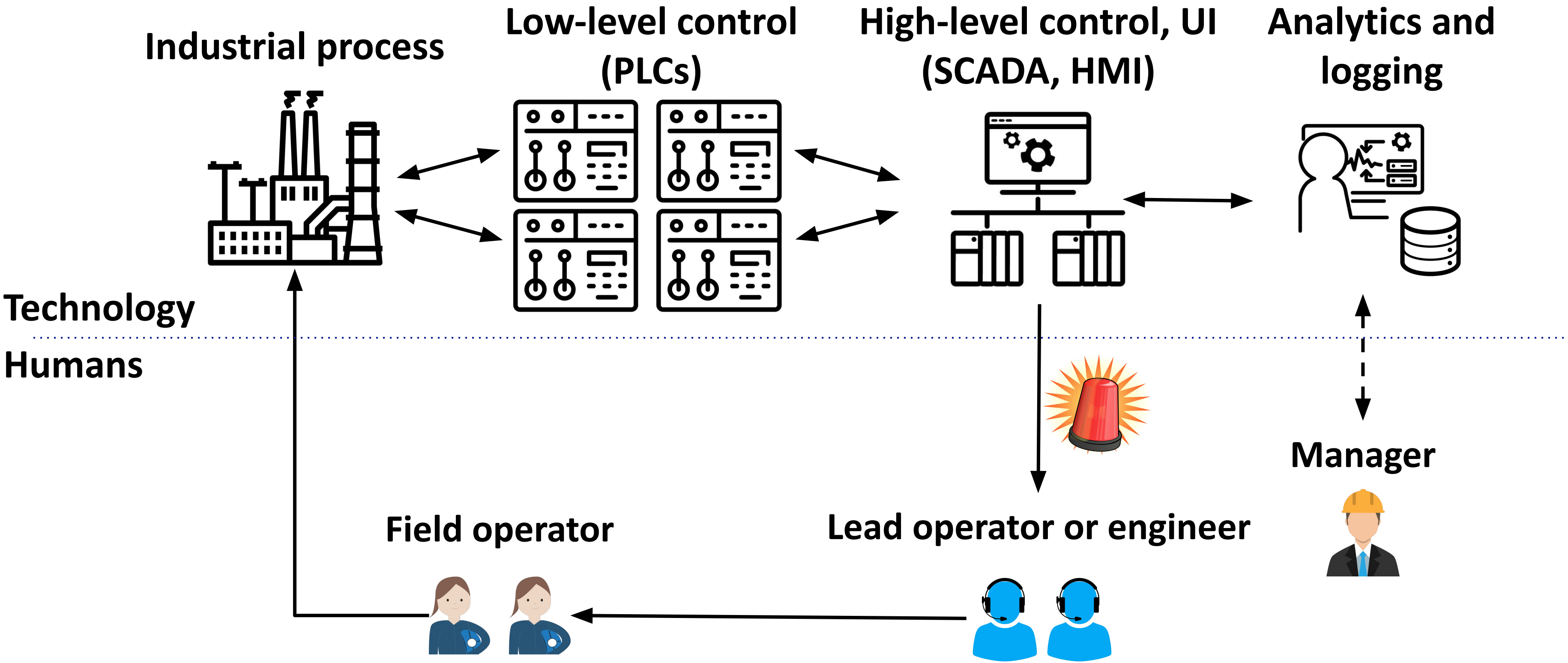

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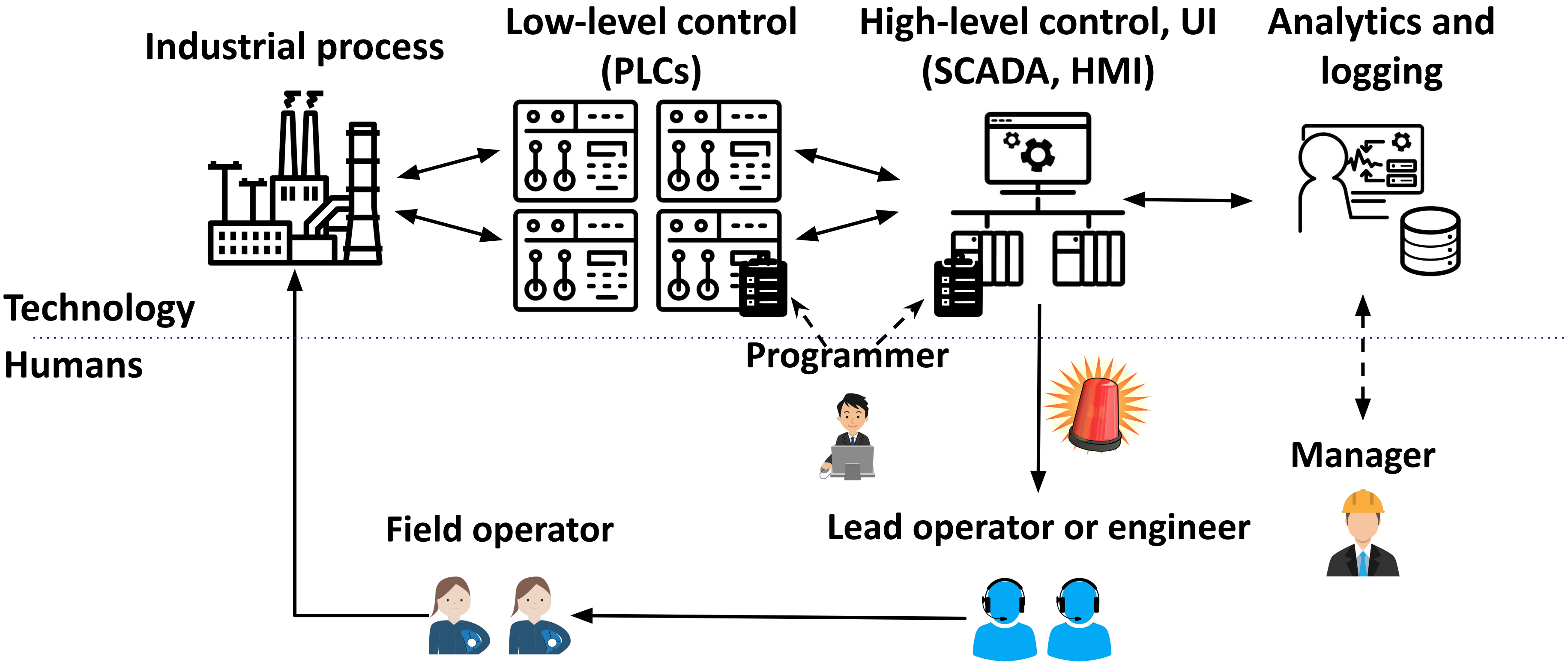

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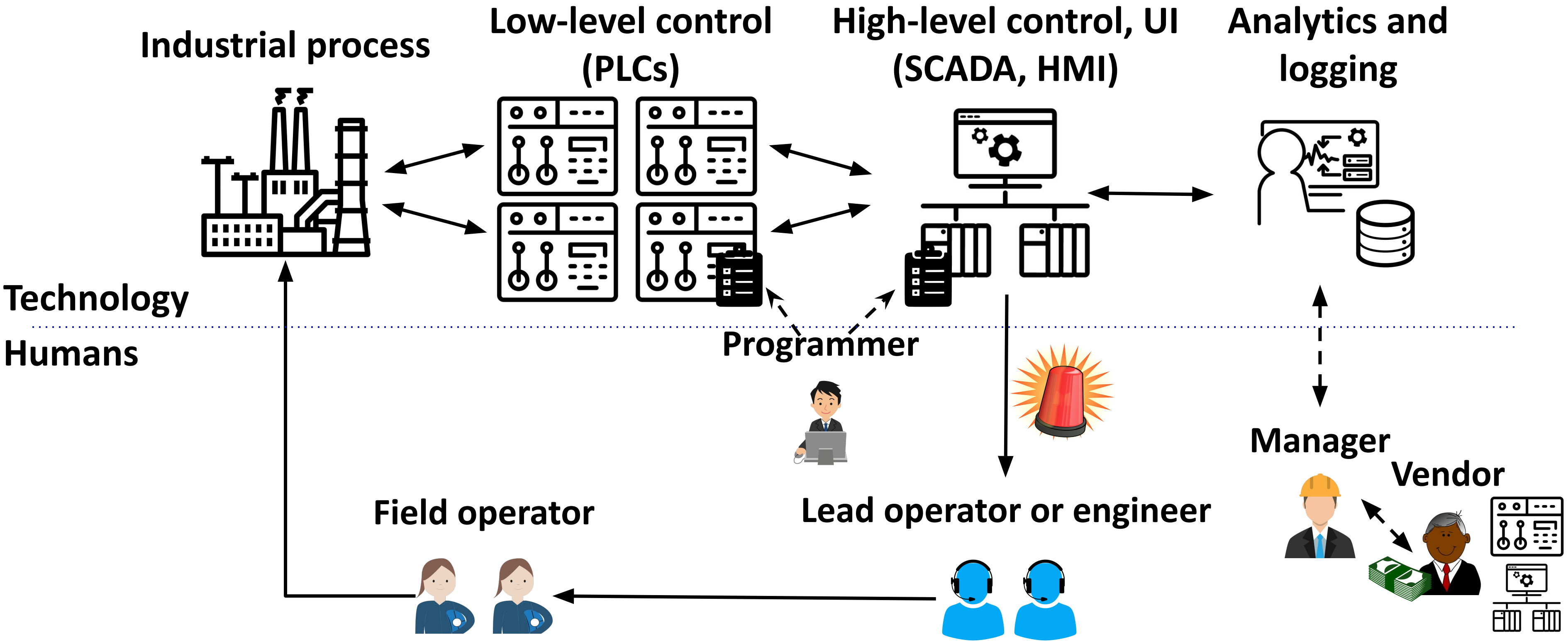

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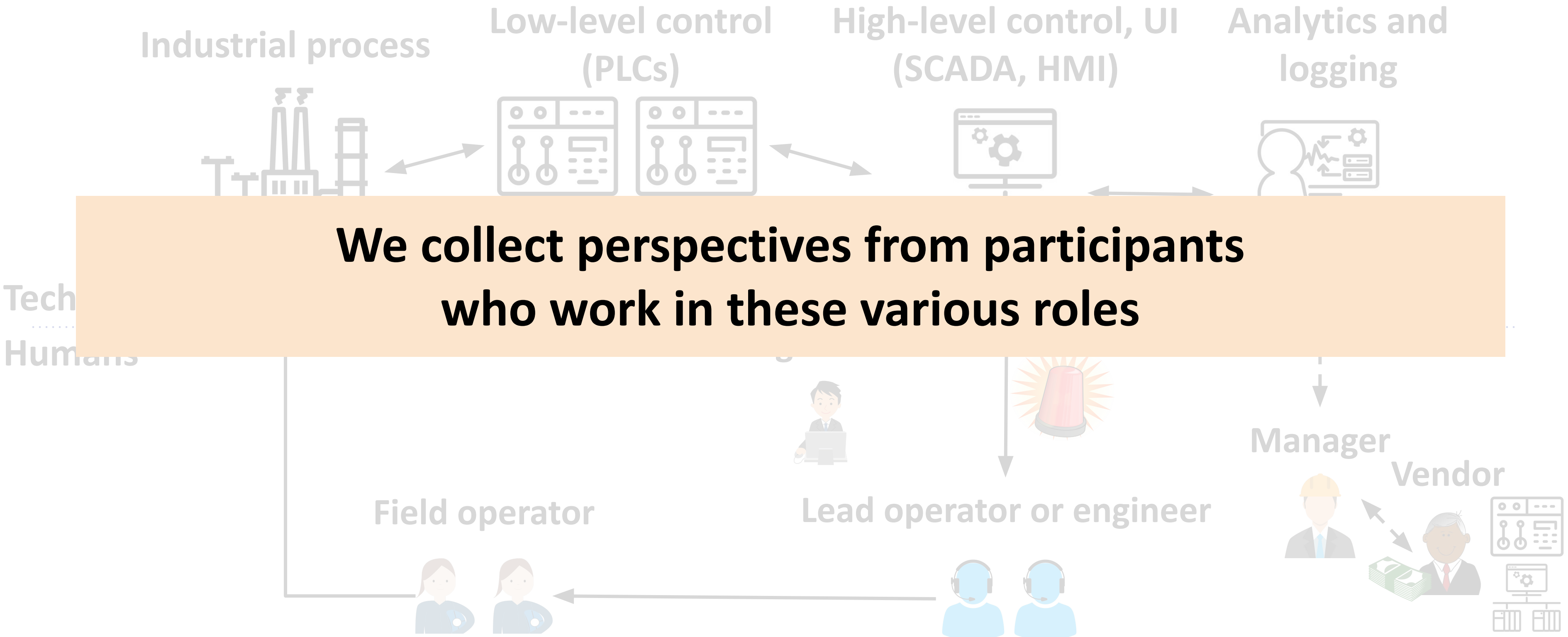

We collect perspectives from participants who work in these various roles

We recruited a variety of participants

Recruitment: 𝕏 in ✉

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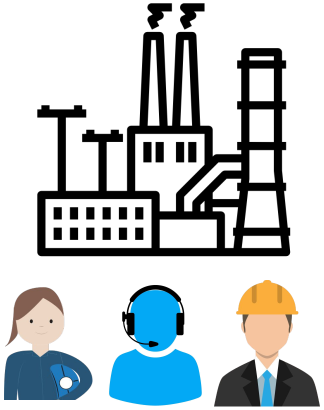
Recruitment: X in ✉



x 13

Operations

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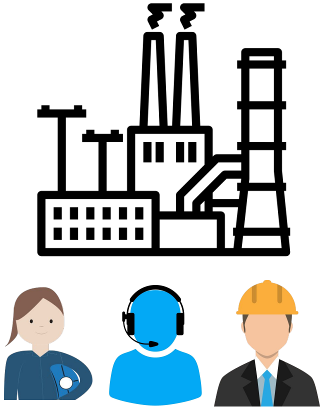

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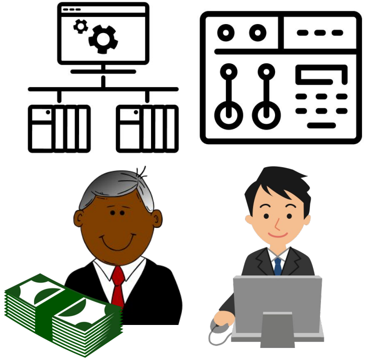

x 5

Vendors

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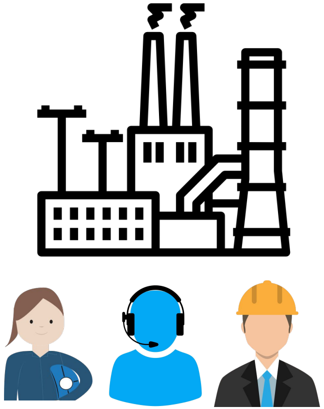
Recruitment:



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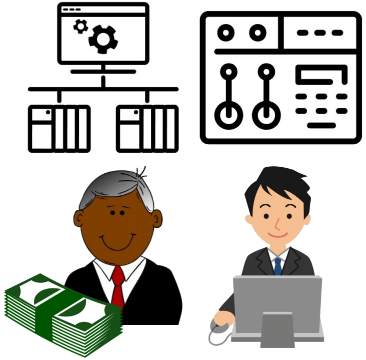

x 5

Vendors

- Electricity
- Oil and gas
- Manufacturing
- Water treatment

We use an indirect approach in interviews

- Challenge: Few practitioners with AI expertise

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- **An indirect approach** via semi-structured interviews:
    - Technology and tasks for alarms
    - Adopting new technology in ICS
    - Perceptions of AI for ICS

We use an indirect approach in interviews

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- Qualitative coding and analysis for themes relevant to AI adoption

What types of things did we learn about ICS?

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Technology and infrastructure	- For collecting and using process data - For building alarm systems

ICS alarm systems: different shapes and sizes!

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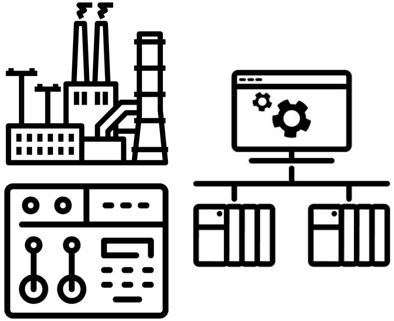
- Logic: High or low values, rate of change, or combinations
- Locations: Logic in sensors, PLCs, or SCADA
  - Forwarded and displayed in different locations



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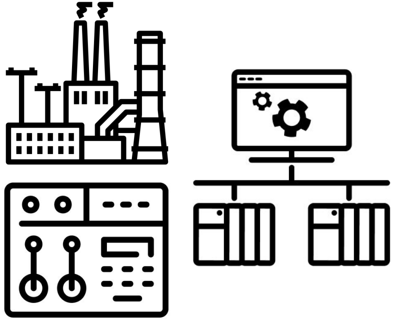
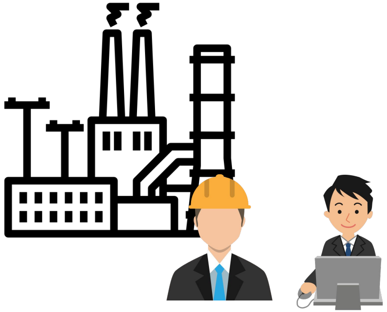
ICS alarm systems use rule sets, but *how* they use them varies:

- Logic: High or low values, rate of change, or combinations
- Locations: Logic in sensors, PLCs, or SCADA
  - Forwarded and displayed in different locations
- People: Written and managed by plant owners or vendors





Takeaway 1: ICS setups vary, limiting the feasibility of general-purpose research solutions

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Research

- *Centralized* data and compute

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Practice

- *Decentralized* data, devices, and user interfaces

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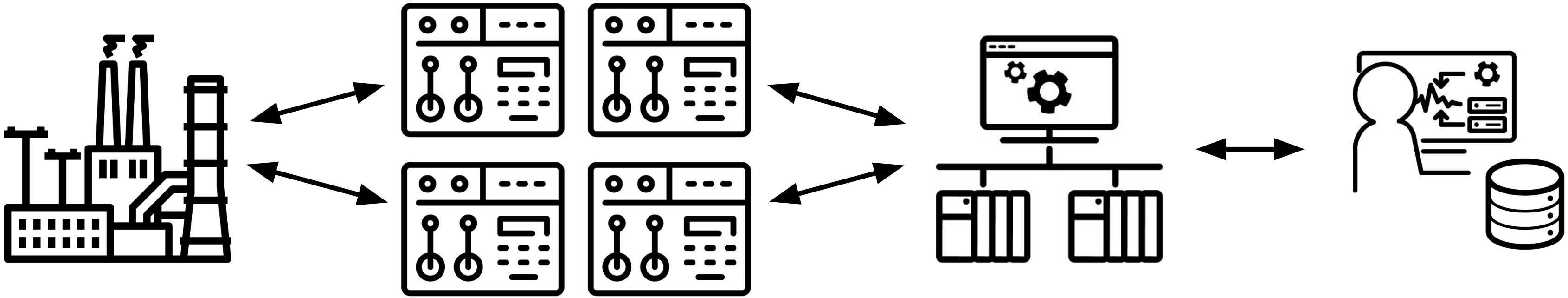

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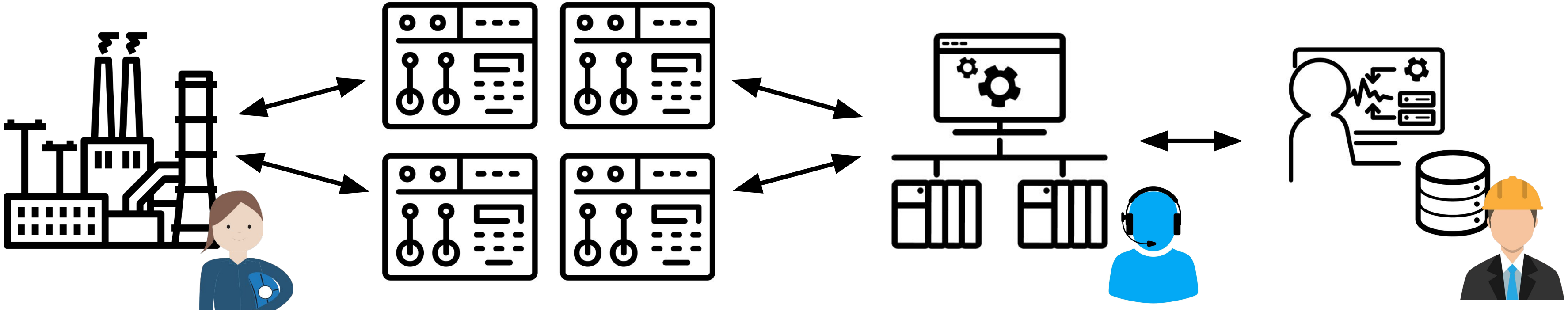

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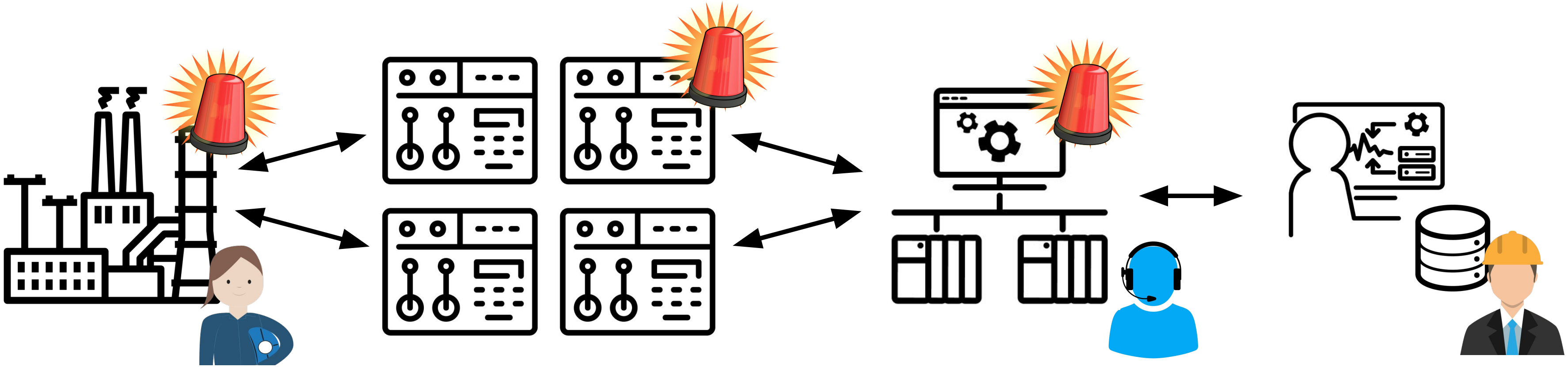

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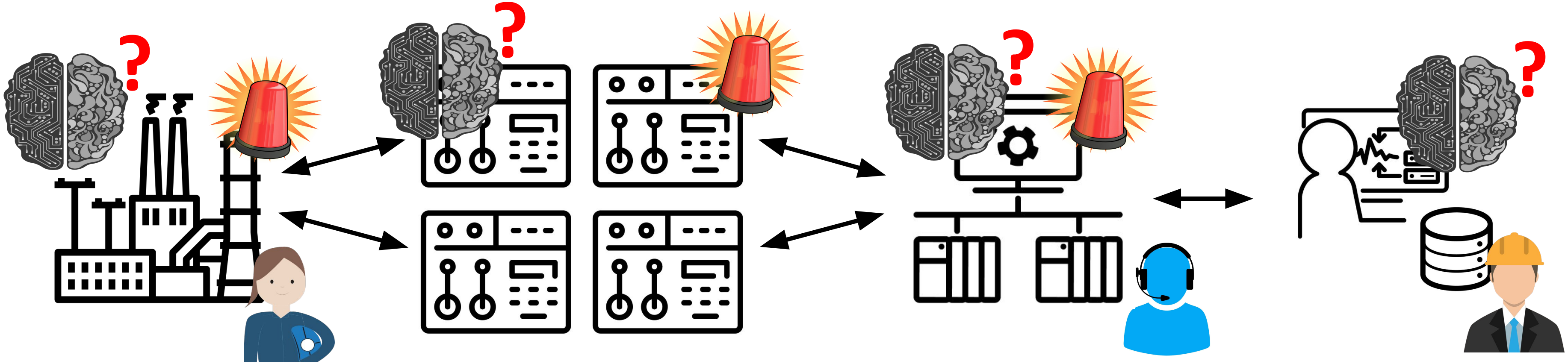

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Practice

- *Decentralized* data, devices, and user interfaces

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Research

- *Centralized* data and compute

Practice

- *Decentralized* data, devices, and user interfaces
- Technological and regulatory constraints

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NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Takeaway 1: ICS setups vary, limiting the feasibility of general-purpose research solutions

Research

- *Centralized* data and compute

Practice

- *Decentralized* data, devices, and user interfaces

We need new deployment models for AI in ICS based on devices, data, and users

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RELIABILITY CORPORATION

What types of things did we learn about ICS?

Technology and infrastructure	• For collecting and using process data • For building alarm systems
Human factors	• Human tasks involved in alarm systems • Pain points when using alarm systems • Pain points from working in ICS environments

Common human tasks in alarm workflows

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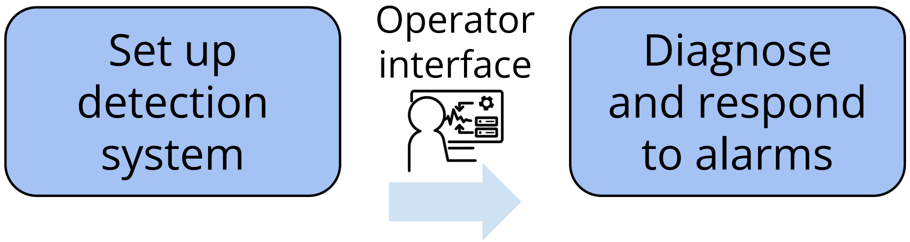
Set up detection system

Common human tasks in alarm workflows



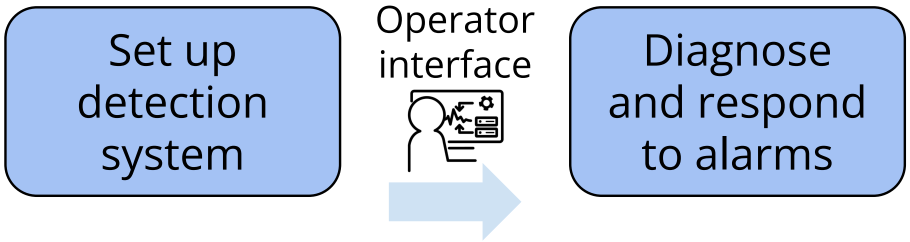
Set up detection system

Operator interface

Diagnose and respond to alarms

Common human tasks in alarm workflows

- Alarm diagnosis: Determining and performing follow-up actions



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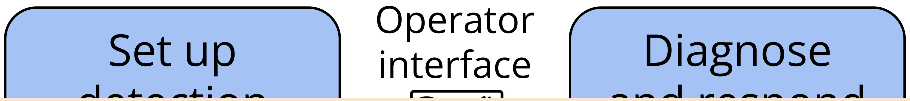
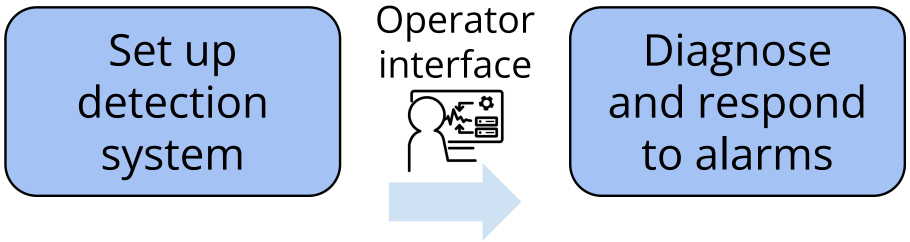


[...] our greatest challenge is ***training the staff that's still fairly new*** *[...] what the* ***appropriate level of response*** *is. –P18*

Common human tasks in alarm workflows

- Alarm diagnosis: Determining and performing follow-up actions
  - Relies on **intuition and experience**



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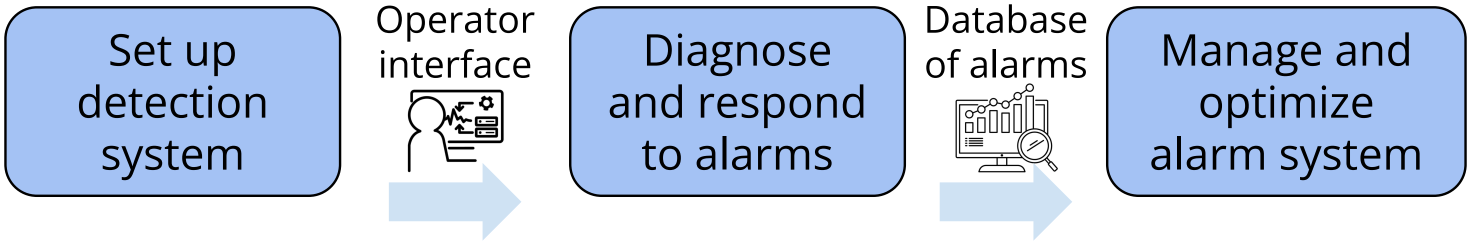

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Database of alarms

Manage and optimize alarm system

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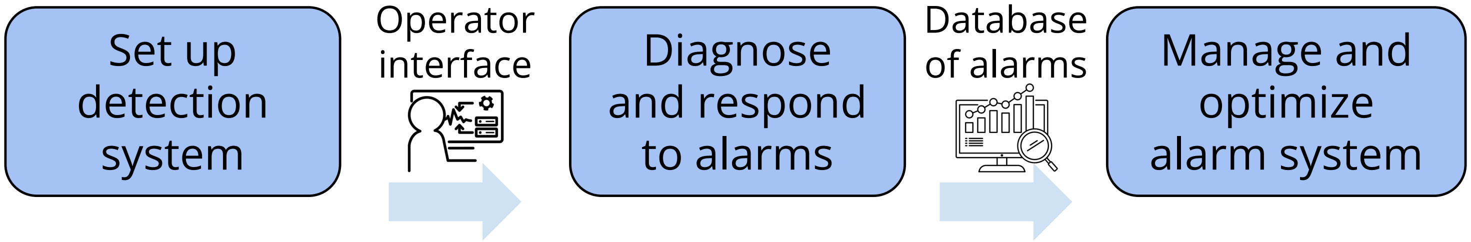
- Alarm management: Using prior alarm data to optimize alarm systems



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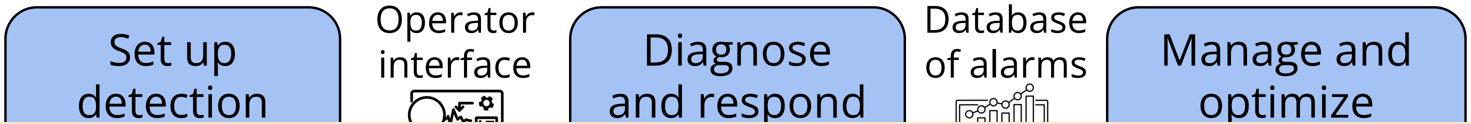
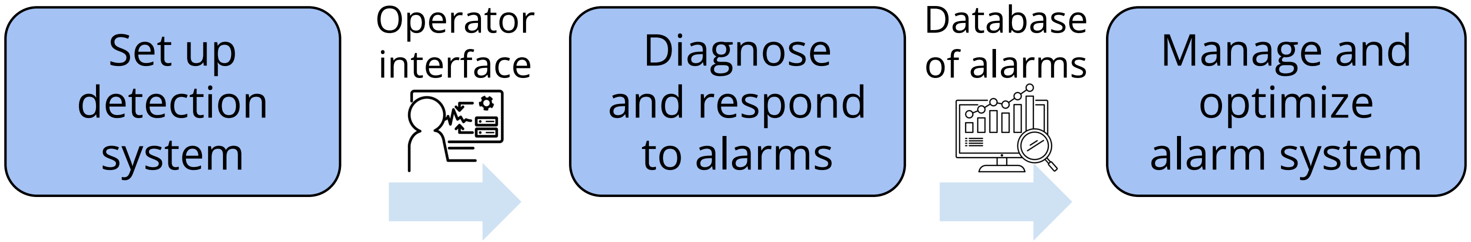


*We **looked at every single alarm** that we have, and challenged if you need the alarm, and then what the alarm point should be. And that was a significant **year and a half of, at least 10 hours a week**. –P13*

Common human tasks in alarm workflows

- Alarm diagnosis: Determining and performing follow-up actions
  - Relies on **intuition and experience**
- Alarm management: Using prior alarm data to optimize alarm systems
  - Determining **what should be an alarm** is difficult


Set up detection system
Operator interface
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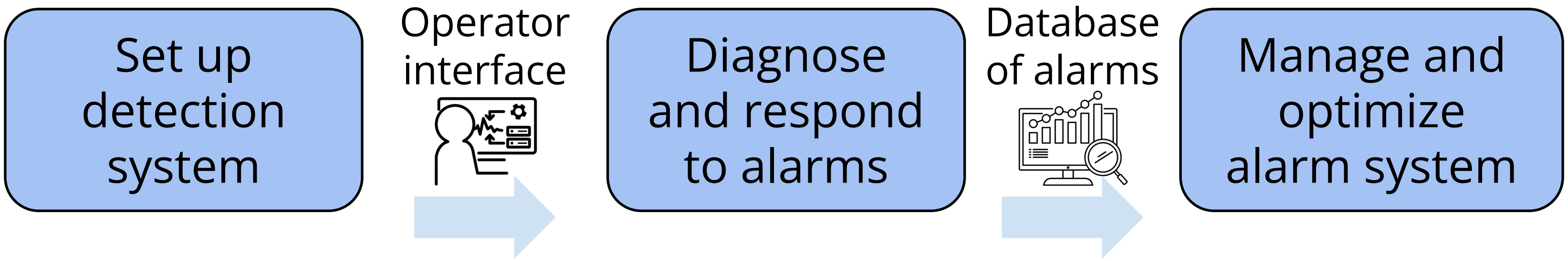
Takeaway 2: Operators want help with tasks beyond anomaly detection



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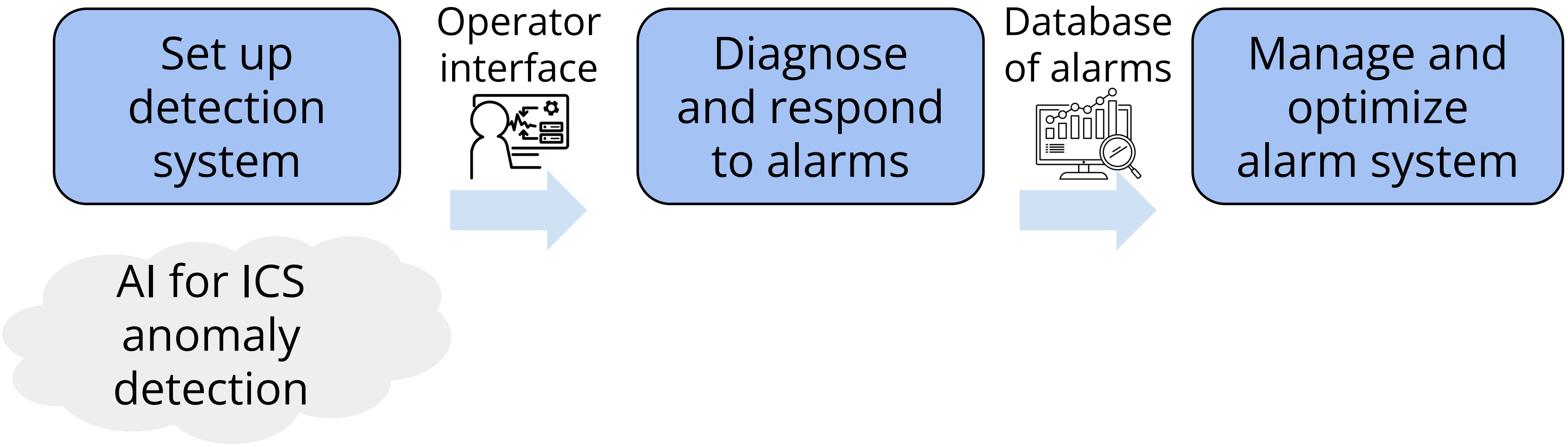

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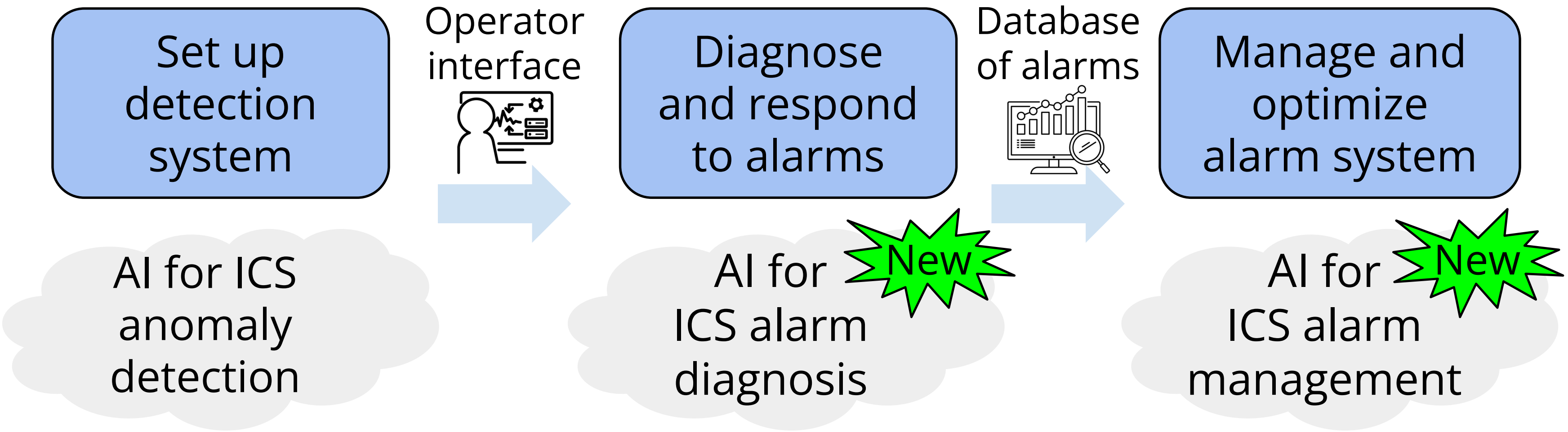

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New

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New

What types of things did we learn about ICS?

Technology and infrastructure	• For collecting and using process data • For building alarm systems
Human factors	• Human tasks involved in alarm systems • Pain points when using alarm systems • Pain points from working in ICS environments
AI adoption	• Perspectives on vendors and tool adoption • Perspectives on how AI could help them

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*We now have 1000s of examples of: the data was doing this, it led to this root cause analysis, and it led to this action. [...] we can begin to look at applying deep learning, because **we have the necessary data to train that**. –P1*

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The management of our plant, they don't really trust AI because they ***don't have a solid understanding of how it works****. –P17*

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*To implement [AI], the good ways all involve: Here's how it works, here's what it's looking at, breaking it down and **putting a lot more transparency behind it**. –P11*

Adopting AI to Protect Industrial Control Systems:
Assessing Challenges and Opportunities from the Operators’ Perspective

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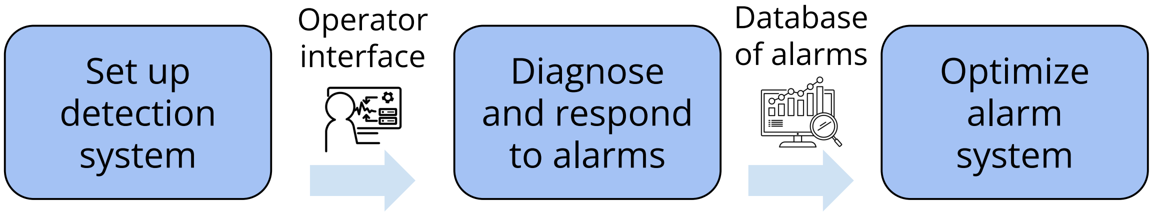

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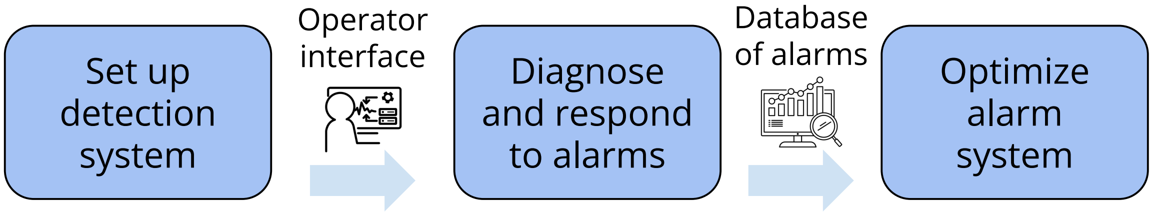

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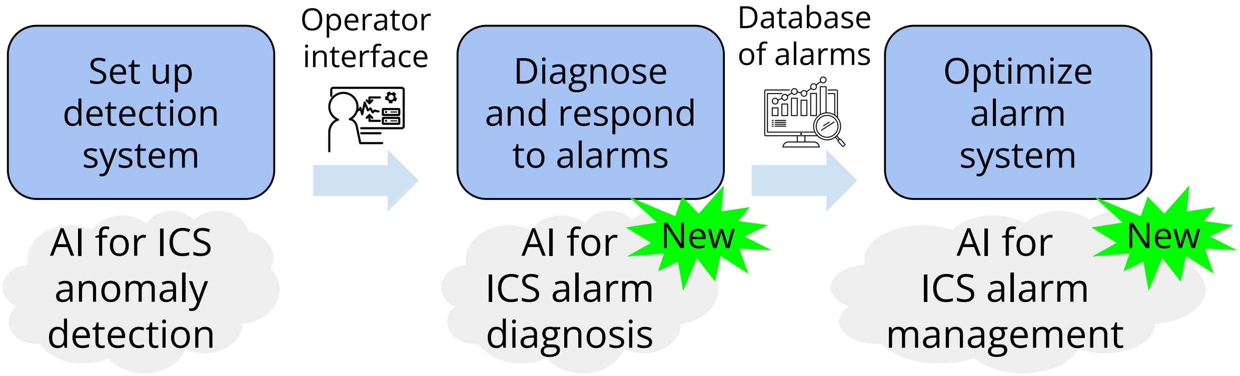
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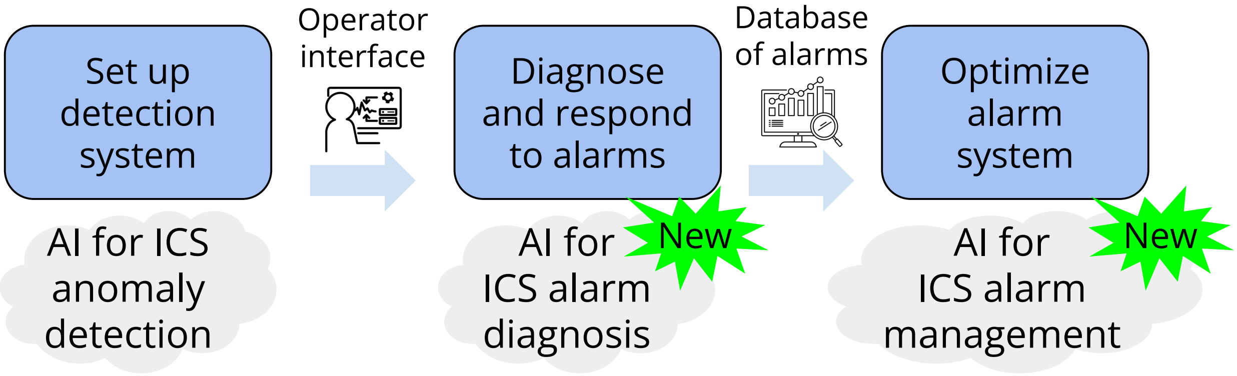
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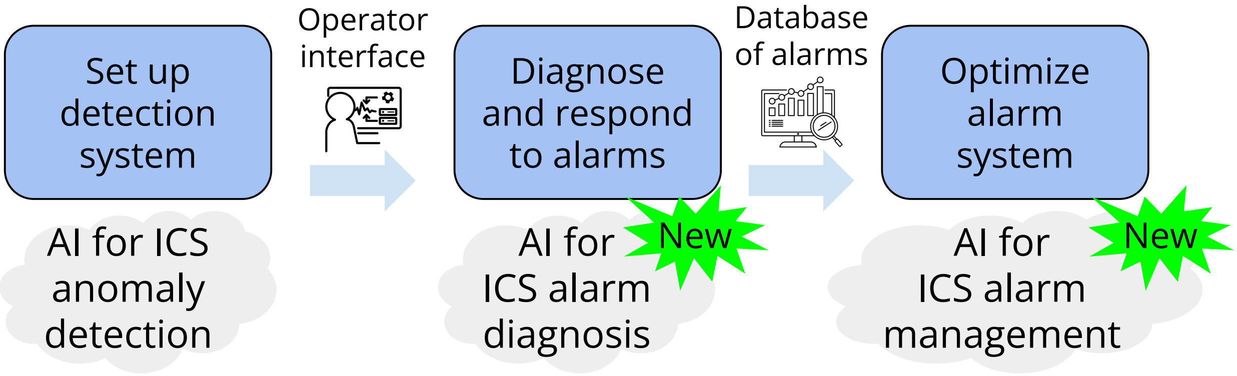

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- Demonstrate AI transparency through interactive pilot projects