Safety-Security Convergence of Industrial Control Systems

« Attacks against SCADA made slightly boring with formal methods »

Maxime PUYS

Dec. 13th, 2024

Today's question: How to assess the real impact of cyber-attacks against ICS?

Two Types of IOT

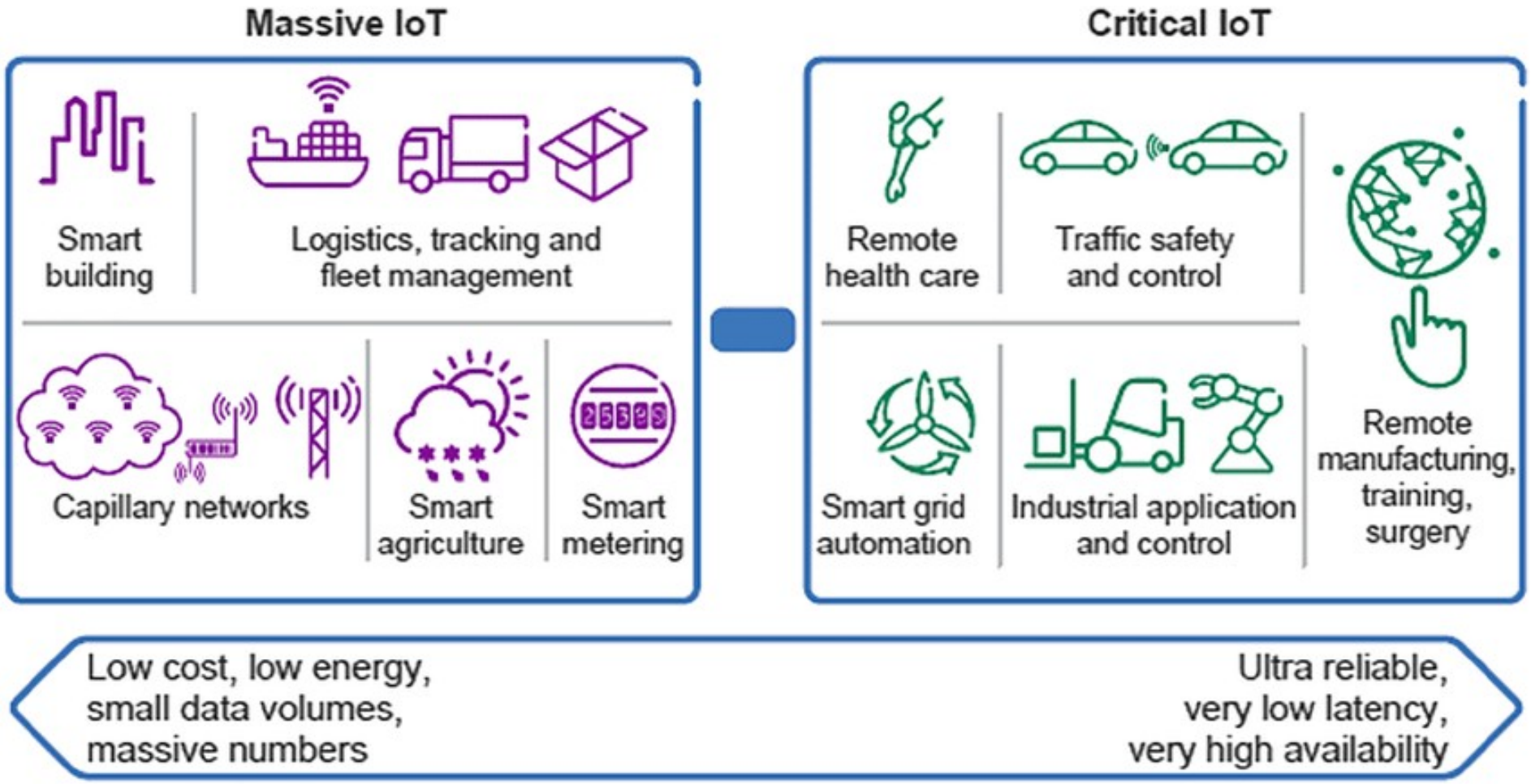


Figure: [Alq19]

Two Types of IOT

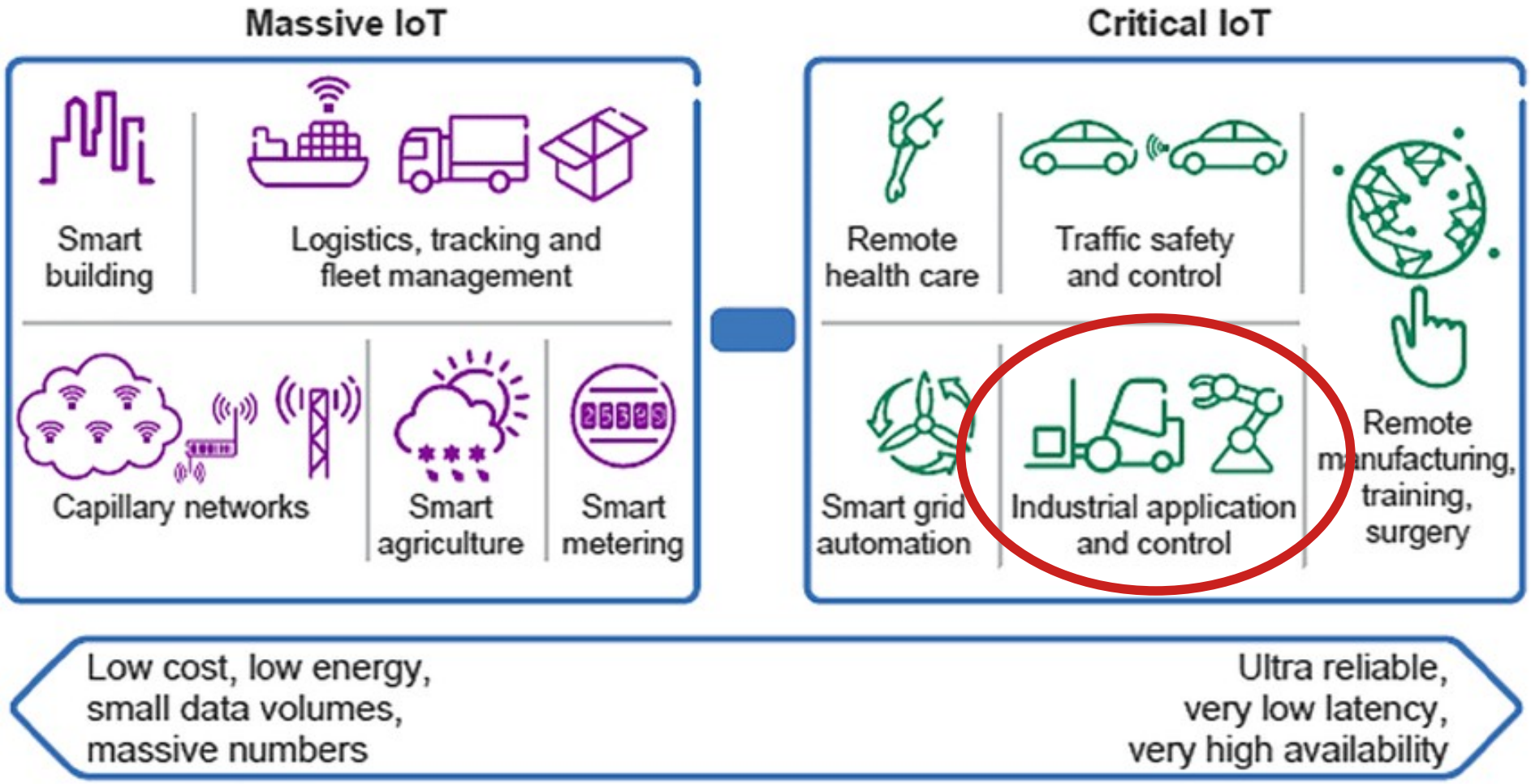
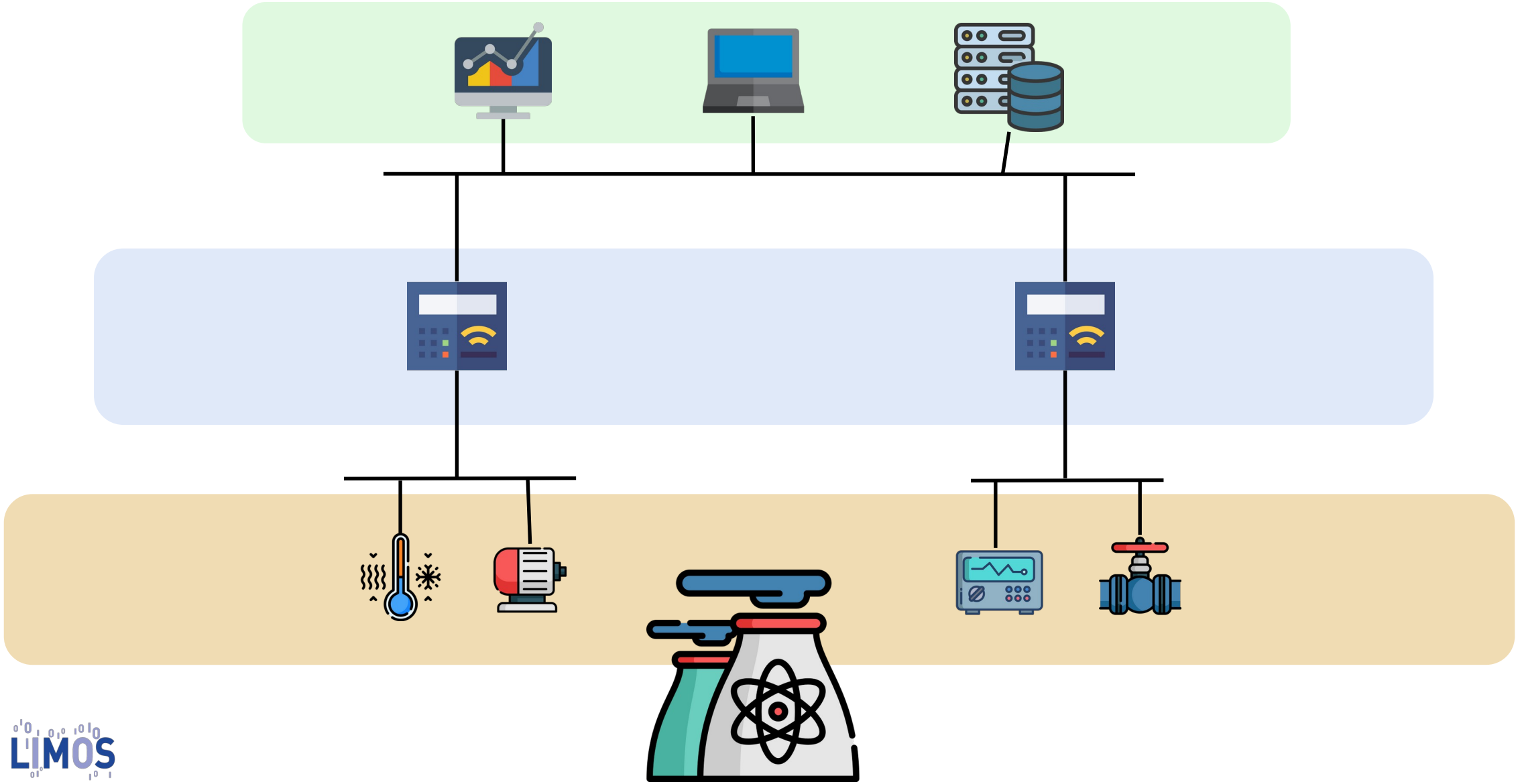
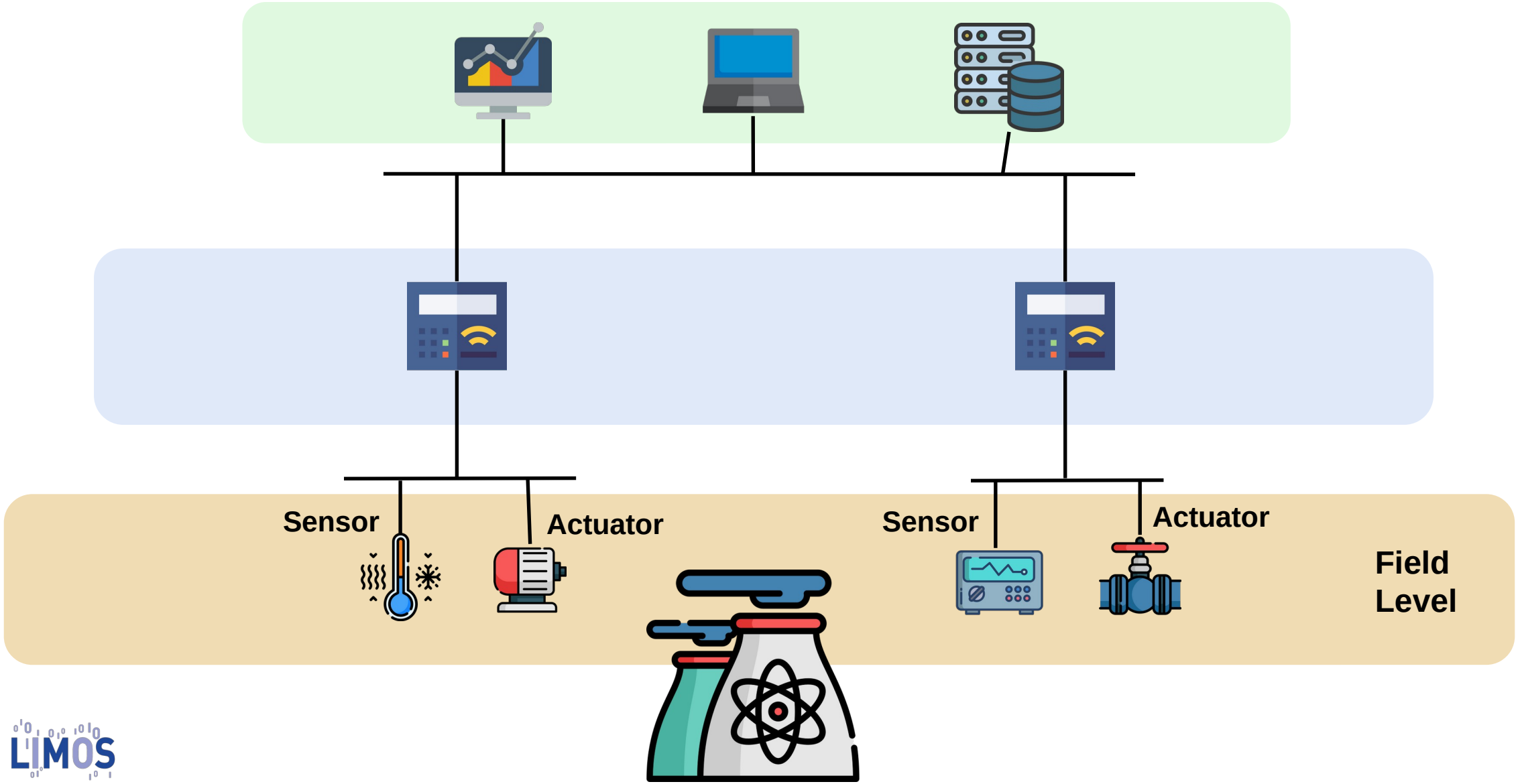


Figure: [Alq19]

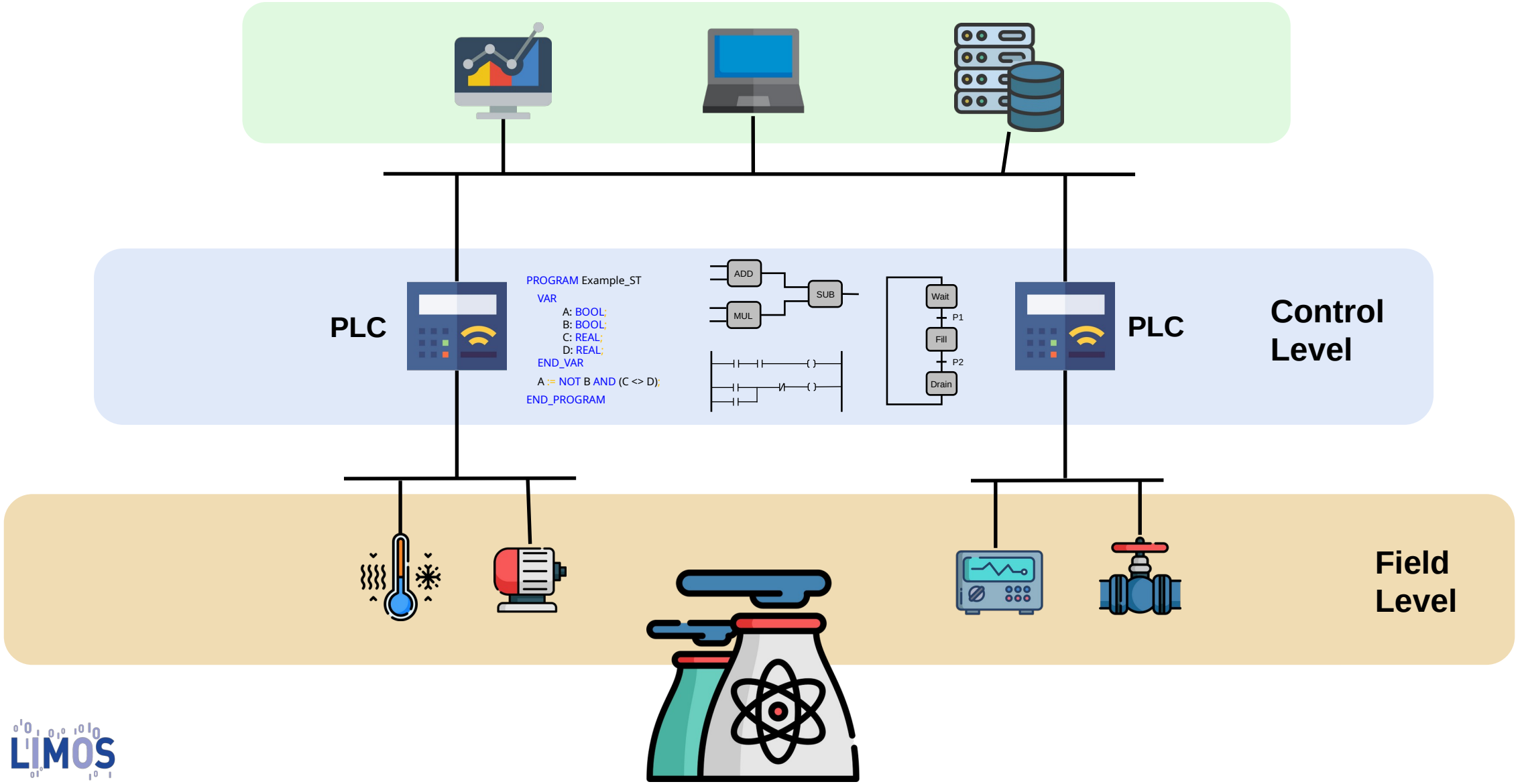
Context



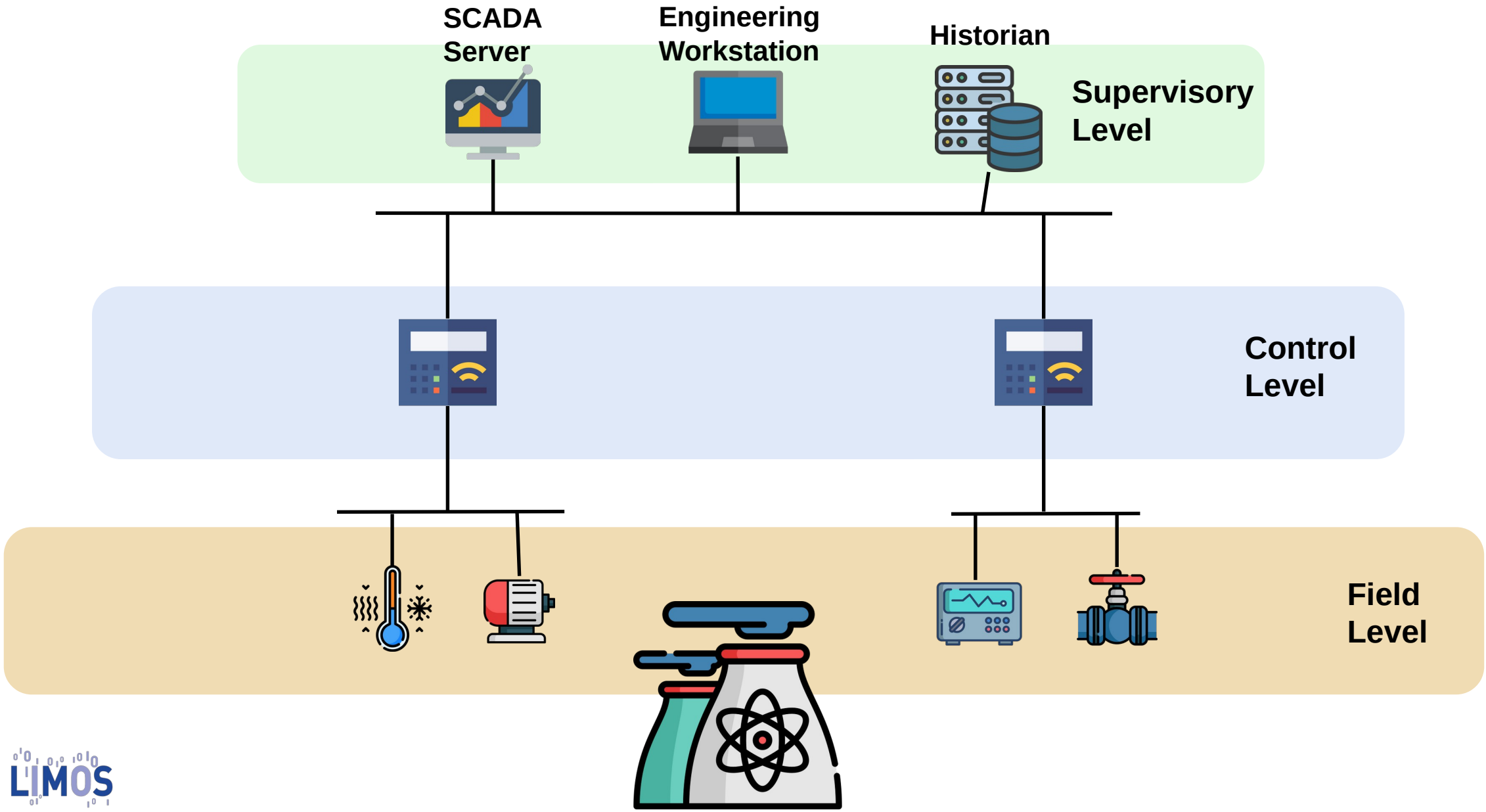
Context



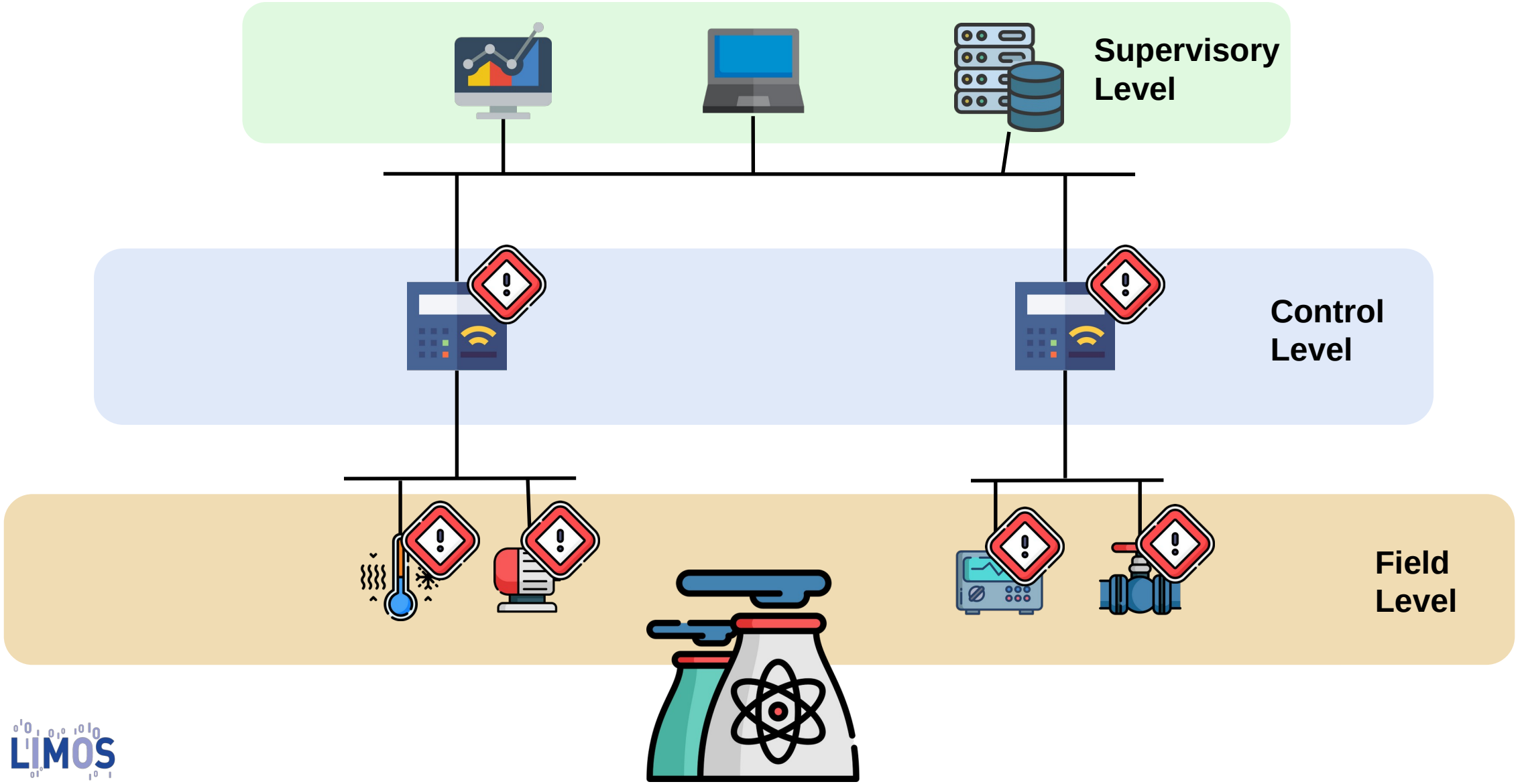
Context


PLC
PROGRAM Example_ST
VAR
A: BOOL;
B: BOOL;
C: REAL;
D: REAL;
END_VAR
A := NOT B AND (C <> D);
END_PROGRAM
ADD
SUB
MUL
Wait
P1
Fill
P2
Drain
PLC
Control Level
Field Level

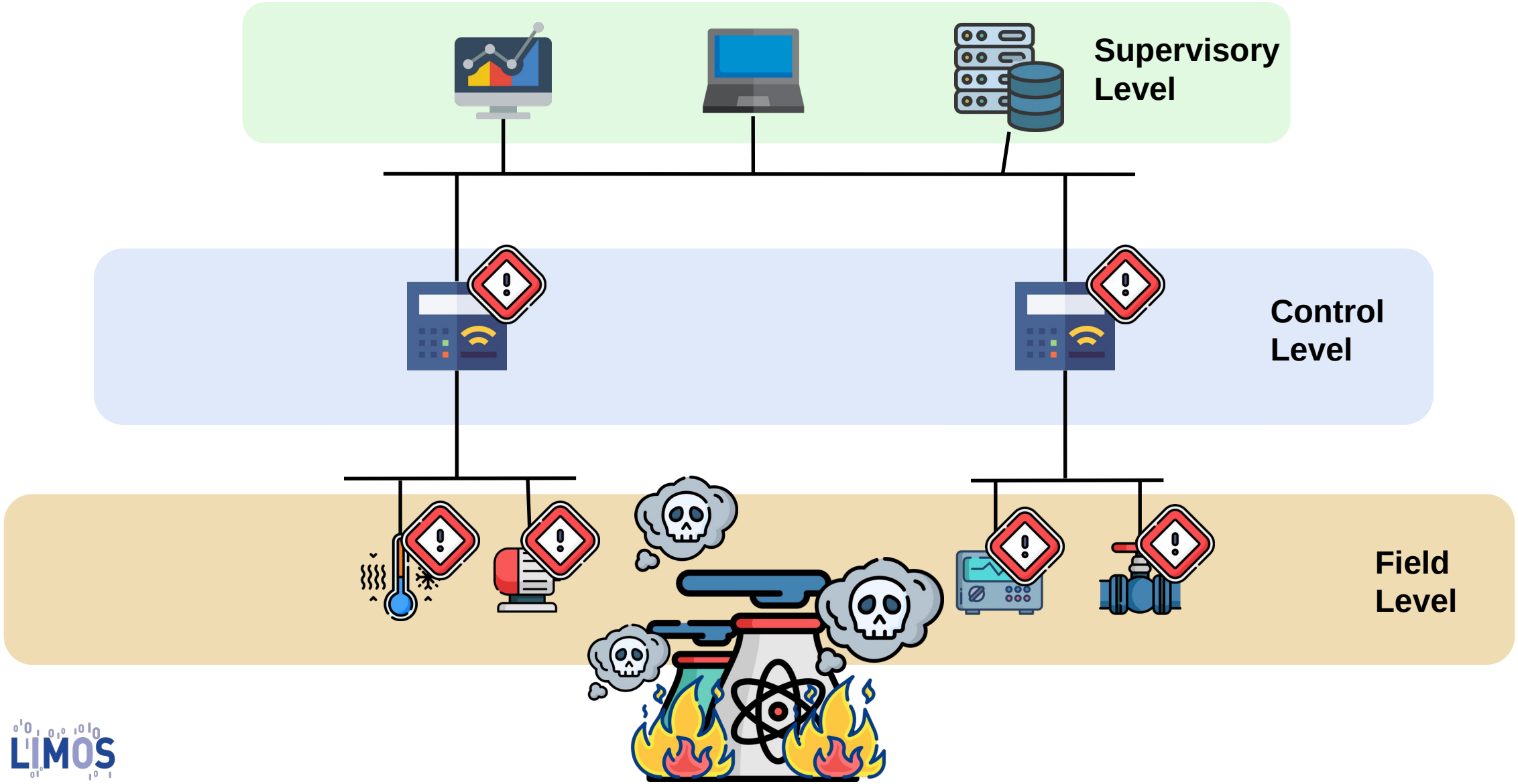
Context


SCADA Server
Engineering Workstation
Historian
Supervisory Level
Control Level
Field Level

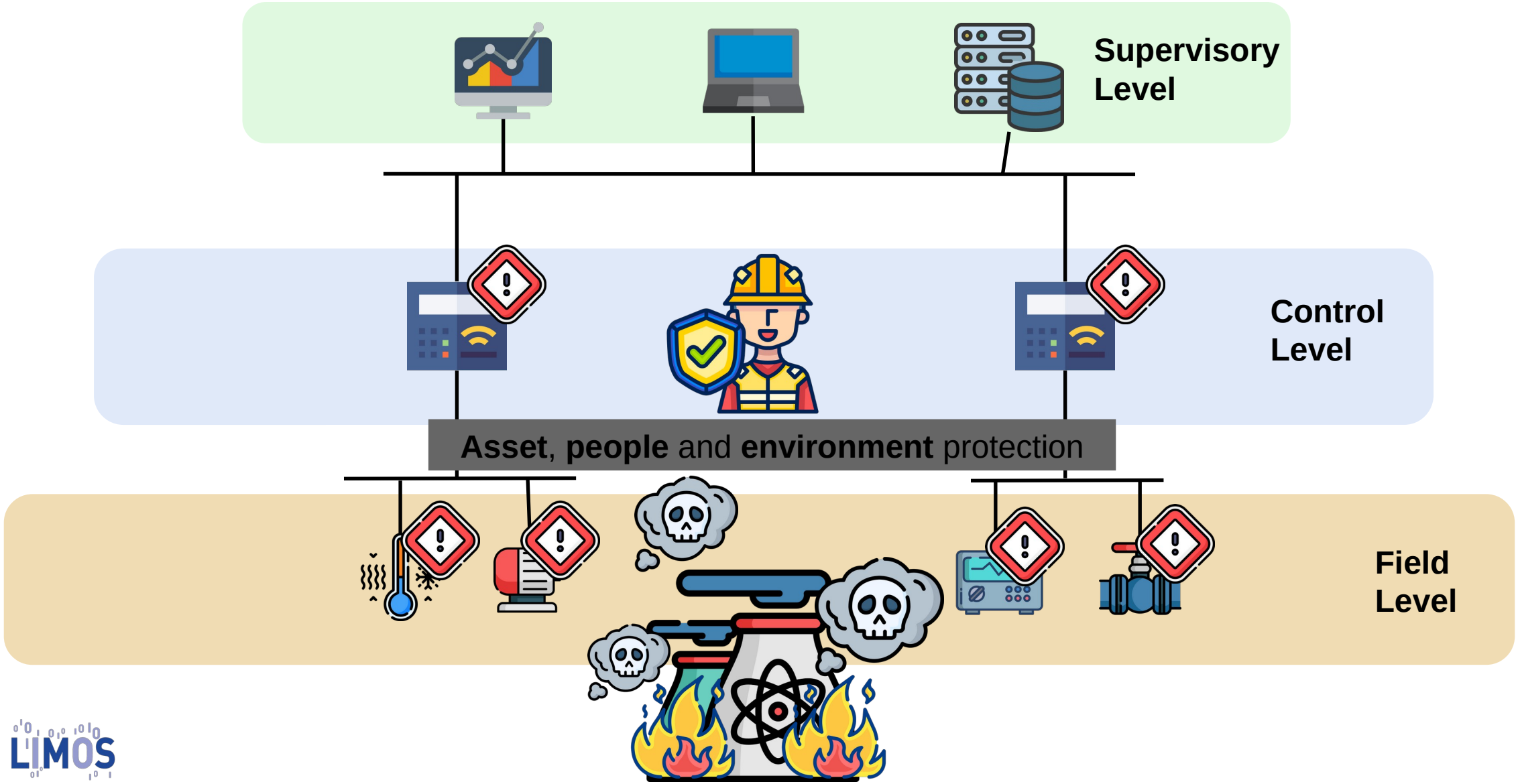
Context



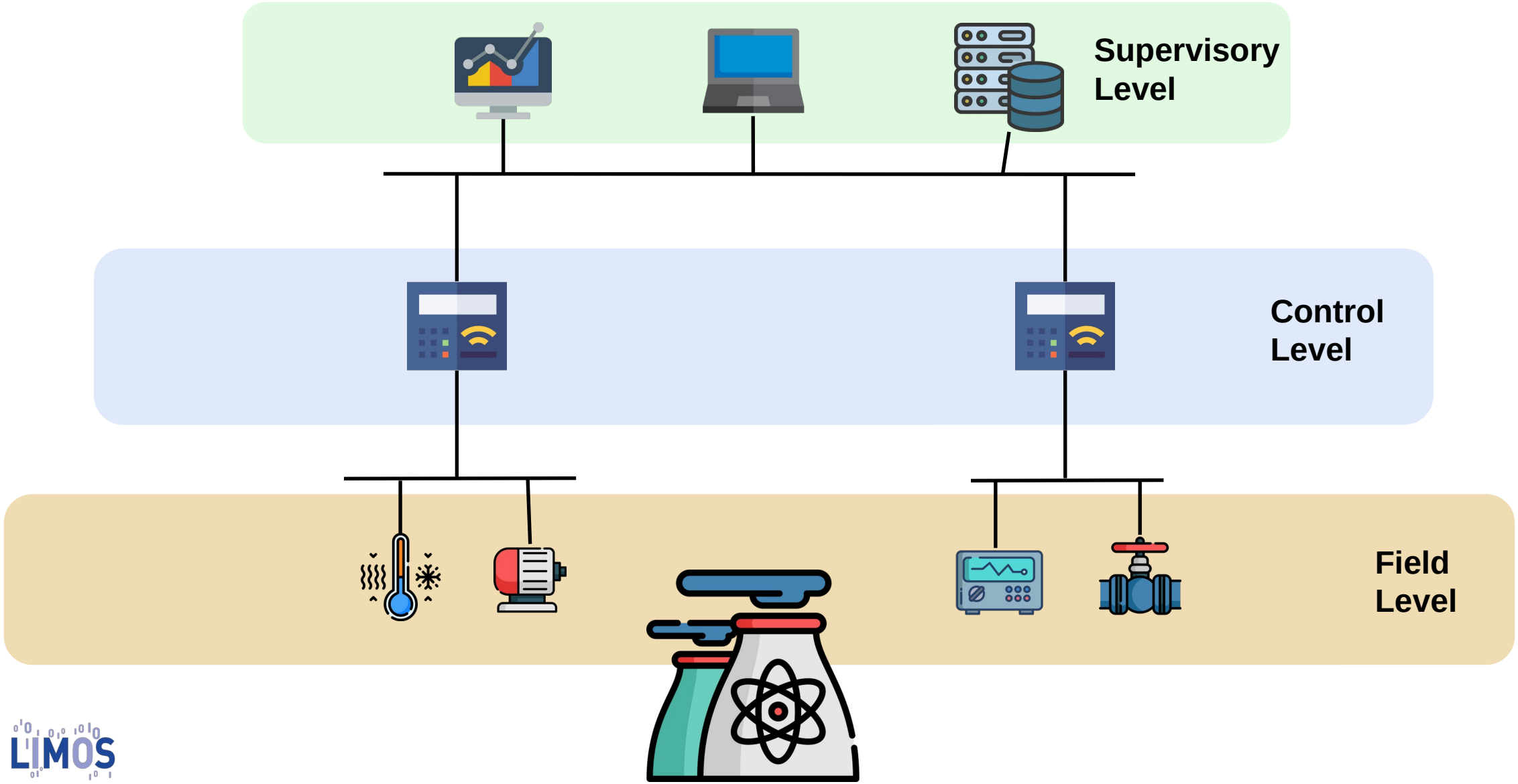
Context



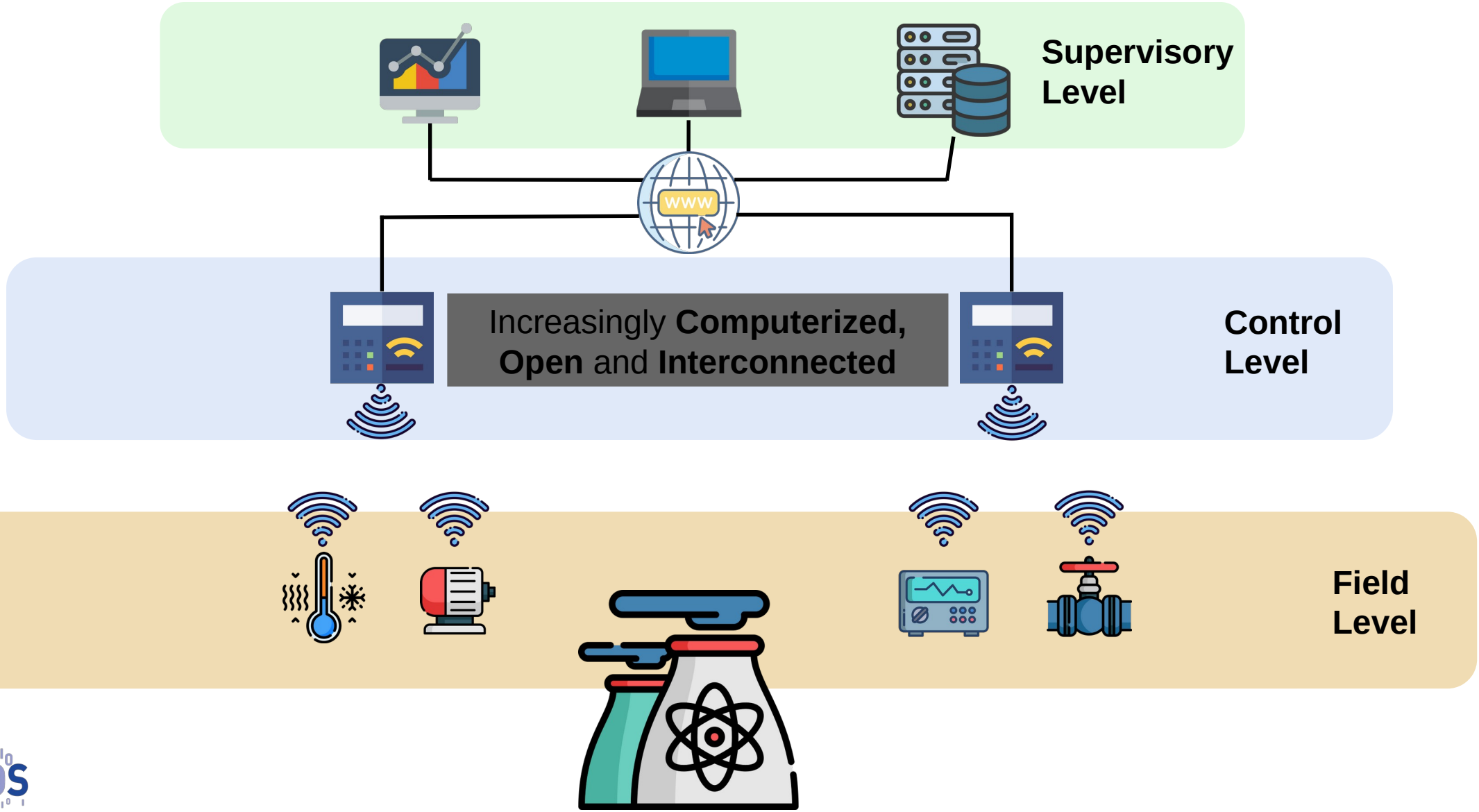
Context


Supervisory Level
Control Level
Asset, people and environment protection
Field Level

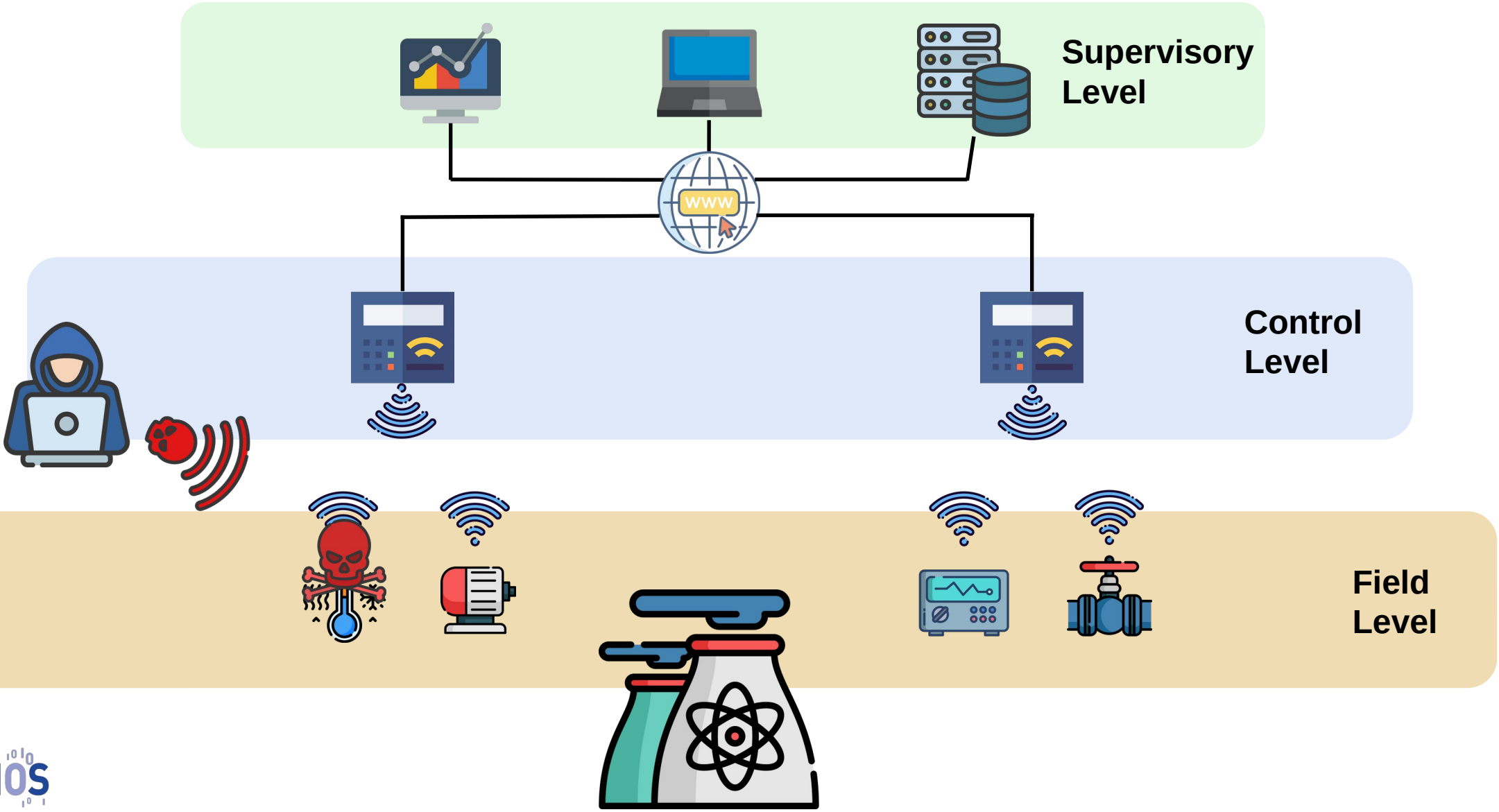
Context



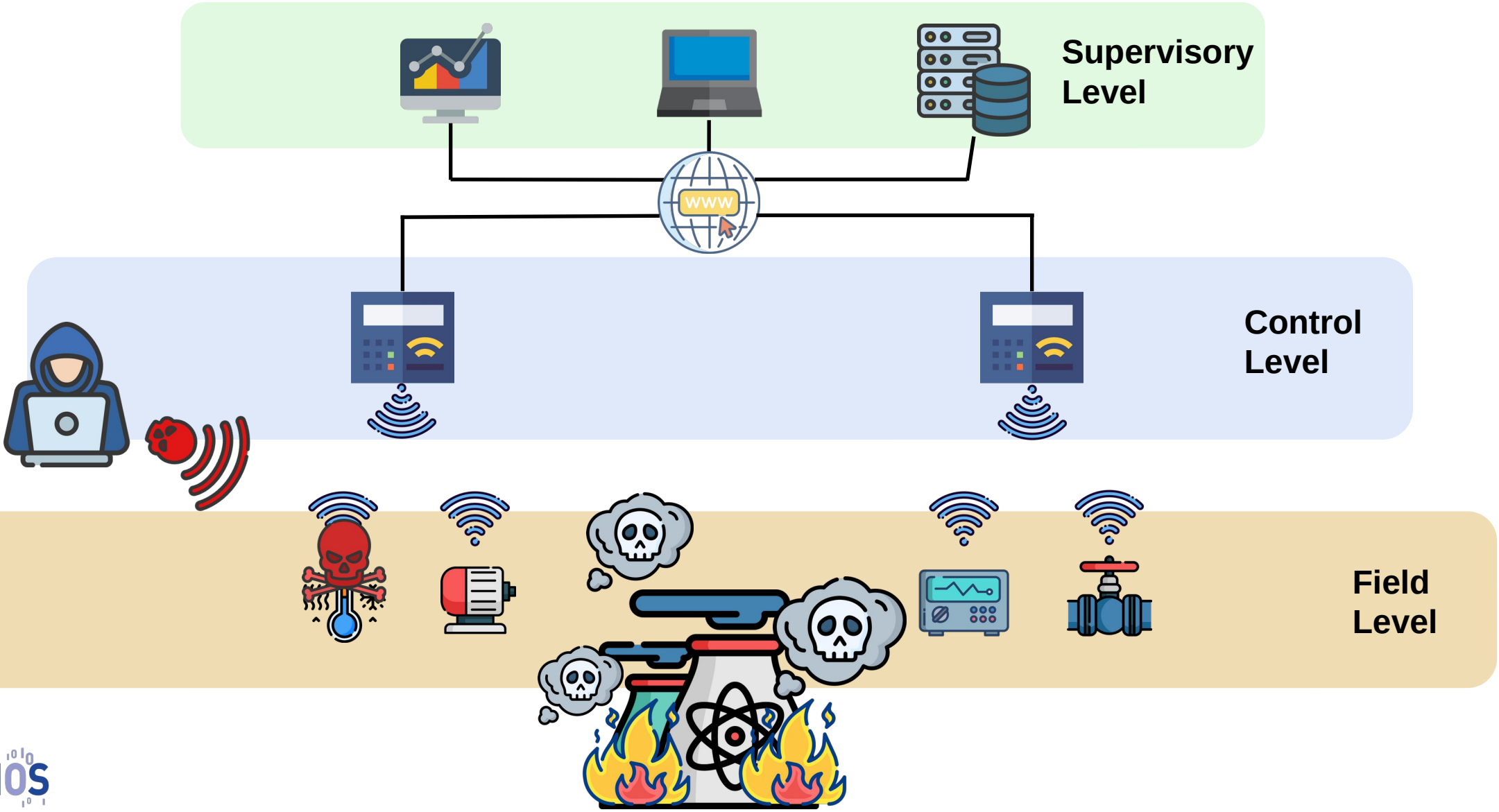
Context


Supervisory Level
WWW
Increasingly Computerized, Open and Interconnected
Control Level
Field Level

Context

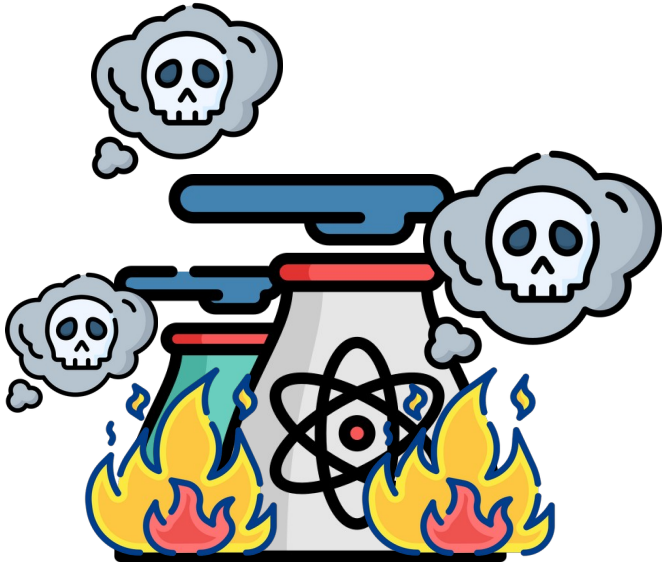


Context



Goal

How to Identify Cyberattacks that Compromise System Safety



Goal

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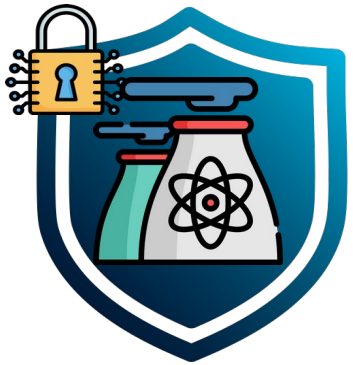


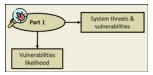
Protection against (cyber)**interference** with the proper and intended system **operation**[1]

Asset, **people** and **environment** protection against process **hazards**

[1] IEC 62443-1-1. Industrial communication networks – Network and system security – Part 1-1 : Terminology, concepts and models.

Contents

Cybersecurity Risk Assessment for System Safety



What an attacker can do

What an attacker might do

Is it serious ?


Literature Review & Classification


Identifying Cybersecurity Risk for System Safety

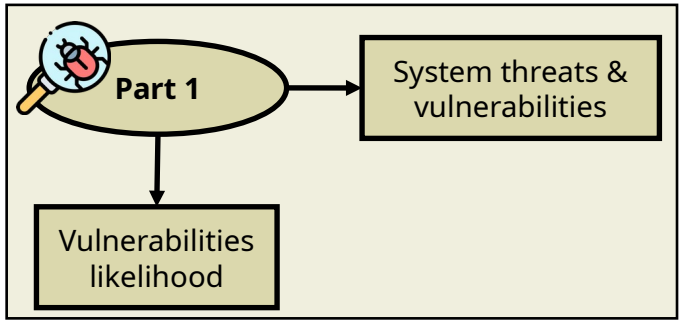

PLC-Logic Based Cybersecurity Risk Identification


Conclusion and perspectives

UNIVERSITÉ Clermont Auvergne LIMOS

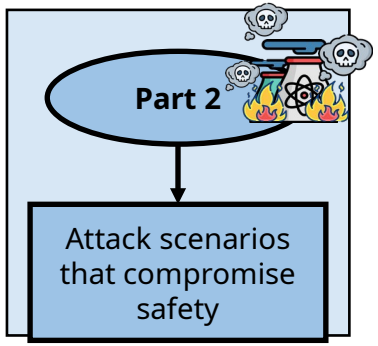
Cybersecurity risk assessment for system safety

What an attacker <u>can do</u>



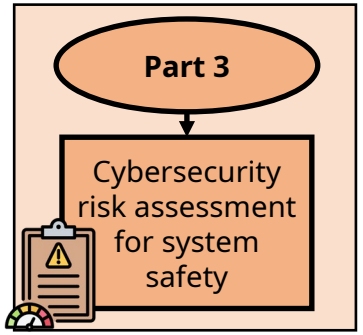
Threat modeling tool

What an attacker <u>might do</u>



Attack scenarios

Is it serious?



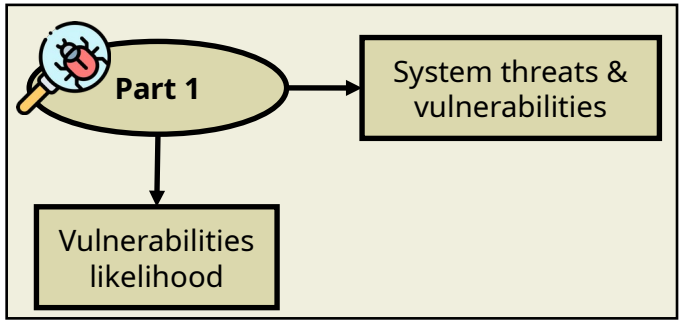
Risk matrix

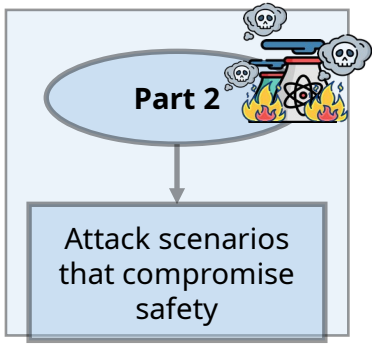
Cybersecurity risk assessment for system safety

What an attacker <u>can do</u>

What an attacker <u>must do</u>

Is it serious?

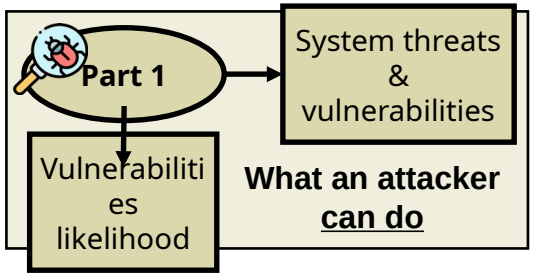




Threat modeling tool

Attack scenarios

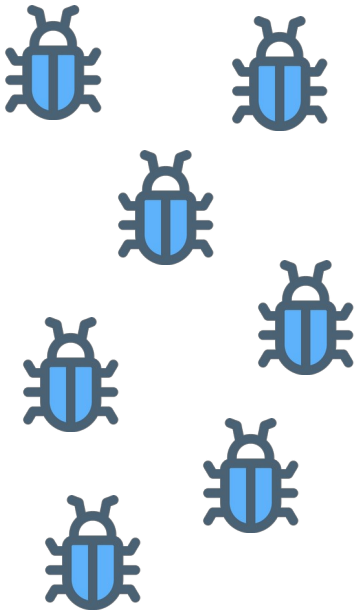
Risk matrix



Threat modeling

An attacker

Vulnerabilities



Threats

S

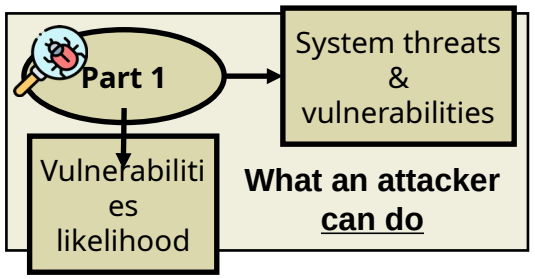
T

R

I

D

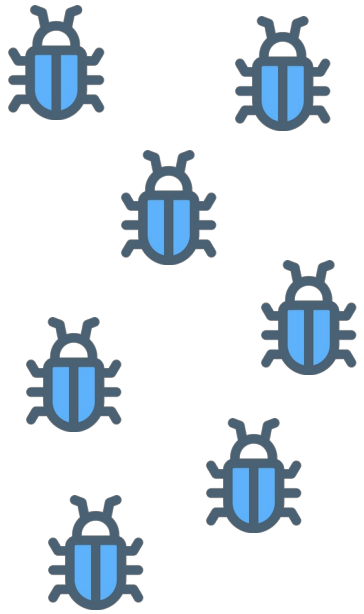
E



Threat modeling

An attacker

Vulnerabilities



Threats

Spoofing

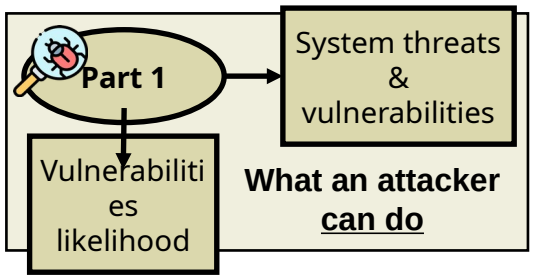
Tampering

Repudiation

Information disclosure

Denial of service

Elevation of privilege



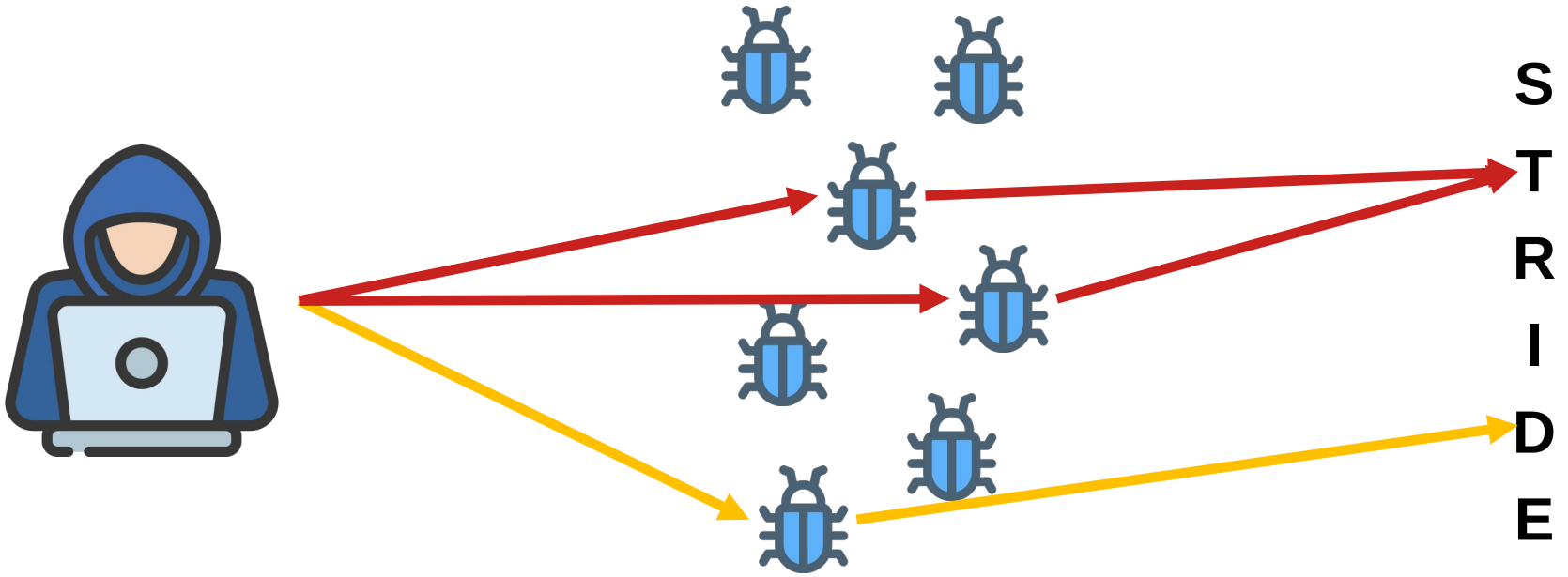
Threat modeling

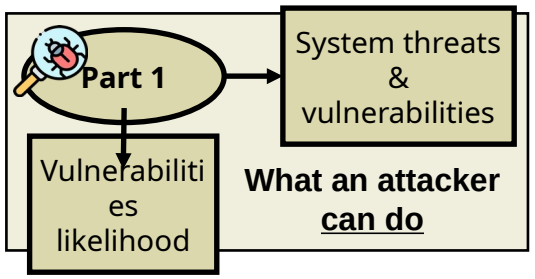
Cyberattack

An attacker

Vulnerabilities

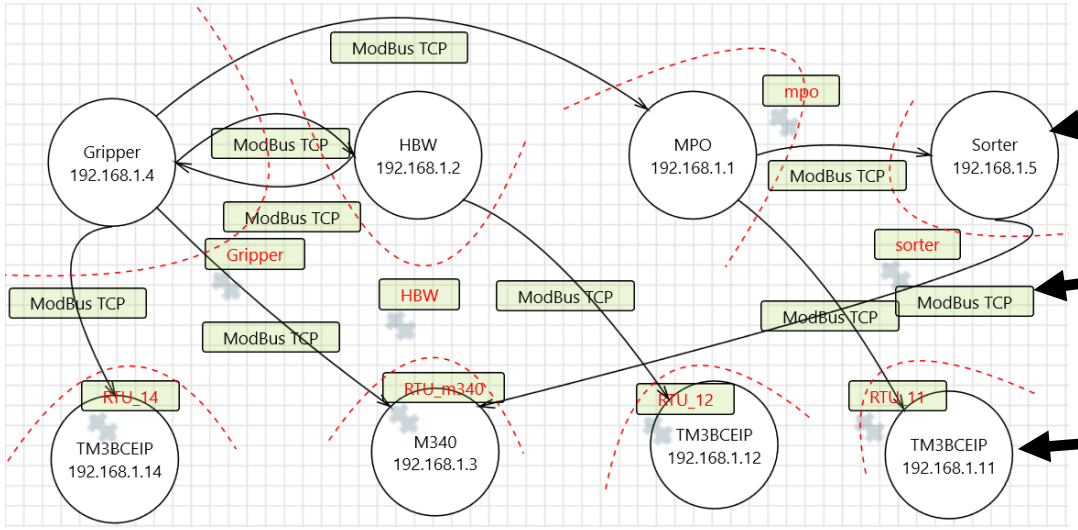
Threats



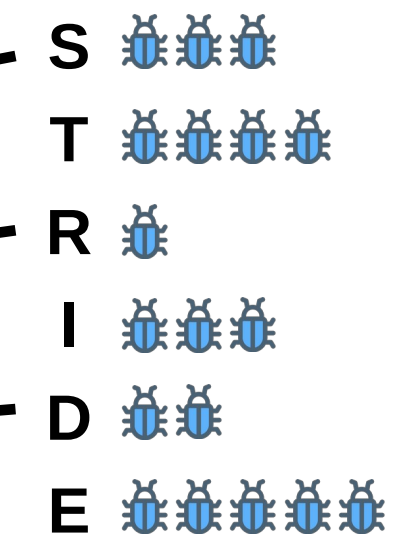


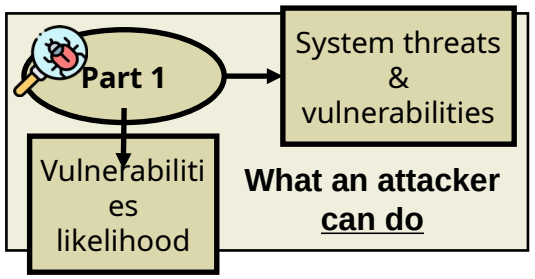
Threat modeling

System model



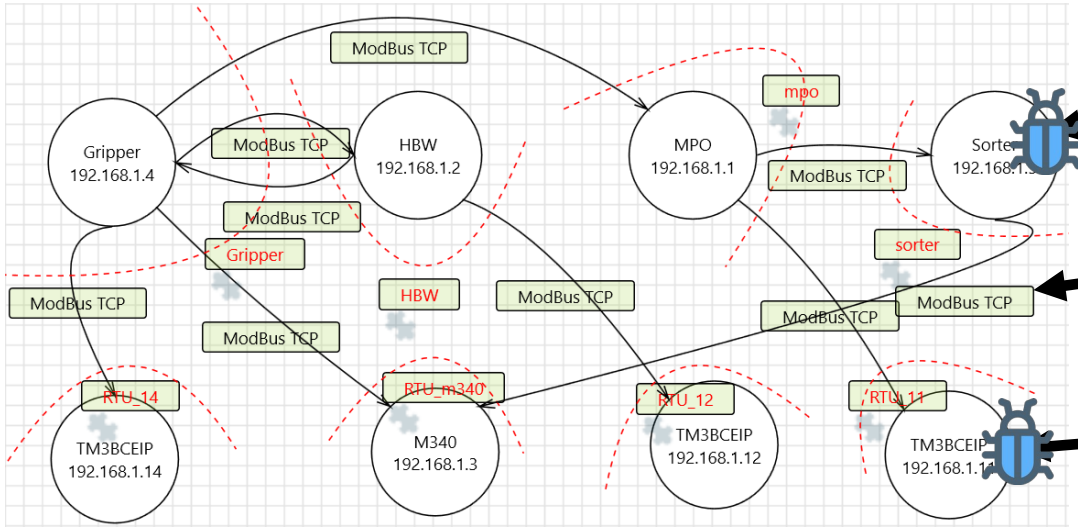
Threats



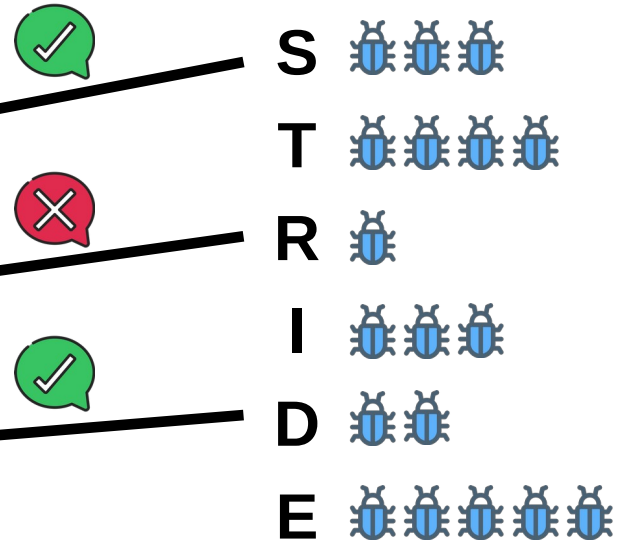


Threat modeling

System model



Threats

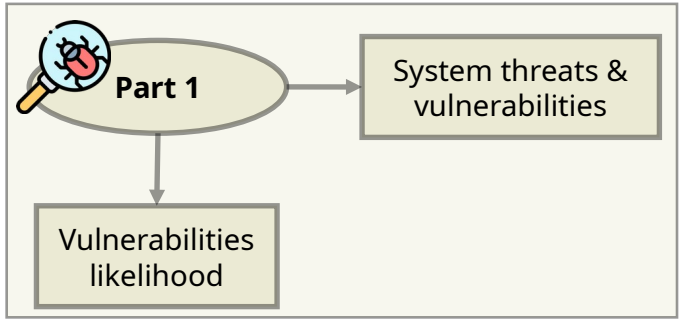


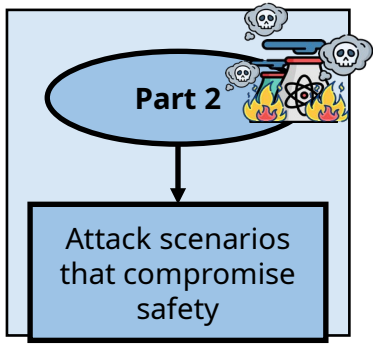
Cybersecurity risk assessment for system safety

What an attacker <u>can do</u>

What an attacker <u>might do</u>

Is it serious?

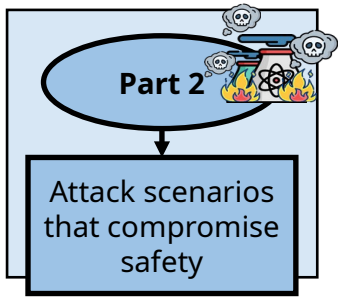




Threat modeling tool

Attack scenarios

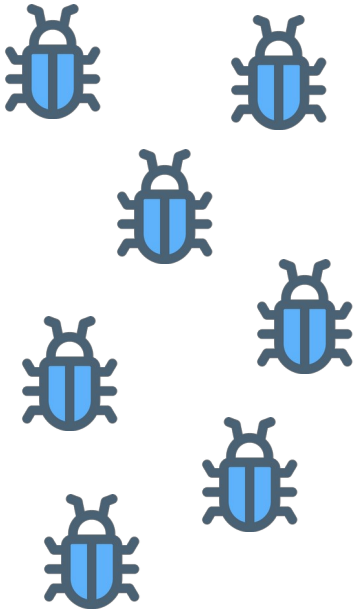
Risk matrix



Attack scenarios

An attacker

Vulnerabilities



Threats

S

T

R

I

D

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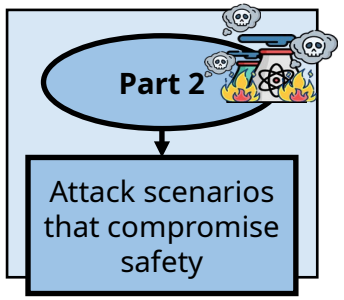
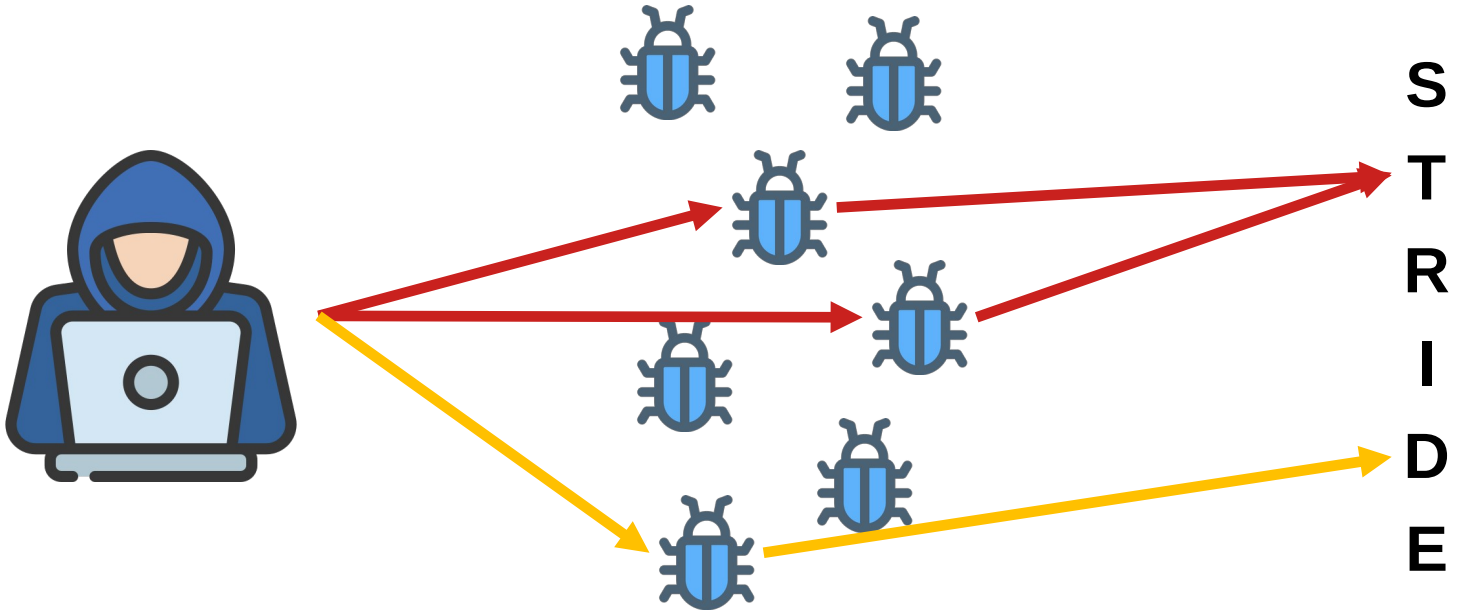


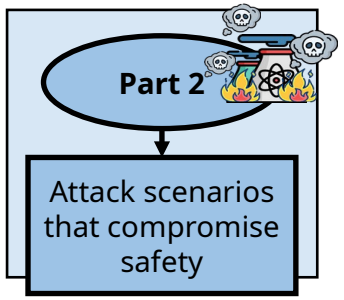
Attack scenarios

An attacker

Vulnerabilities

Threats





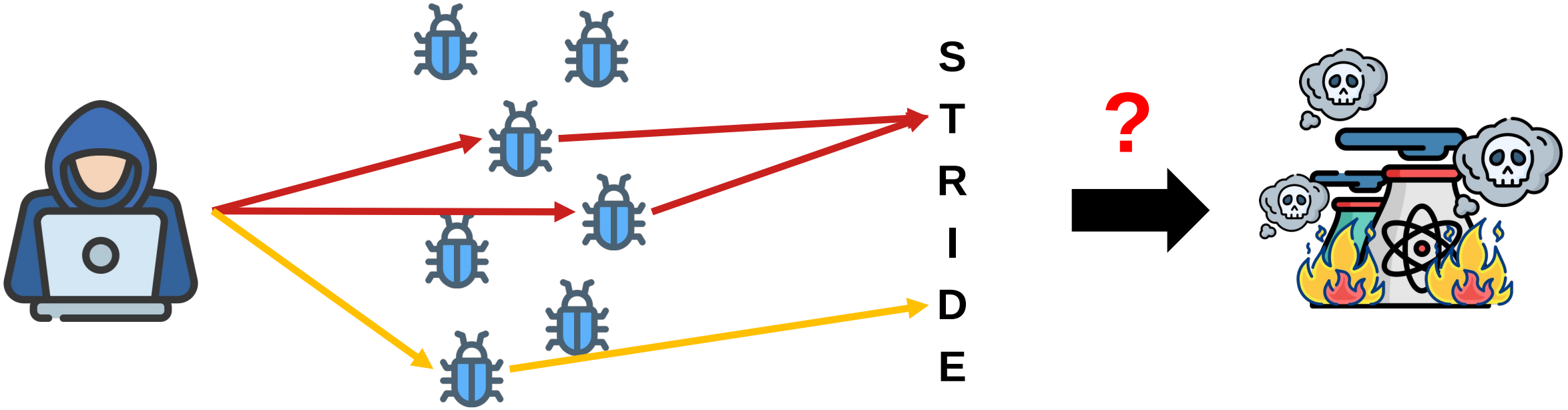
Attack scenarios

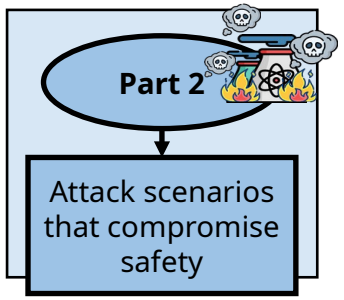
An attacker

Vulnerabilities

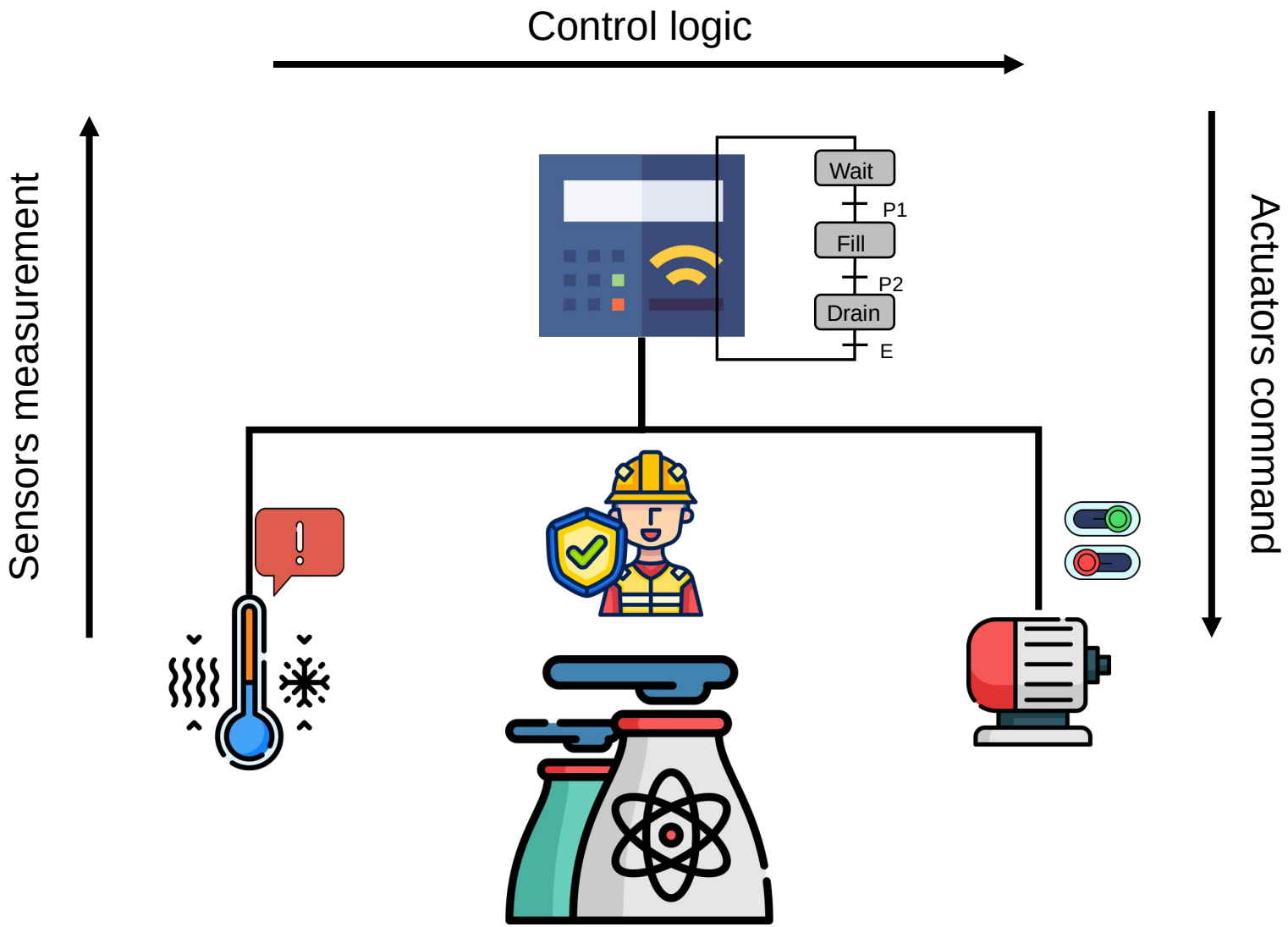
Threats

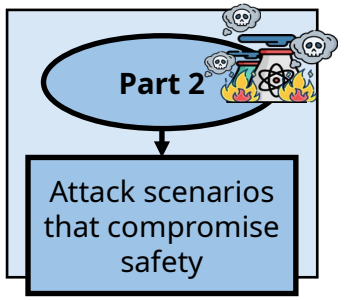
Objective



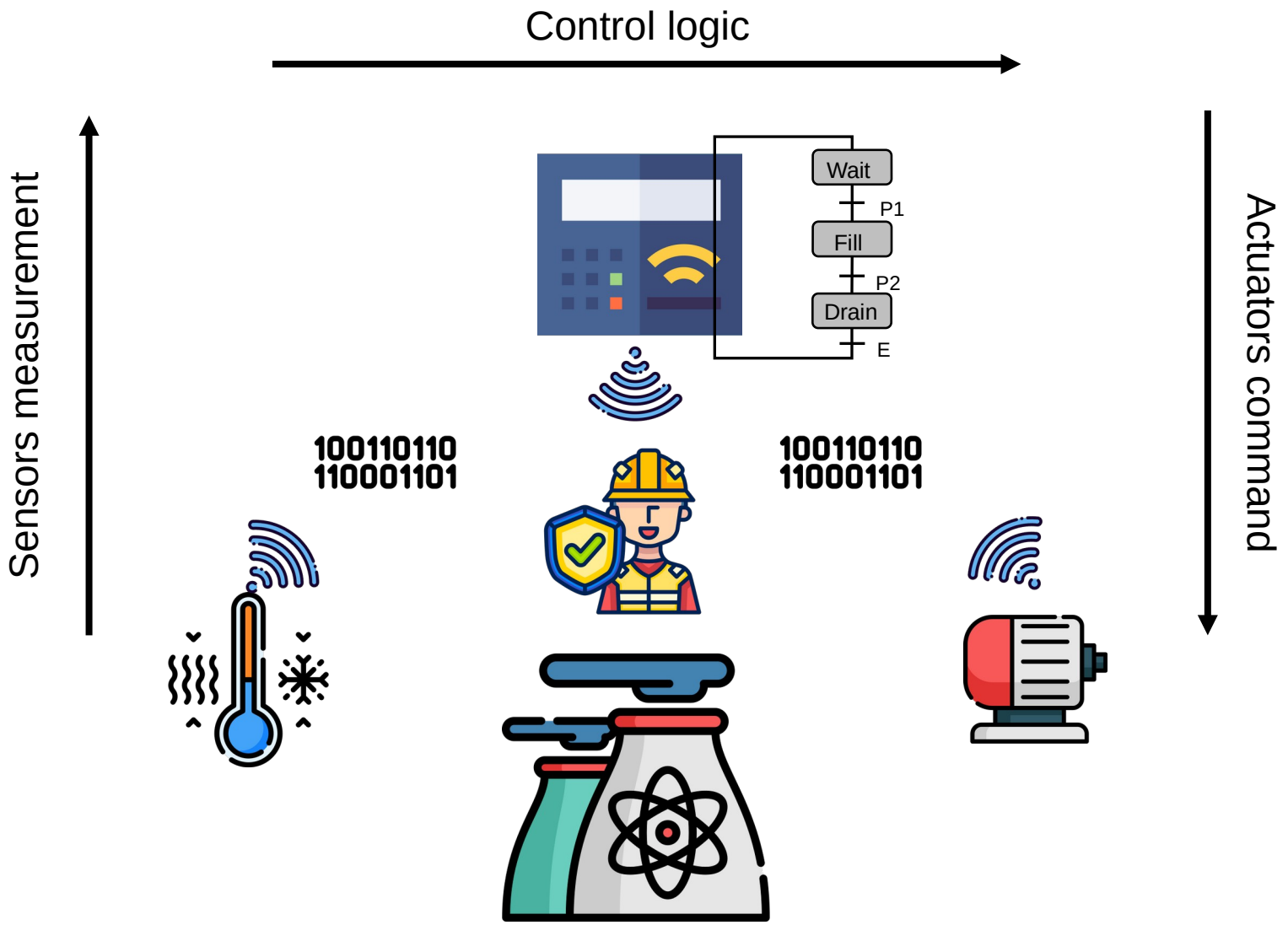


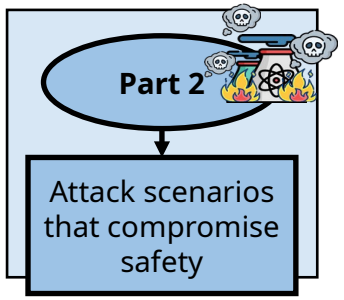
Control loop





Attack scenarios





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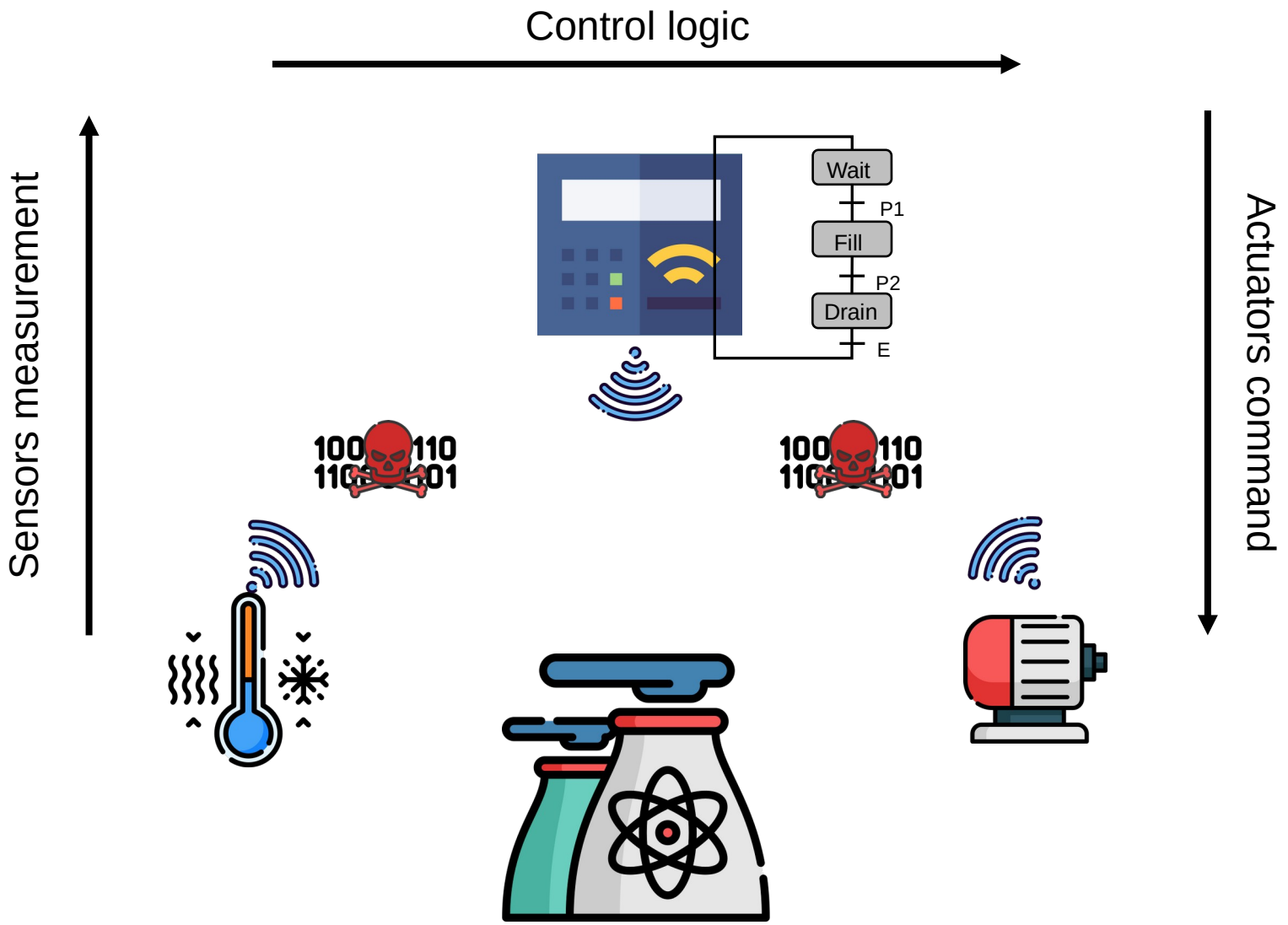
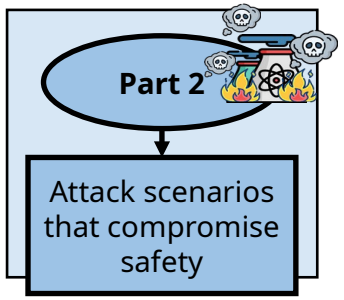
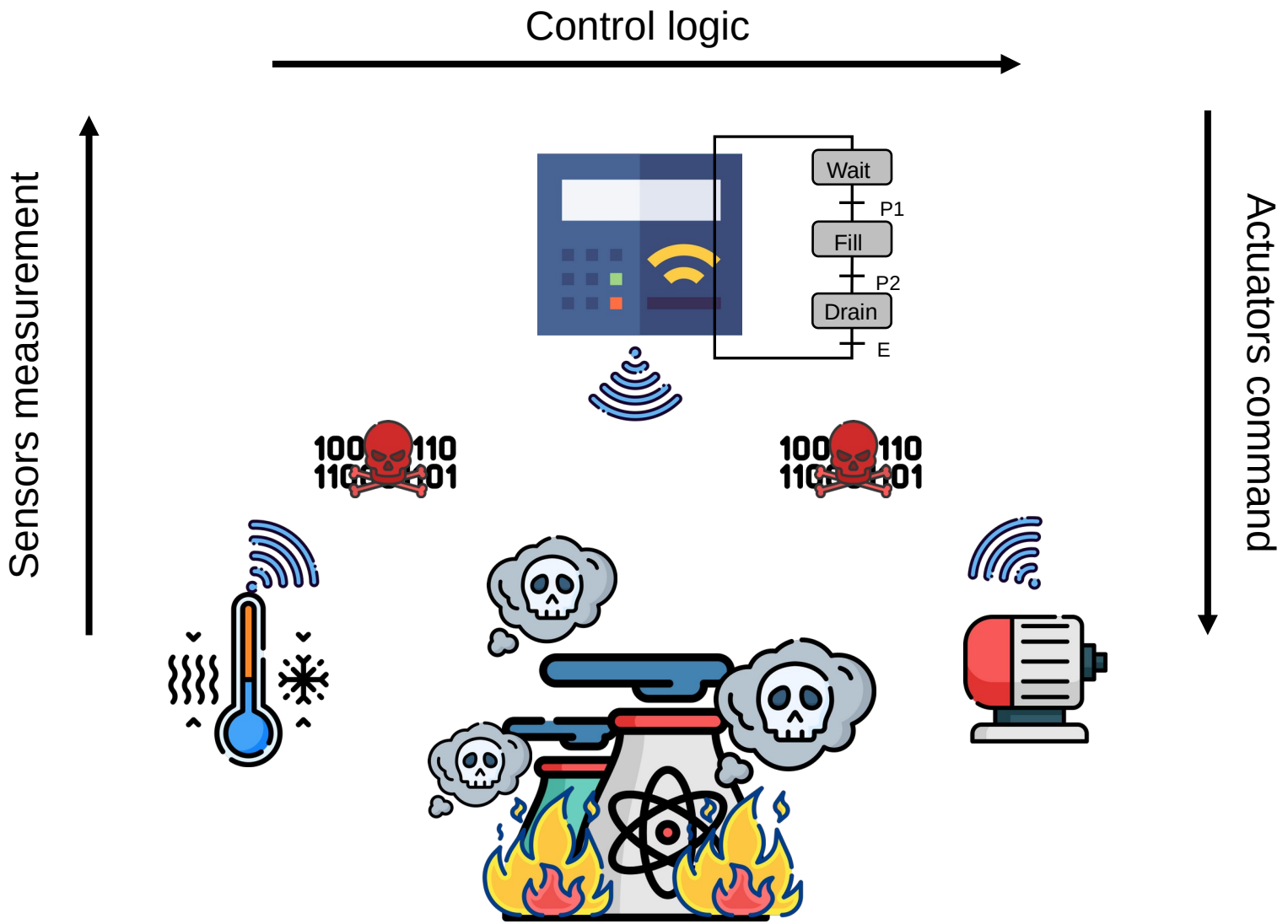




Attack scenarios

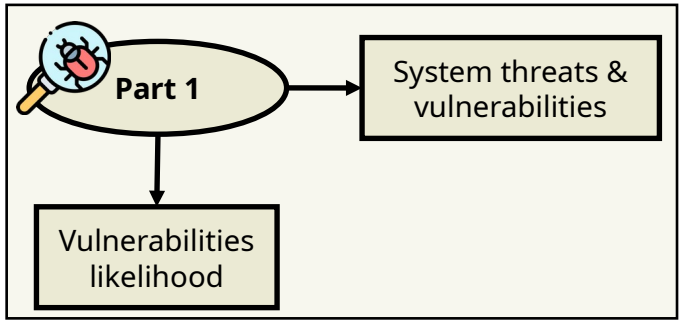


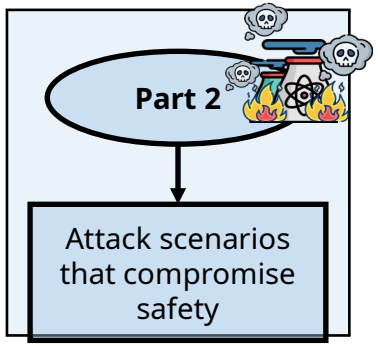
Cybersecurity risk assessment for system safety

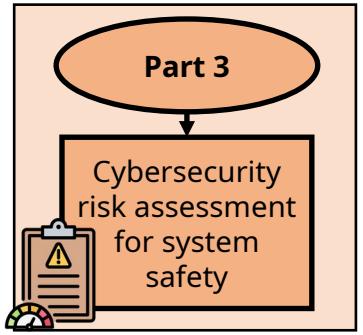
What an attacker <u>can do</u>

What an attacker <u>might do</u>

Is it serious?



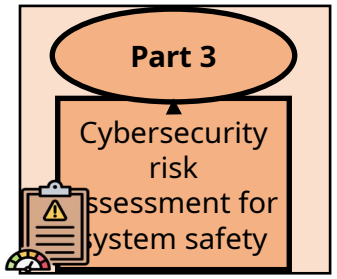




Threat modeling tool

Attack scenarios

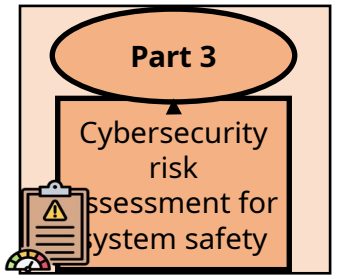
Risk matrix



Risk matrix

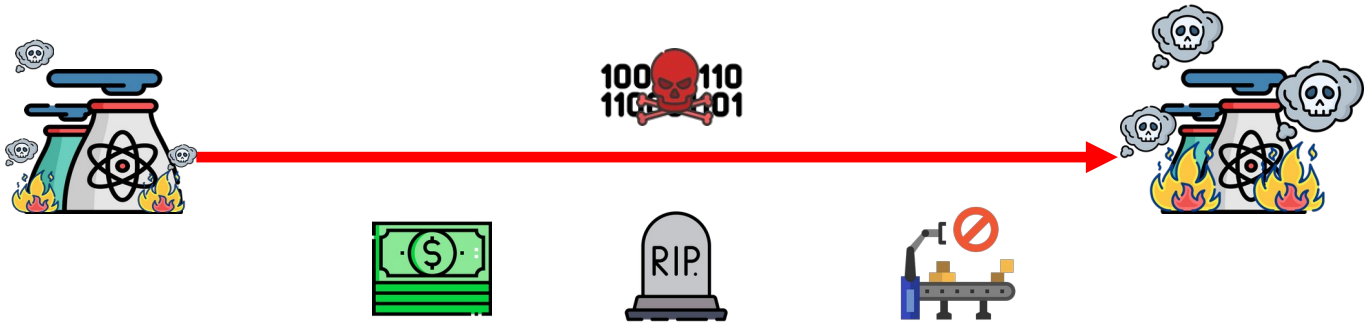
Standard **IEC 62443-3-2/ISO 31010 risk matrix**

Likelihood		Severity A	Severity B	Severity C	Severity D	Severity E
	Critical (9.0 - 10.0)					
	High (7.0 - 8.9)					
	Medium (4.0 - 6.9)					
	Low (0.1 - 3.9)					

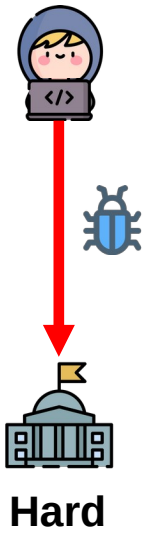


Risk matrix

Safety expert



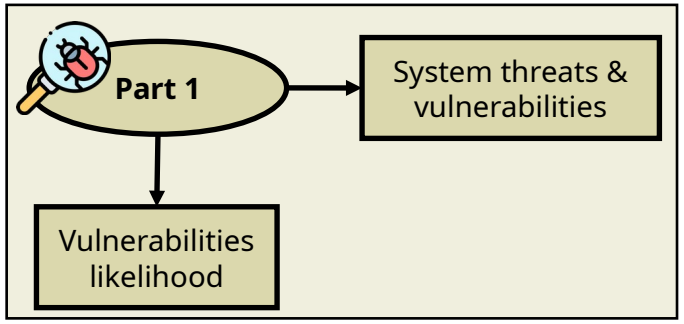
Exploitability score (CVSS 3.1)

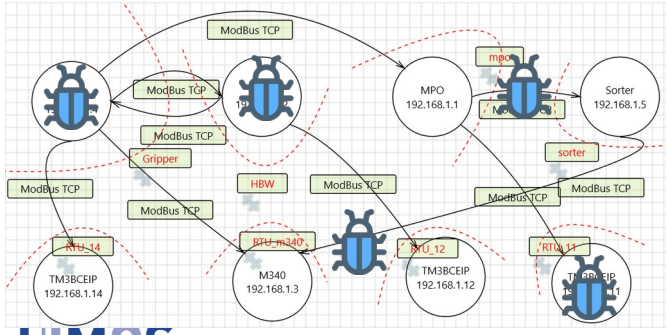


Likelihood	Severity A	Severity B	Severity C	Severity D	Severity E
Critical (9.0 - 10.0)	✓		✓		✓
High (7.0 - 8.9)				✓	
Medium (4.0 - 6.9)	✓		✓		
Low (0.1 - 3.9)		✓			✓

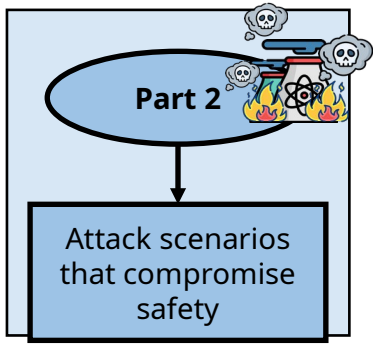
Cybersecurity risk assessment for system safety

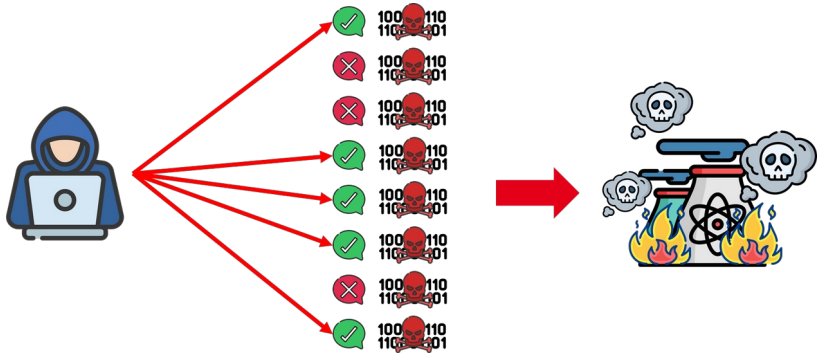
What an attacker <u>can do</u>



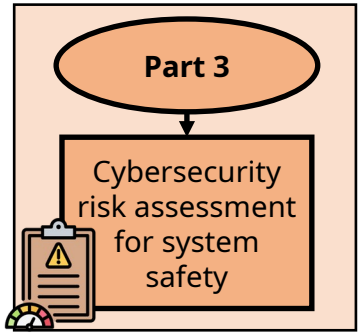


What an attacker <u>might do</u>





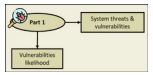
Is it serious?



Likelihood	Severity A	Severity B	Severity C	Severity D	Severity E
Critical (9.0 - 10.0)					
High (7.0 - 8.9)					
Medium (4.0 - 6.9)					
Low (0.1 - 3.9)					

Contents

Cybersecurity Risk Assessment for System Safety



What an attacker can do

What an attacker might do

Is it serious ?

Literature Review & Classification


Identifying Cybersecurity Risk for System Safety


PLC-Logic Based Cybersecurity Risk Identification


Conclusion and perspectives

Literature Review & Classification

Unified

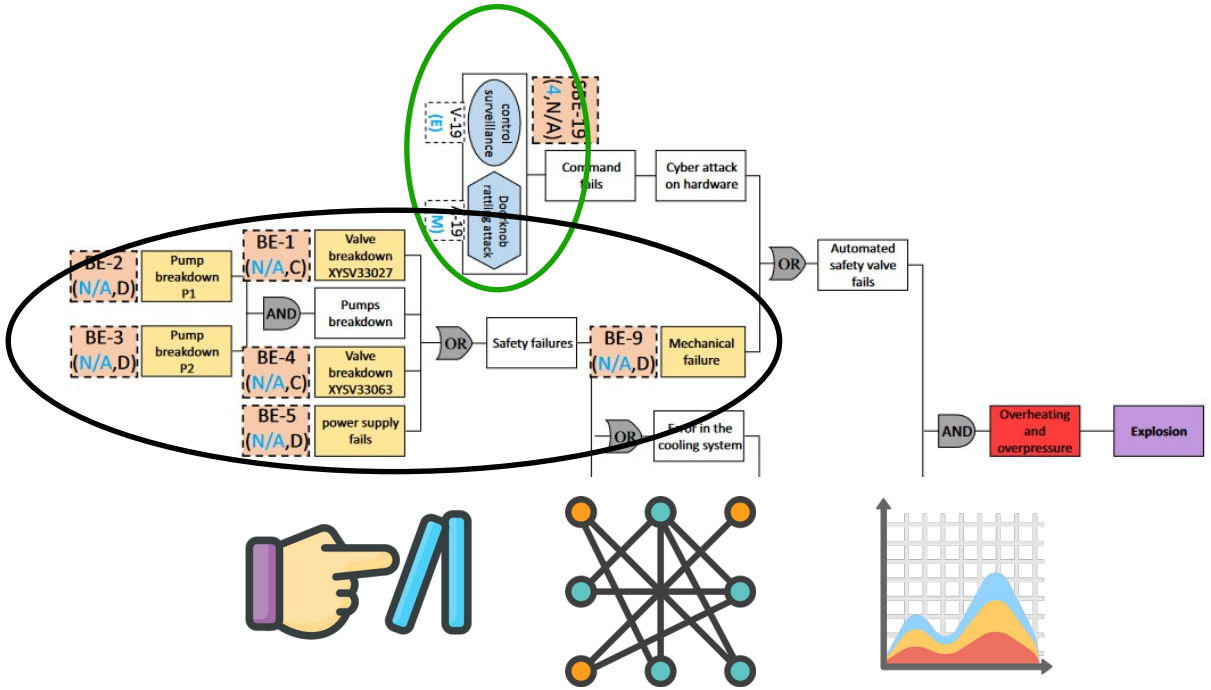
Integrated

Literature Review & Classification

Unified

Integrated

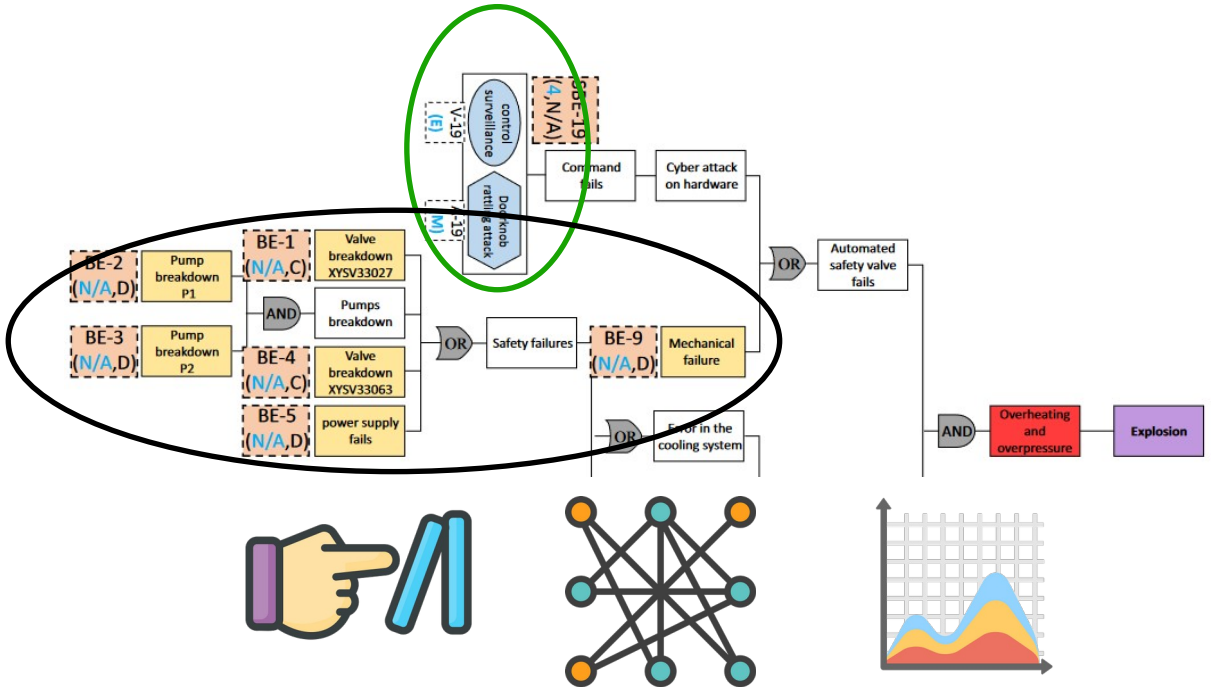
→ Single method



Literature Review & Classification

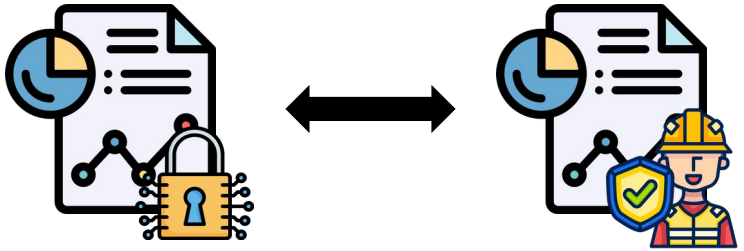
Unified

→ Single method



Integrated

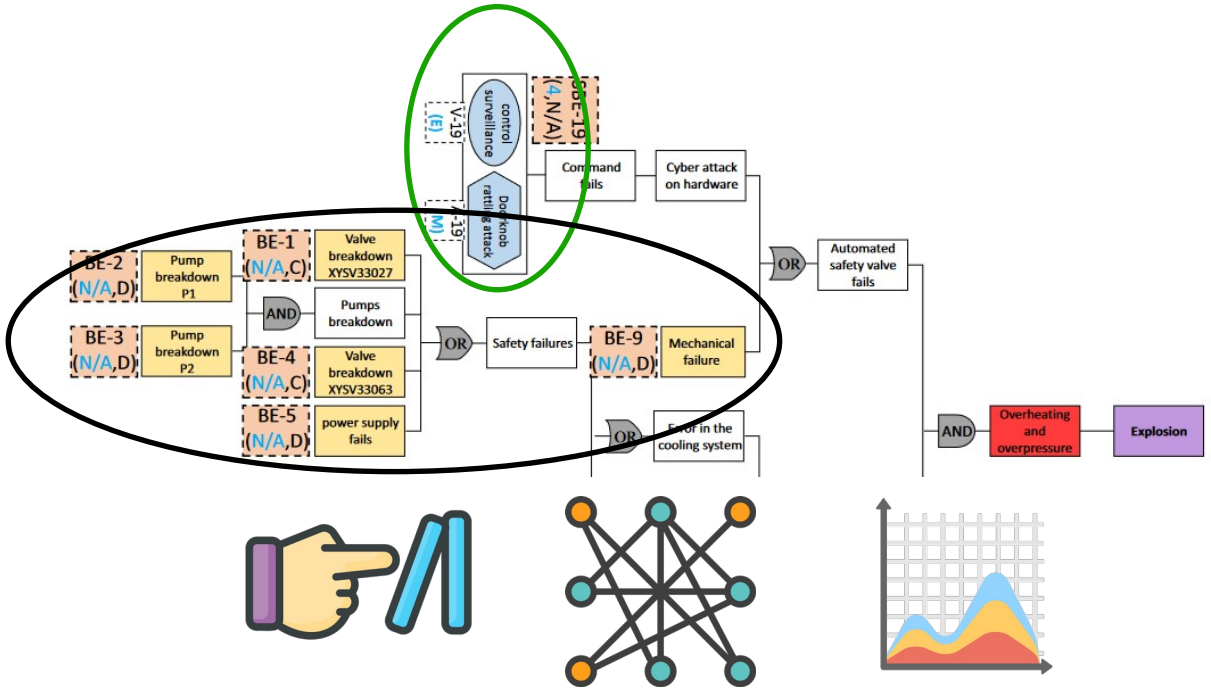
→ Separate method



Literature Review & Classification

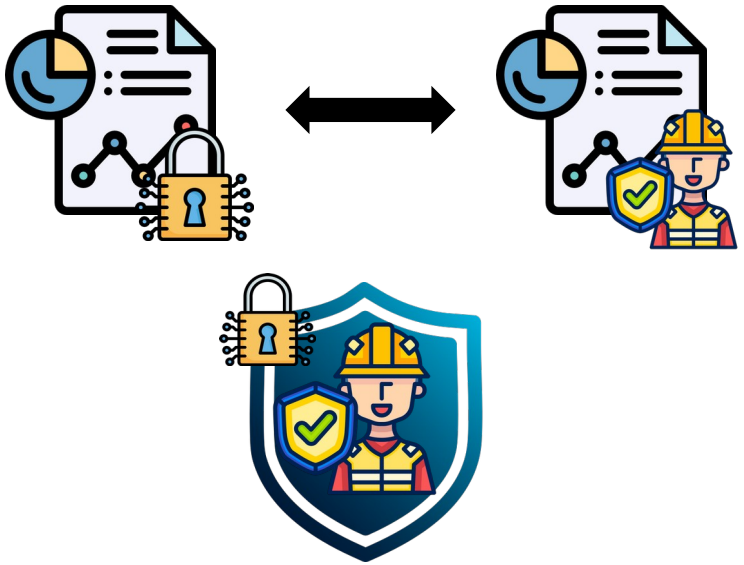
Unified

→ Single method



Integrated

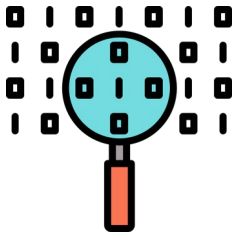
→ **Separate method**



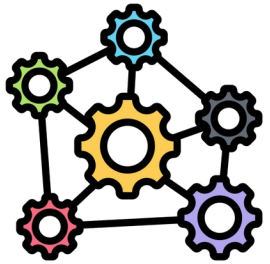
Literature Review & Classification

Integrated

Fine granularity



System size

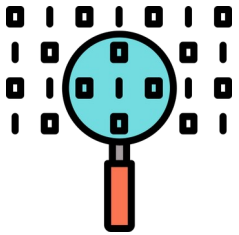


+20 sensors & actuators

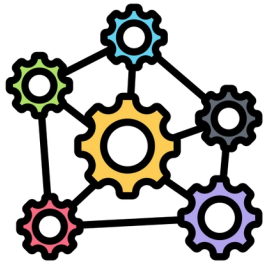
Literature Review & Classification

Integrated

Fine granularity



System size



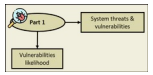
+20 sensors & actuators

Literature Review & Classification

Methods	Integrated	System Size	Methods	Integrated	System Size
Winther et al. (2001)	✓	Small	Subramanian et Zalewski (2018)	✘	Small
Cárdenas et al. (2011)	✓	Small	Puys et al. (2018)	✓	Small
Song et al. (2012)	✓	Small	Zhu et al. (2018)	✓	Small
Young et Leveson (2013)	✓	Small	Papakonstantinou et al. (2019)	✘	Small
Kriaa (2015)	✘	Small	Khaled et al. (2020)	✓	Small
Sabaliauskaite et al. (2015)	✘	Small	Kumar et al. (2020)	✘	Small
Mesli-kesraoui et al. (2016)	✓	Small	Hosseini et al. (2021)	✘	Small
Subramanian et Zalewski (2016)	✘	Small	Oueidat et al. (2021)	✘	Small
Rocchetto et Tippenhauer (2017)	✓	Large	Bhosale et al. (2023)	✓	Small
Friedberg et al (2017)	✘	Small	Eckhart et al. (2022)	✓	Small
Abdo et al. (2018)	✘	Small	Földvári et al. (2023)	✘	Small
Cheh et al. (2018)	✓	Small	Son et al. (2023)	✓	Small
			This work	✓	Large

Contents

Cybersecurity Risk Assessment for System Safety



What an attacker can do

What an attacker might do

Is it serious ?

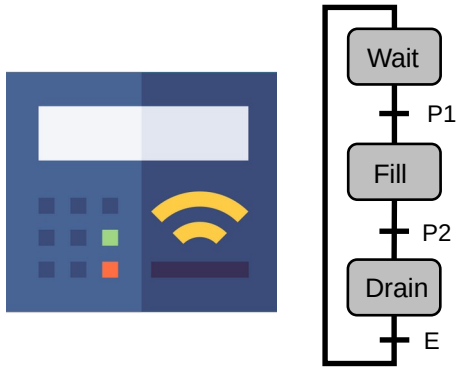
Literature Review & Classification

Identifying Cybersecurity Risk for System Safety

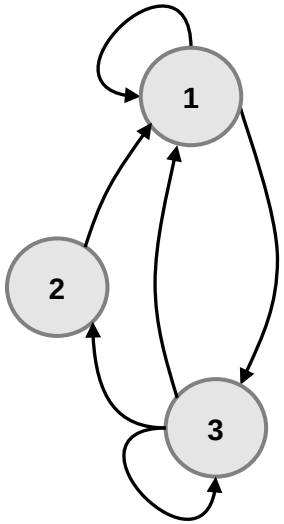
PLC-Logic Based Cybersecurity Risk Identification

Conclusion and perspectives

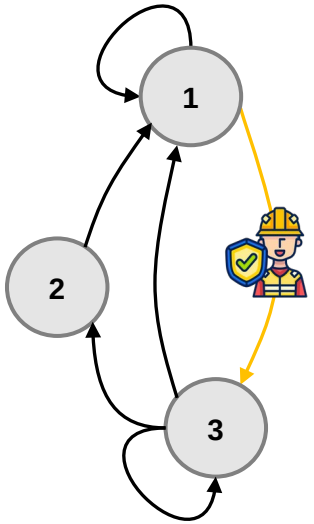
PLC-Logic Based Cybersecurity Risk Identification



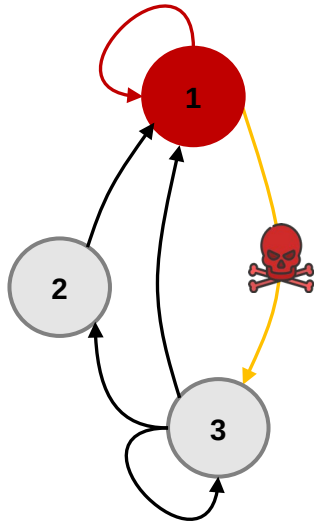
PLC logic



System model

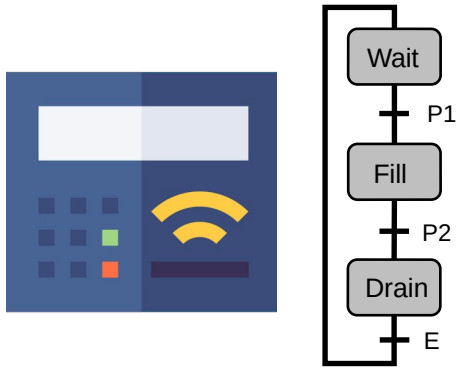


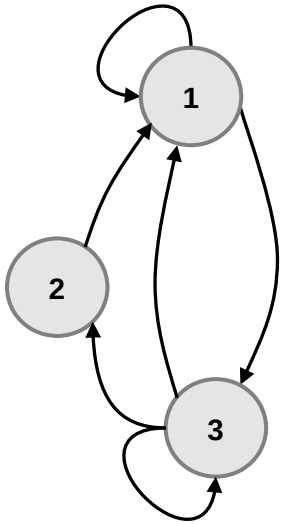
Safety

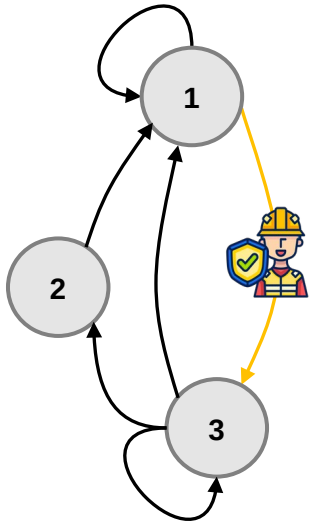


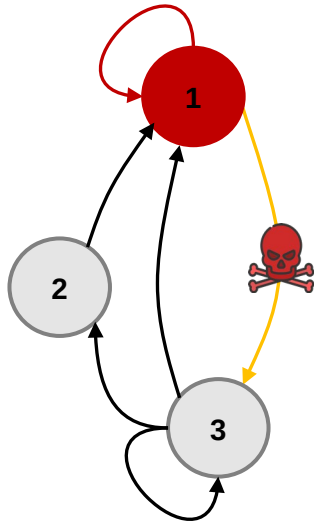
Attack scenarios

PLC-Logic Based Cybersecurity Risk Identification



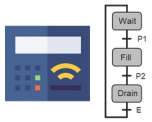




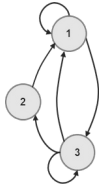


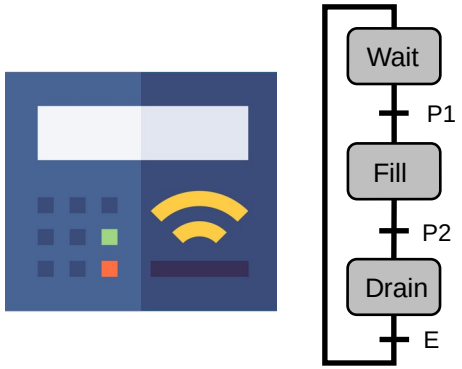
PLC logic **System model** **Safety** **Attack scenarios**

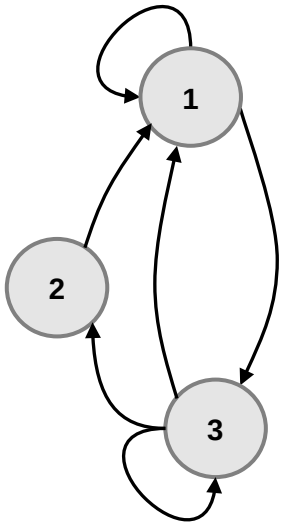
Model building **Threat model application**



Model Building





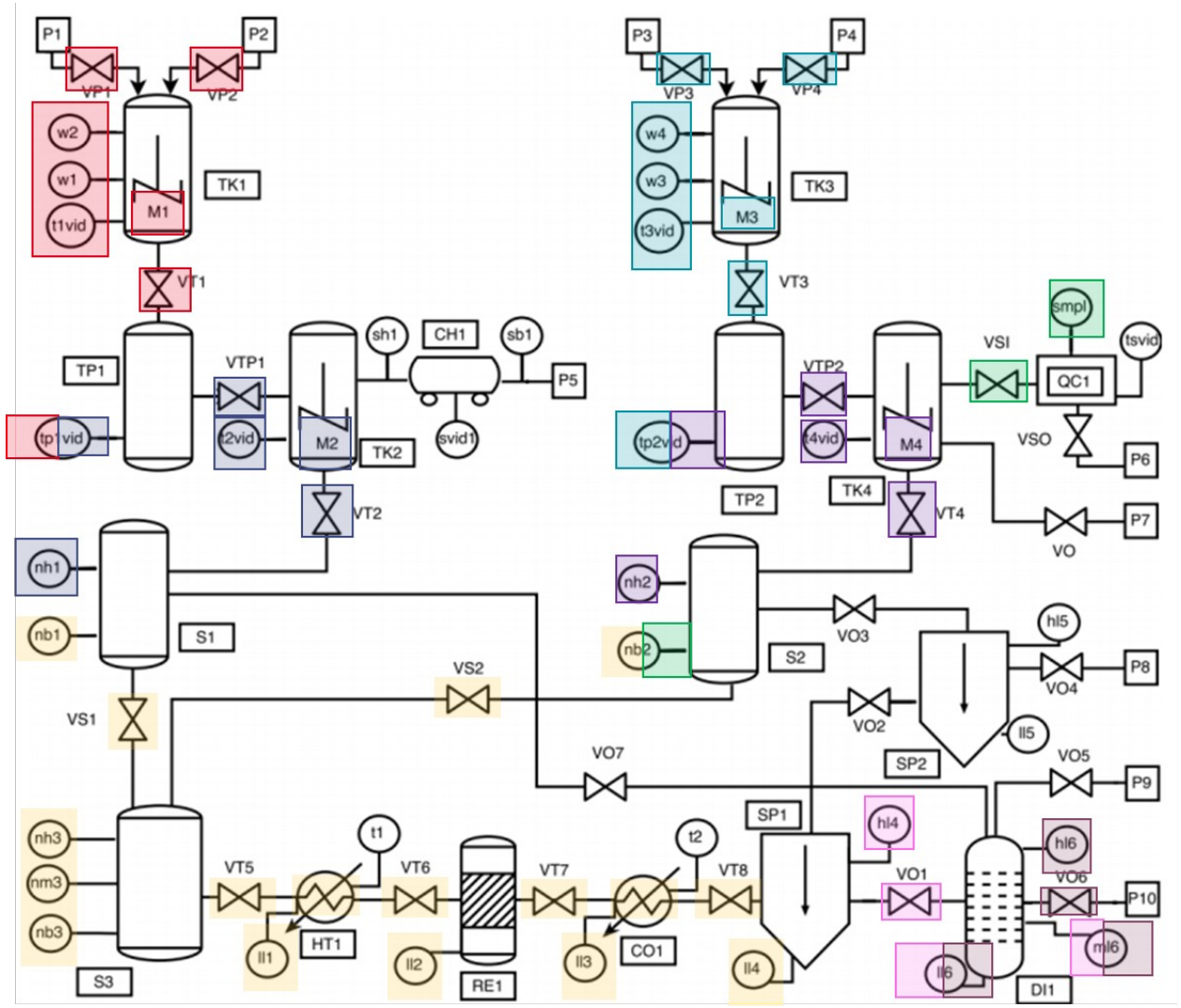


PLC logic **System model**

Model building

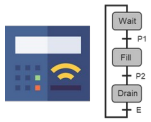
Objective

Tennessee Eastman Physical Process

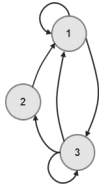


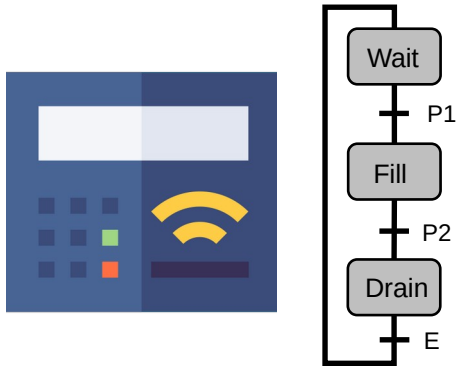
26 sensors
24 actuators

McAvoy, T. J., & Ye, N. (1994). Base control for the Tennessee Eastman problem. Computers & Chemical Engineering, 18(5), 383-413.

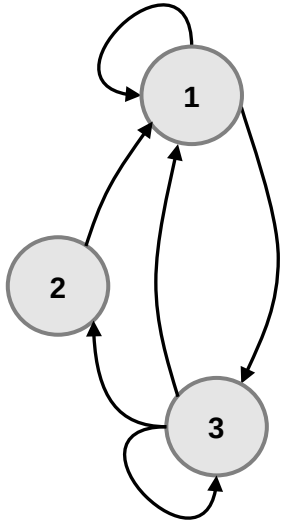


Model Building

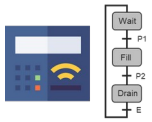




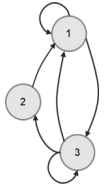
PLC logic

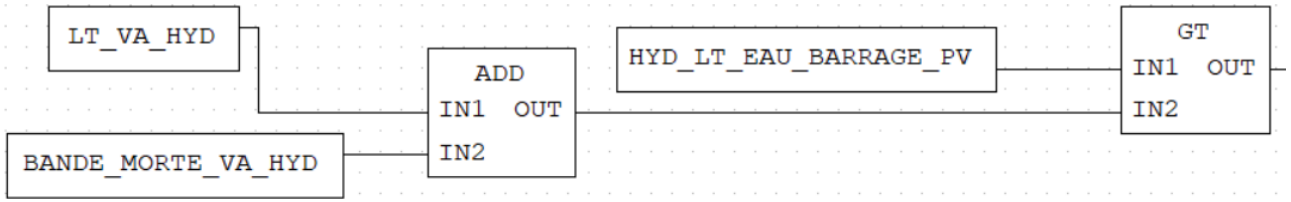


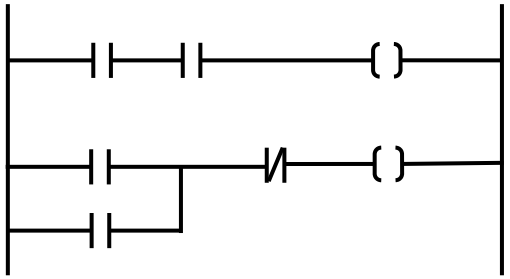
System model

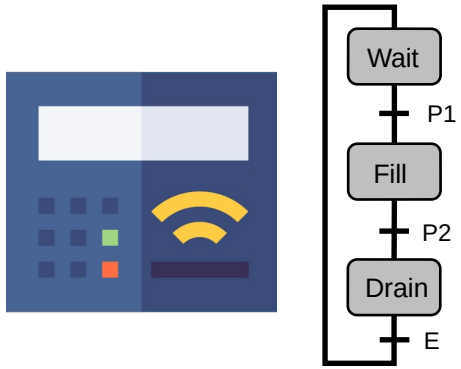


Model Building



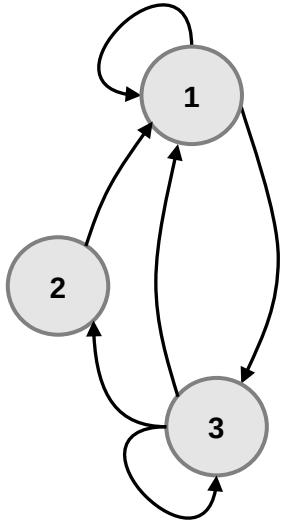






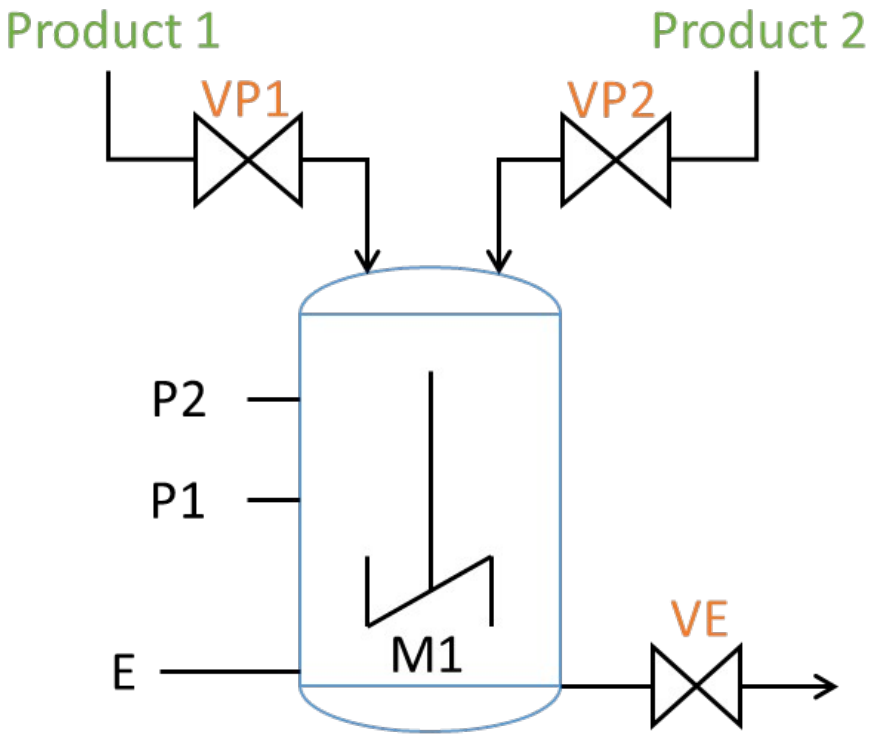

```
PROGRAM Example_ST
  VAR
      A: BOOL;
      B: BOOL;
      C: REAL;
      D: REAL;
  END_VAR
  A := NOT B AND (C <> D);
END_PROGRAM
```

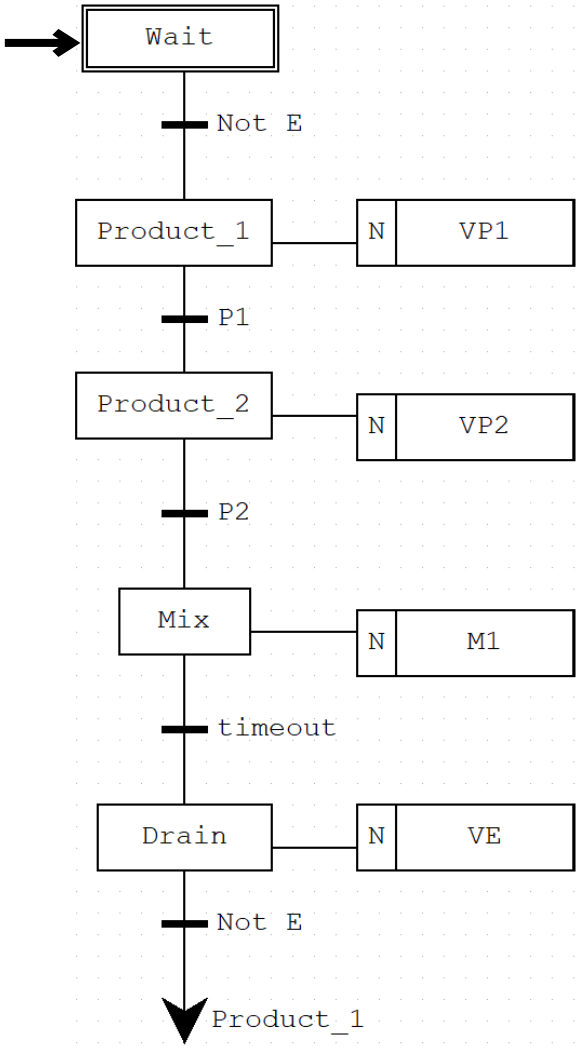
Sequential Function Chart (SFC)



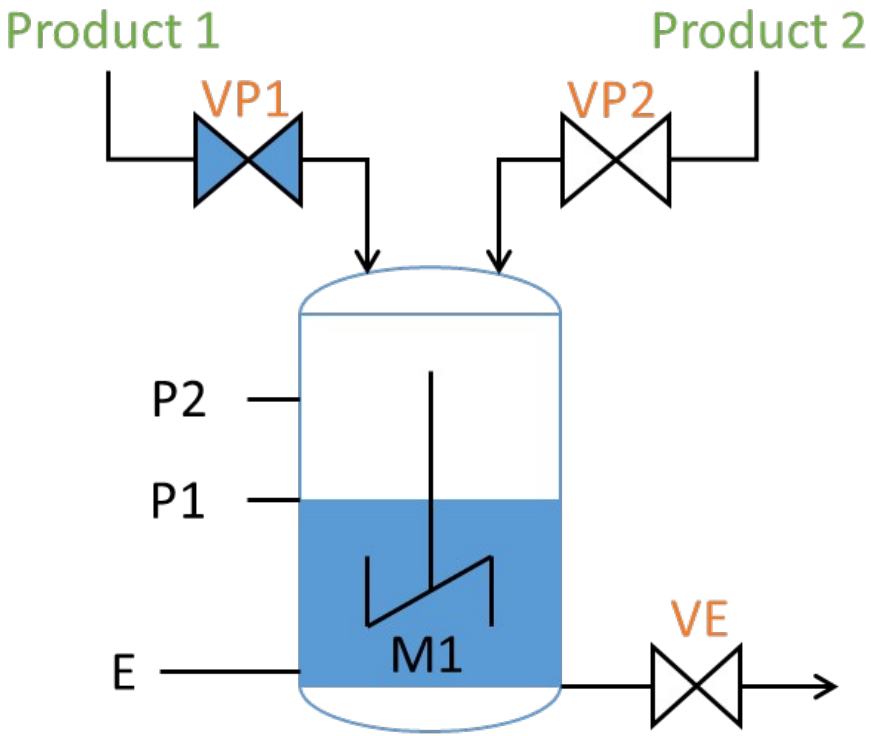
System model

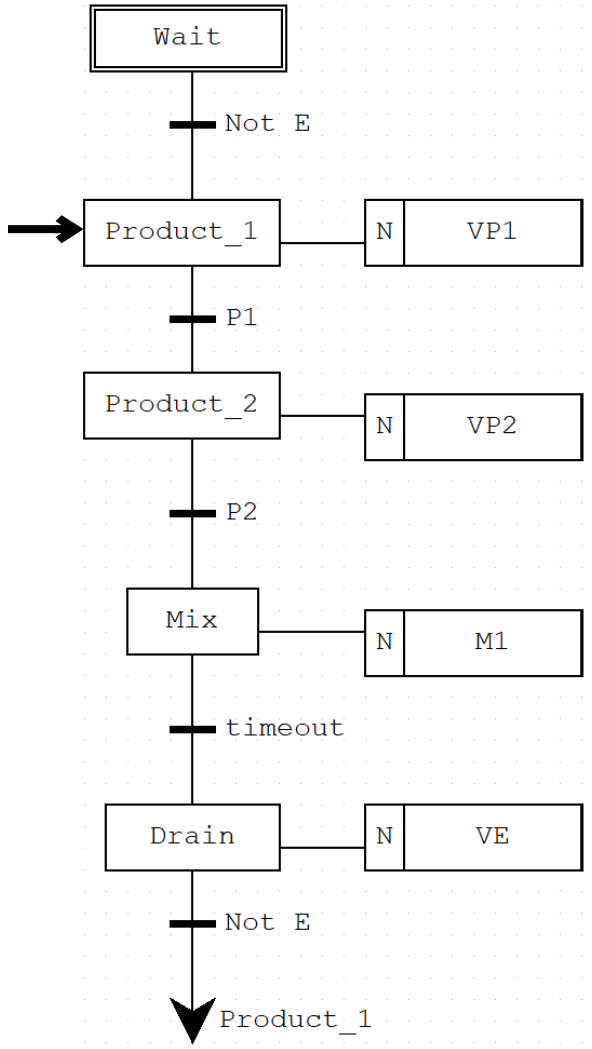
Model Building



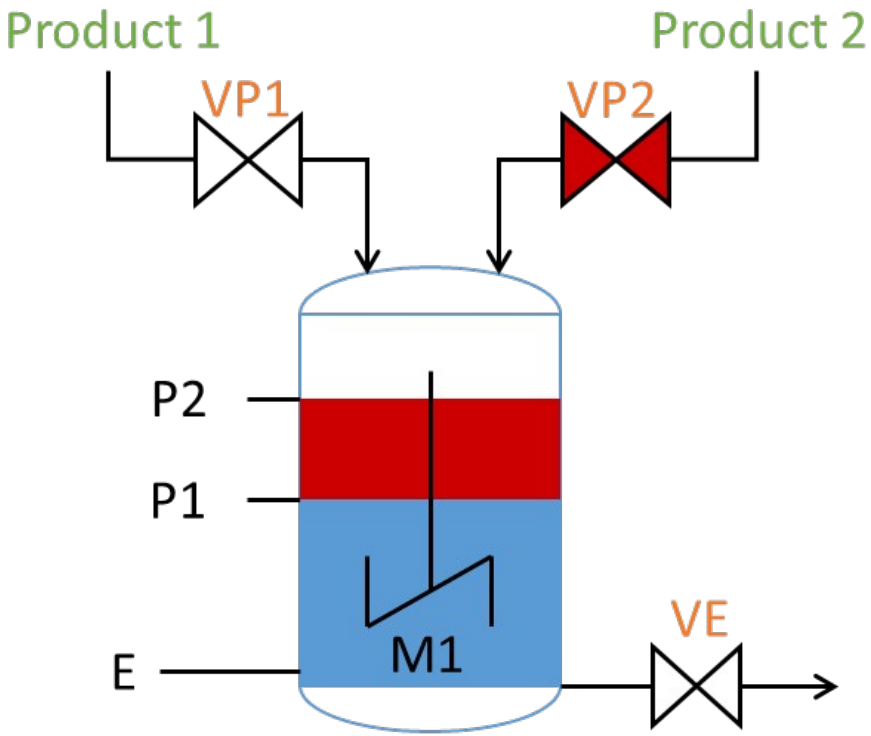


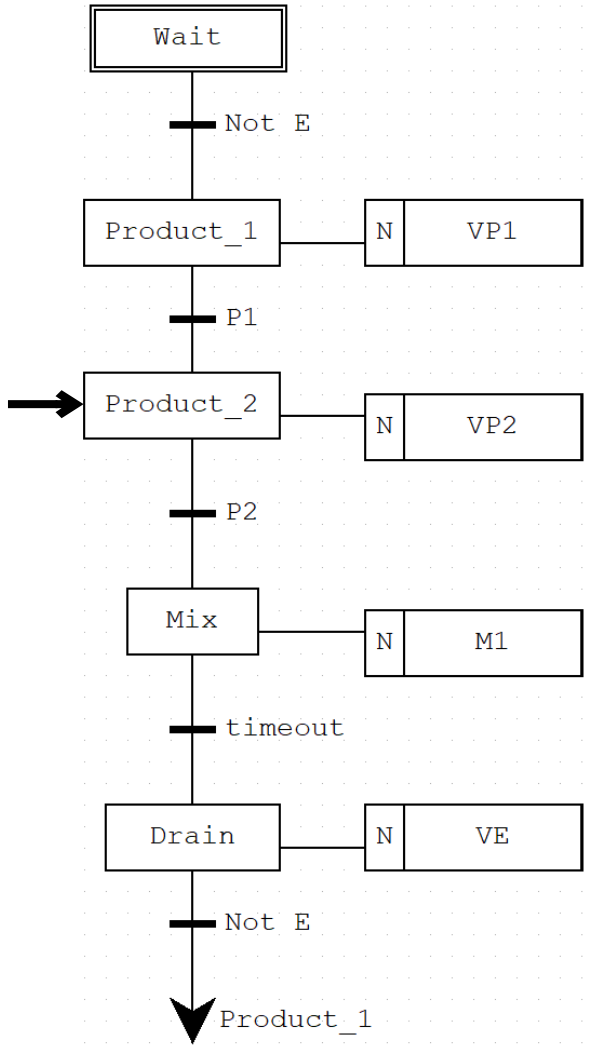
Model Building



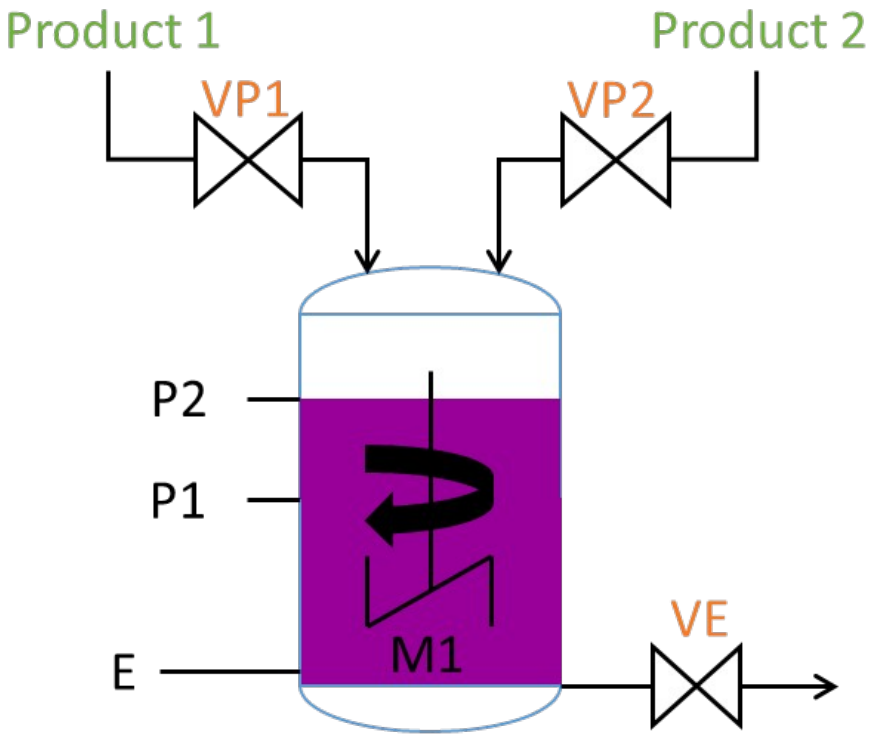


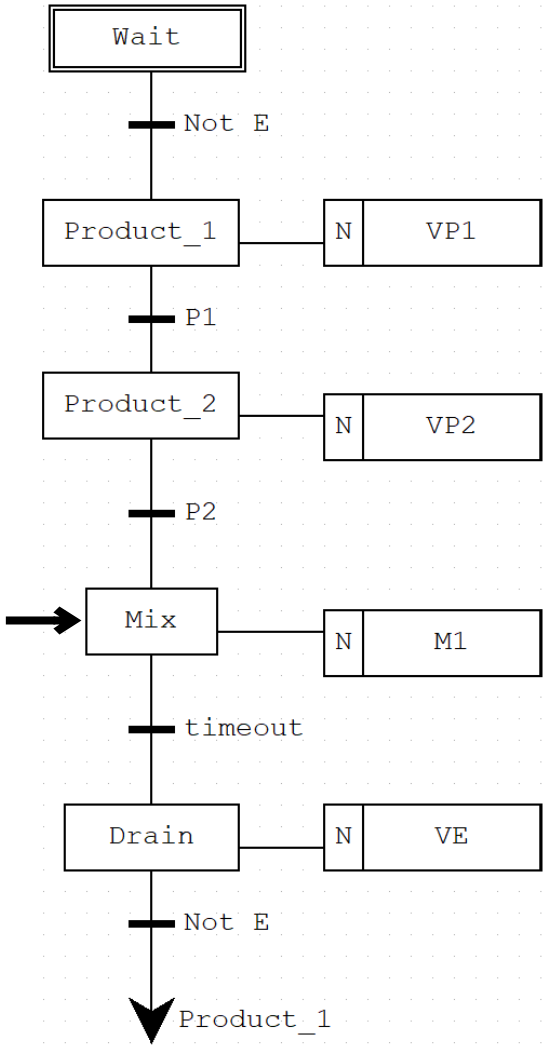
Model Building



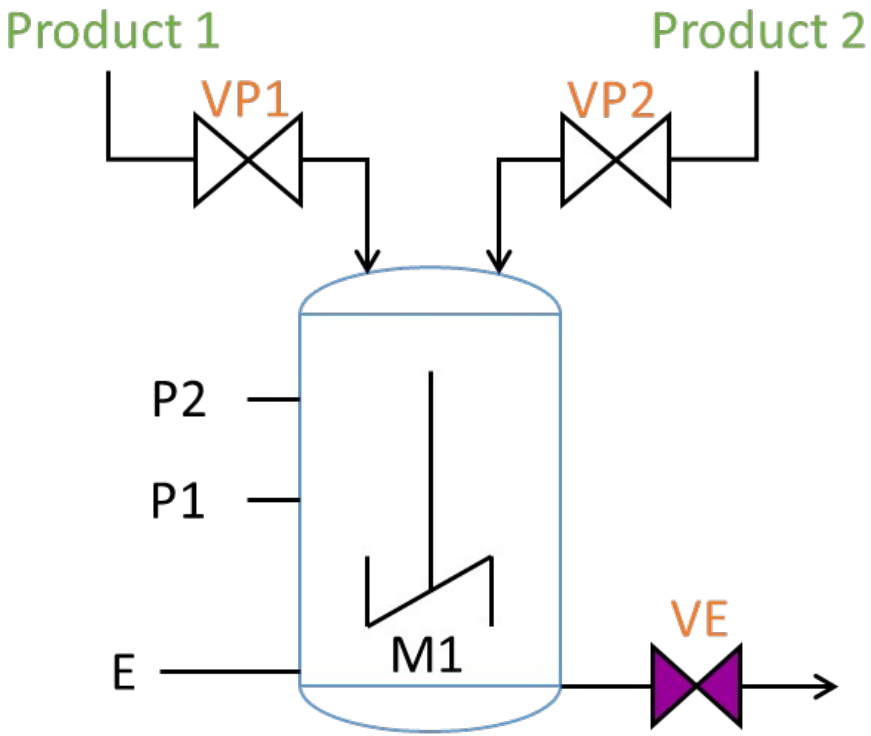


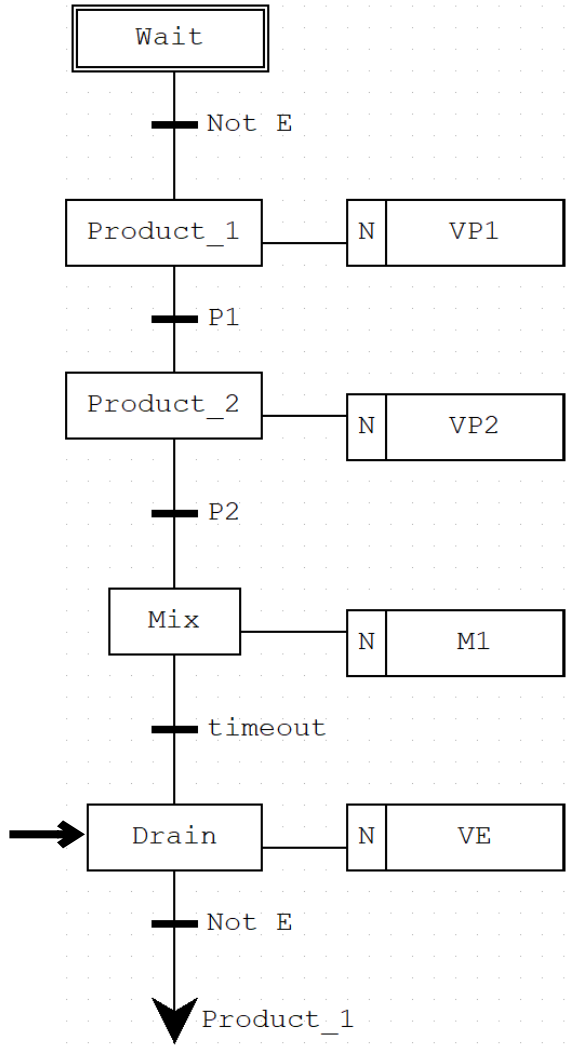
Model Building



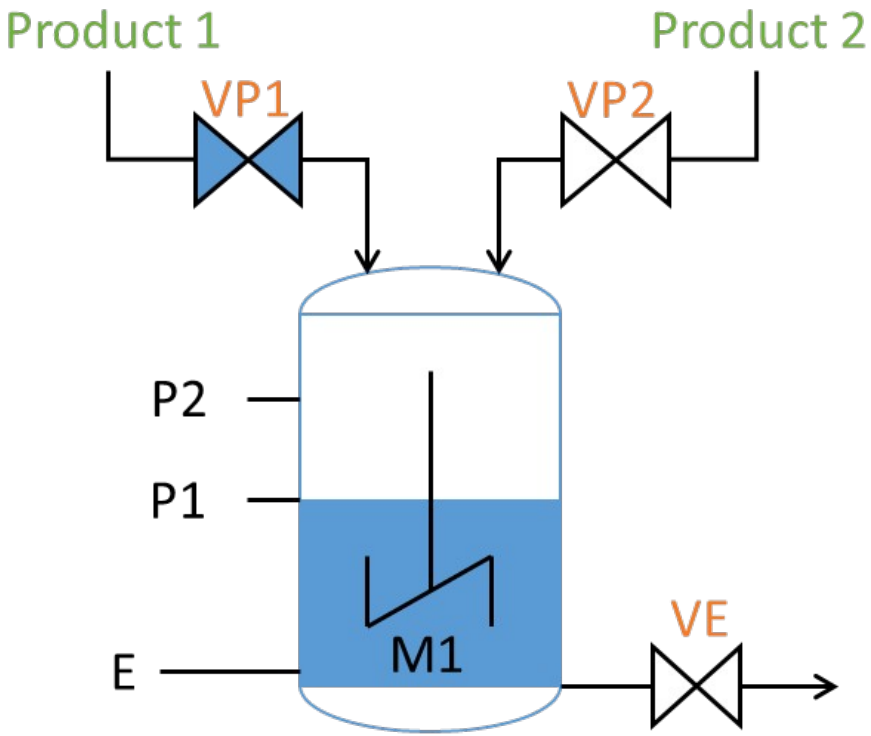


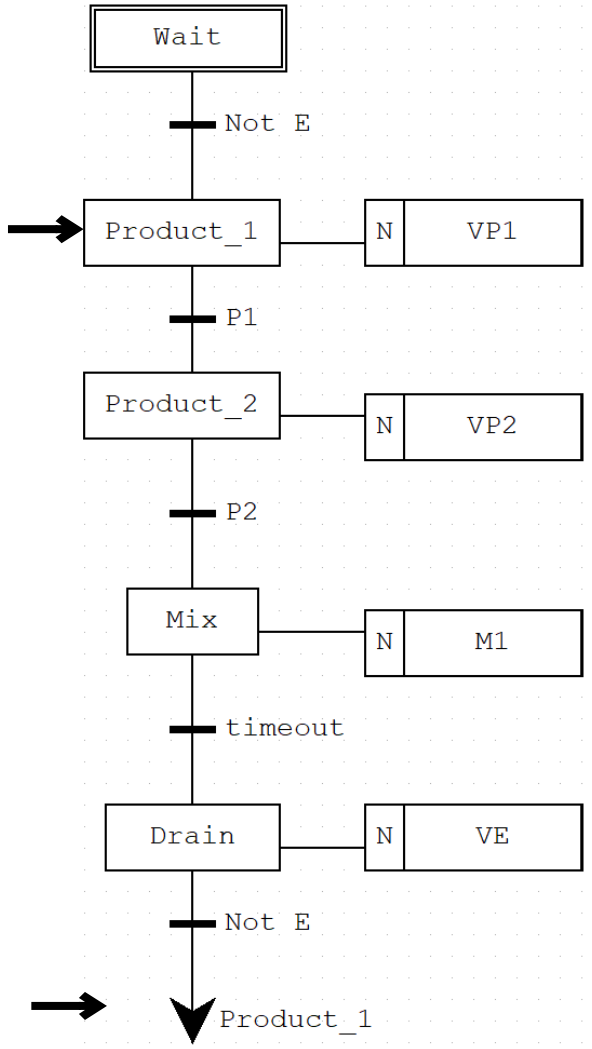
Model Building

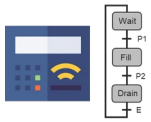




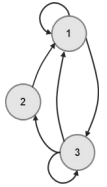
Model Building

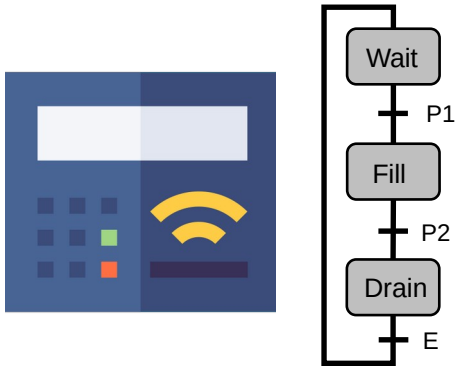






Model Building





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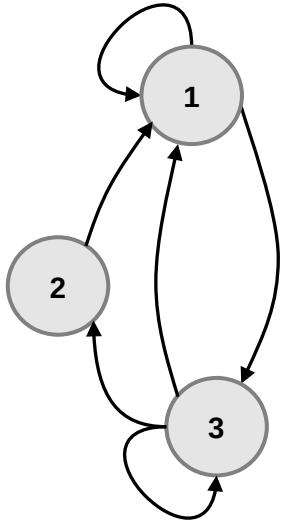
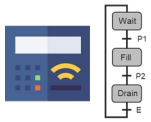
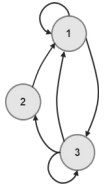
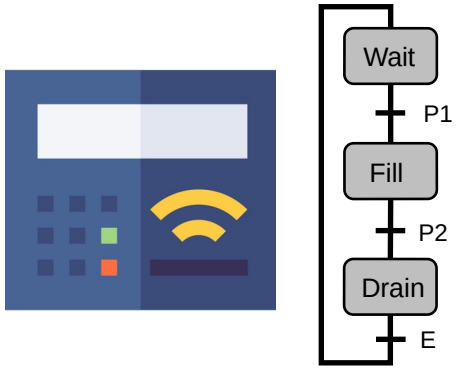


System model



Model Building





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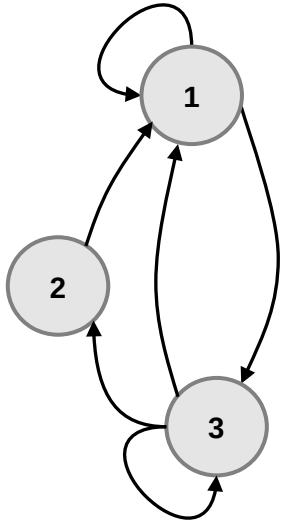
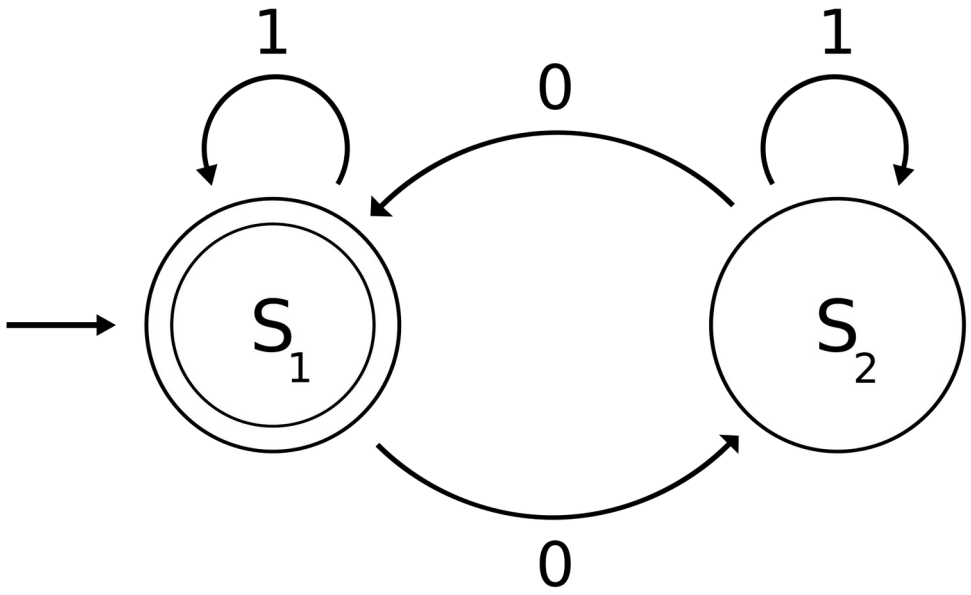
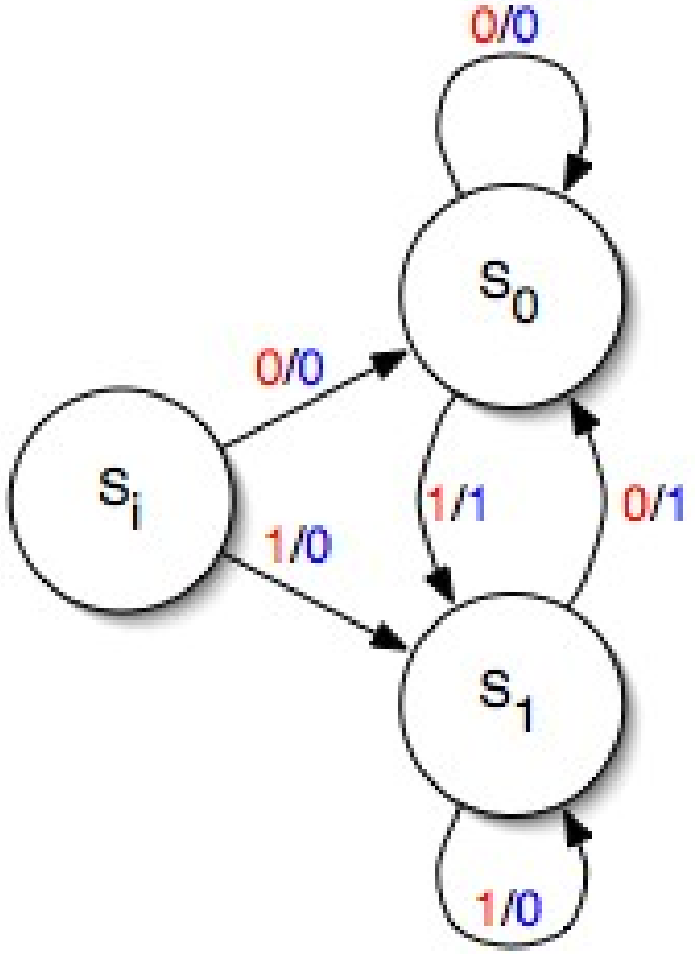


Finite-state transducer

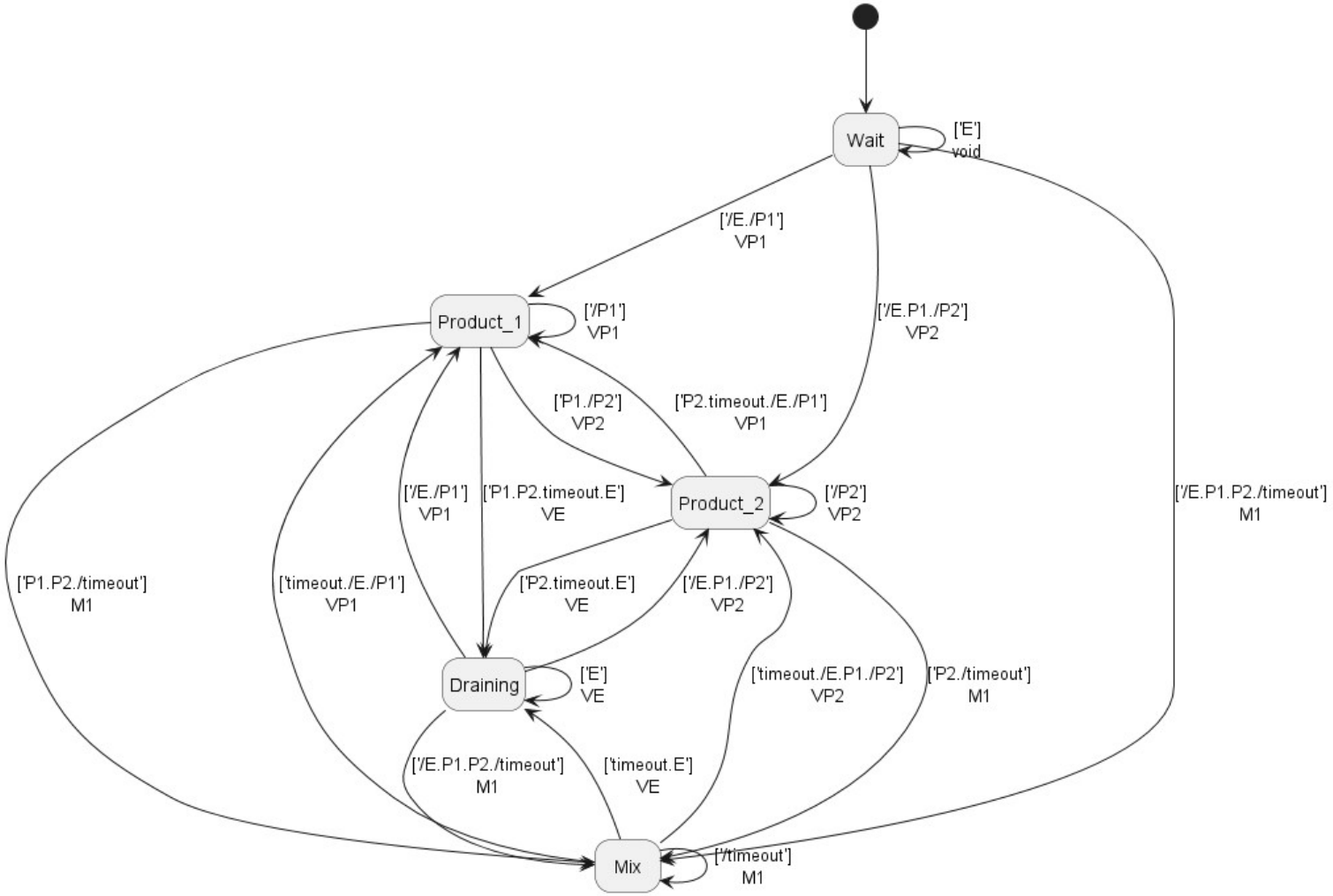


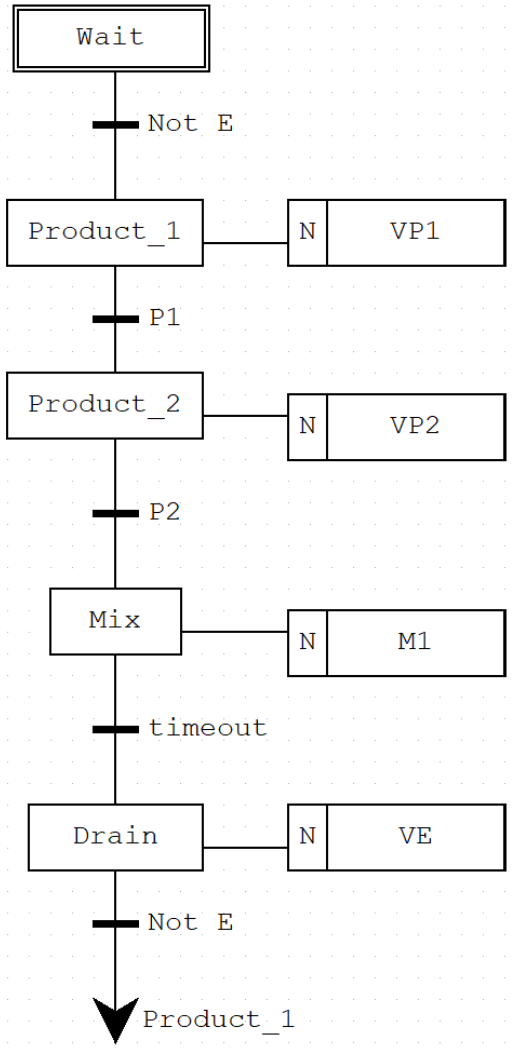
Finite State Machine



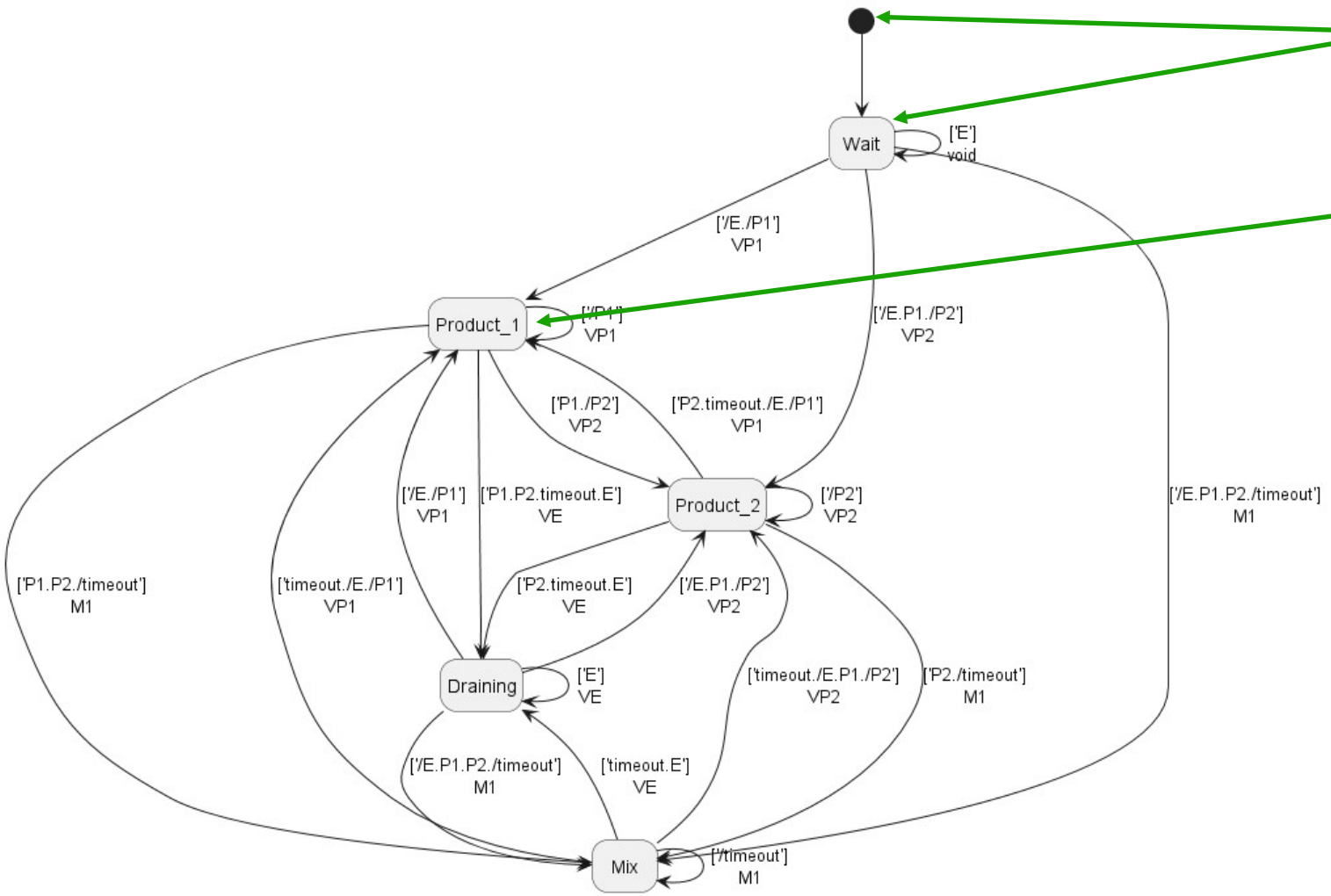
Finite State Transducer
Mealy Machine

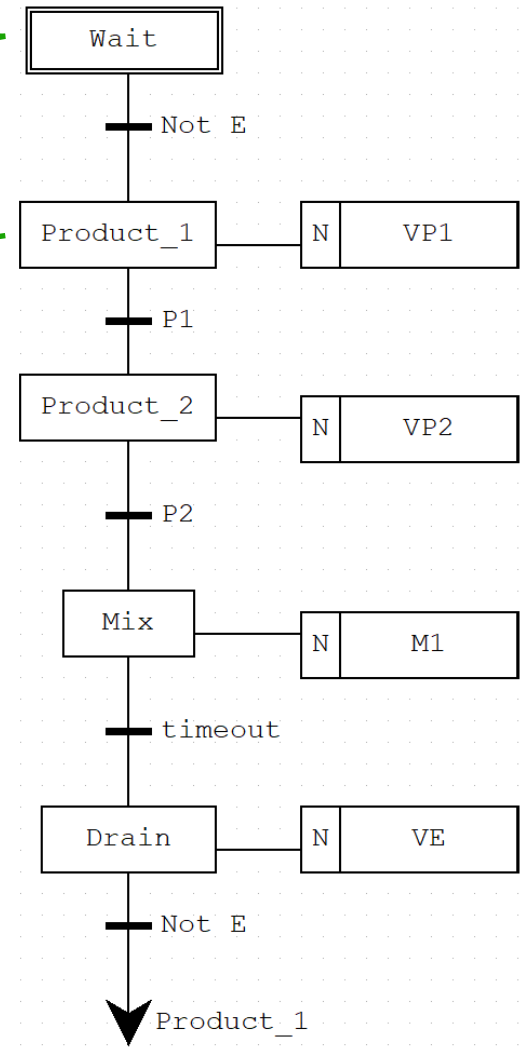
Model Building

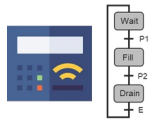




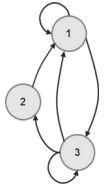
Model Building

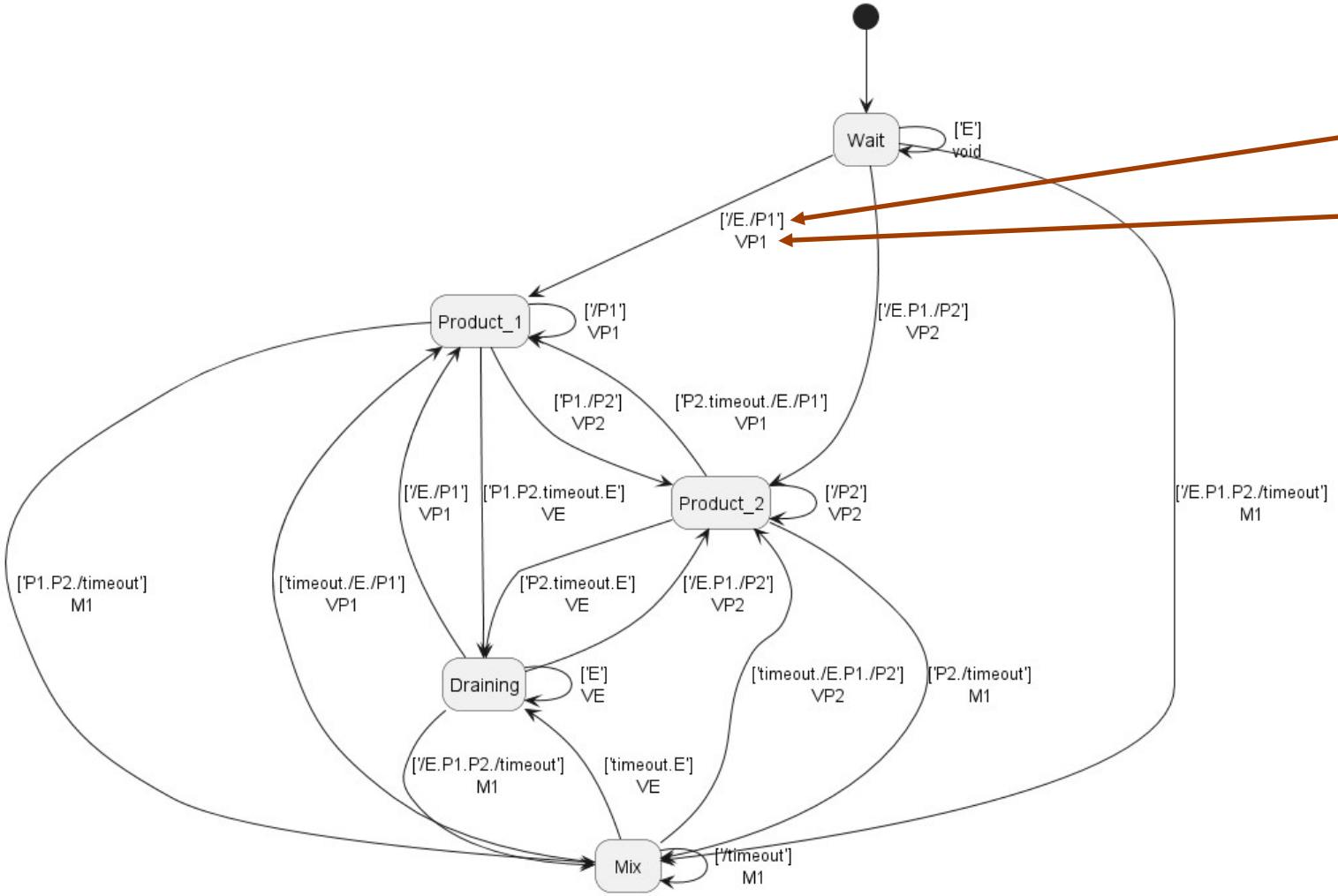


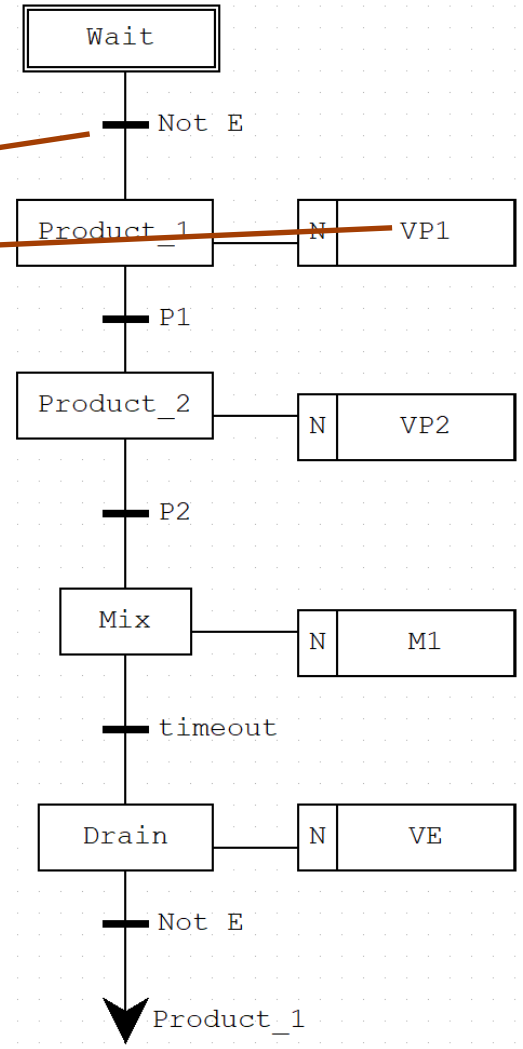




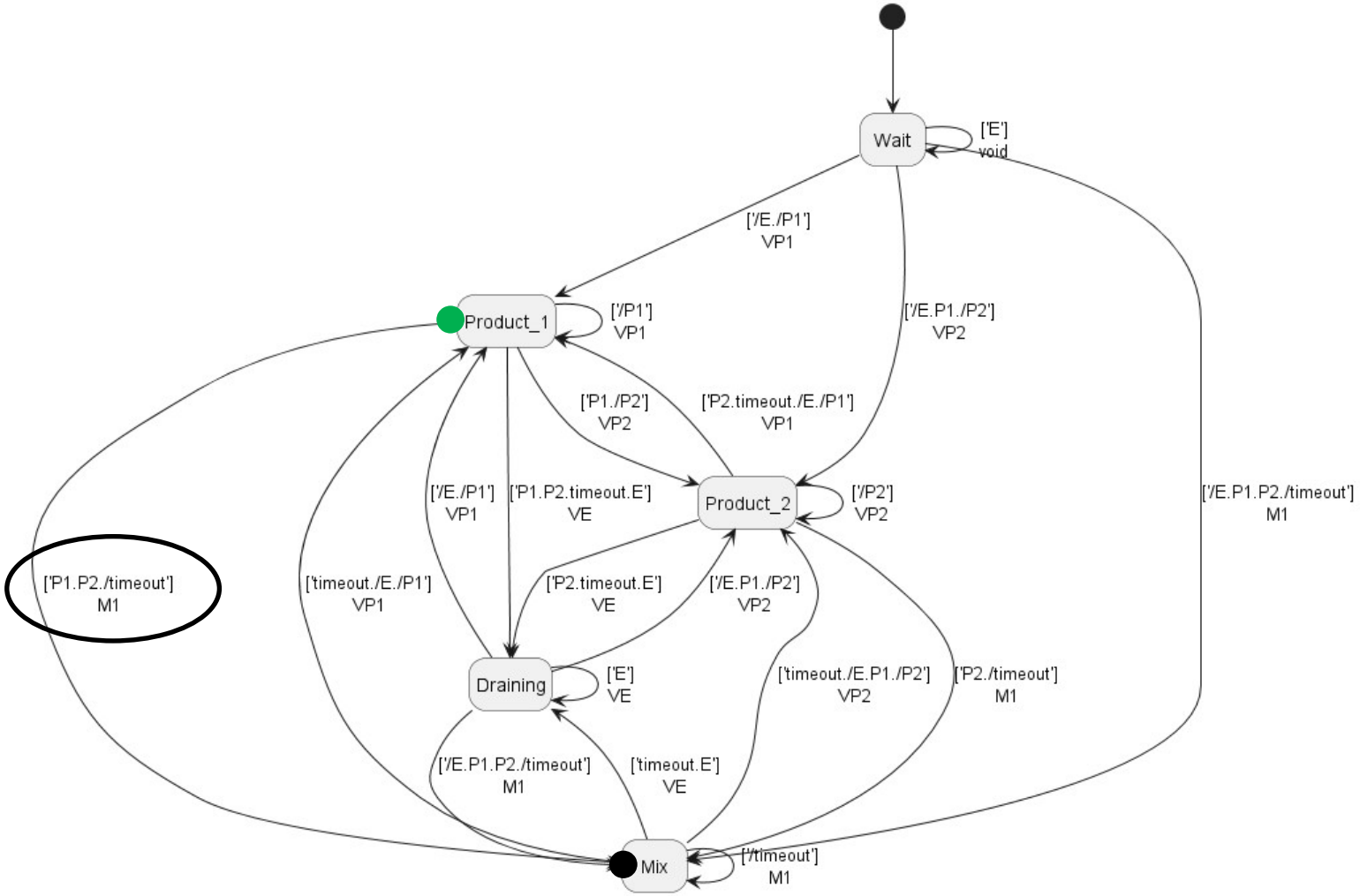
Model Building

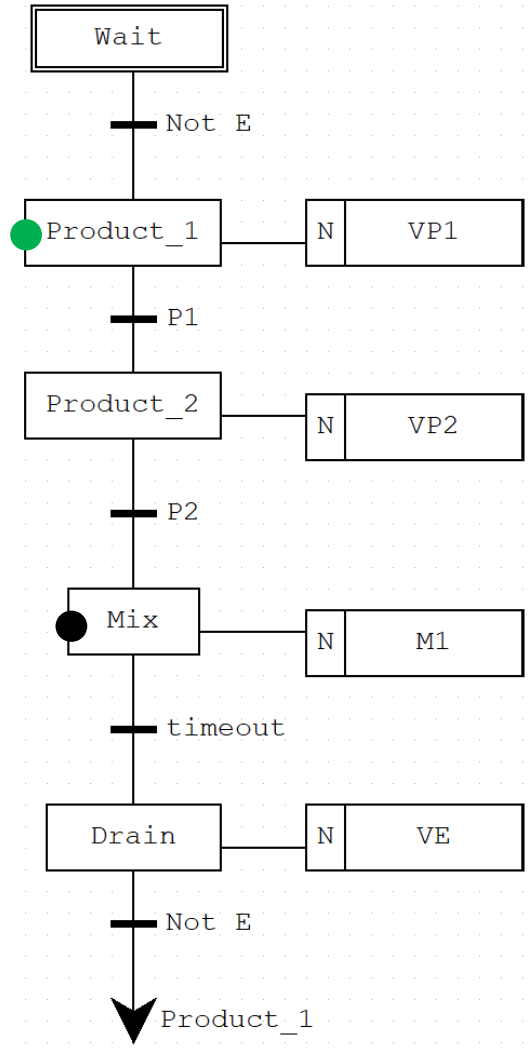






Model Building

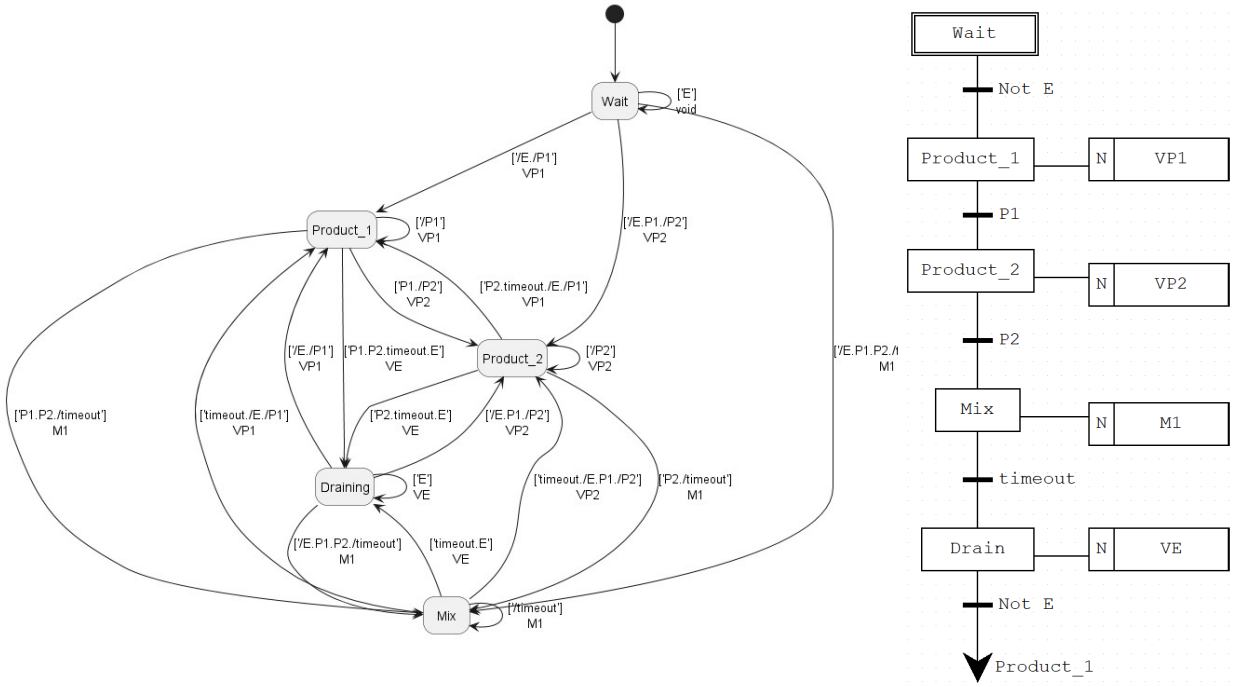




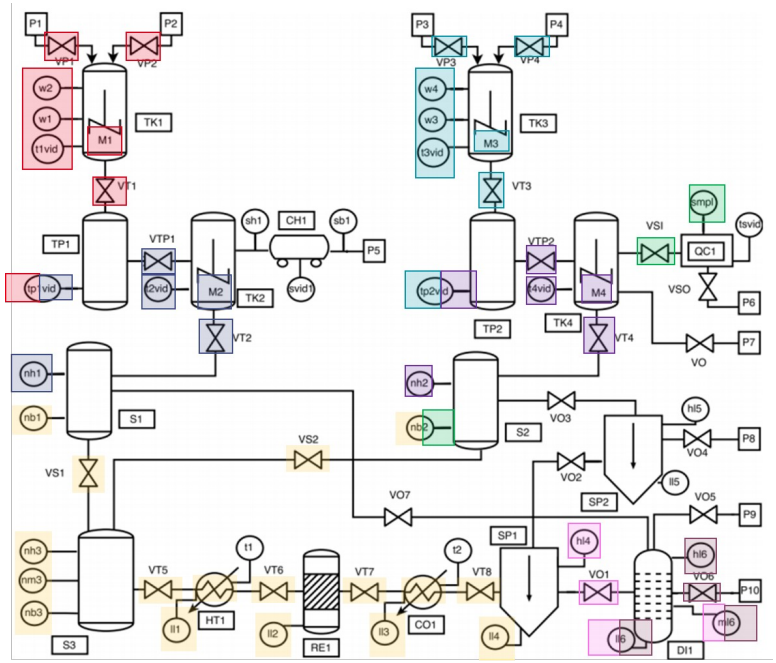
Calculate once upstream

Calculate each time

Objective

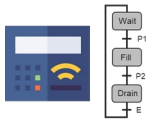


VS.

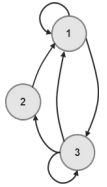


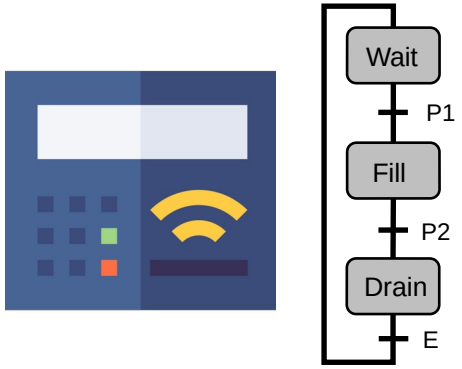
5 states

6.7 x 10^5 states



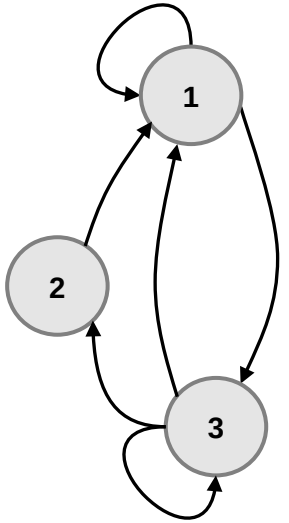
Model Building



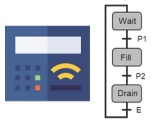


SFC

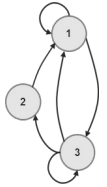
TELOCO

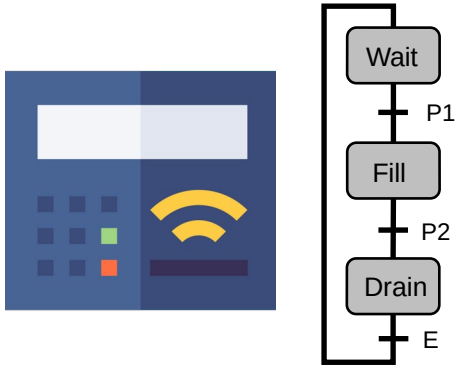


Finite-state transducer



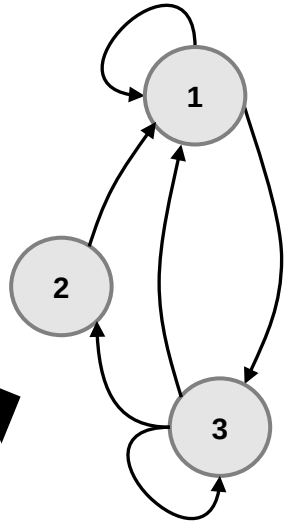
Model Building





SFC

TELOCO



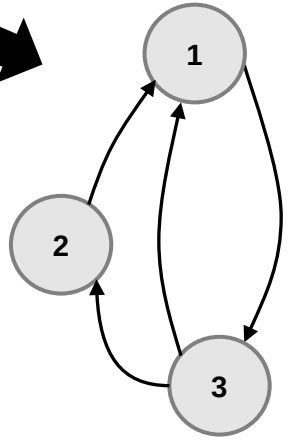
Mealy machine => Too complex

Requires Boolean minimization of transitions

Complexity = 2^{inputs} x states

Tennessee-Eastman => 2^{26} x $6{,}7.10^5$

≈ 10^{13}

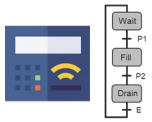


Stable Location Automaton (SLA)

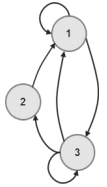
Complexity = $states^2$

Tennessee-Eastman => $(6{,}7.10^5)^2$

≈ 10^{11}

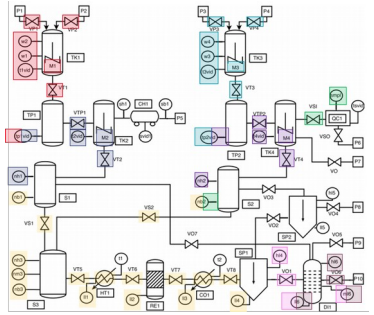


Model Building



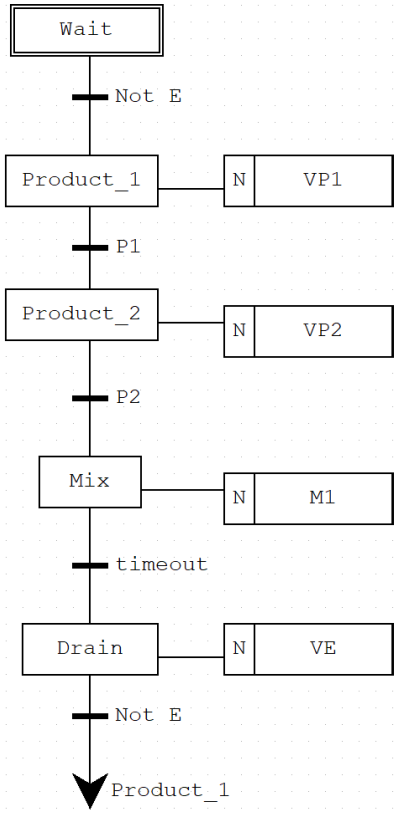
Modeling Time

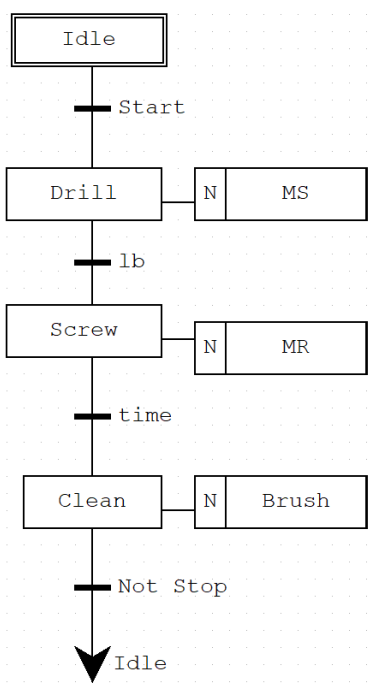
SLA	Mealy	Minimization	Inputs
1 ms	0 ms	372 ms	3
0 ms	0 ms	376 ms	4
0 ms	0 ms	382 ms	5
141 ms	51 ms	505 ms	9
42 ms	162 ms	17 219 ms	13
21 973 ms	30 190 ms	65 813 ms	13
1 320 ms	15 143 ms	1 381 511 ms	16
2 625 ms	46 875 ms	X	17
50 036 ms	994 192 ms	X	18
1 091 838 ms	X	X	18
X	X	X	26

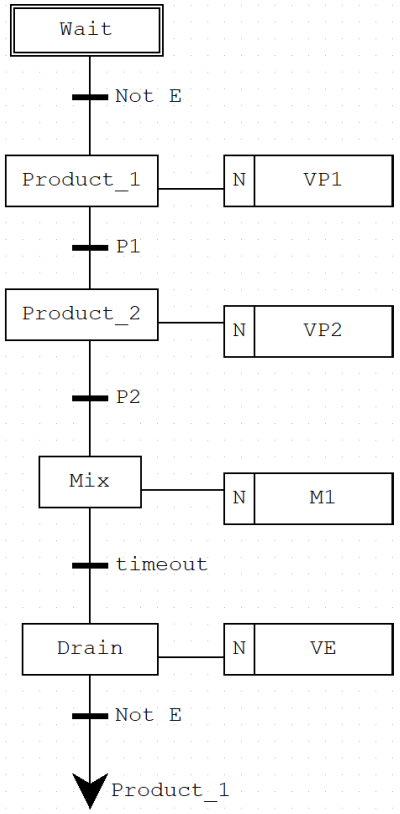


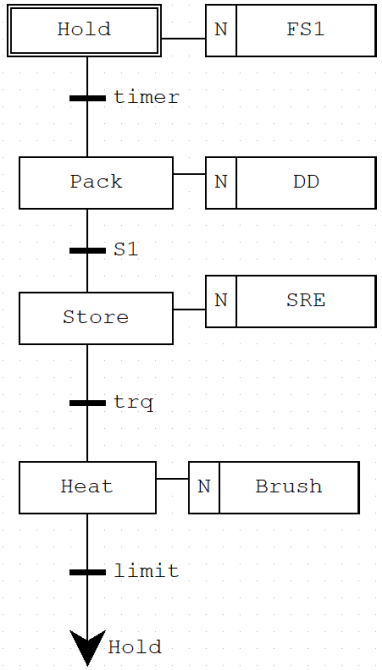
Tennessee-Eastman →

→ **Intel(R) Core(TM)i5-8365U @1,60GHz-1,90GHz and 16 Go of RAM.**

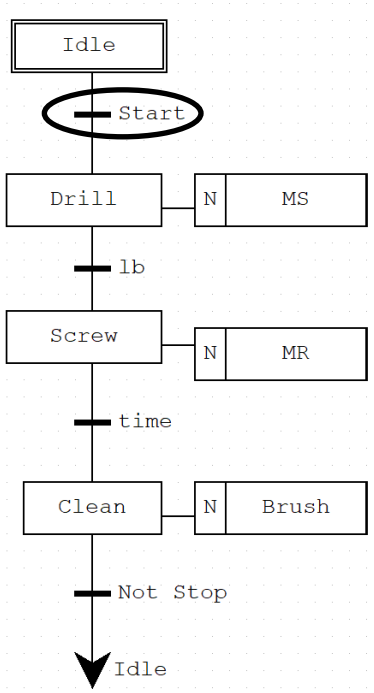

Wait
Not E
Product_1
N
VP1
P1
Product_2
N
VP2
P2
Mix
N
M1
timeout
Drain
N
VE
Not E
Product_1

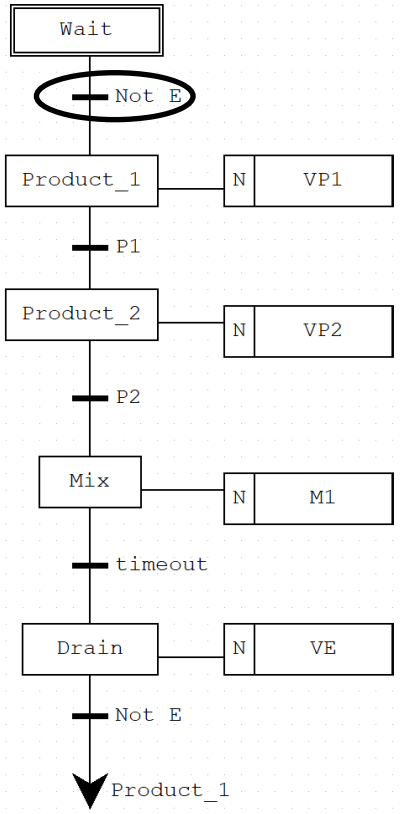


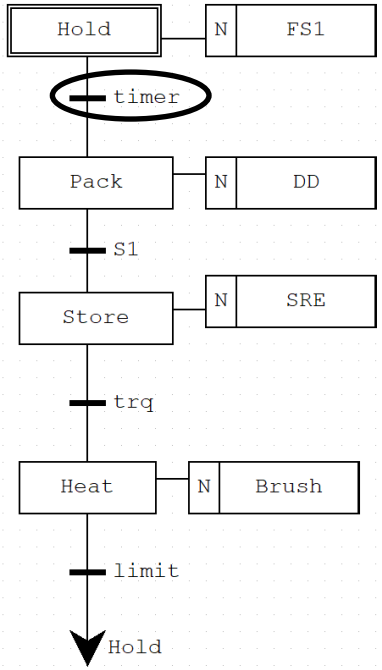




/!\ Not one big SFC but multiple smaller running at the same time







/!\ In the worst case, # states is not the sum of all states but the product

4 inputs
6 states

4 inputs
6 states

4 inputs
4 states

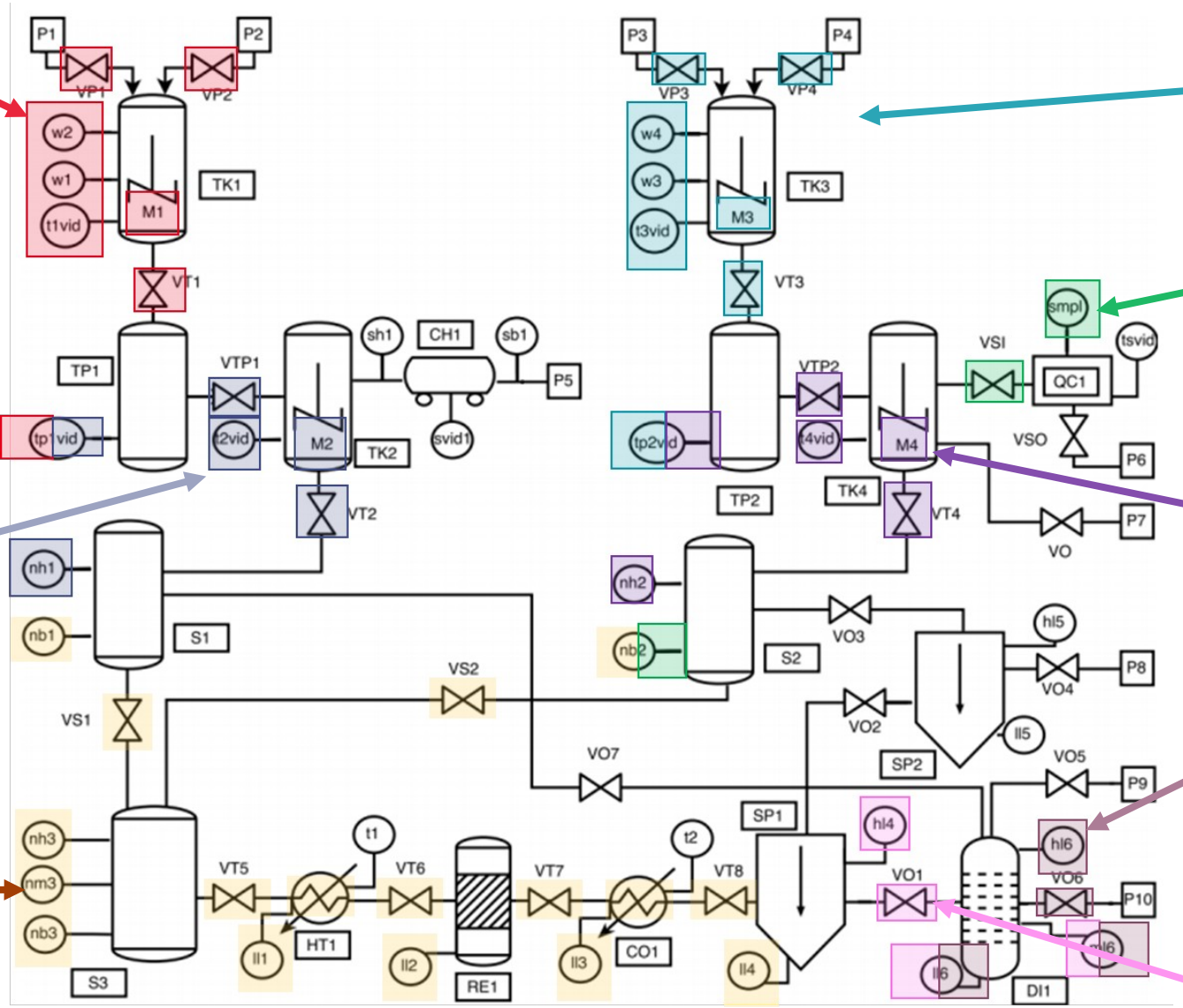
4 inputs
5 states

5 inputs
6 states

3 inputs
3 states

13 inputs
13 states

4 inputs
4 states

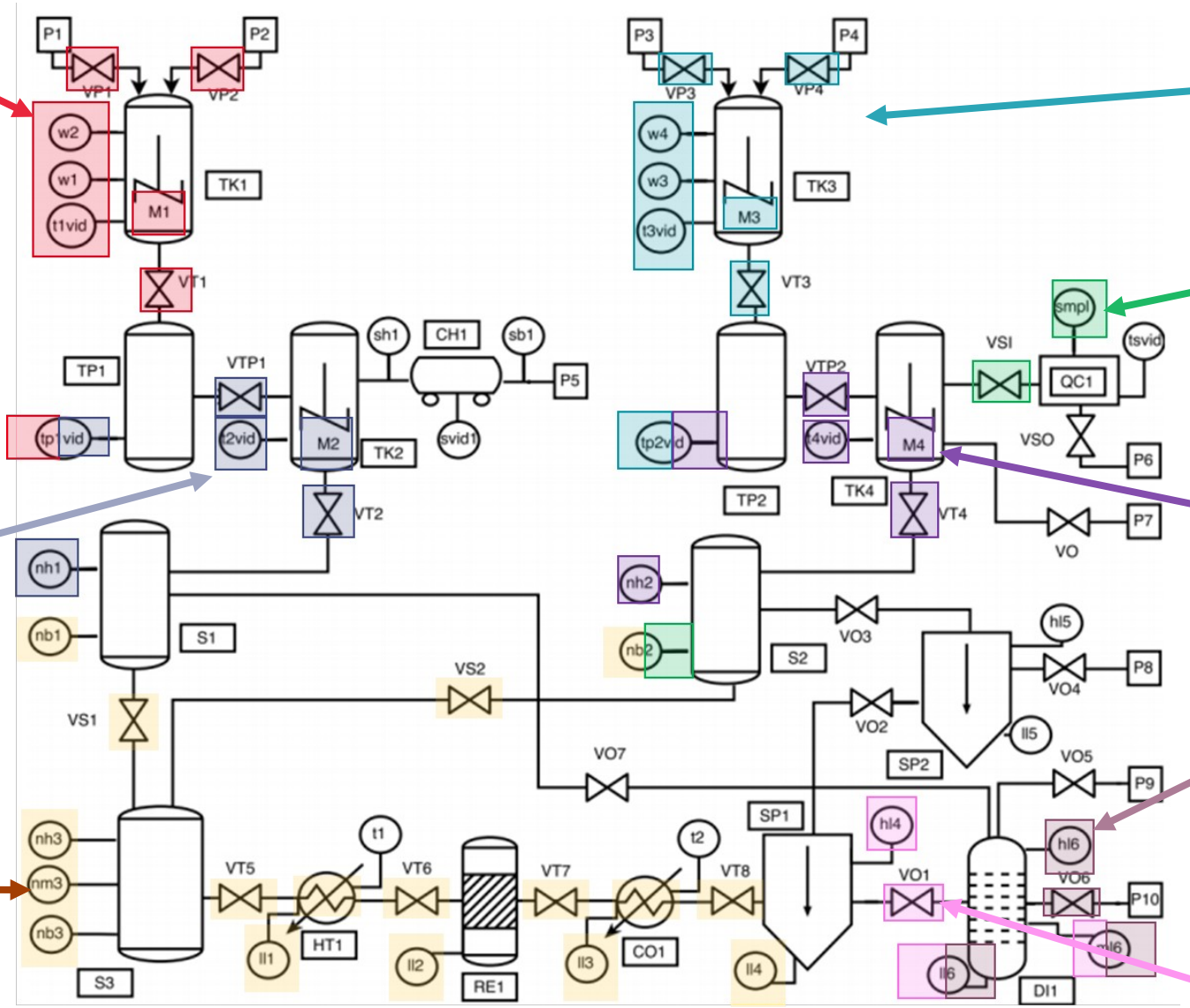


4 inputs
6 states

TOTAL: 6,7 . 10^5

4 inputs
5 states

13 inputs
13 states



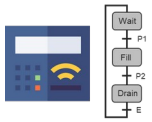
4 inputs
6 states

4 inputs
4 states

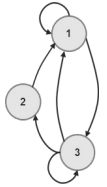
5 inputs
6 states

3 inputs
3 states

4 inputs
4 states

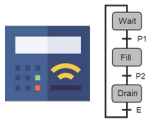


Model Building

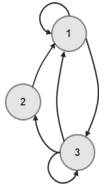


Modeling Time

SLA	Graphs	Inputs
1 ms	1	3
0 ms	1	4
0 ms	1	5
42 ms	1	13
141 ms	2	9
1 320 ms	2	16
2 625 ms	2	17
21 973 ms	3	13
50 036 ms	3	18
1 091 838 ms	4	18
X	8	26



Model Building



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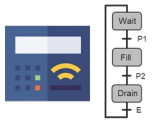
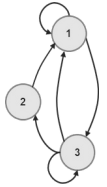


Model Building



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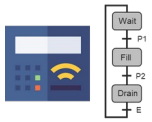
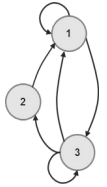


Model Building



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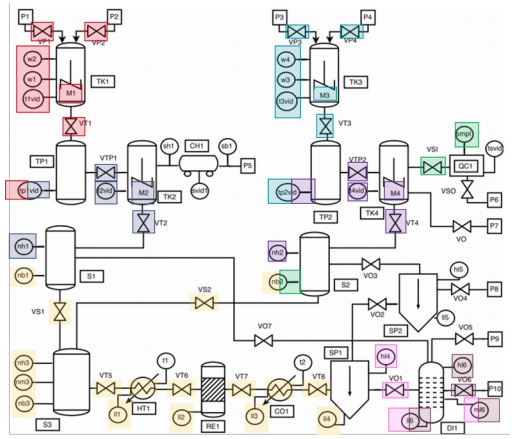
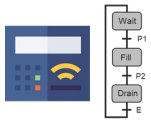
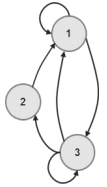
0 ms	1	5
42 ms	1	13
141 ms	2	9
1 320 ms	2	16
2 625 ms	2	17
21 973 ms	3	13
50 036 ms	3	18
1 091 838 ms	4	18
X	8	26

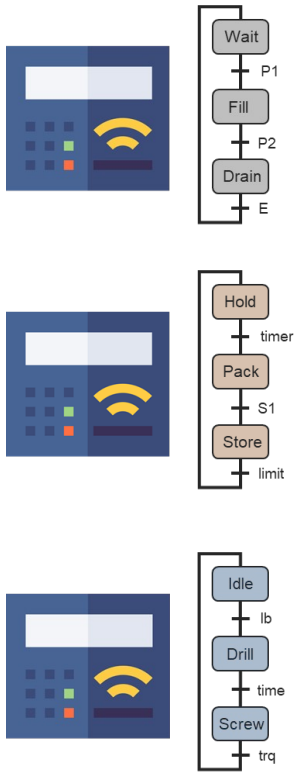


Tennessee-Eastman →



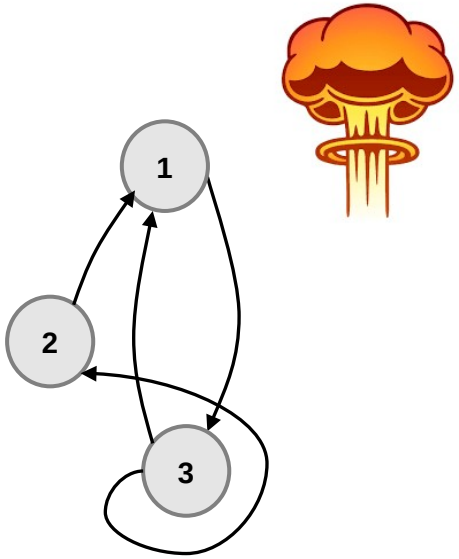
Model Building



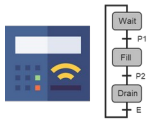


SFC

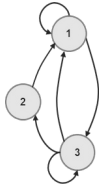
TELOCO

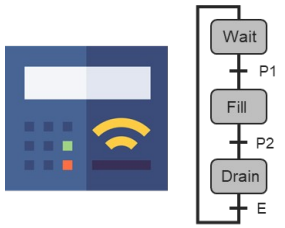


Stable Location Automaton (SLA)



Model Building





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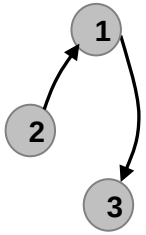

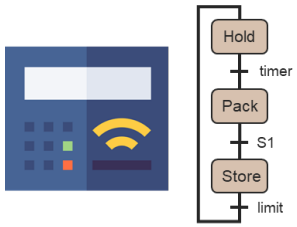

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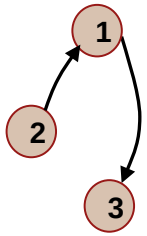
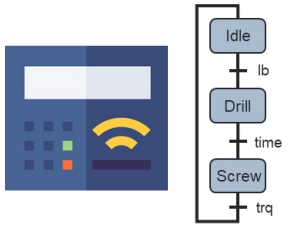
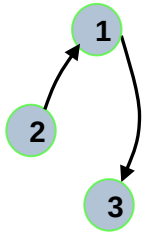




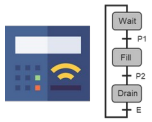
TELOCO



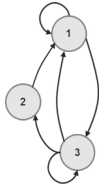
SFC

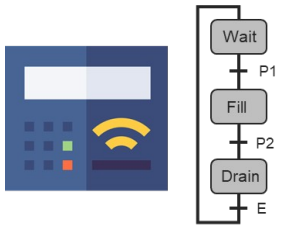
Stable Location Automaton (SLA)

Decomposition



Model Building





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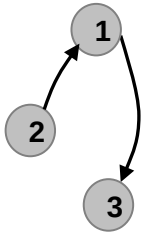
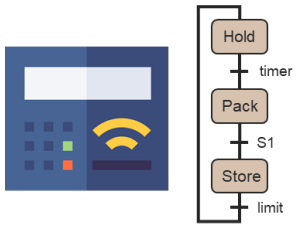


↓ *graph*



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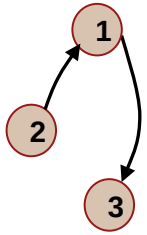
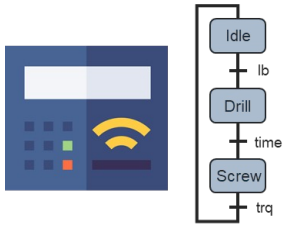


↓ *graph*



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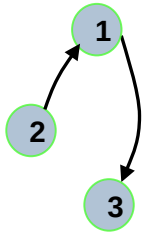
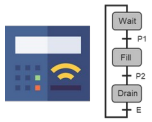


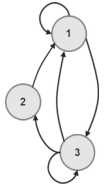
↓ *graph*

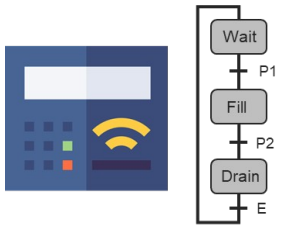
SFC

Stable Location Automaton (SLA)



Model Building





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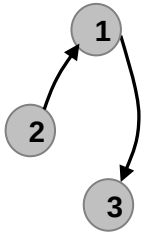
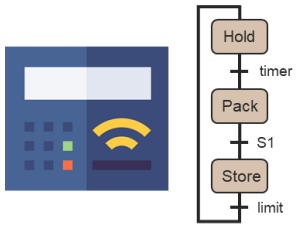


$\downarrow graph$

$2^{\downarrow Tr}$



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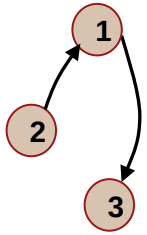
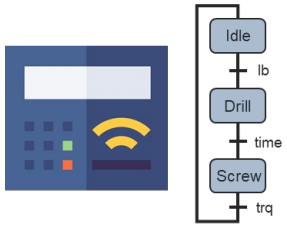


$\downarrow graph$

$2^{\downarrow Tr}$



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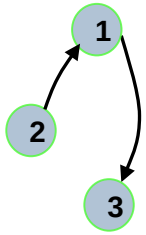
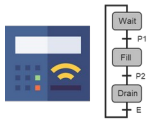


$\downarrow graph$

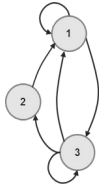
$2^{\downarrow Tr}$

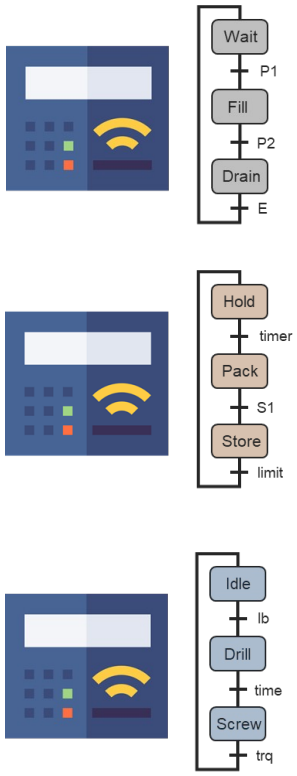
SFC

Stable Location Automaton (SLA)



Model Building





SFC

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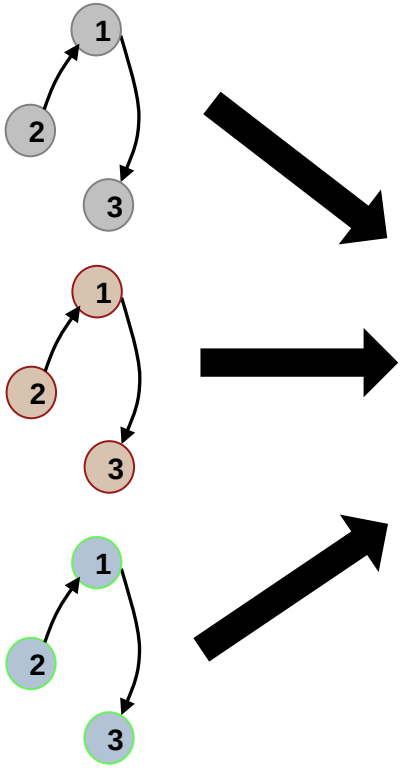
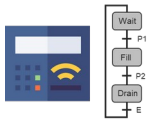
TELOCO

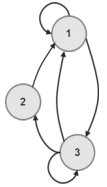


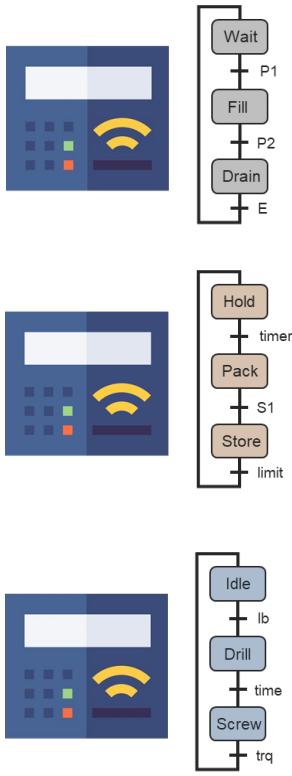
Stable Location Automaton (SLA)

Strong product of graphs



Model Building





SFC

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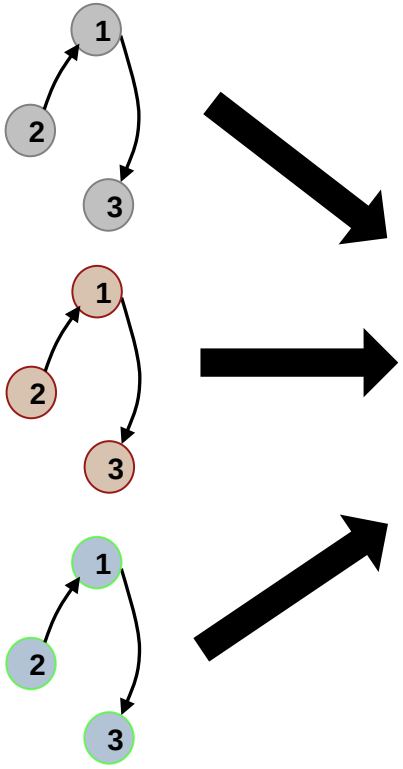
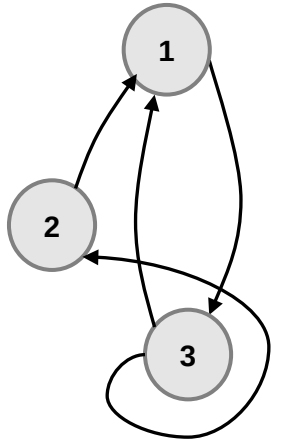
TELOCO



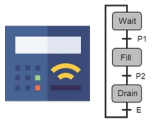
Stable Location Automaton (SLA)

Strong product of graphs

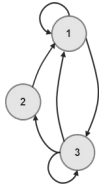


≈ SLA

≠ non-minimal transducer

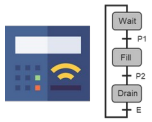


Model Building

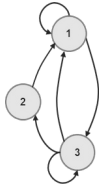


	Strong Product	SLA
4 graphs	2 636 ms	1 091 838 ms
5 graphs	43 420 ms	**X**
6 graphs	2 223 811 ms	**X**
8 graphs	**X**	**X**

Memory limitation
(375Gb RAM)



Model Building



	Strong Product	SLA
4 graphs	2 636 ms	1 091 838 ms
5 graphs	43 420 ms	**X**
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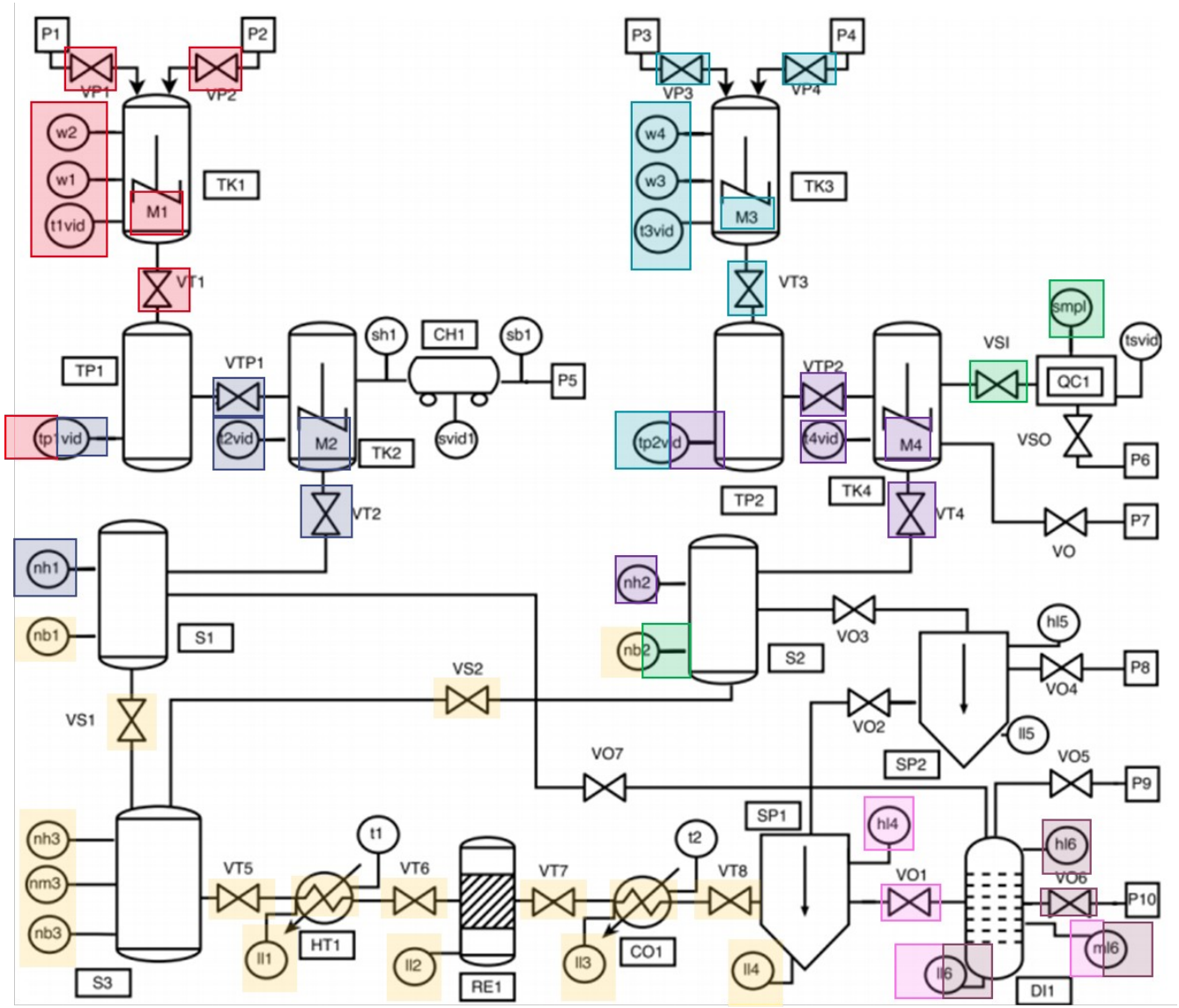
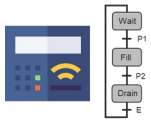
8 graphs	**X**	**X**

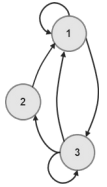
→ **Decomposition into sub-processes**

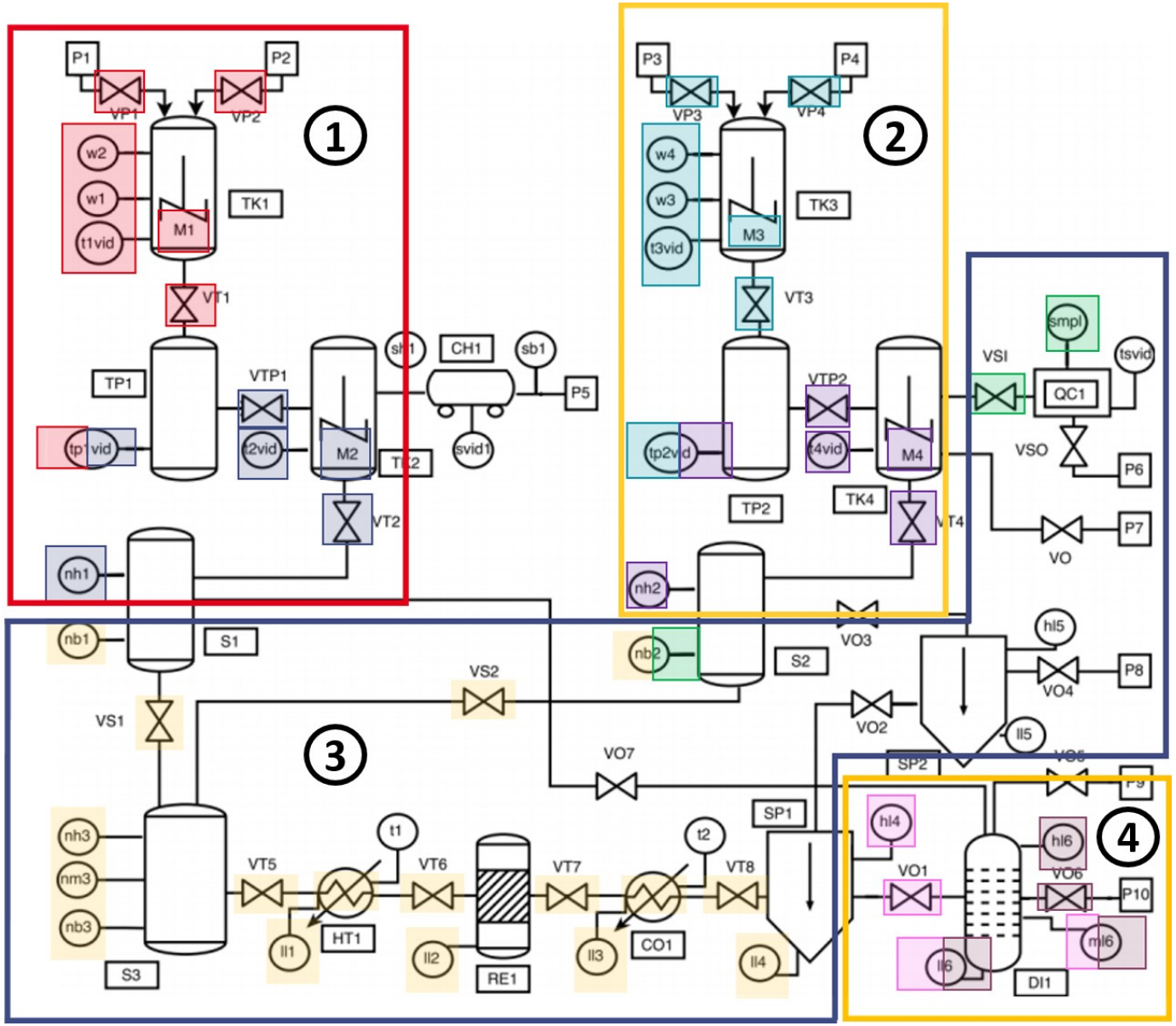
Model Building

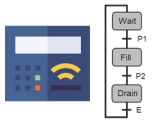




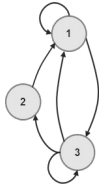
Model Building

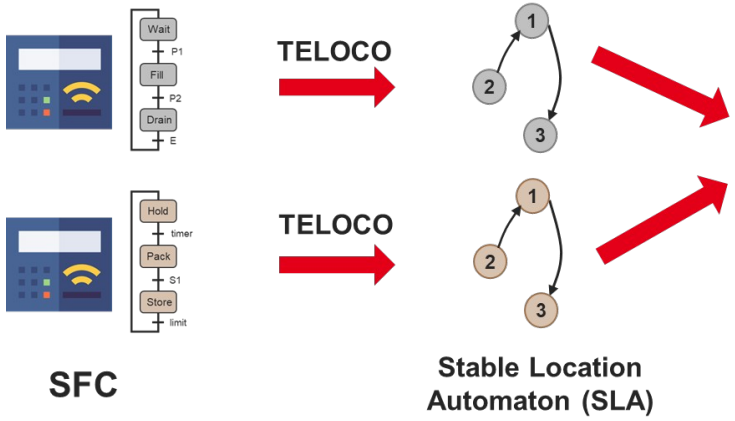






Model Building

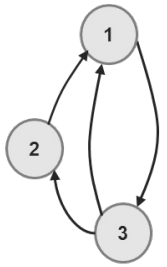




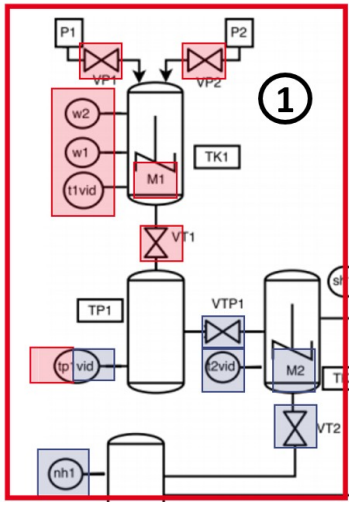
SFC

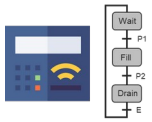
Stable Location Automaton (SLA)

Strong product of graphs

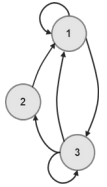


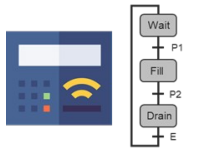
Sub-process 1

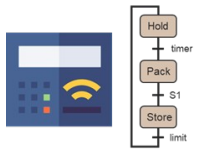




Model Building



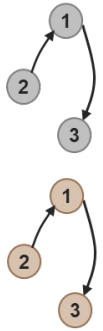




SFC

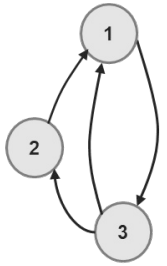
TELOCO

TELOCO

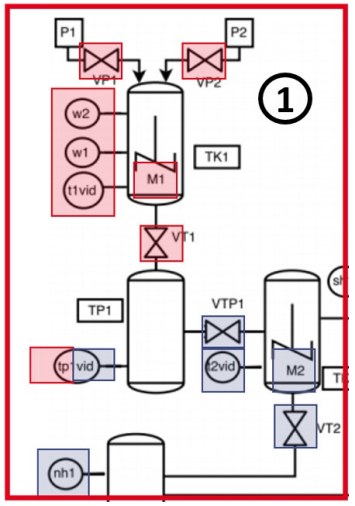


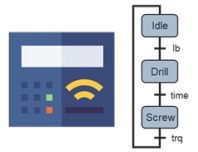
Stable Location Automaton (SLA)

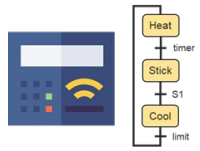
Strong product of graphs



Sub-process 1







SFC

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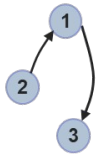
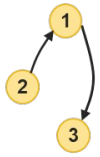
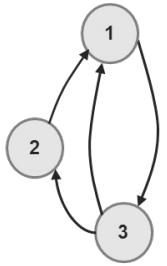
TELOCO





Stable Location Automaton (SLA)

Strong product of graphs



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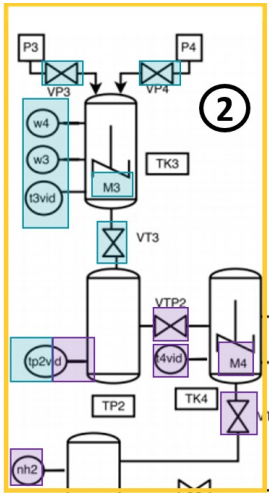
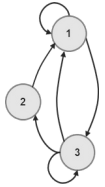
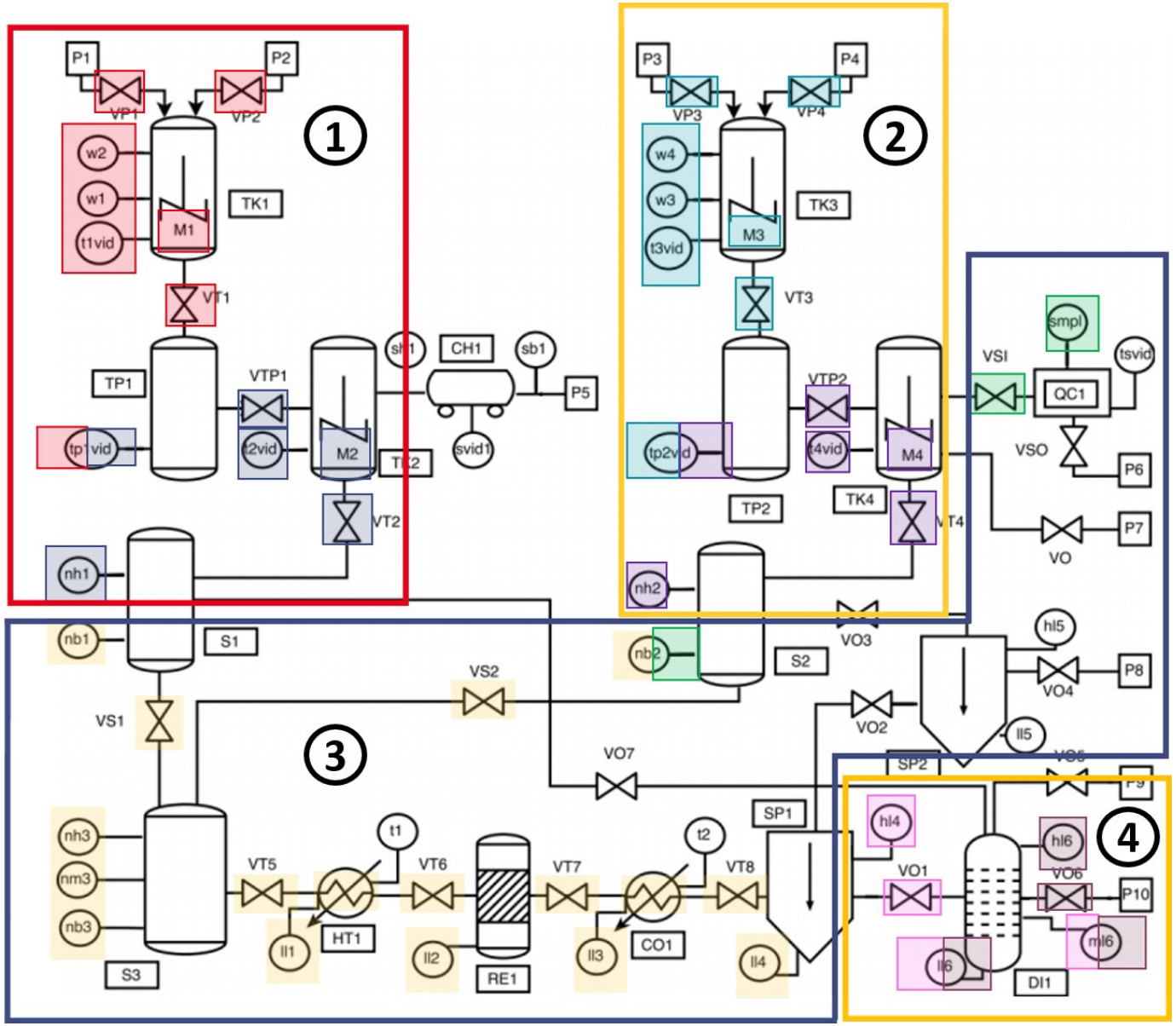
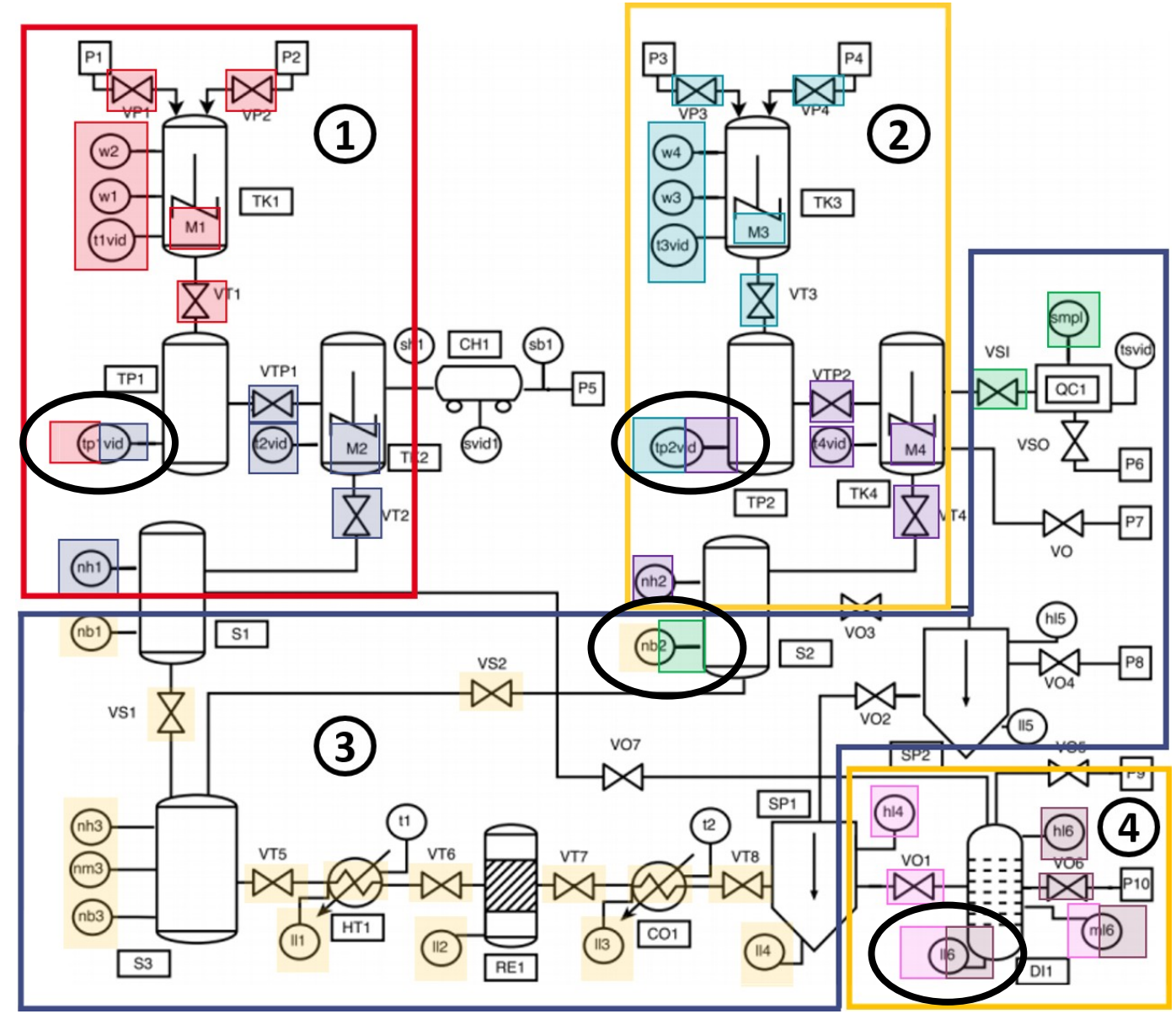


Model Building





Model Building



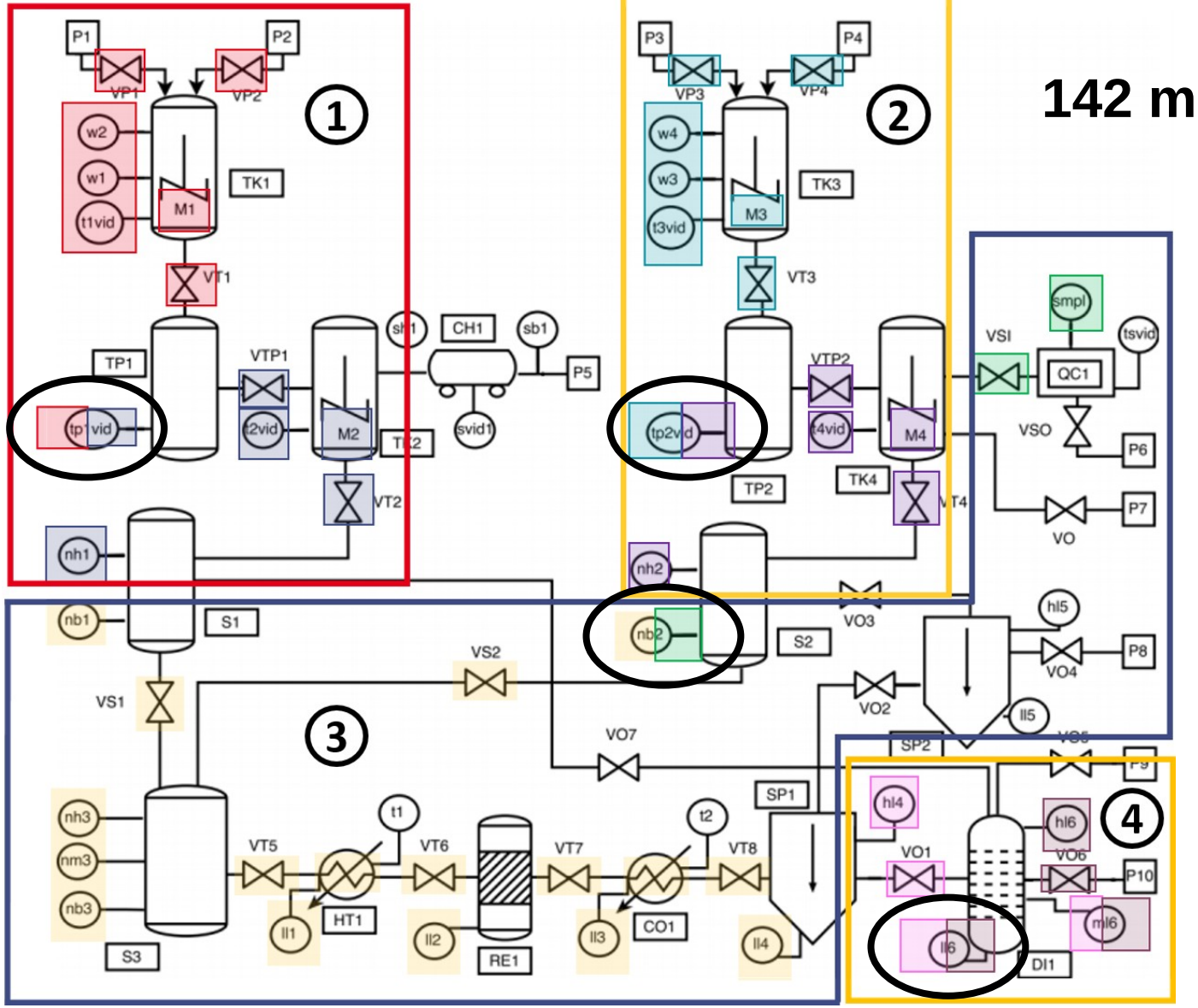
Model Building

156 ms

142 ms

319 ms

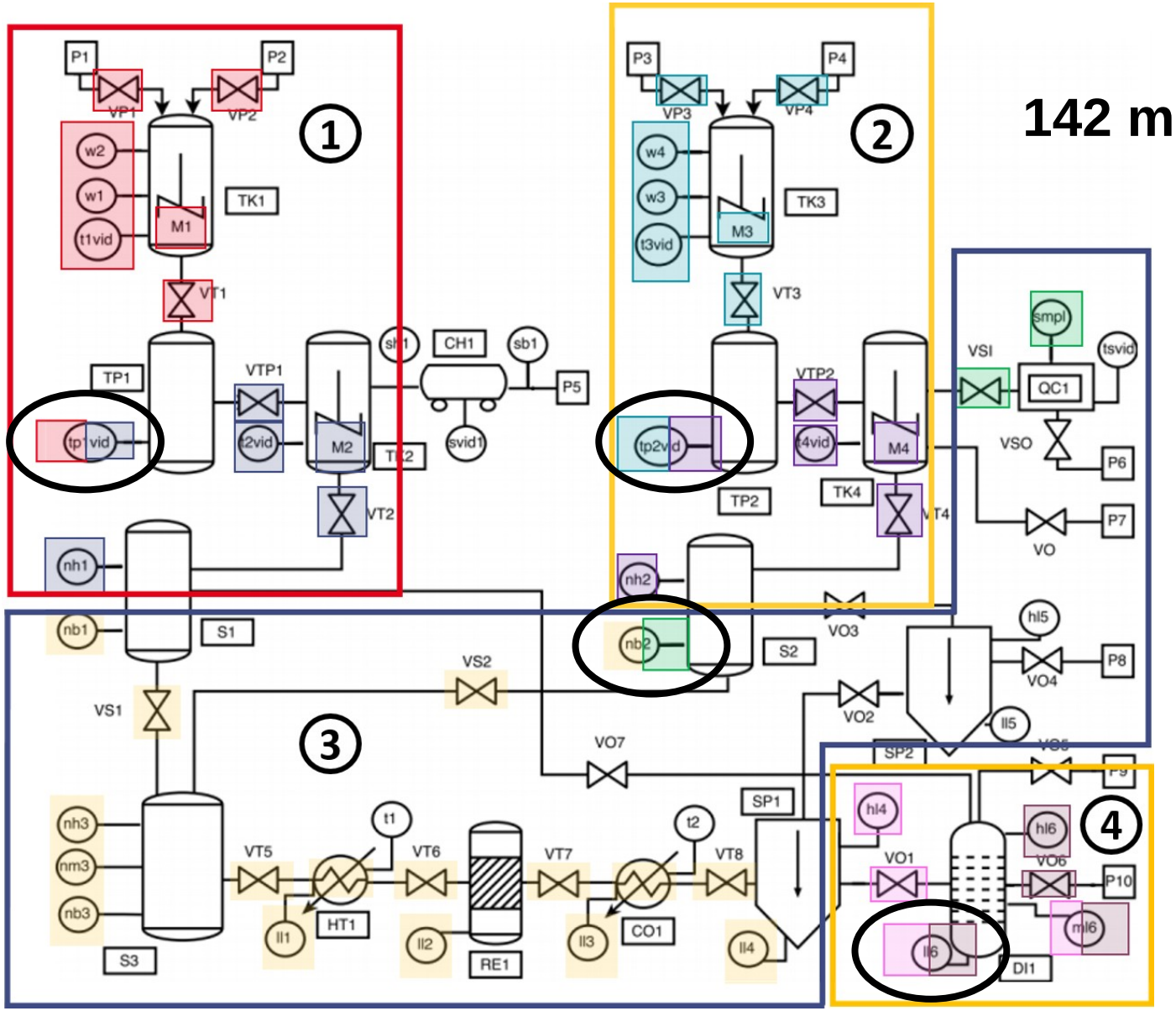
133 ms



Model Building

156 ms

142 ms



156 ms

Global = 750 ms

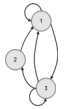
319 ms

133 ms

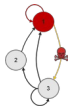
Contents

Identifying Cybersecurity Risk for System Safety

PLC-Logic Based Cybersecurity Risk Identification

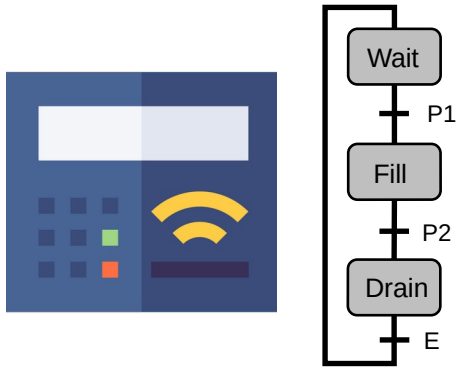


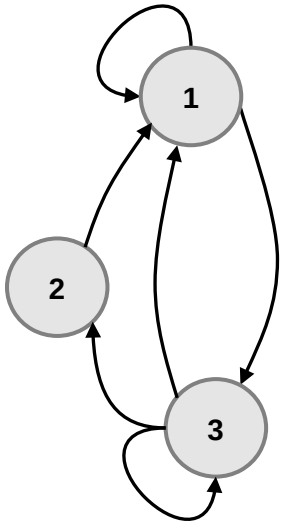
Model building

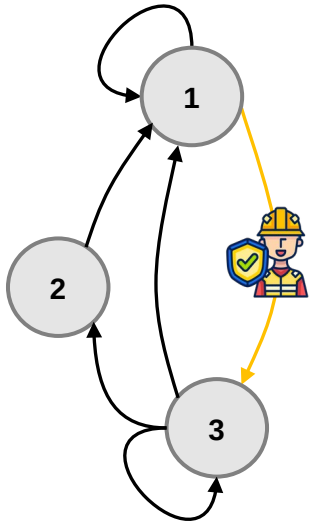


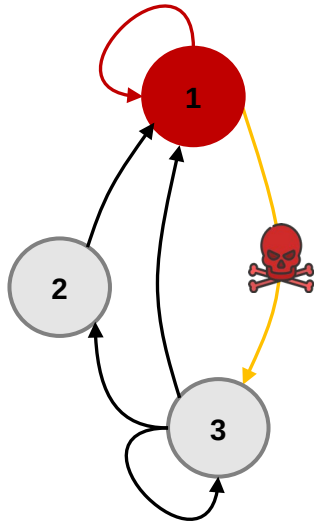
Threat model application

PLC-Logic Based Cybersecurity Risk Identification



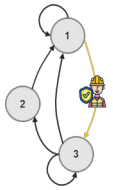




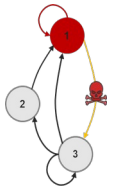


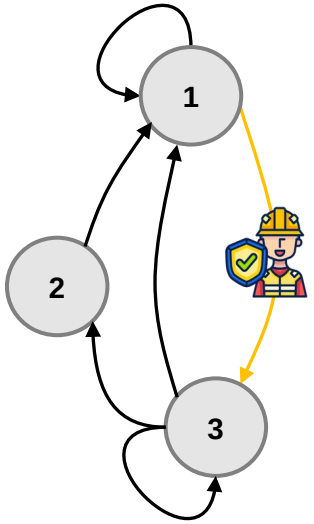
PLC logic **System model** **Safety** **Attack scenarios**

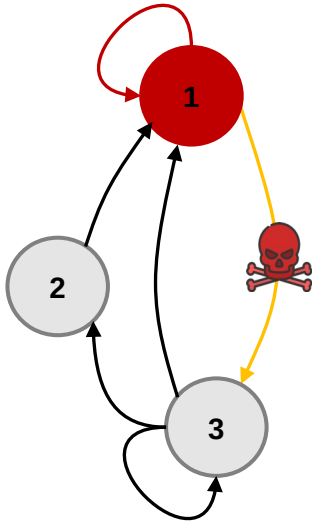
Model building **Threat model application**



Threat model application

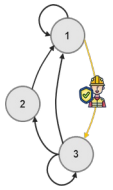






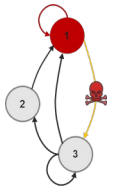
Safety **Attack scenarios**

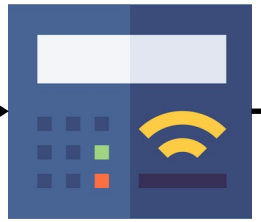
Threat model application



Threat model application

Threat model



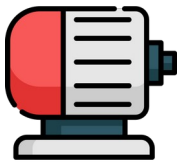


Sensors measurement

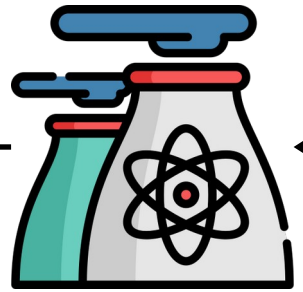
Actuators command

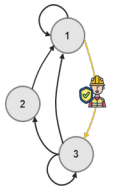
System state* → Command

Limit state → Protective command



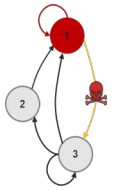
*Sensors measurement (inputs) & PLC internal variables



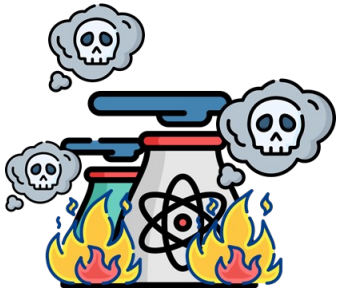


Threat model application

Threat model



Process Hazard Analysis (PHA)

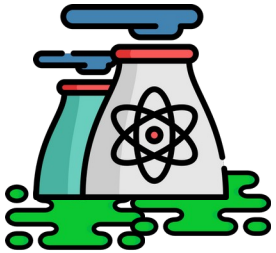


Sensor A & Actuator 1

Sensor A /Actuator 1

(Sensors B & /C) & /Actuator 2

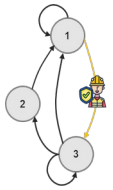
Sensors B & /C Actuator 2



Sensor D & (Actuators 3 | 4)

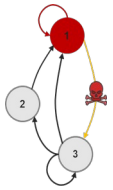
Sensor D /Actuator 3 & /Actuator 4

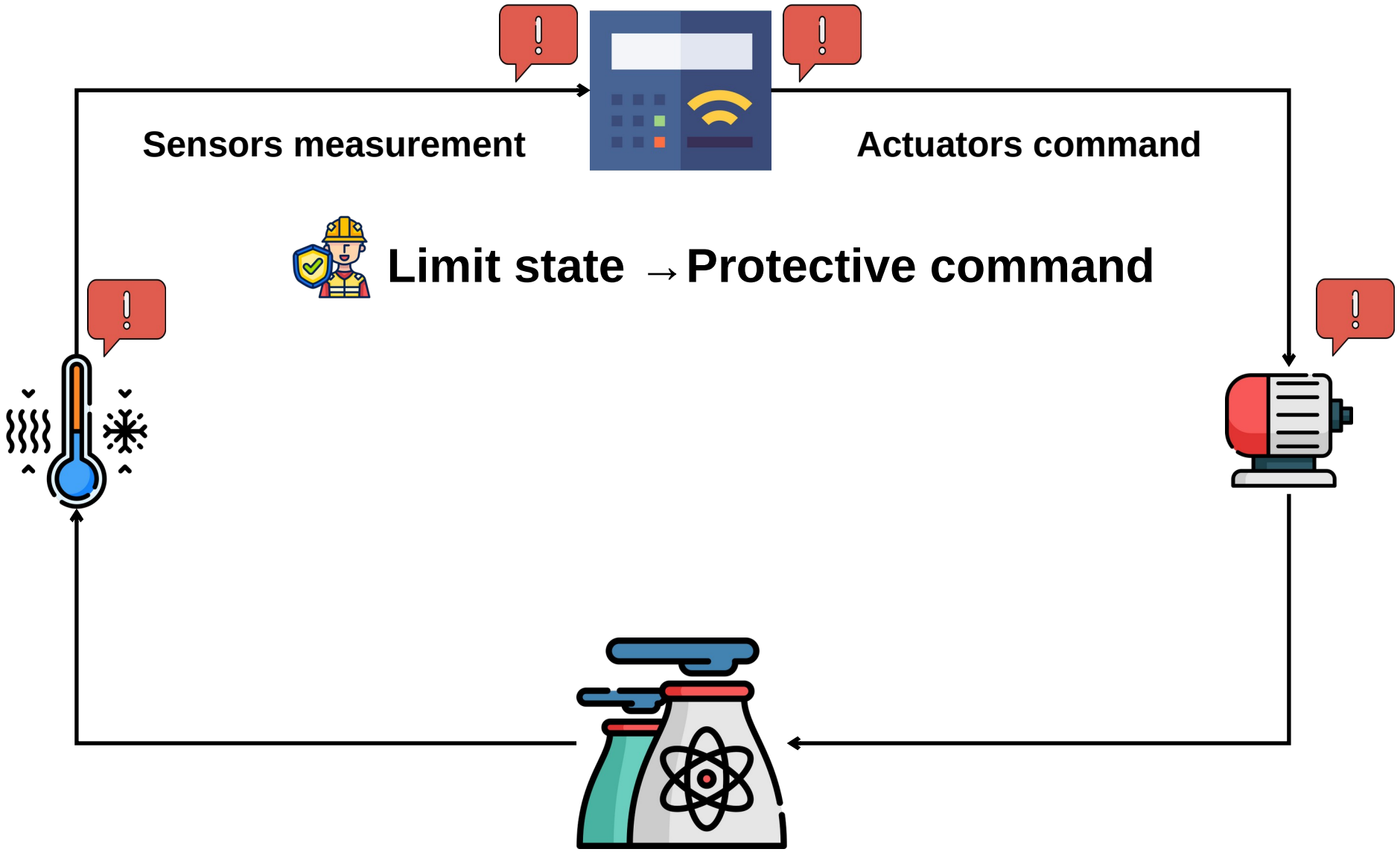
Limit state → Protective command

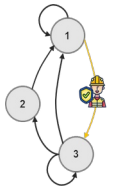


Threat model application

Threat model

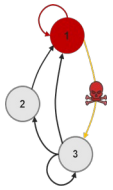


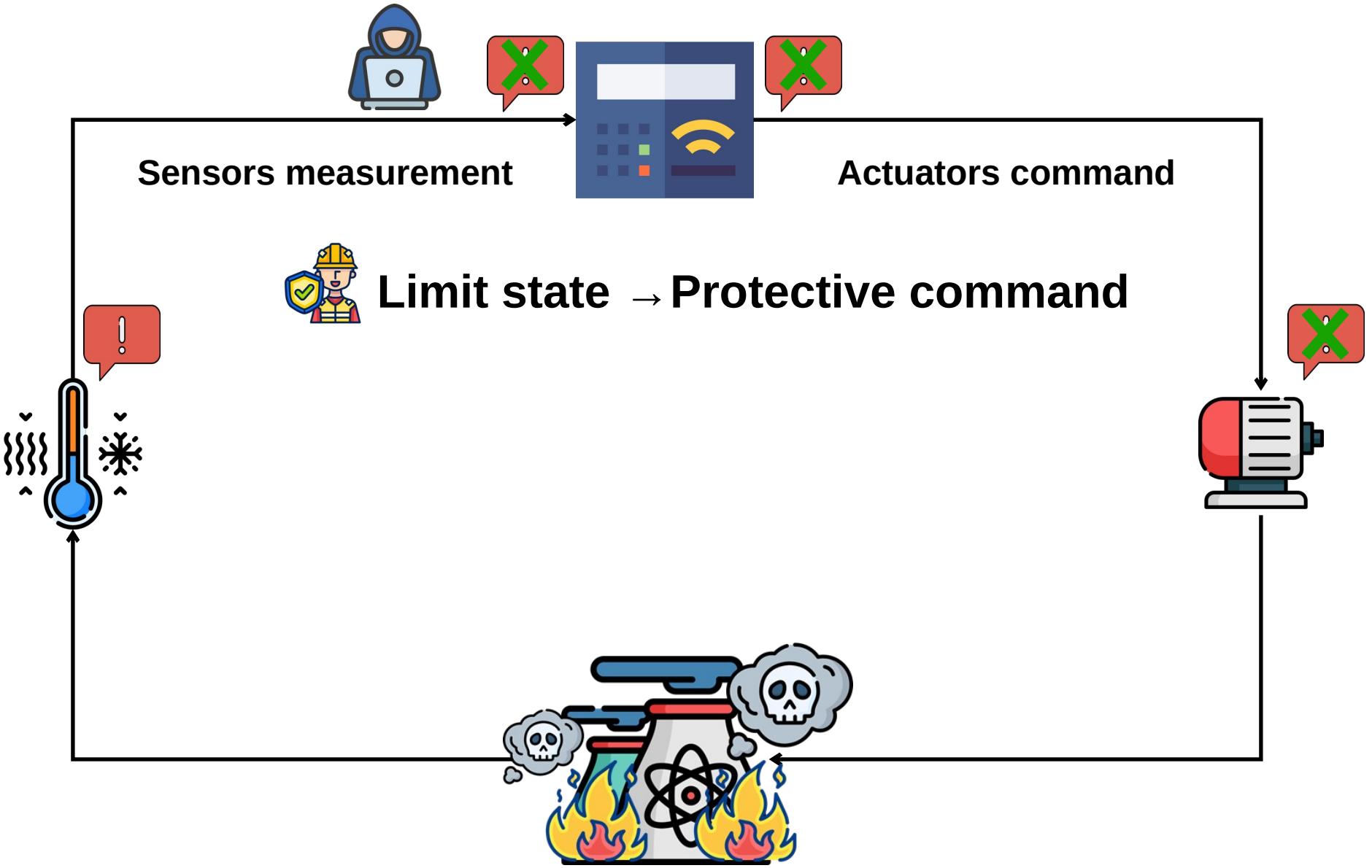


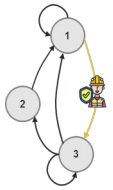


Threat model application

Threat model

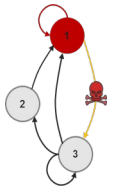


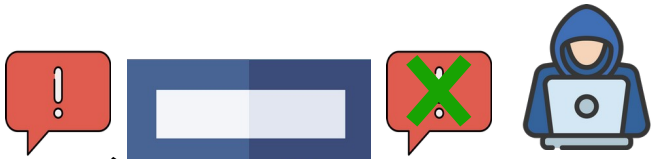




Threat model application

Threat model

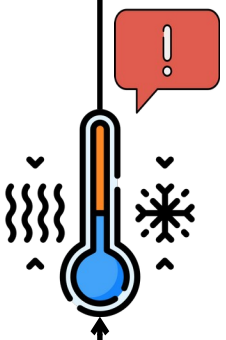


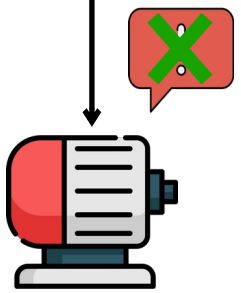


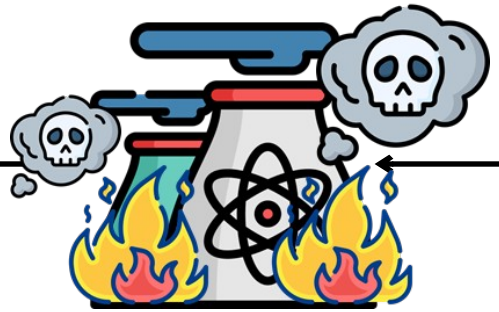
Sensors measurement

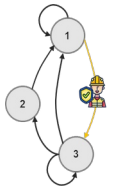
Actuators command

Limit state → Protective command



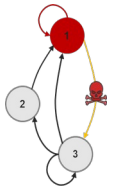


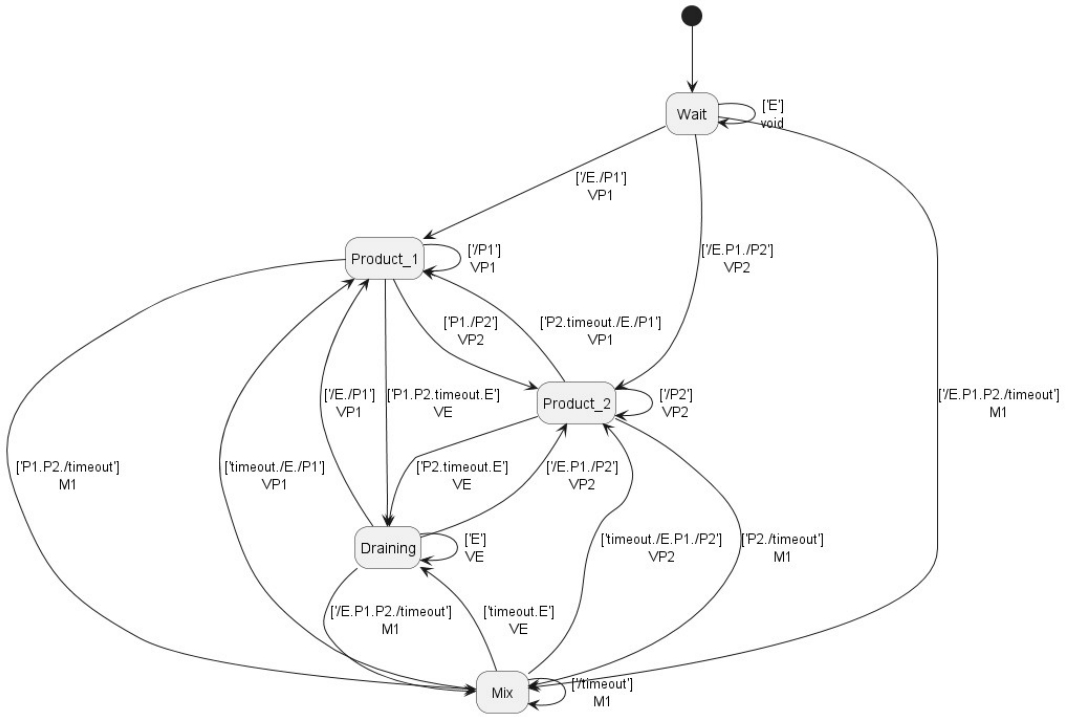


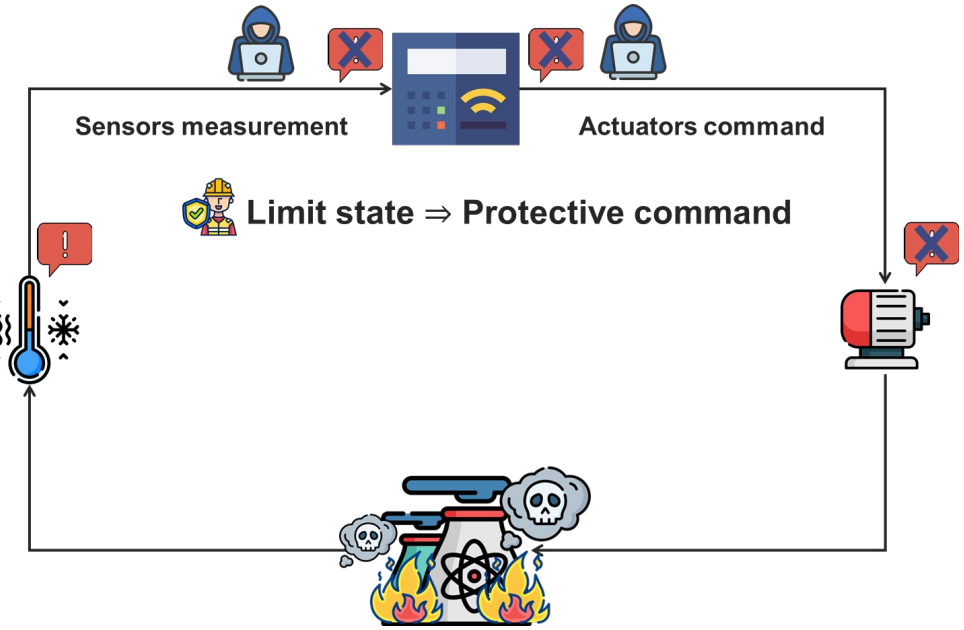


Threat model application

Application







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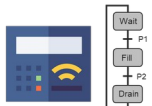
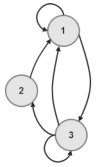
System Model ⟷ **Threat Model**

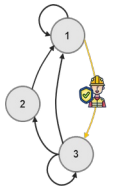
Threat model application



PLC logic

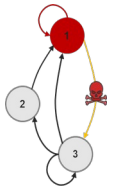


System model



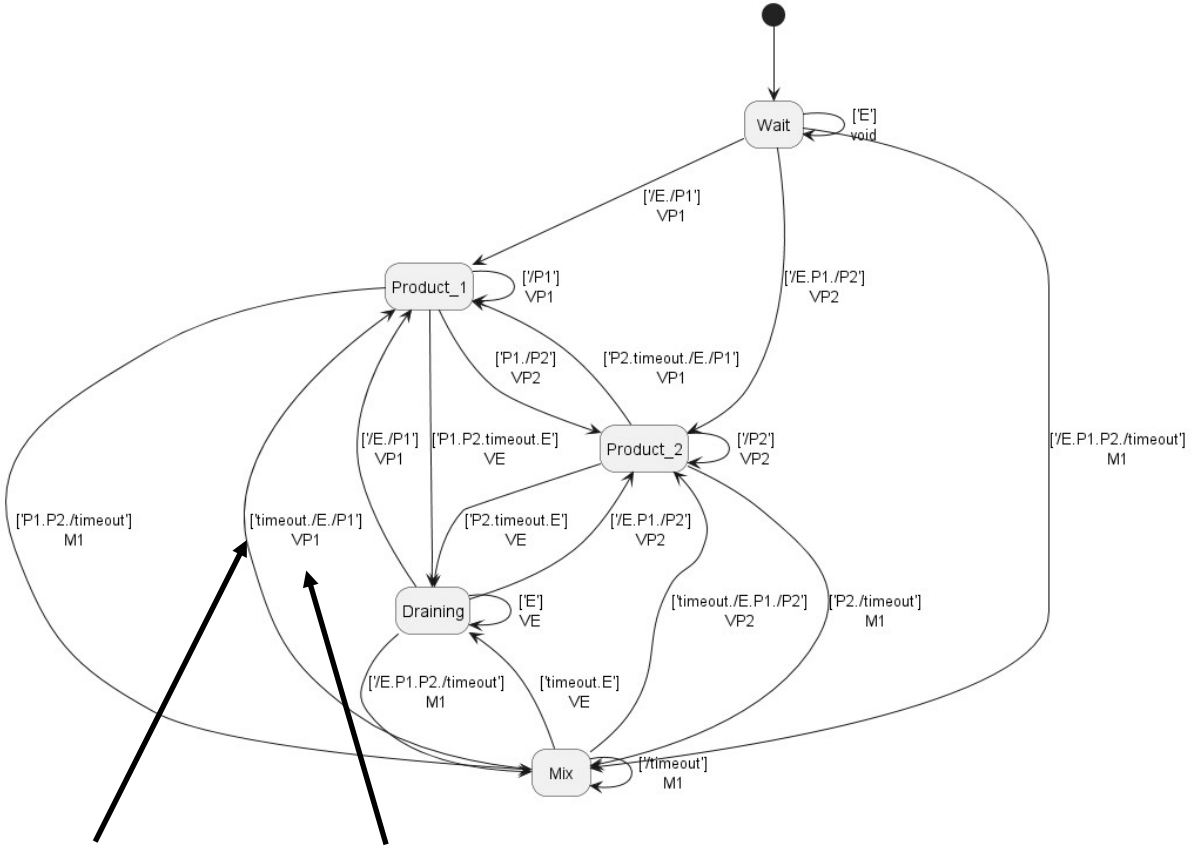
Threat model application

Application



Inputs ⟹ Outputs

Limit state → Protective command

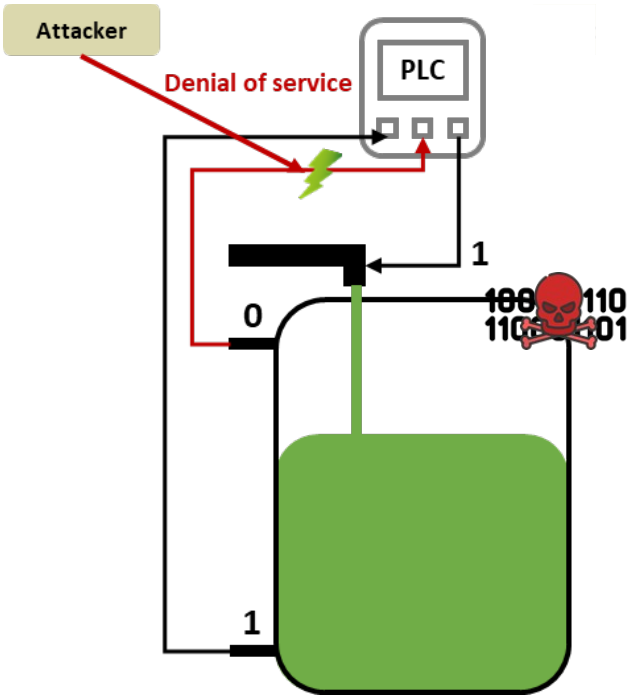


Inputs ⟹ Outputs ➡ SLA transition

Threat model application

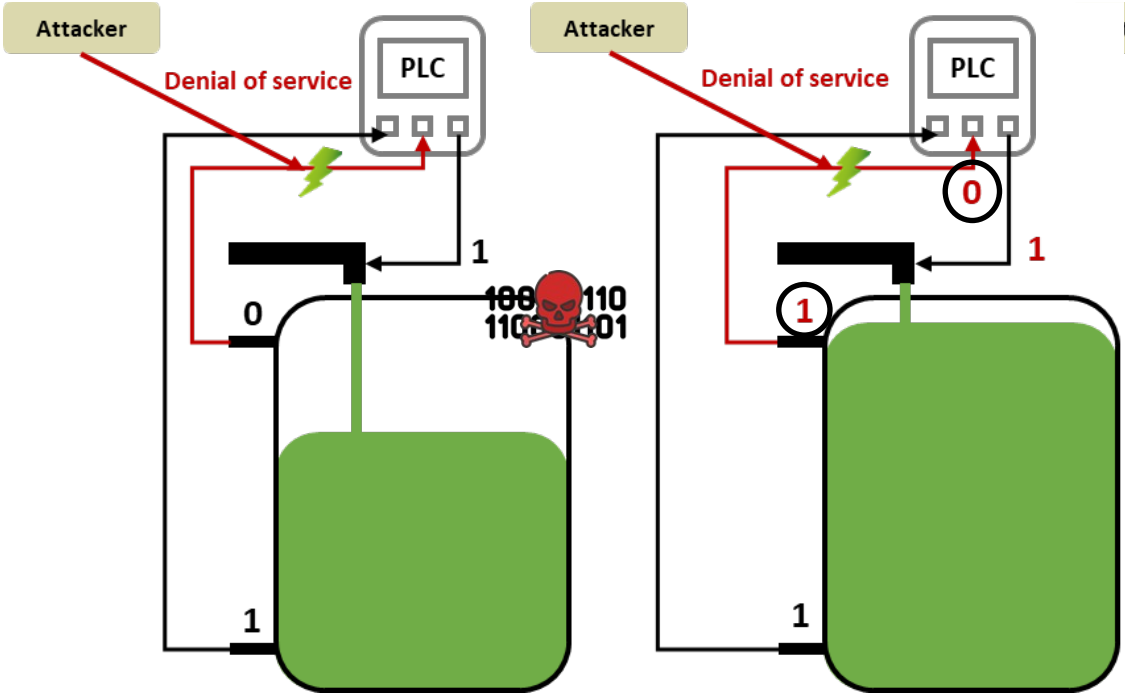
Application

Block a state change



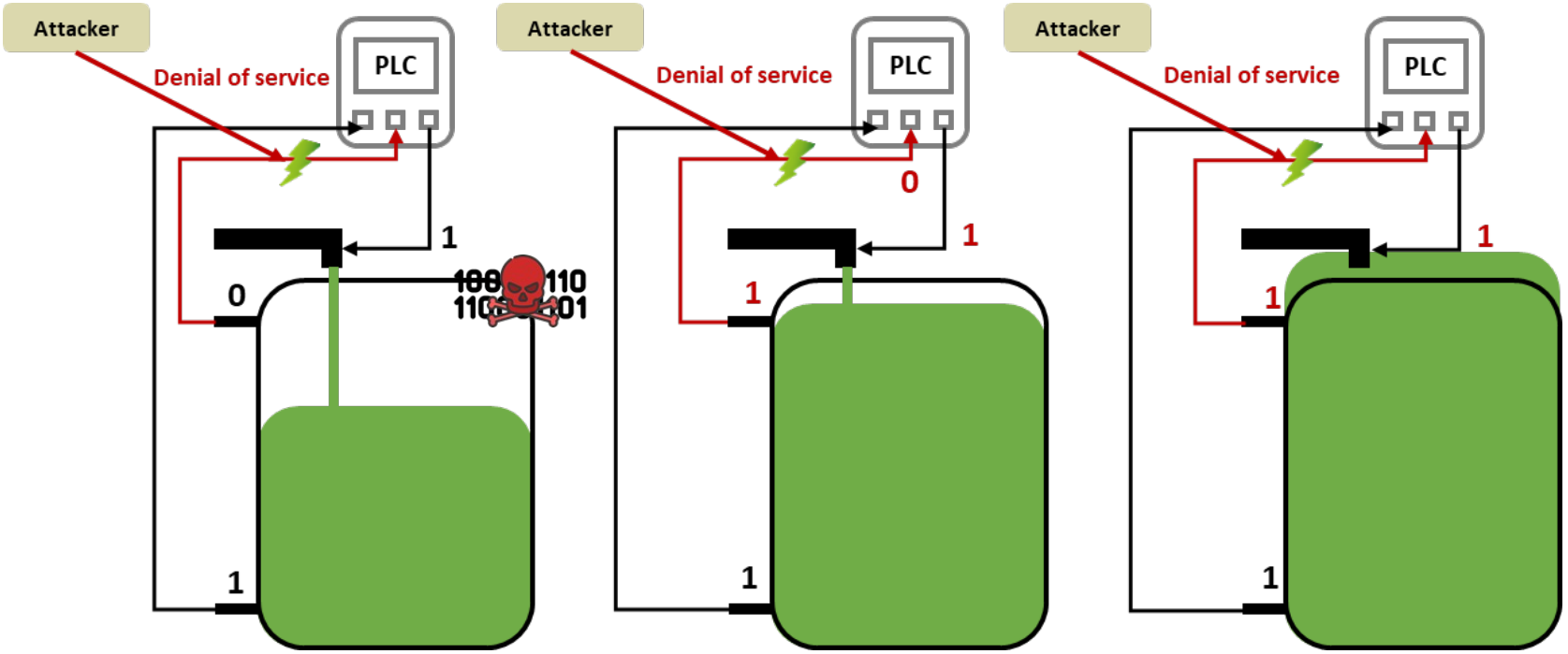
Threat model application
Application

Block a state change



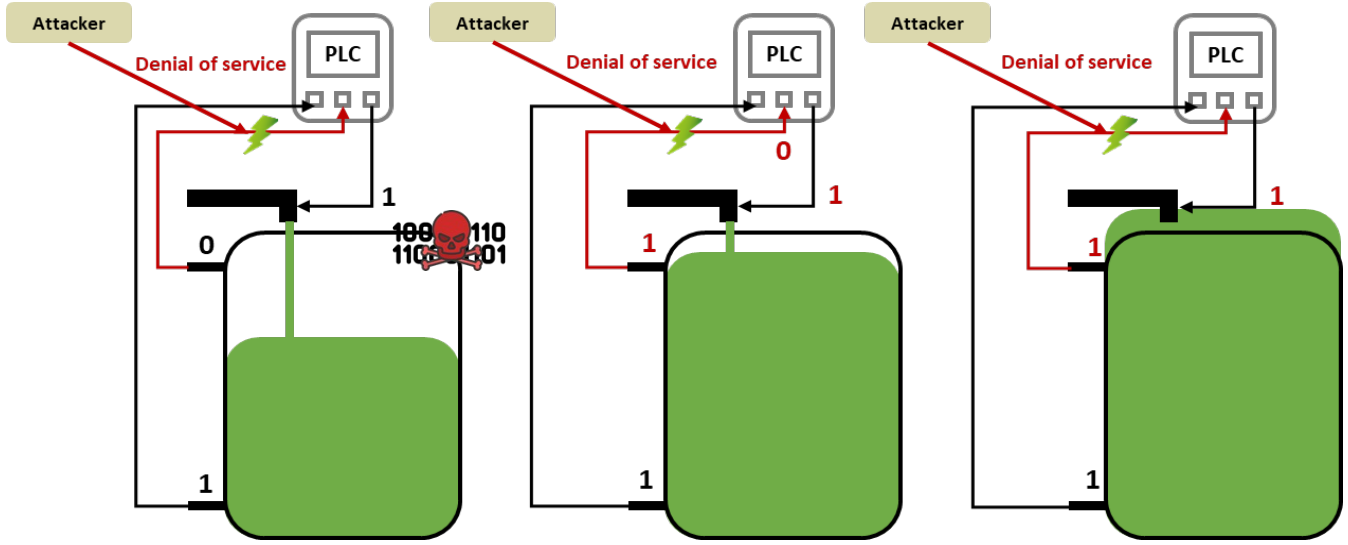
Threat model application
Application

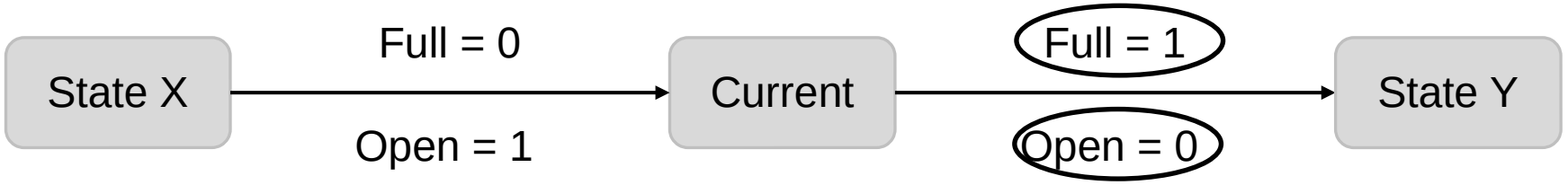
Block a state change



Threat model application
Application

Block a state change

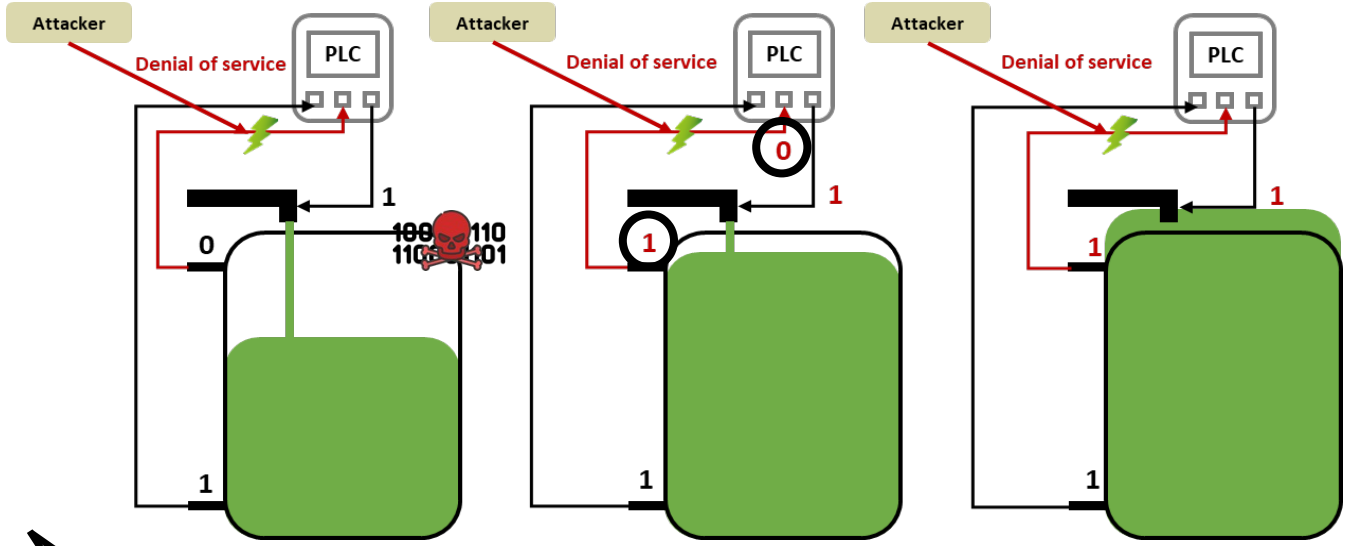




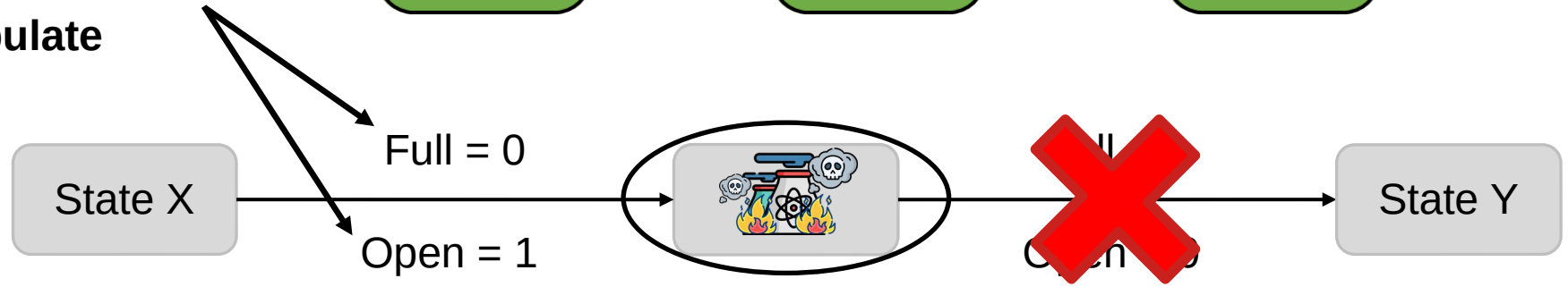
Limit state ⇒ Protective command

Threat model application
Application

Block a state change



Variables to manipulate

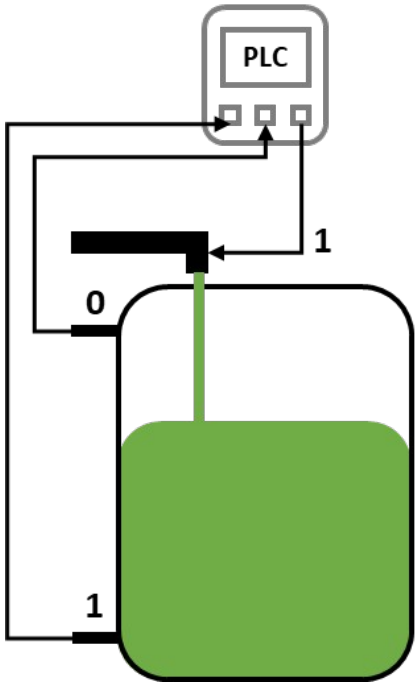


Limit state ⇒ Protective command

Threat model application

Application

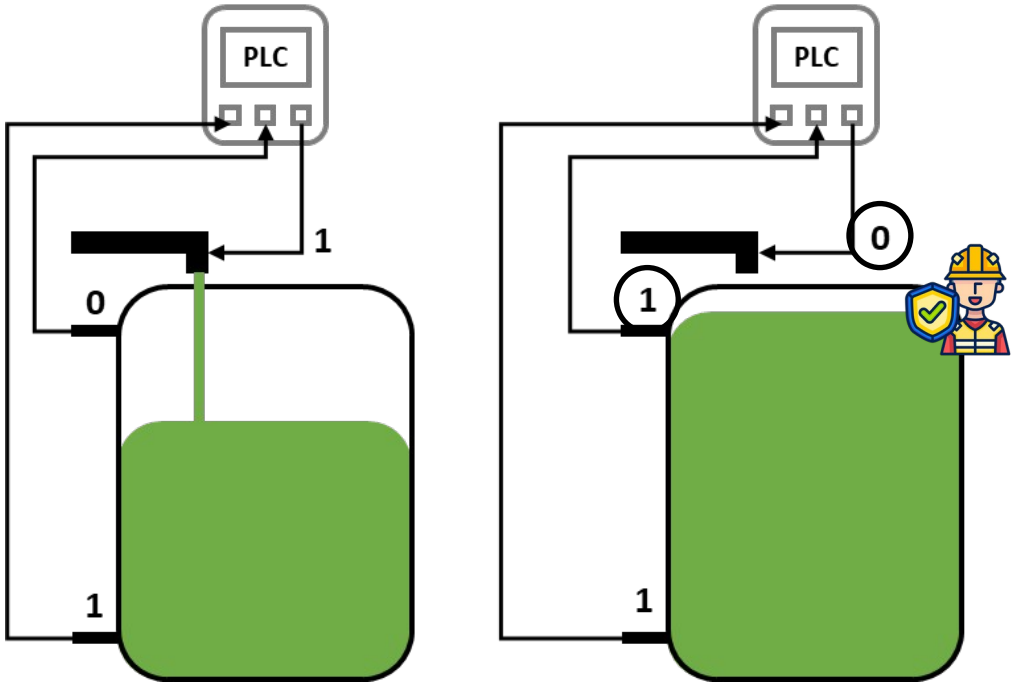
Force a state change



Threat model application

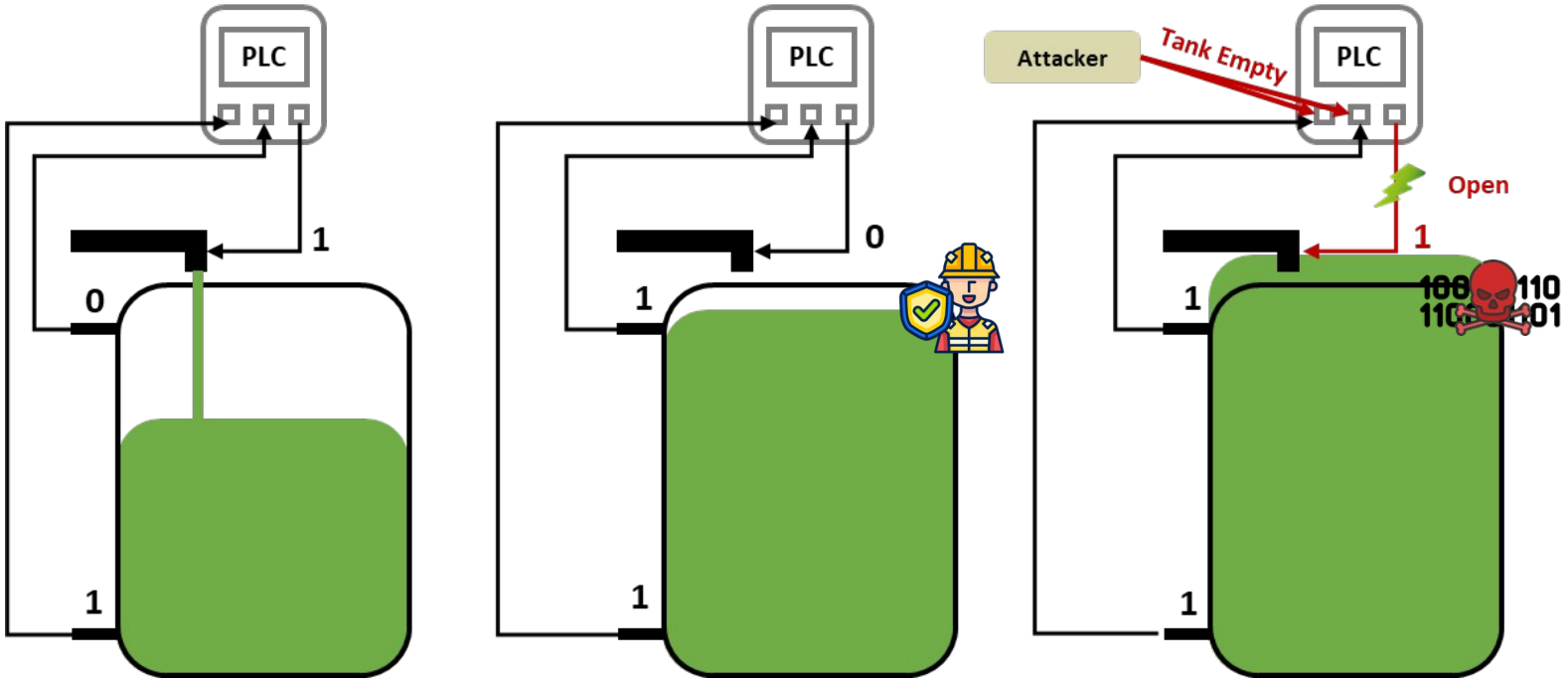
Application

Force a state change



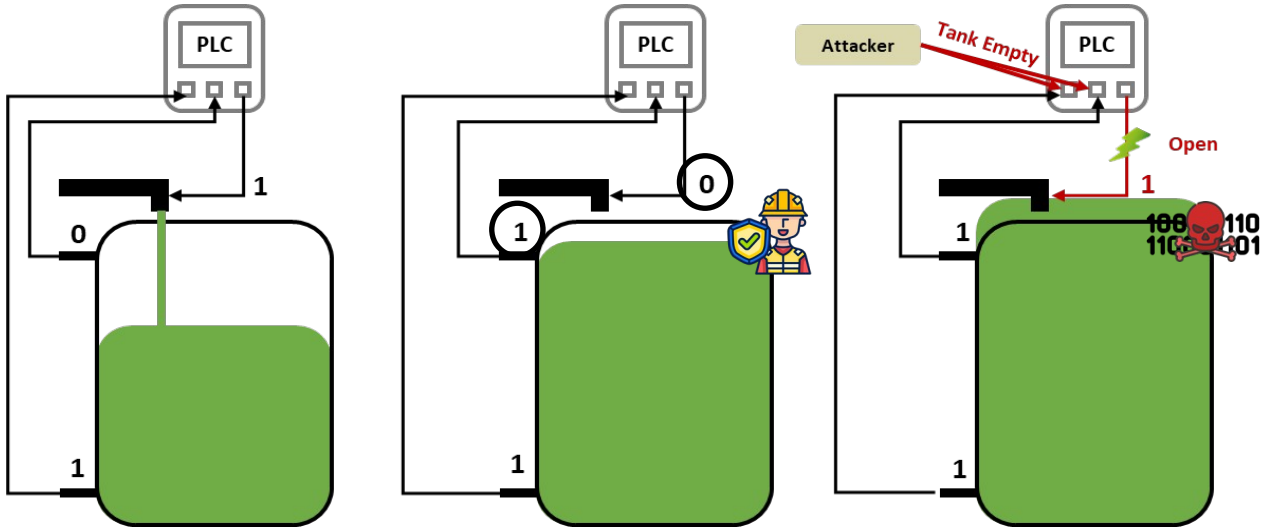
Threat model application
Application

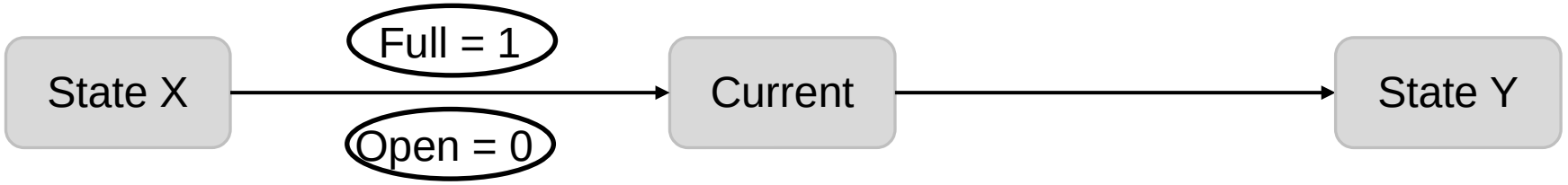
Force a state change



Threat model application
Application

Force a state change

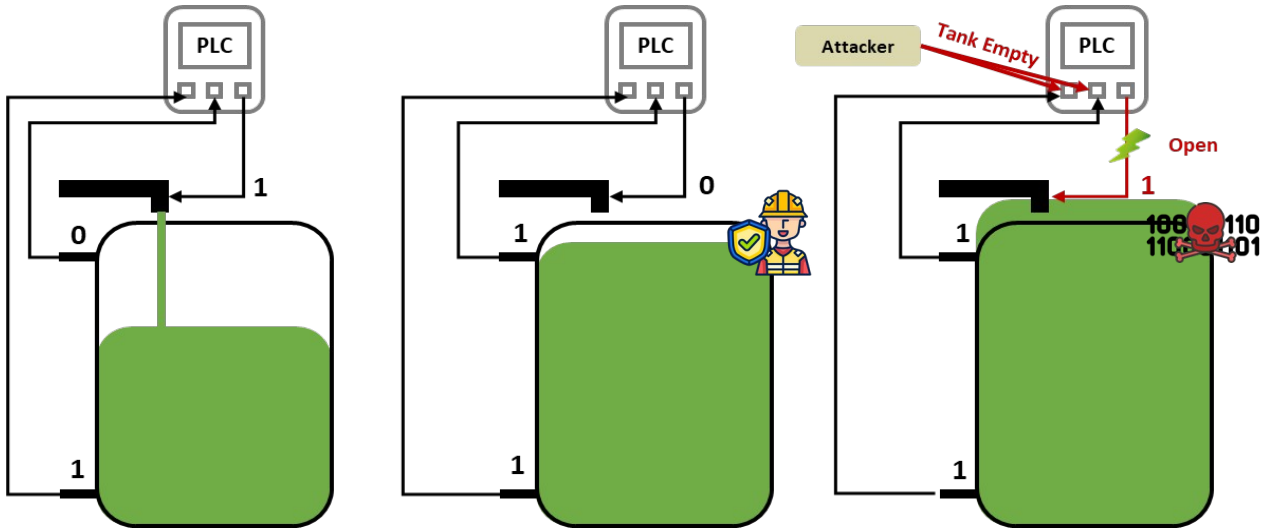




Limit state ⇒ Protective command

Threat model application
Application

Force a state change



Variables to manipulate

State X

Full = 1

Open = 0

Current

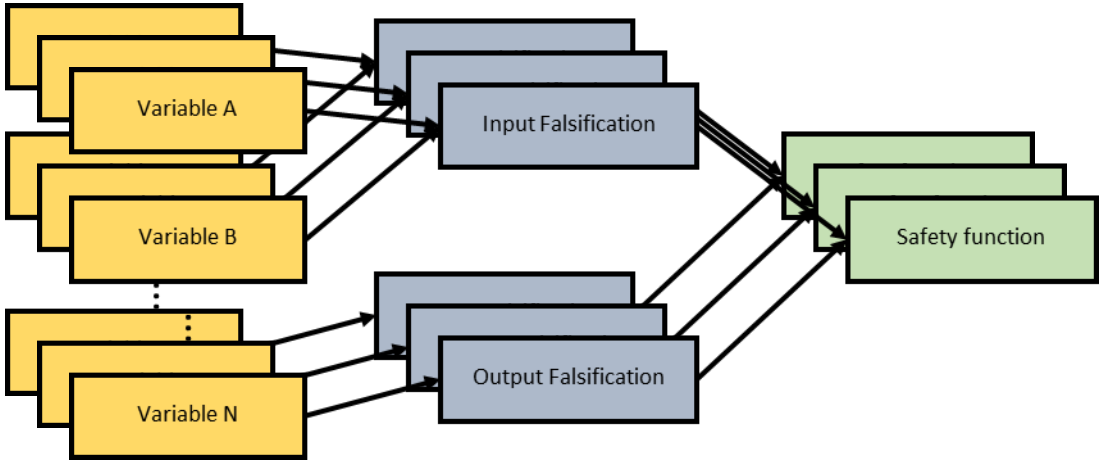
Full = 0

Open = 1

Limit state ⇒ Protective command

Threat model application

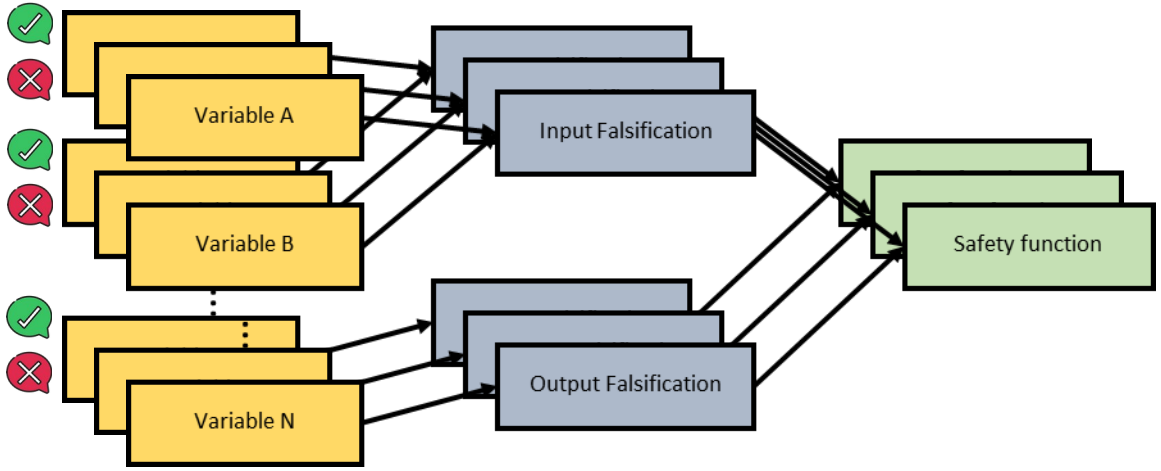
Application



Theoretical Attack Scenarios

Threat model application
Application

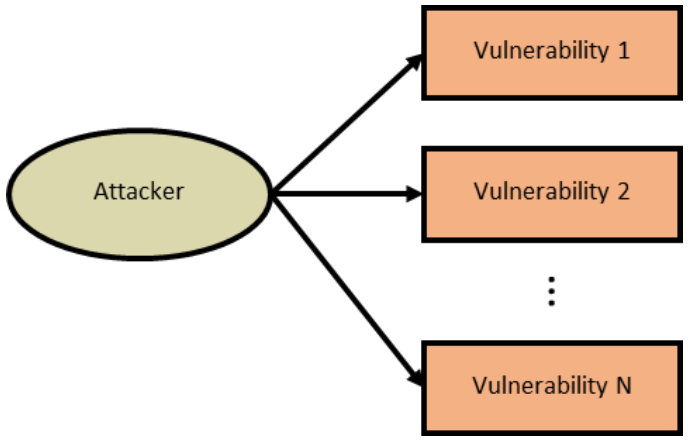
Realizable?



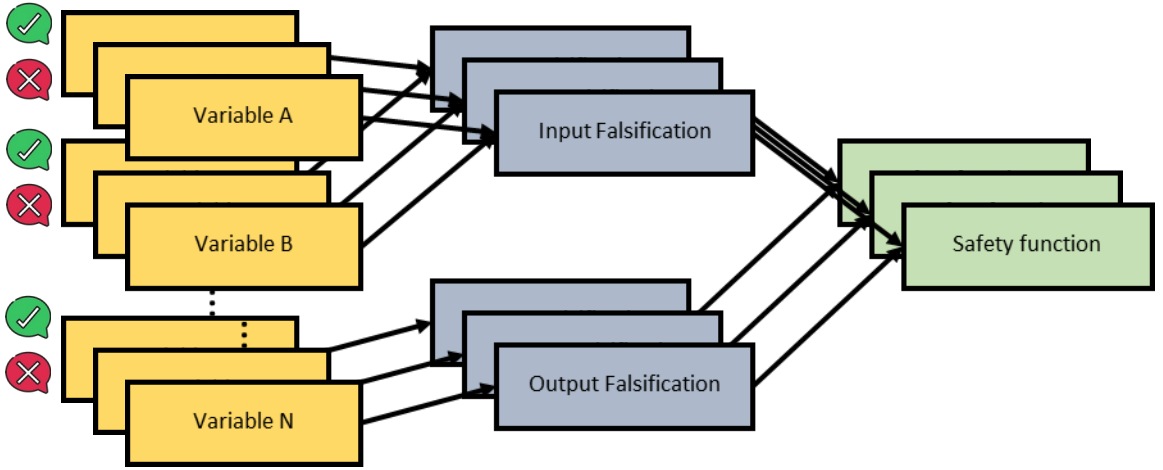
Theoretical Attack Scenarios

Threat model application

Application



Realizable?

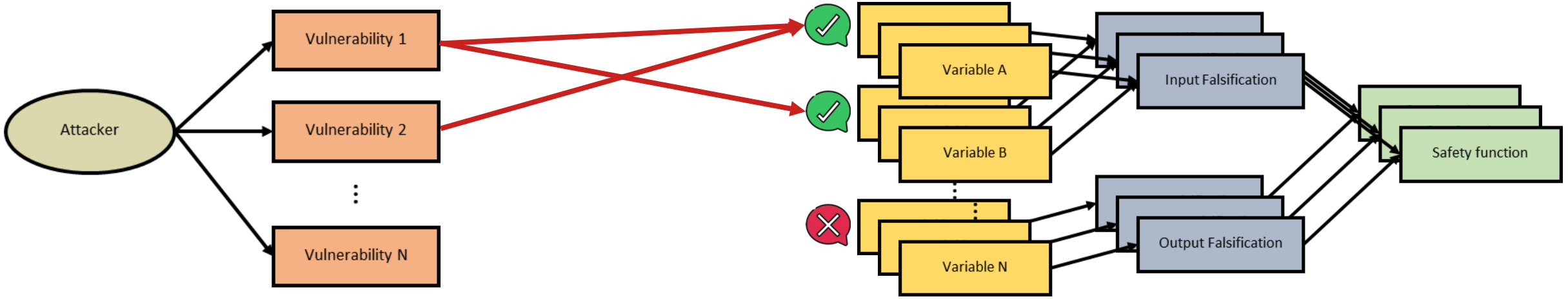


System Vulnerabilities

Theoretical Attack Scenarios

Threat model application

Application

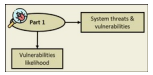


System Vulnerabilities

Theoretical Attack Scenarios

Contents

Cybersecurity Risk Assessment for System Safety



What an attacker can do

What an attacker might do

Is it serious ?

Identifying Cybersecurity Risk for System Safety

Literature Review & Classification

PLC-Logic Based Cybersecurity Risk Identification

Conclusion and perspectives

Conclusion & Perspectives

→ **Main Goal: Predict impacts of cyberattacks on safety**
  → *“Is this cyberattack impacting the real world?”*

→ **Attempts to model large industrial control systems**
  → Still facing combinatorial explosion
  → But able to represent realistic-ish systems

→ **A very simplified attacker model based on safety protective commands**

Perspectives:

→ **Take into account other PLC program languages (Ladder, FBD, etc) and discrete/continuous variables:**
  → Will most likely involve SMT solvers and optimization techniques
→ **Consider more powerful attacker models:**
  → Not limited to 1 step...
  → Attack trees, Markov chains, Dolev Yao intruder, etc

Thank you for your attention

Picture by tasukaran from Pixabay - Pictograms designed by Freepik - Domino effect icons created by lutfix – Flaticon -State of the art icons created by Three musketeers - Flaticon

Conclusion & Perspectives

International Peer-Reviewed Conferences with Proceedings

M. Da Silva, M. Puys, P.-H. Thevenon, et S. Mocanu, « **PLC Logic-Based Cybersecurity Risks Identification for ICS** », in *Proceedings of the 18th International Conference on Availability, Reliability and Security*, Benevento Italy: ACM, août 2023, p. 1-10. doi: 10.1145/3600160.3605067.

M. Da Silva, M. Puys, P.-H. Thevenon, S. Mocanu, et N. Nkawa, « **Automated ICS template for STRIDE Microsoft Threat Modeling Tool** », in *Proceedings of the 18th International Conference on Availability, Reliability and Security*, Benevento Italy: ACM, août 2023, p. 1-7. doi: 10.1145/3600160.3605068.

International Peer-Reviewed Journals *(under review)*

M. Da Silva, M. Puys, P.-H. Thevenon, et S. Mocanu, **Safety-Security Convergence: Automation of IEC 62443-3-2,** Computers & Security.

National Events (RESSI)

M. Da Silva, M. Puys, P.-H. Thevenon, et S. Mocanu, **Automatisation de l'analyse des risques de cybersécurité des systèmes industriels**. In *Rendez-Vous de la Recherche et de l'Enseignement de la Sécurité des Systèmes d'Information, RESSI 2022, Chambon-sur-Lac, France*, 2022.

M. Da Silva, M. Puys, P.-H. Thevenon, et S. Mocanu, **Convergence sûreté-sécurité des Systèmes de Contrôle Industriel**. In *Rendez-Vous de la Recherche et de l'Enseignement de la Sécurité des Systèmes d'Information, RESSI 2024, Eppe-Sauvage, France*, 2024.

Patent

Mike Da Silva, Pierre-Henri Thevenon, Maxime Puys, Stéphane Mocanu. **Procédé et dispositif d'identification des risques de cyberattaques**. France, N° de brevet: FR3144328. 2024. **Method and device for identifying risks of cyberattacks**. United States, Patent n° : US20240211607A1. 2024.