Kaspersky Industrial Cybersecurity Conference 2019

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Validating defense mechanisms of cyber-physical systems via attack tools

Francisco Furtado

Salimah Liyakkathali

SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN

iTrust Centre for Research in Cyber Security

Agenda

iTrust

Cyber physical attacks & defense

A6 Tool

Demo

Findings & Conclusion

WHO WE ARE

FUNDING

NATIONAL RESEARCH FOUNDATION
PRIME MINISTER'S OFFICE
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ADSC

WHO WE ARE

FOCUS AREAS

CPS

Enterprise Security

IoT

iTrust
Centre for Research in Cyber Security

DISTINCTIVE VALUES

Applied Research

Testbeds

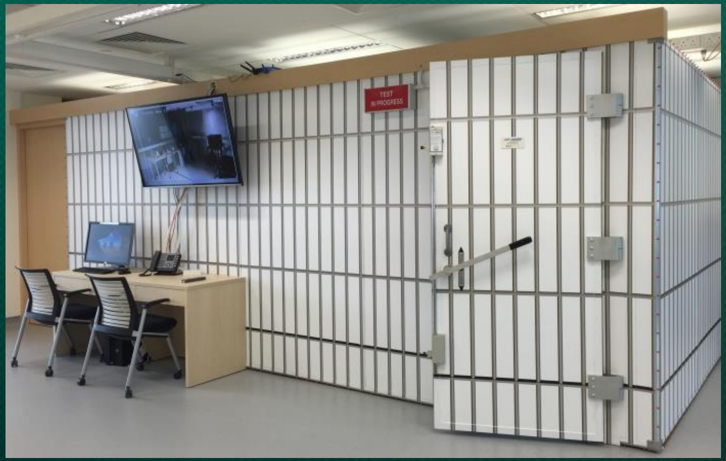
Multi-disciplinary

Students

Industry Collaboration

TESTBEDS

(IoT) Automatic Security



Secure Water Treatment (SWaT)

Electric Power and Intelligent Control (EPIC)

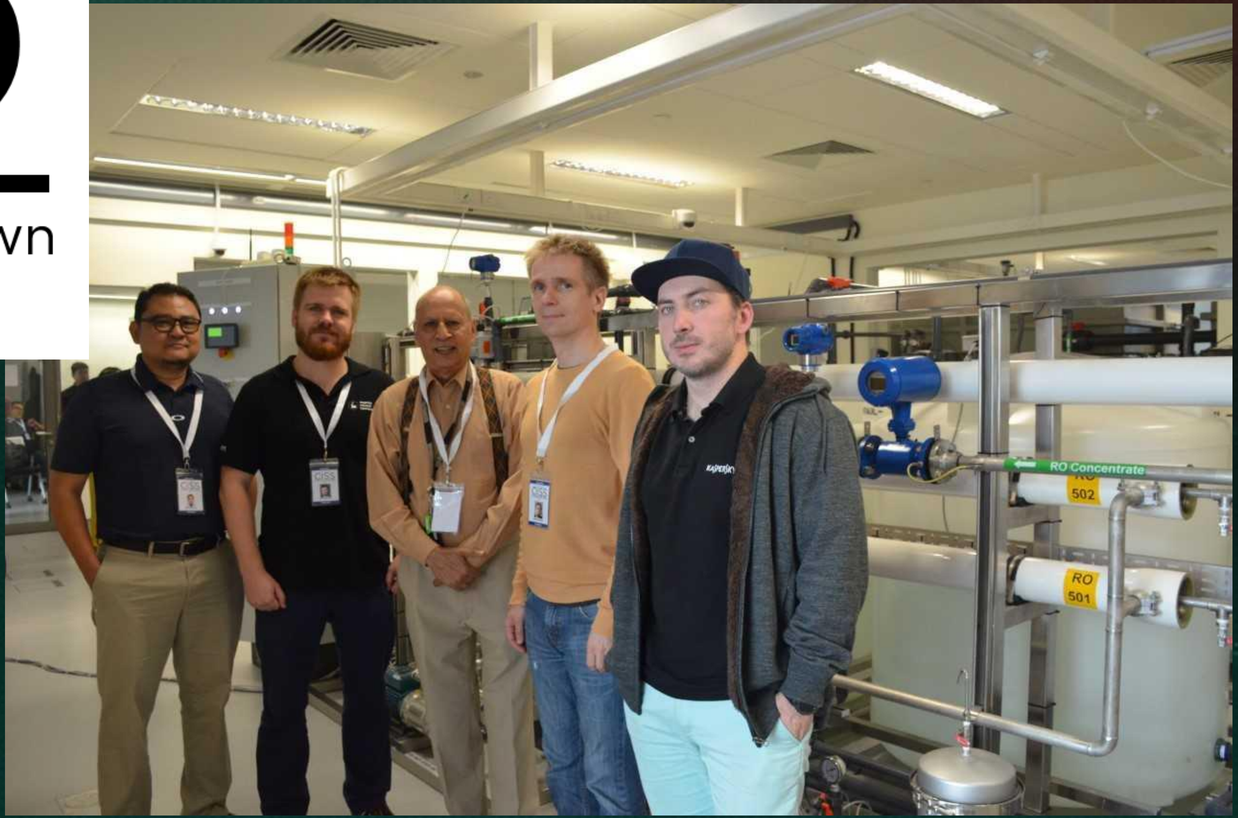
Water Distribution (WADI)

iTrust Event

CISS

Critical Infrastructure Security Showdown

2019



Cyber physical attacks

Maroochy shire sewage

Blaster worm

13 US auto plants

Offshore oil platform

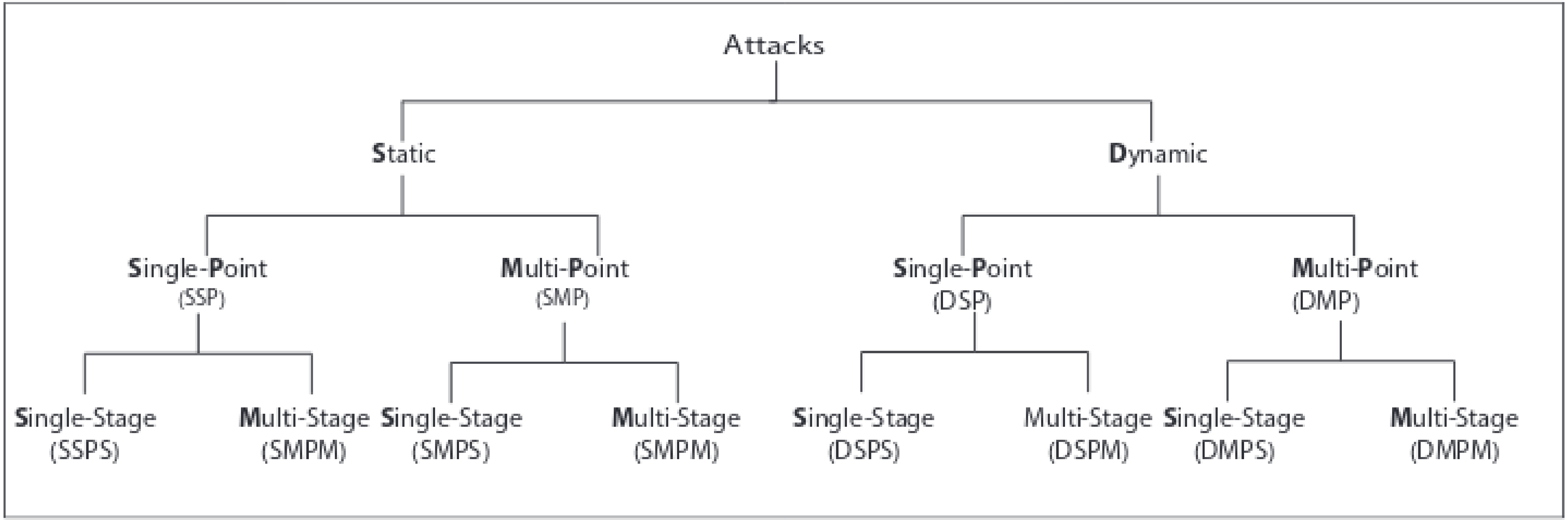
Petro chemical plant

Discovery of Stuxnet

Ukraine power grids

TRITON attack

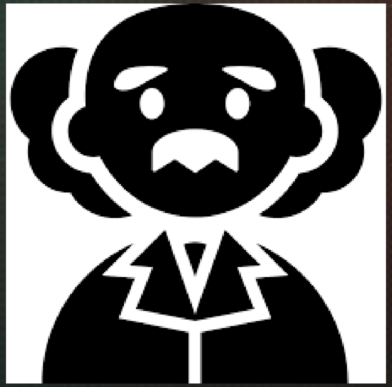
Attacks in ICS

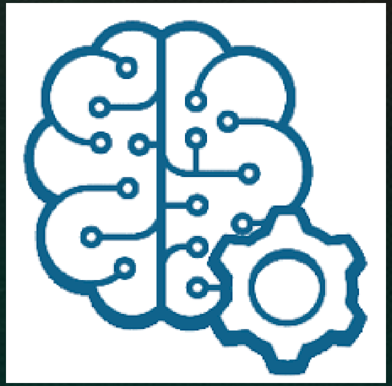


Goh, Jonathan, et al. "A dataset to support research in the design of secure water treatment systems." *International Conference on Critical Information Infrastructures Security*. Springer, Cham, 2016.

Cyber physical defence mechanism

- Anomaly Detection Mechanisms (ADM)
  - Design-based
  - Machine learning-based





Distributed Attack Detection (DAD)

- Design based ADM
- Uses invariants obtained from plant design
- Invariants cannot be compromised
- Attacks: 56 , Detected: 45

EFFECTIVENESS OF DAD IN DETECTING ATTACKS

Experiments	Attack Type	Attacks	Detected
Exp-A	SS	10	10
	SM	5	5
	DS	3	5
	DM	2	2
	Total	**20**	**20**
Exp-I	SS	11	9
	SM	1	1
	SS: Physical	1	1
	DoS (HMI)	3	0
	DoS (SCADA)	1	0
	DoS (PLC-HMI)	1	0
	Total	**18**	**11**
Exp-S	S1 (SS)	4	0
	S2 (SS)	13	13
	Total	**17**	**13**
Exp-DoS	DoS (PLC)	1	1
	Total	**1**	**1**

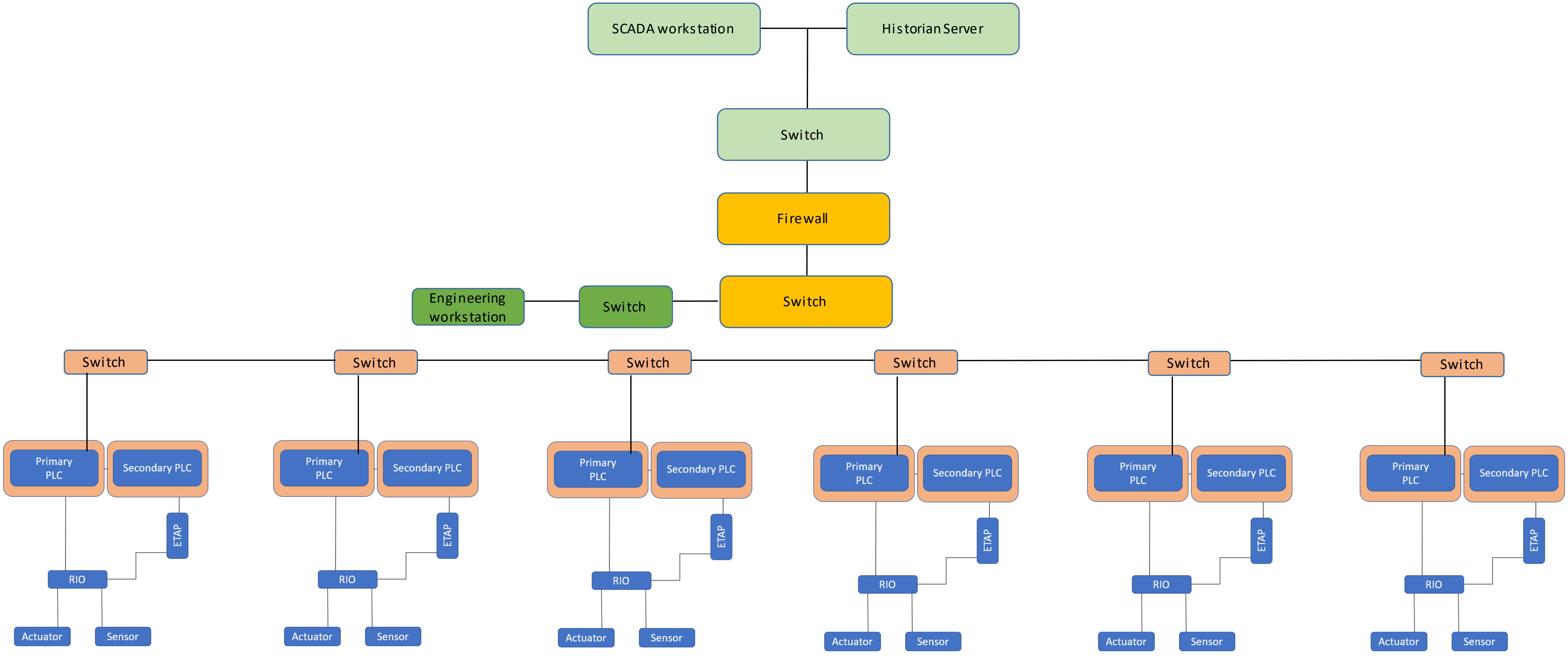
Sridhar Adepu, and Aditya Mathur. "Distributed detection of single-stage multipoint cyber attacks in a water treatment plant." *Proceedings of the 11th ACM on Asia Conference on Computer and Communications Security*. ACM, 2016.

Sridhar Adepu, and Aditya Mathur. "Distributed Attack Detection in a Water Treatment Plant: Method and Case Study". *IEEE Transactions on Dependable and Secure Computing,2018*

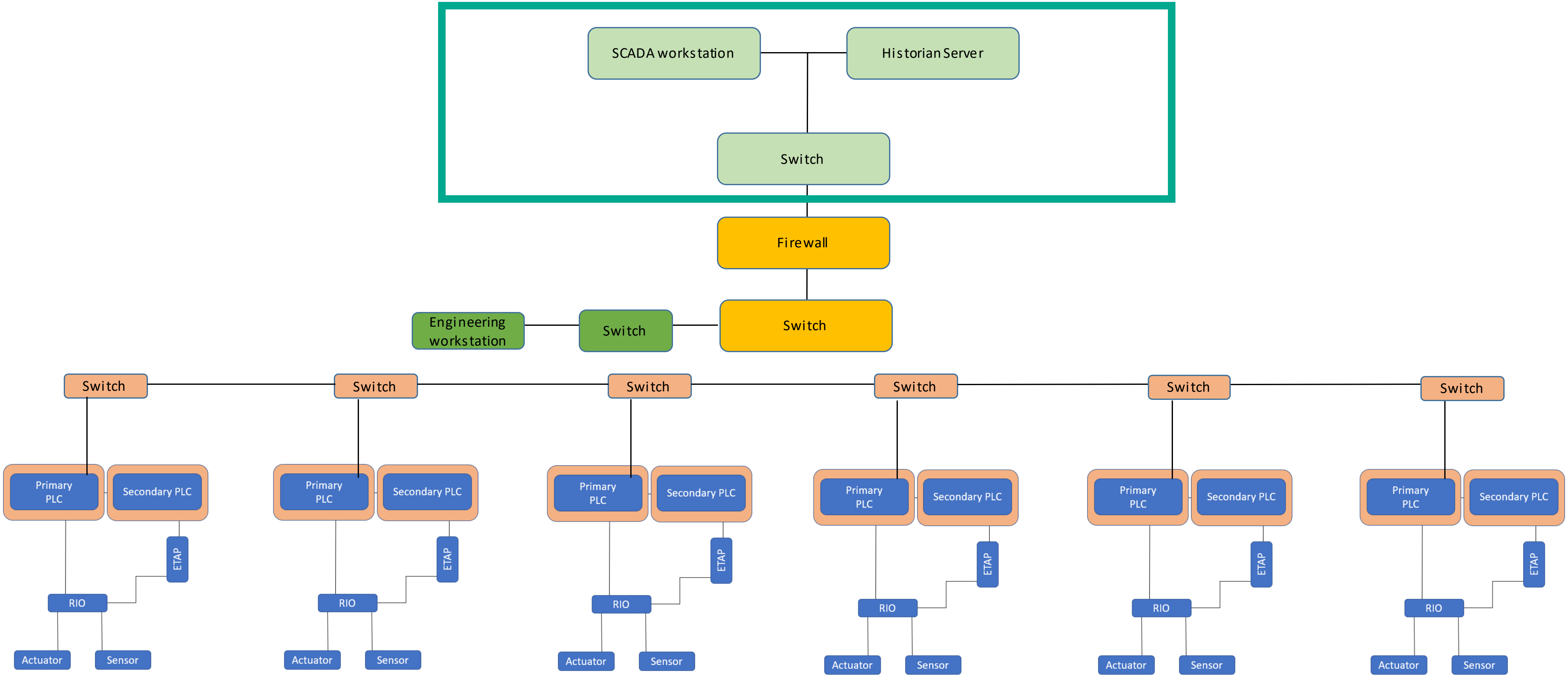
Why is there a need for an

attack tool ?

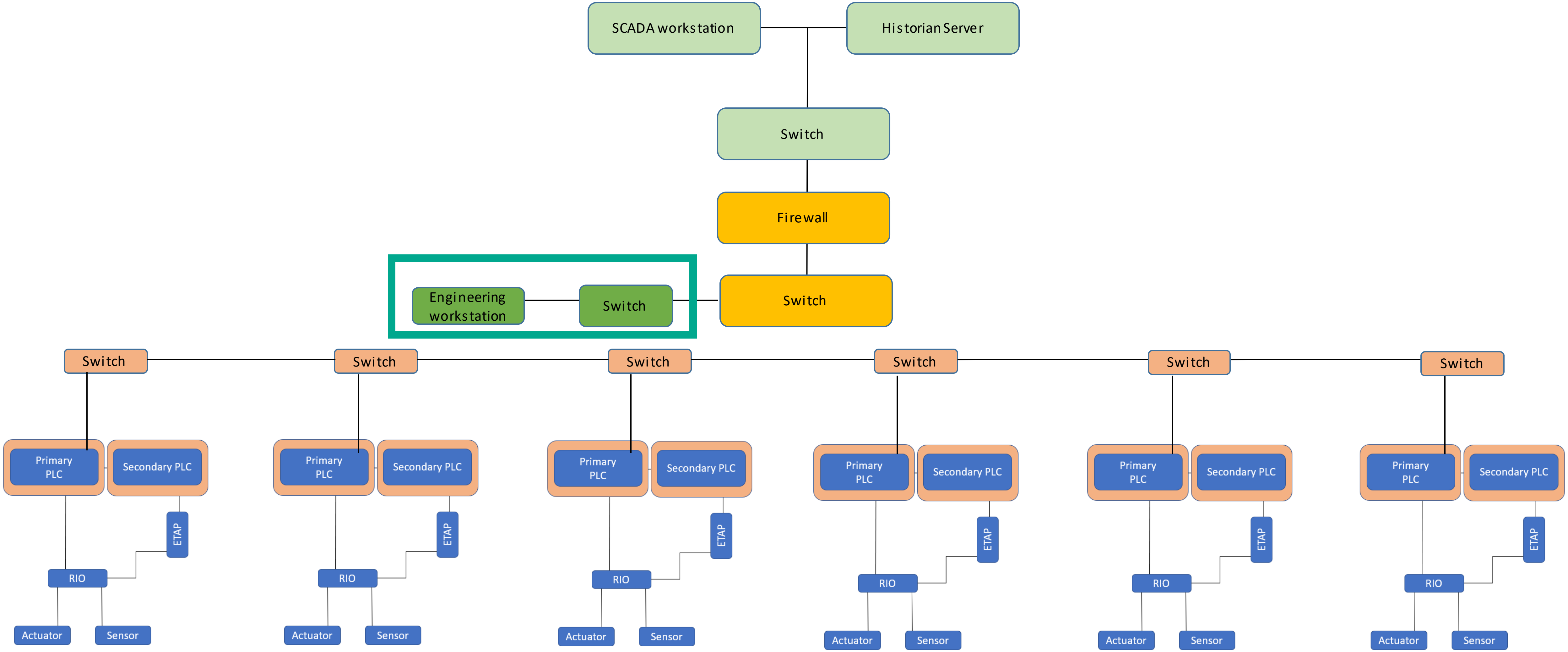
SWaT Network Architecture



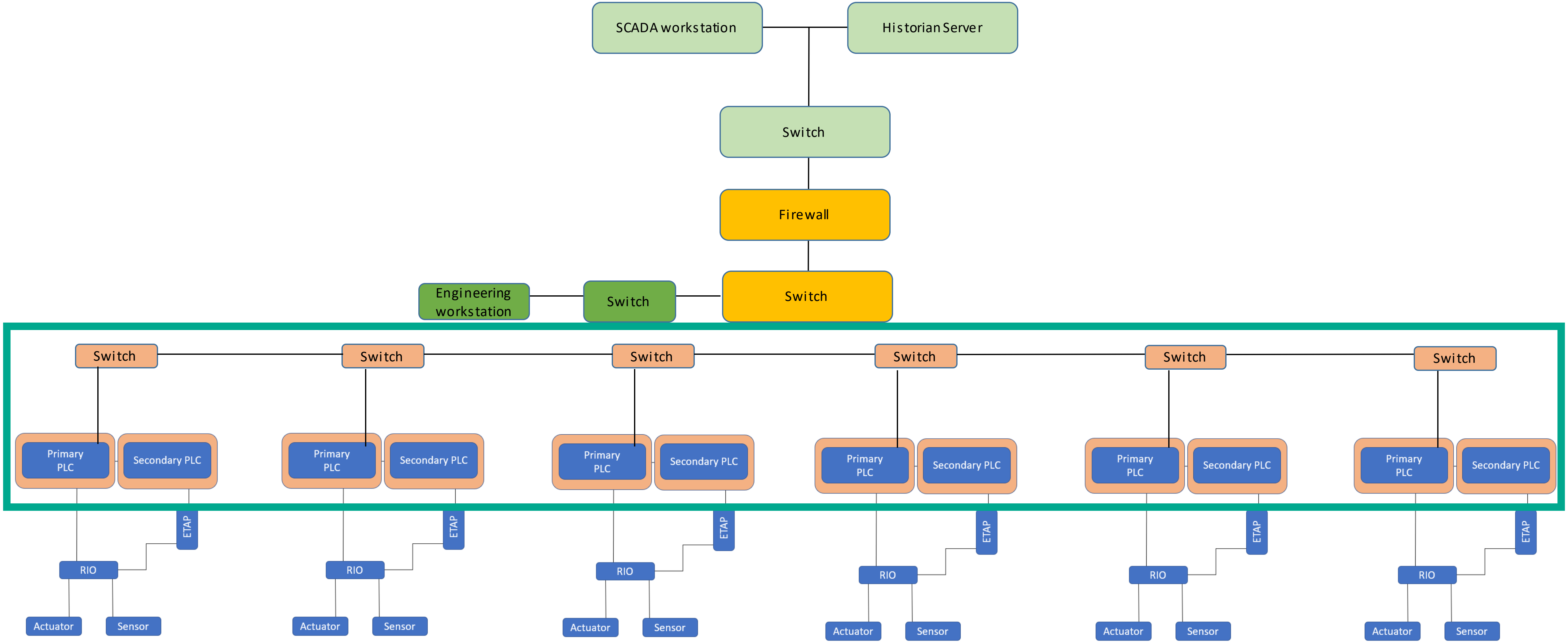
Level 3 – Operation Management



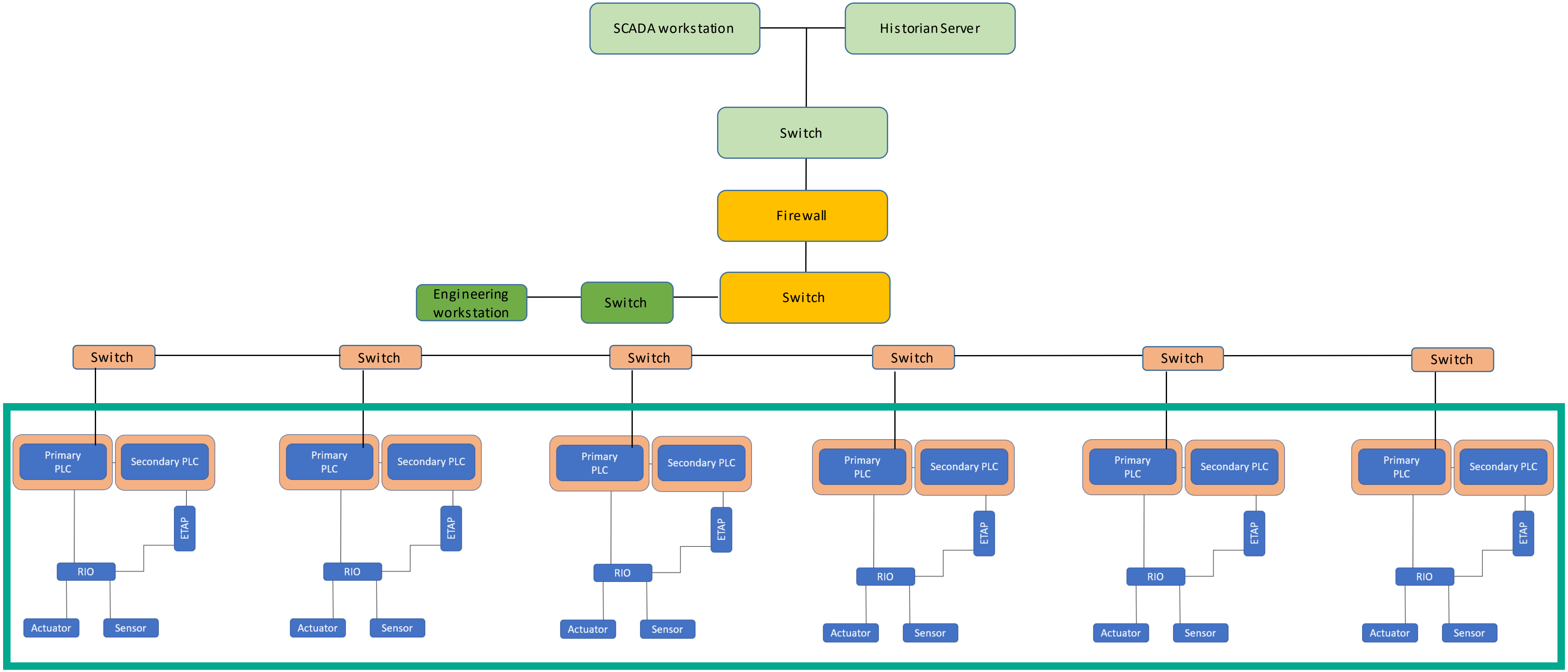
Level 2 – Supervisory Control

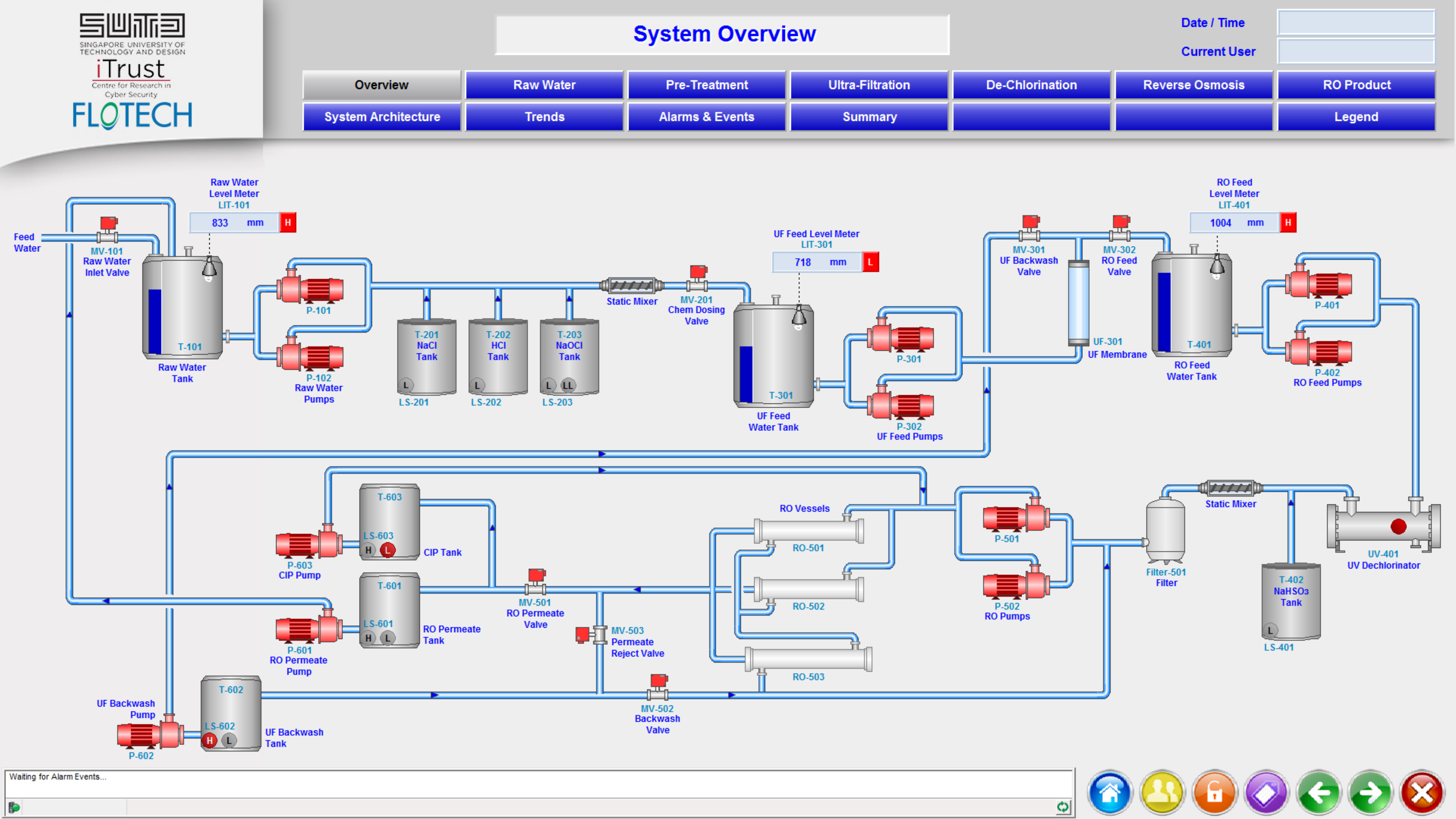


Level 1 – Plant control network



Level 0 - Process





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Ultra-Filtration
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RO Product
System Architecture
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833 mm
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T-101
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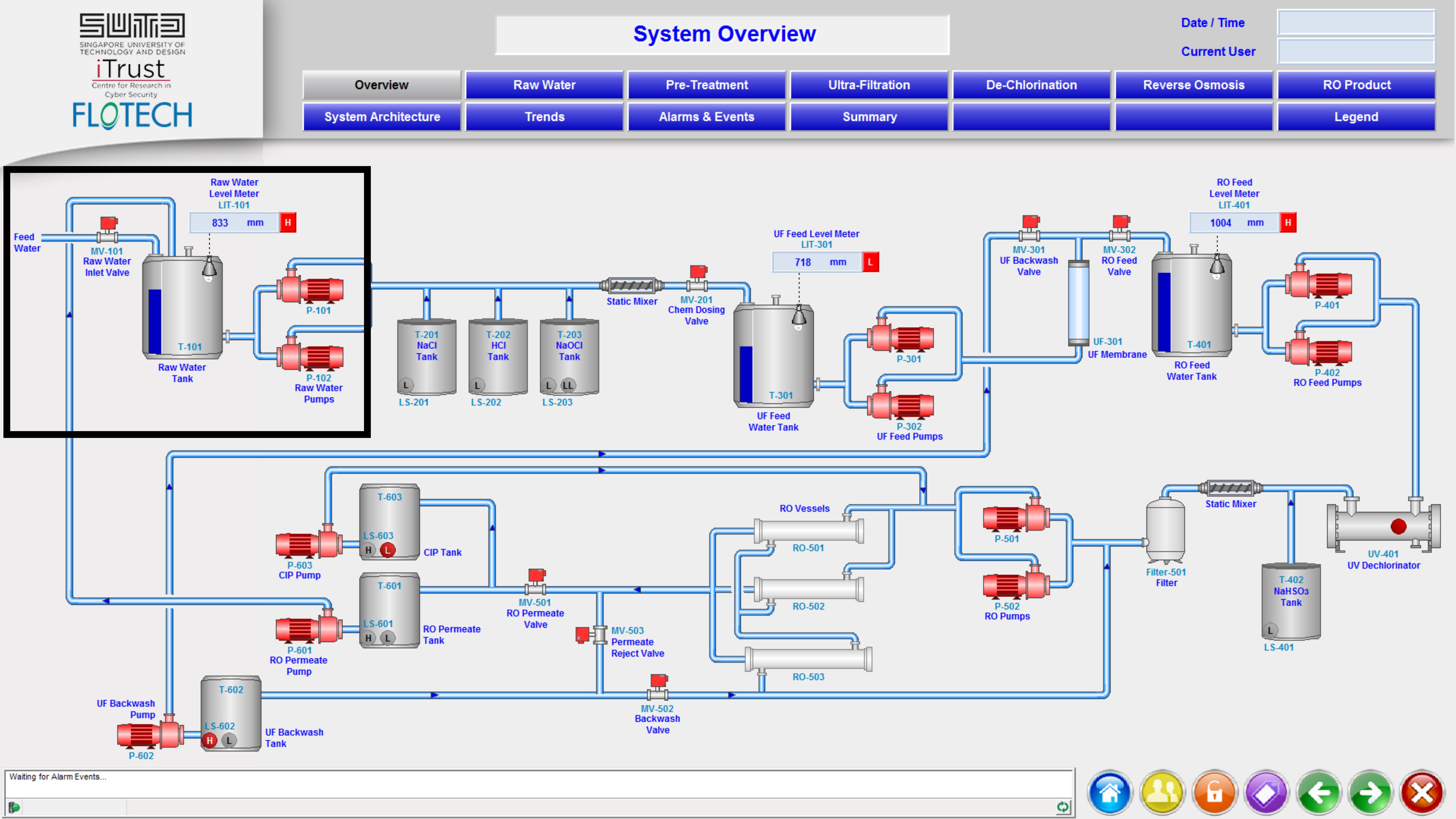
Waiting for Alarm Events...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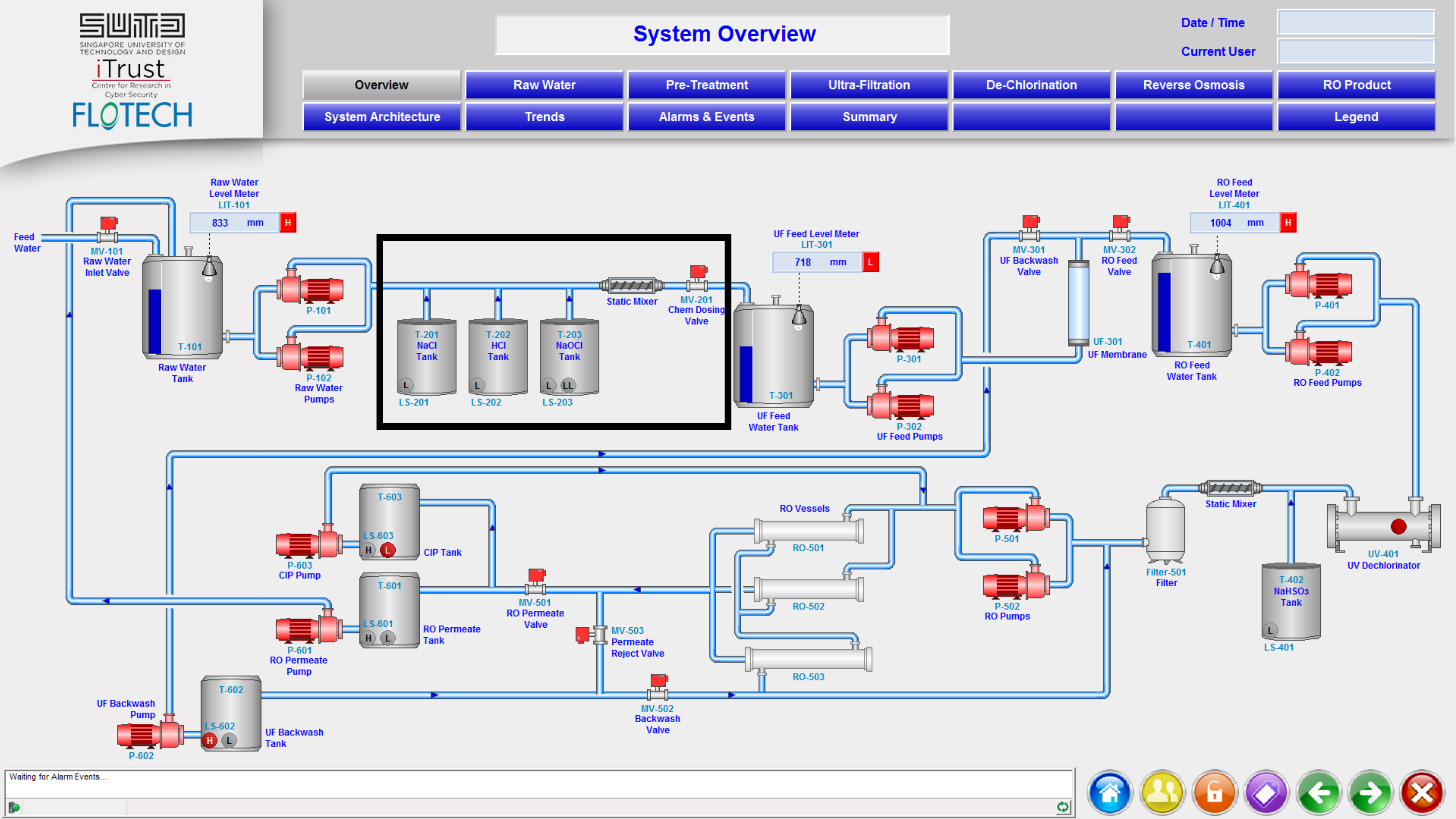
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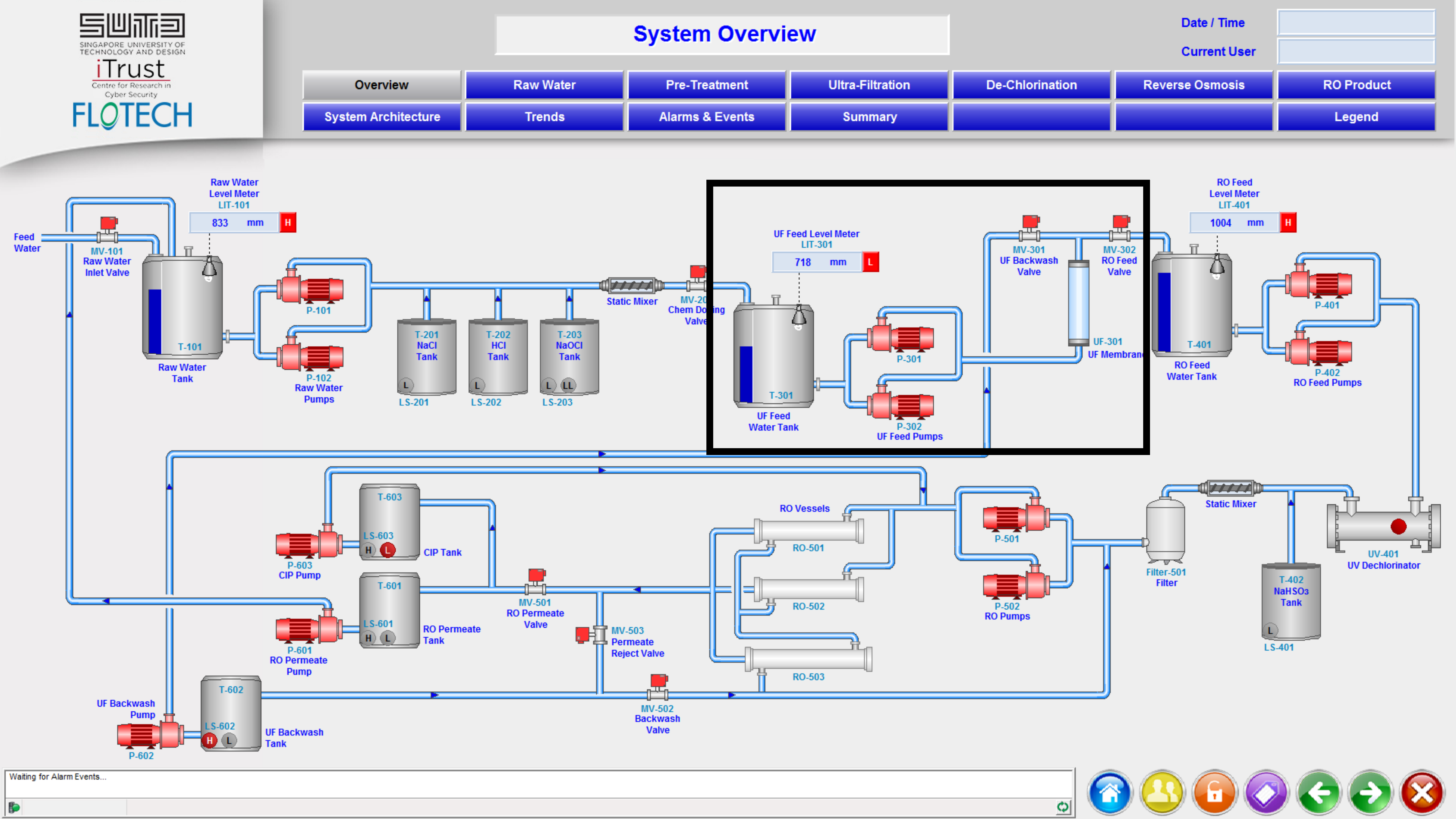

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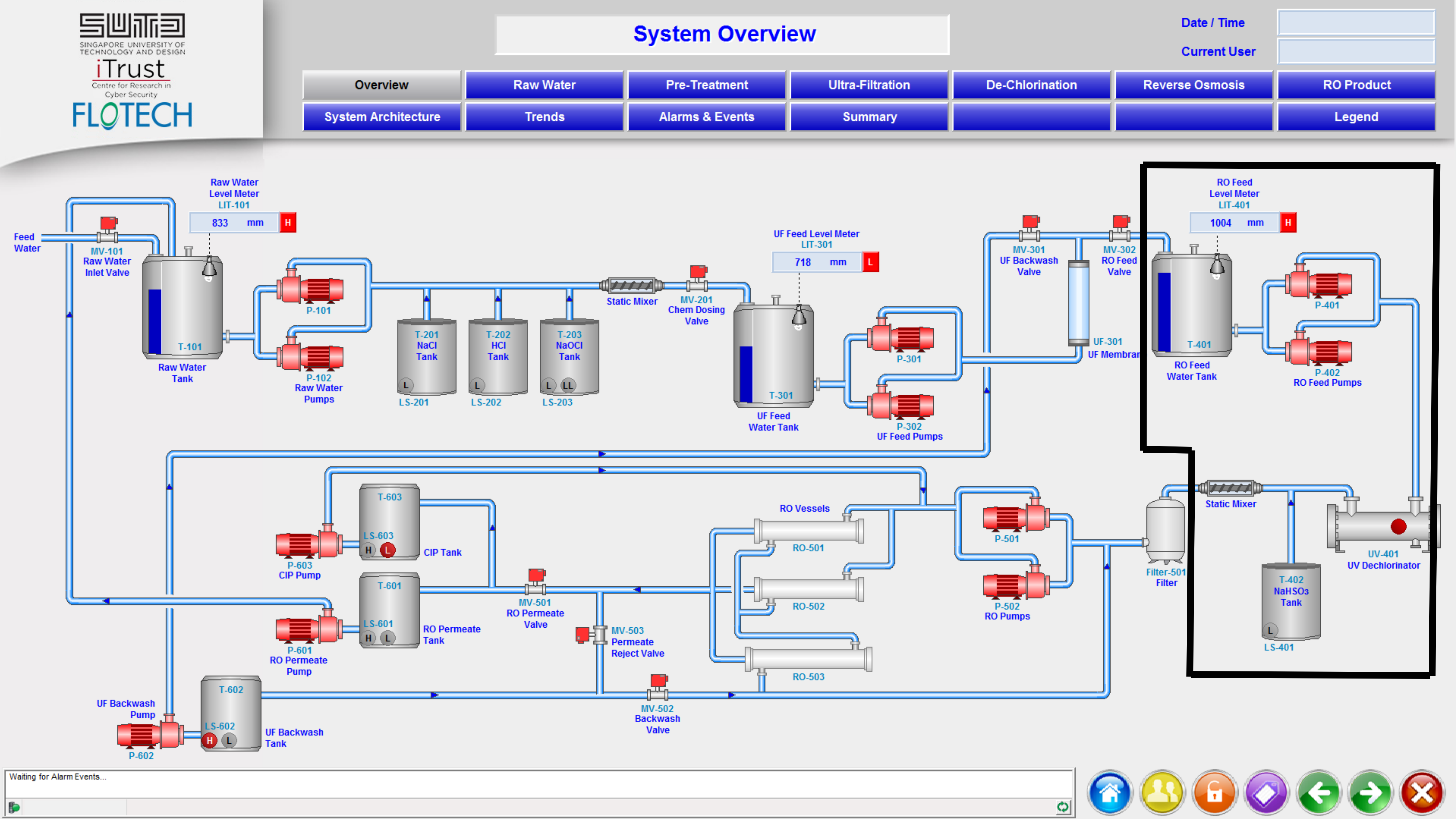
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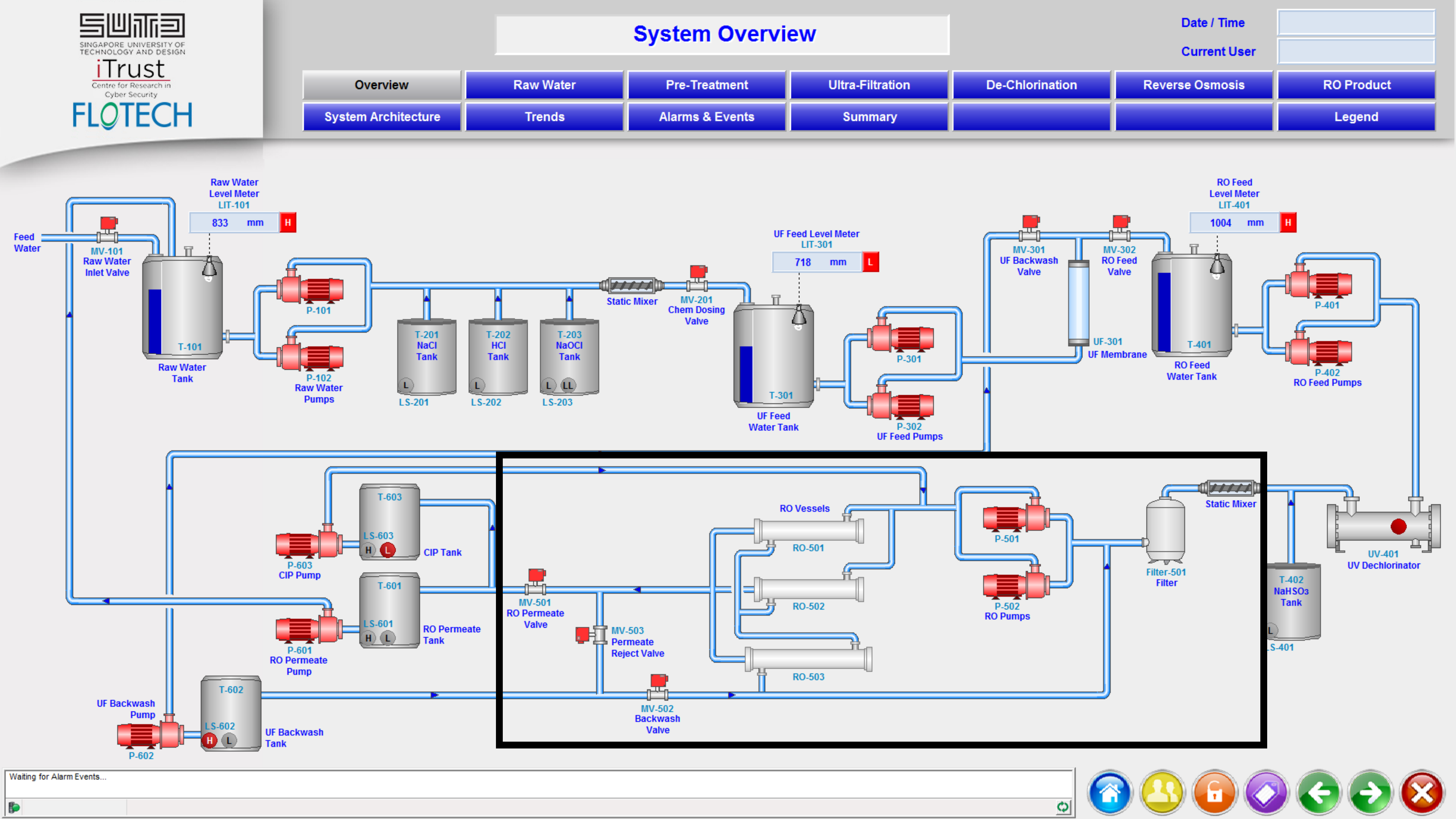
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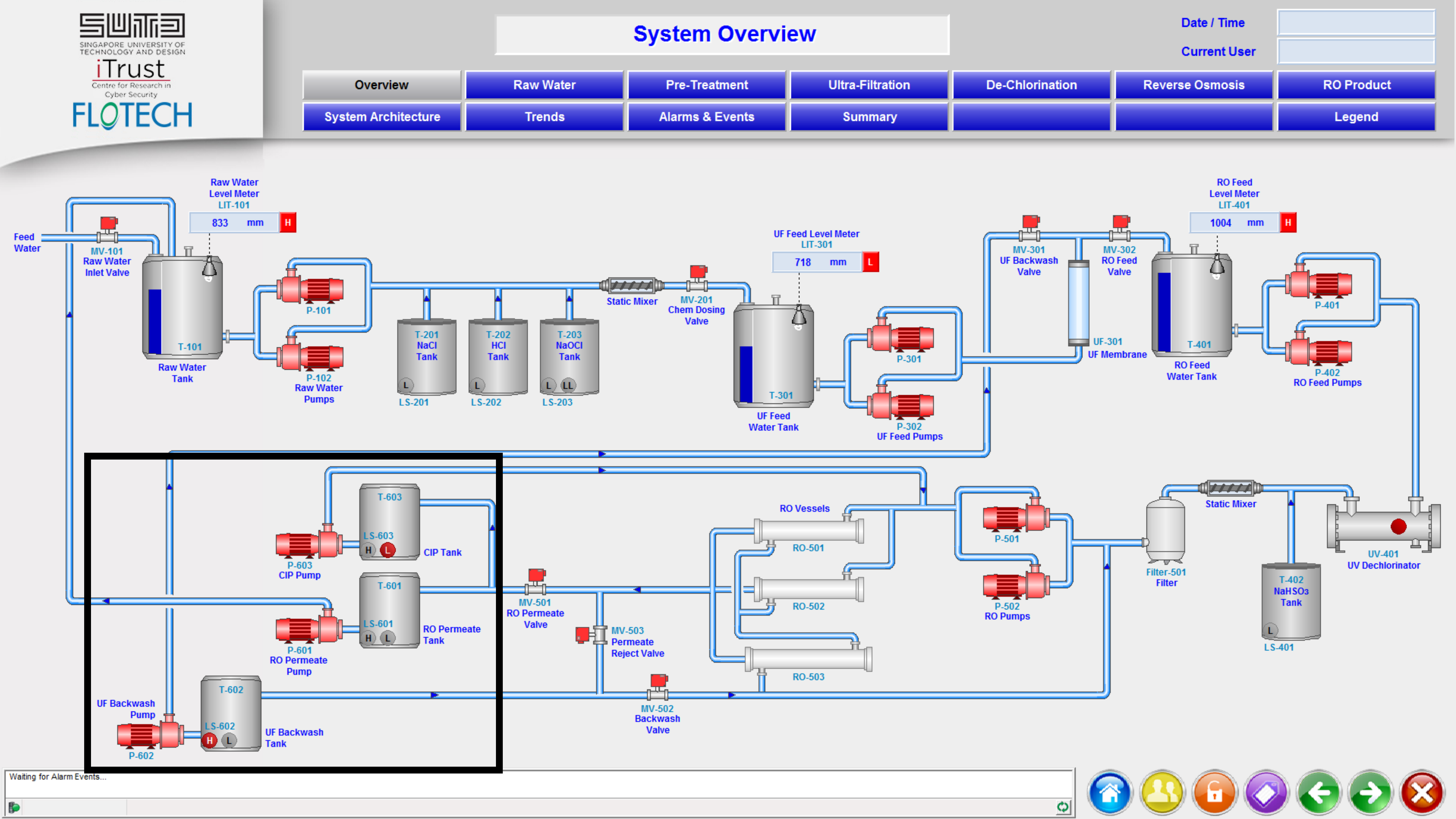
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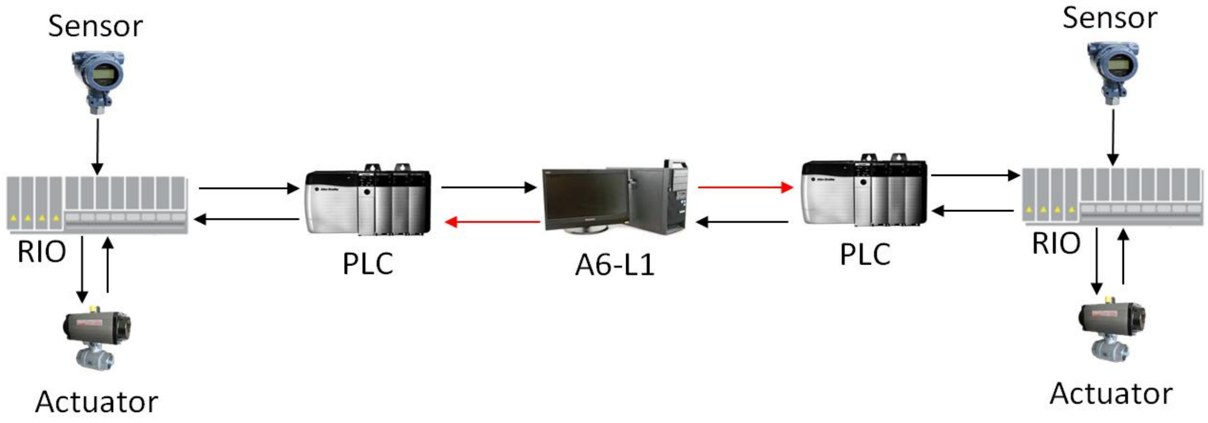
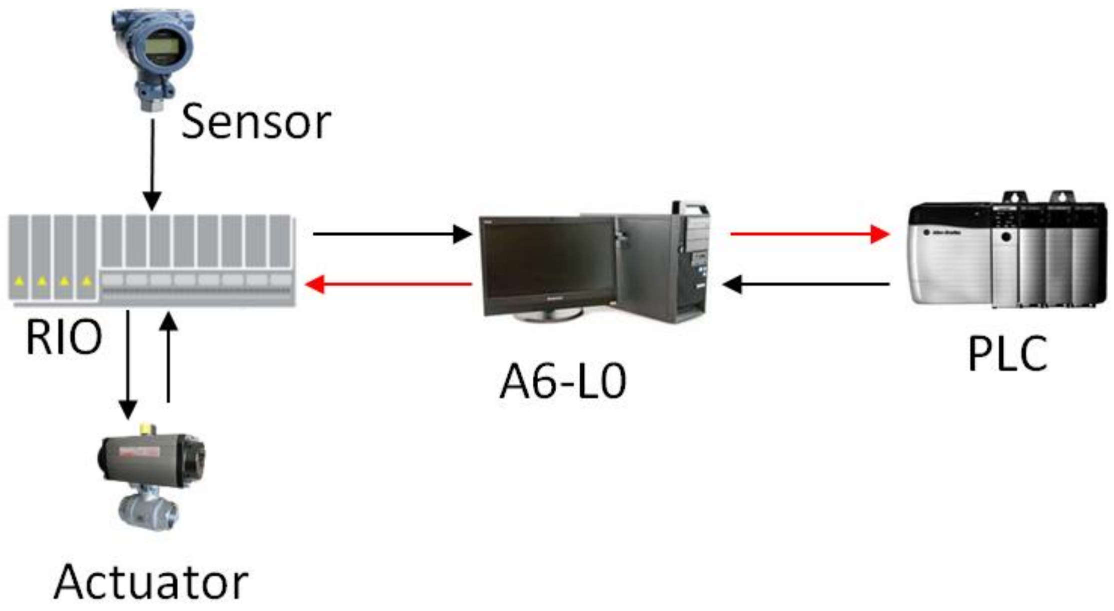
A6 Tool suite tool

A6-L1



A6 Tool suite tool

A6-L0



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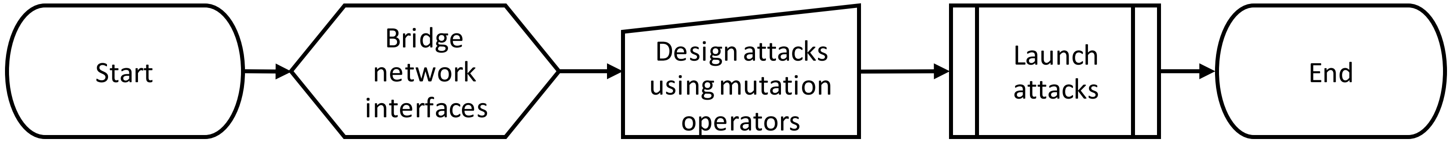
Urbina, David I., et al. "Attacking Fieldbus Communications in ICS: Applications to the SWaT Testbed." *SG-CRC*. 2016.

Attack Design

A6 - L1



A6 – L0

Mutation Operators

Operator	Description	Example
Add Static Delta (ASD)	Adds/subtracts an absolute, unchanging δ to state measurements	ASD(500) ⇒ Before: LIT101=300 After: LIT101=800
Add Limits Delta (ALD)	Adds/subtracts random value between -δ and +δ to state measurements	ALD(10) ⇒ Before: LIT101=300 After: LIT101=307
Add Random Delta (ARD)	Adds/subtracts a random value between δ1 and δ2 to state measurements	ARD(100, 200) ⇒ Before: LIT101=300 After: LIT101=450 ARD(100, 200) ⇒ Before: LIT101=300 After: LIT101=450

Mutation Operators

Operator	Description	Example
Set to Zero	Set state measurement to zero	Before: MV101=1 After: MV101=0
Set to One	Set state measurement to one	Before: P101=0 After: P101=1
Set to Static	Set state measurement to static value	STS(756) ⇒ Before: LIT101=300 After: LIT101=756
Set to Random	Set state measurement to a random value between $\delta 1$ and $\delta 2$	STR(100, 200) ⇒ Before: LIT101=300 After: LIT101=179

Mutation Operators

Operator	Description	Example
Bit Shift Left	State measurement is bit-shifted to left by δ bits	BSL(4) ⇒ Before: LIT101=300 After: LIT101=5982.85
Bit Shift Right	State measurement is bit-shifted to right by δ bits	BSR(4)⇒ Before: LIT101=300 After: LIT101=3356044.00

Command Validators

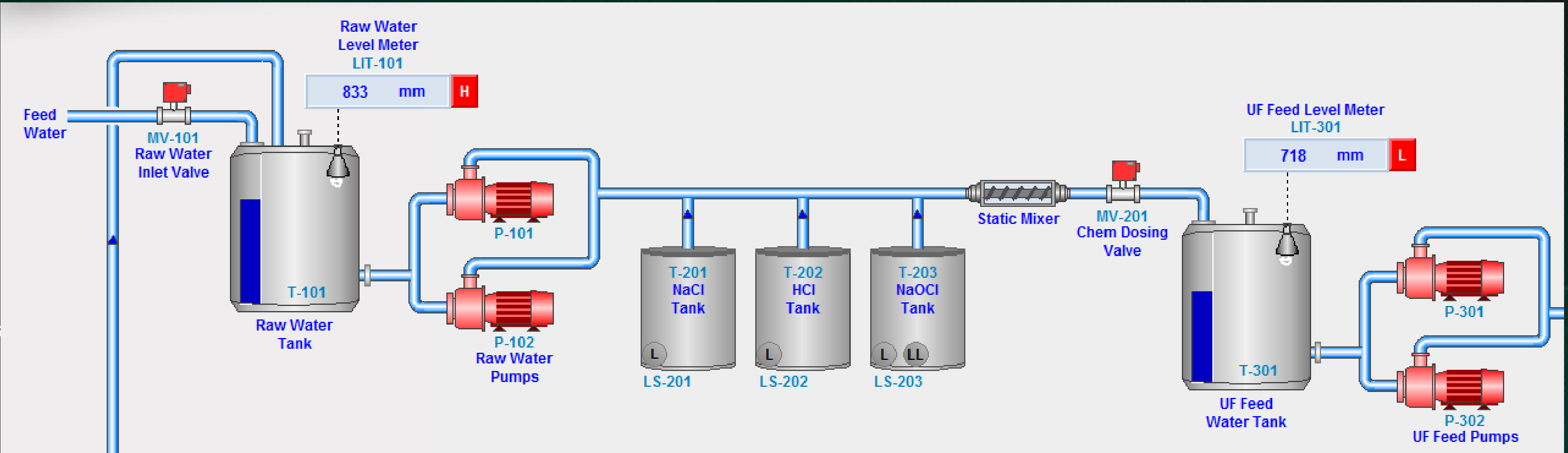
Operator	Description	Example
Valid	Set state measurement to valid input	Before: P101 = 1 (On) After: P101 = 0 (Off)
Invalid	Set state measurement to invalid input	Before: P101 = 0 (Off) After: P101 = -5 (Invalid)

L1 Attack Demo

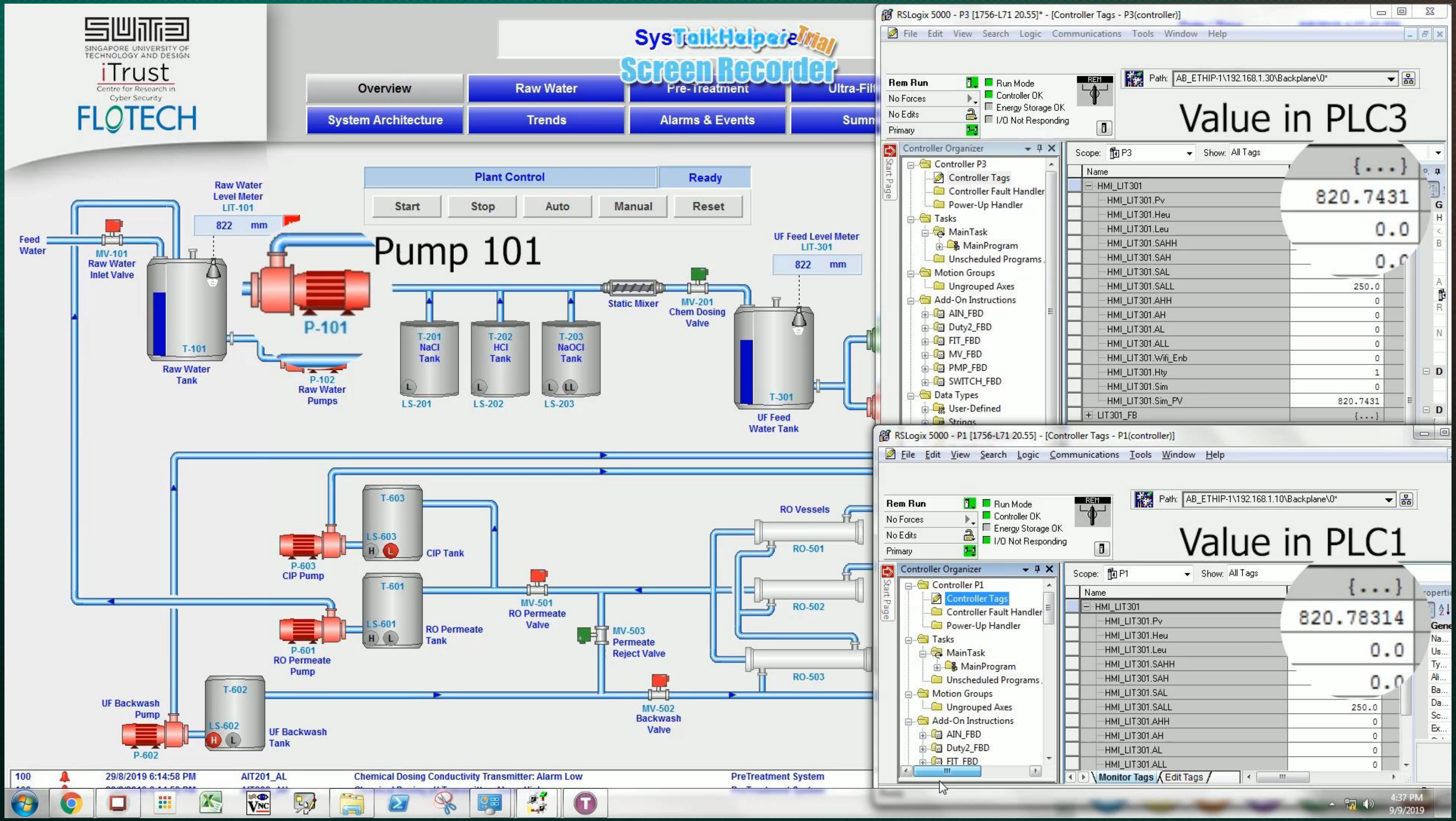
Stage 1 strategy is to have P101 and P102 be interlocked with LIT301

- Low Setpoint: 800mm ⇒ P101/P102 START
- High Setpoint: 1000mm ⇒ P101/P102 STOP

SSPMS Attack: Mutating of LIT301 value to LOW from PLC3 to PLC1



Kaspers



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L0 Attack Demo

Stage 1 strategy is to have MV101 be activated by LIT101

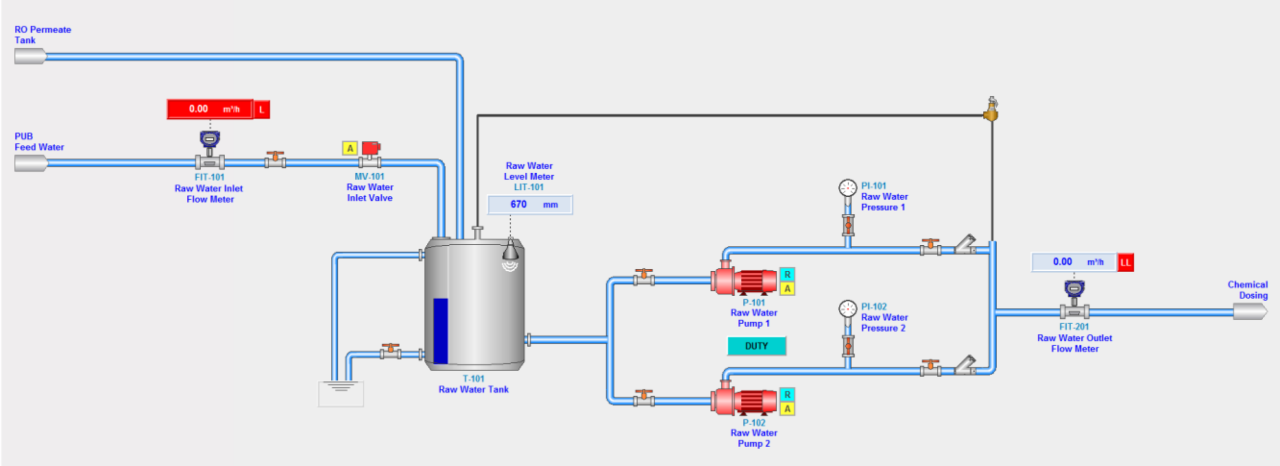
a) Low Low Setpoint: 250mm & P101/P102 STOP AND MV101 OPEN

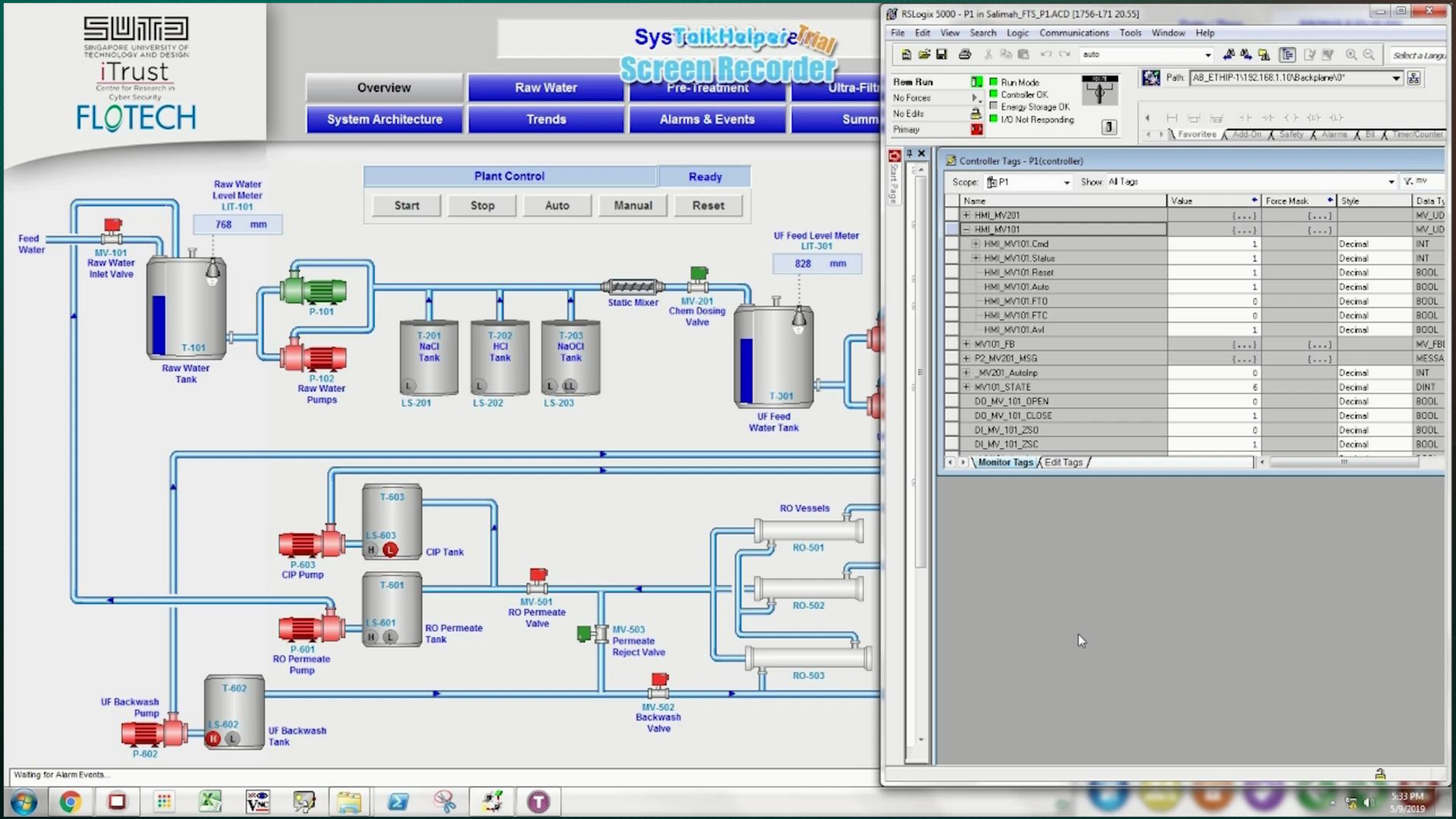
b) Low Setpoint: 500mm MV101 OPEN

c) High Setpoint: 800mm MV101 CLOSE

d) High High Setpoint: 1200mm Alarm

SSSMP Attack: Mutating P101 & MV101 status to PLC1 and command to actuators





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Findings

1. Out of range values and commands
2. Corelated Invariants across PLCs
3. False positives

Current Work

1. Automated generation of attacks
2. Creating a test suite for ADMs to be tested against and given a benchmark

Specials thanks to

Sridhar Adepu

Gayathri Sugumar

Nils Ole Tippenhauer

Aditya P. Mathur

Questions?

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Thank you!

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