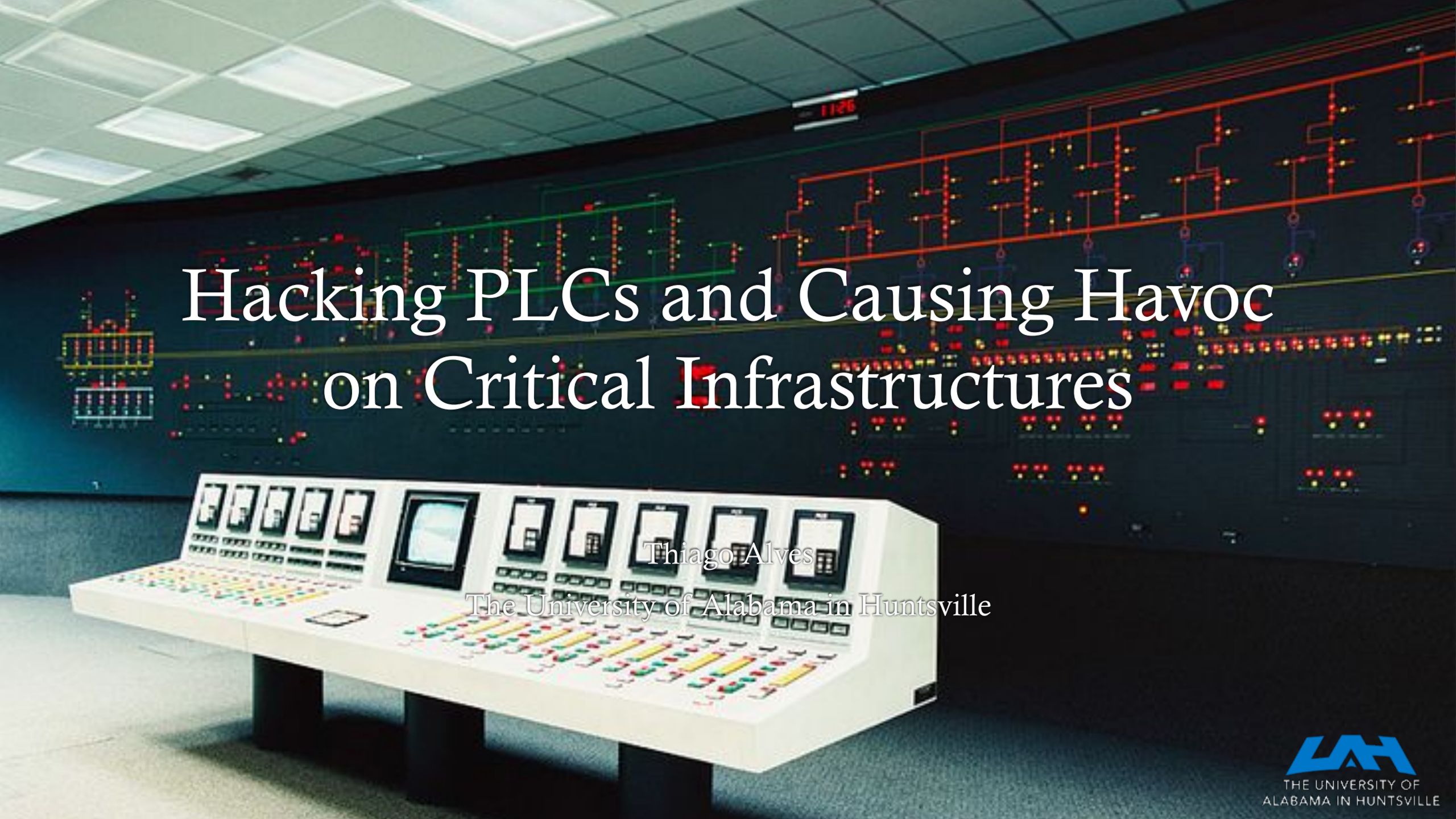


Hacking PLCs and Causing Havoc on Critical Infrastructures

Thiago Alves
The University of Alabama in Huntsville

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

Who am I?

- Ph.D. Student at the University of Alabama in Huntsville
- SCADA Cyber Security Researcher at the Center for Cybersecurity Research and Education (CCRE)
- Creator of the OpenPLC Project: www.openplcproject.com – The first fully open source Programmable Logic Controller

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

Celebrating 9 years Together



"If you want to go fast, go alone.

If you want to go far, go together."

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

Outline

- Background Info
- Attack Vectors
- Demos

THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE

What Is a PLC?

THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE

Programmable Logic Controller

- **Digital Computer** used on Automation
- Input modules **read data** from sensors
- User program **decides what to do** based on the input data
- Output modules **control actuators** on the physical system



THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

Programmable Logic Controller









THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE

Programmable Logic Controller









THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE

Problems with current PLCs

- **Expensive!**
- Rely on legacy technology
- Use unsecure protocols to communicate
- Most companies rather patch than redesign
- Closed source



OpenPLC – An Open Source Controller



http://www.openplcproject.com

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

OpenPLC – Main Components







Runtime

Editor

GUI Builder

THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE

OpenPLC Runtime

Supported platforms



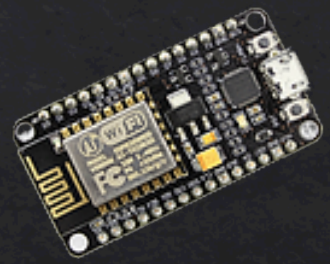
Raspberry Pi



UniPi



PiXtend



ESP8266



Arduino



FreeWave Zumlink



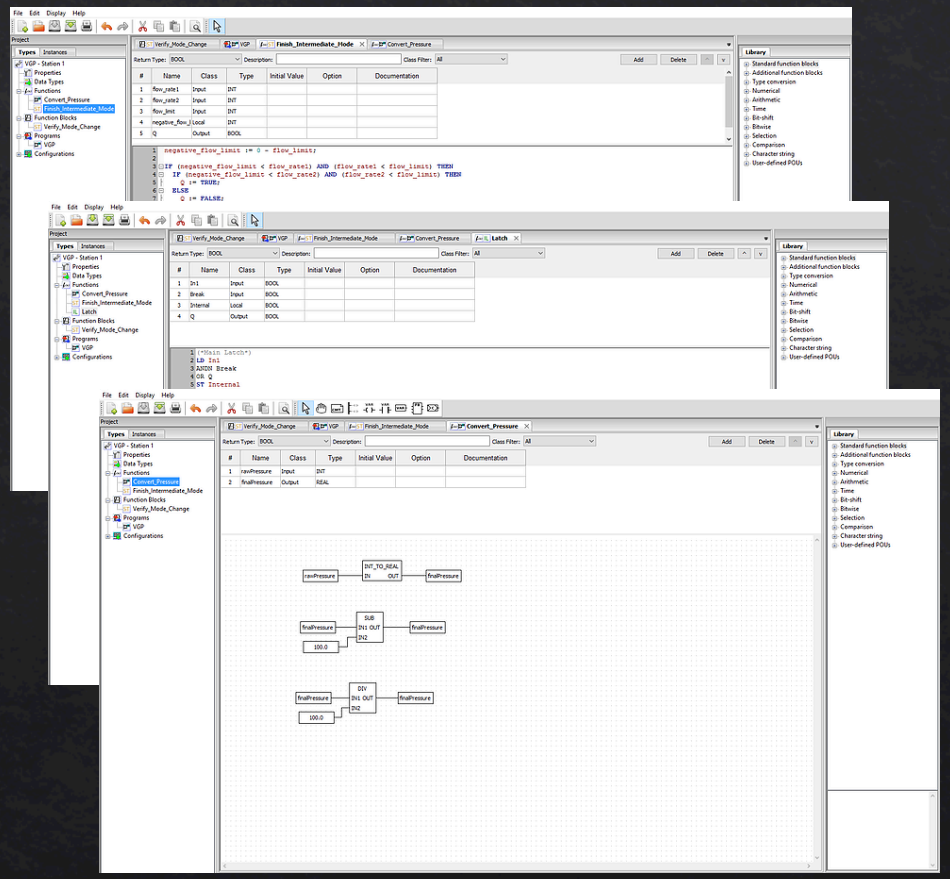
Windows (soft-PLC)

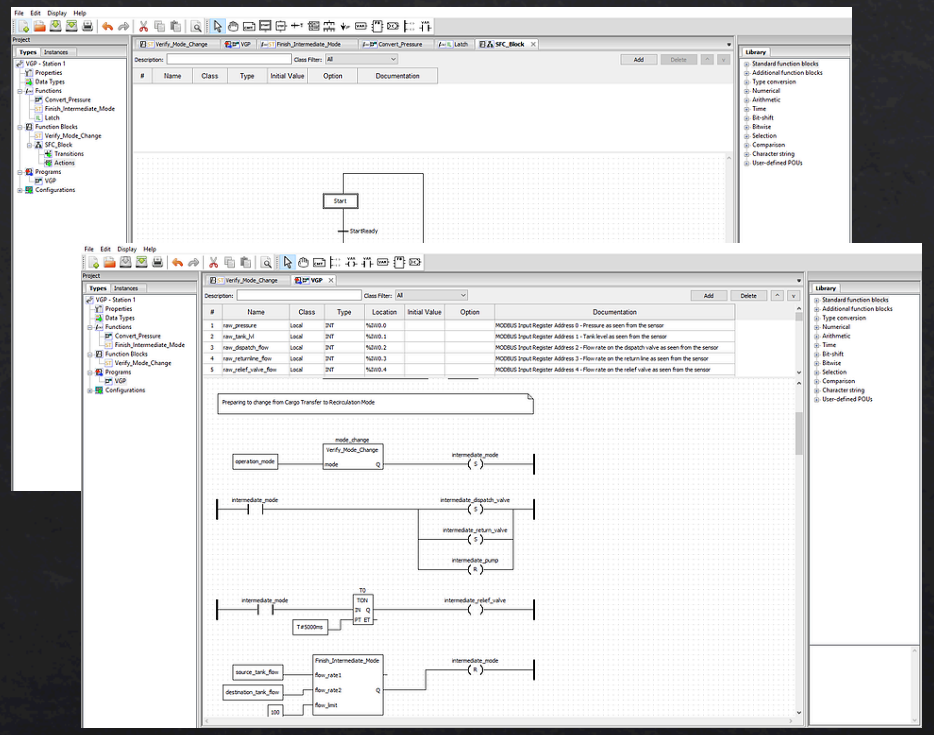


Linux (soft-PLC)

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

OpenPLC Editor

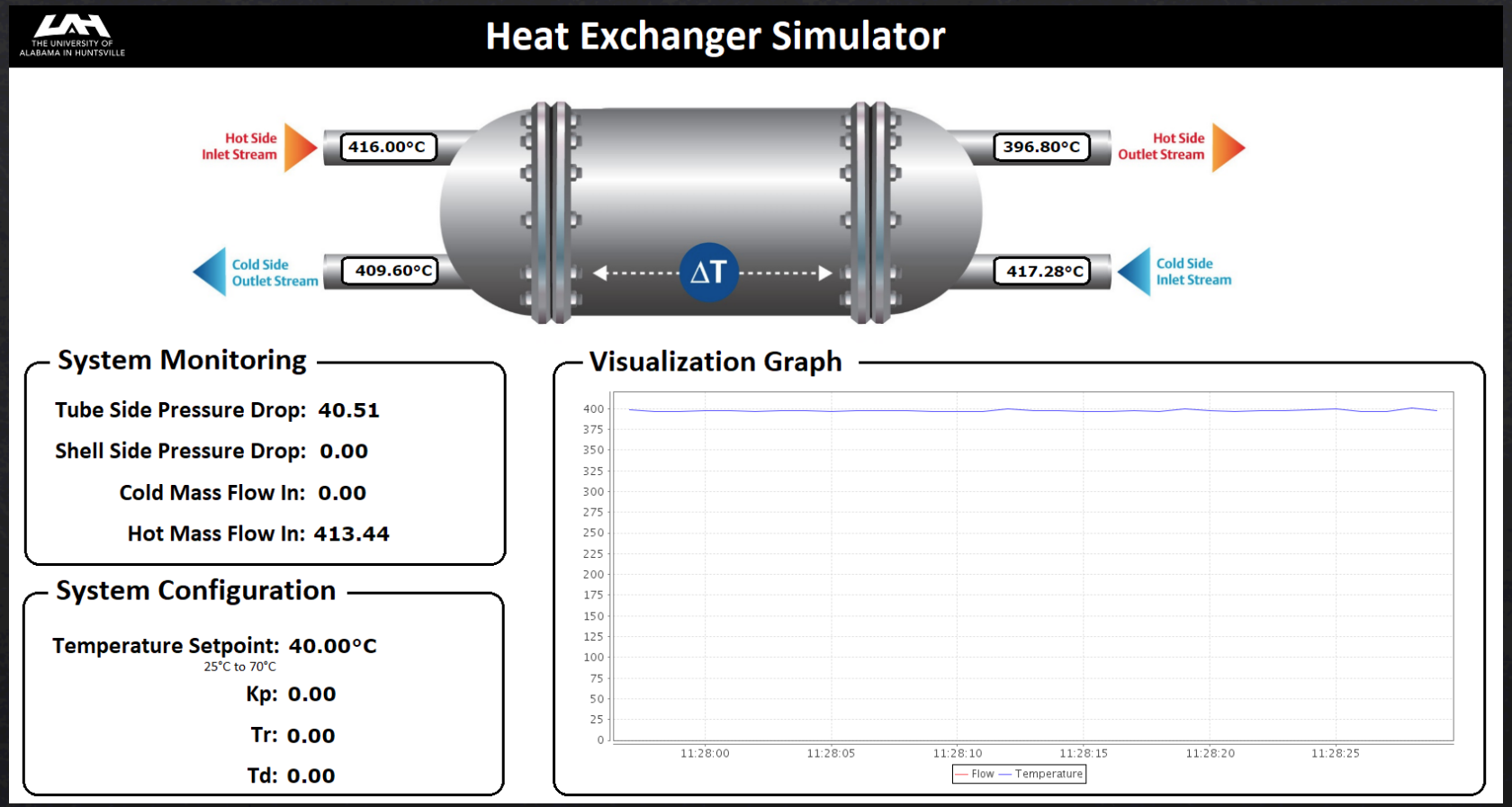




Supports all five IEC 61131-3 programming languages

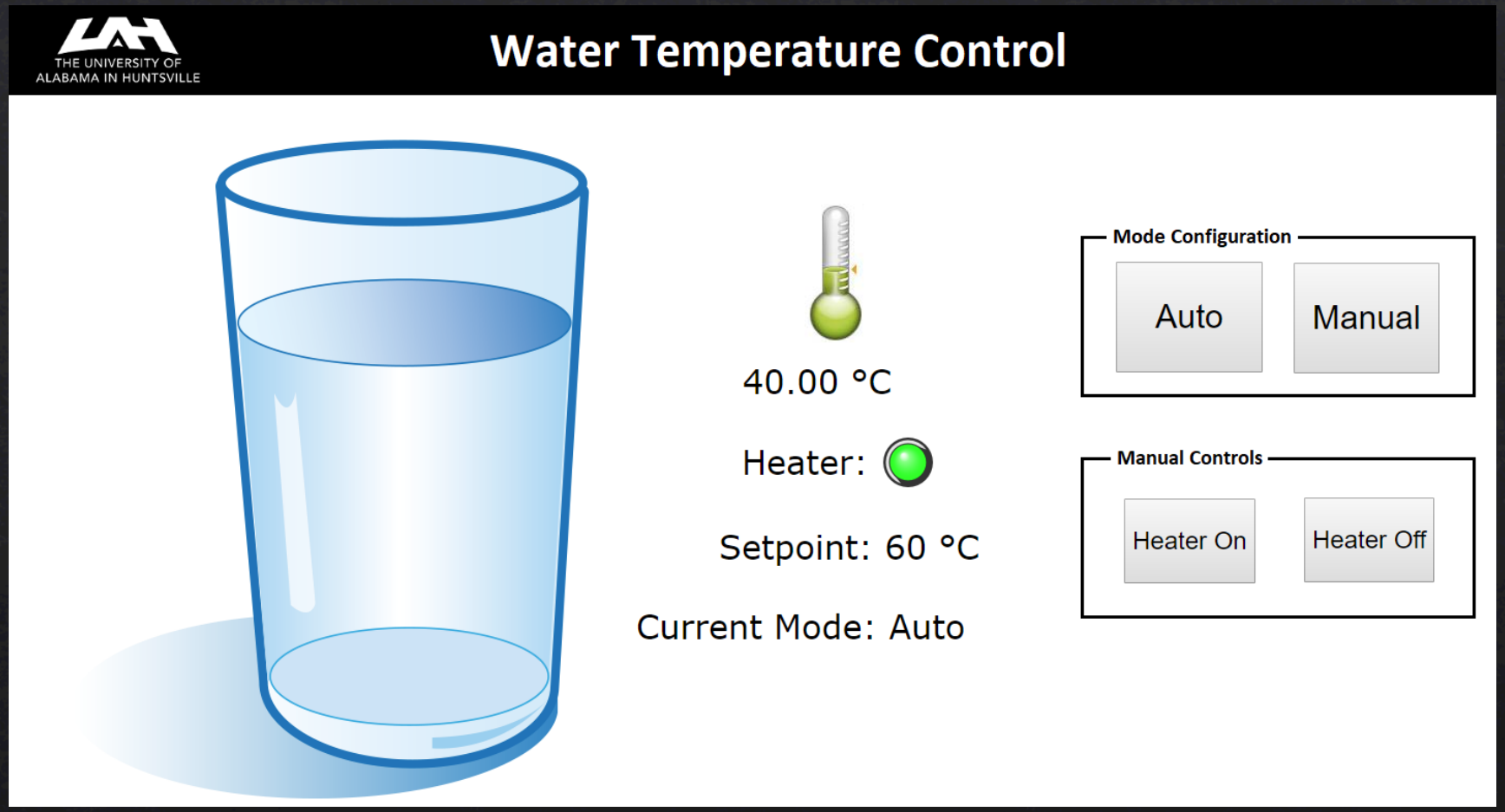
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

ScadaBR



THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

ScadaBR


THE UNIVERSITY OF ALABAMA IN HUNTSVILLE
Water Temperature Control
40.00 °C
Heater:
Setpoint: 60 °C
Current Mode: Auto
Mode Configuration
Auto
Manual
Manual Controls
Heater On
Heater Off

PLC Communications: SCADA Protocols

THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE

Problems with current SCADA Protocols

- Most protocols are derived from legacy Serial RS-485 networks
- No authentication
- No integrity (prevent tampering)
- No confidentiality



Most Popular SCADA Protocol: Modbus

- Very simple
- Based on serial networks
- Commands encoded into Function Codes
- Open: no licensing required



Modbus Frame



Slave ID: Unique address from 1 to 247

Function Code: Tells the slave which command to execute

Data: Self-explanatory!

CRC: Cyclic Redundancy Check used for error detection

THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE

Most used Function Codes

FC01: Read digital outputs

FC02: Read digital inputs

FC03: Read analog outputs

FC04: Read analog inputs

FC05: Write single digital output

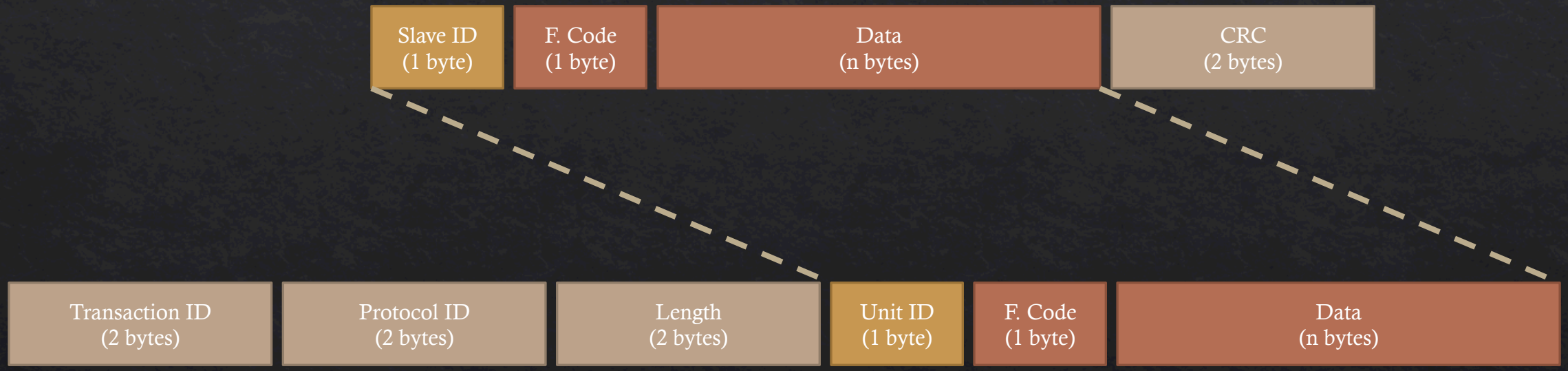
FC06: Write single analog output (or register)

FC15: Write multiple digital outputs

FC16: Write multiple analog outputs (or registers)

THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE

Modbus Frame on TCP

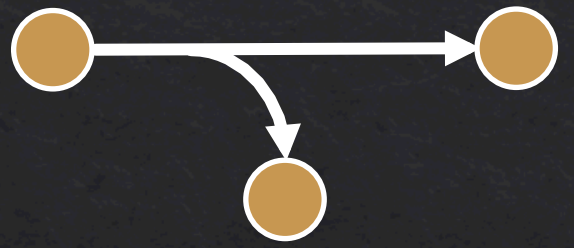


THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE

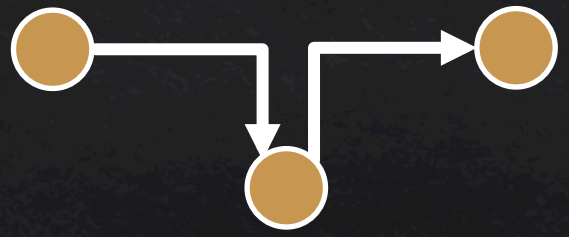
Attack Scenarios



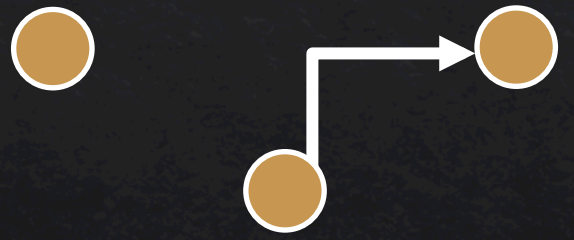
Interruption



Interception



Modification



Injection

THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE

Demo: Live Injection Attack

THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE

One more thing…

THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE

MicroLogix 1400 Series

- Runs VxWorks
- Most popular A-B PLC
- Supports Modbus/TCP
- Can be killed remotely by sending a bad Modbus packet

Rockwell Automation

A-B QUALITY

Allen-Bradley

MICROLOGIX DEADLY PACKETS

Transaction ID	Protocol ID	**Length**	Unit ID	Func. Code	Coil Address	Status
00ad	0000	00ff	01	05	0043	ff00
071b	0000	0006	01			

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

Demo: Remotely Crashing a Micrologix 1400

THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE

Allen-Bradley Recommended Mitigations

- Firmware update - FRN 21.003 fixes this vulnerability
- Disable Modbus/TCP
- Minimize network exposure
- Put PLCs behind a firewall

Rockwell Automation

A-B QUALITY

Allen-Bradley

And one last thing…

THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE

Schneider Unity Protocol

- Runs on top of Modbus/TCP
- Uses Function Code 0x5A
- Used to **configure** and **monitor** the PLC
- Proprietary and undocumented protocol (security by obscurity)



Unity's Function Codes

0x01 - INIT_COMM: Initialize a UMAS communication
0x02 - READ_ID: Request a PLC ID
0x03 - READ_PROJECT_INFO: Read Project Information
0x04 - READ_PLC_INFO: Get internal PLC Info
0x06 - READ_CARD_INFO: Get internal PLC SD-Card Info
0x0A - REPEAT: Sends back data sent to the PLC (used for sync)
0x10 - TAKE_PLC_RESERVATION: Reserve the PLC to a station
0x11 - RELEASE_PLC_RESERVATION: Release the reservation
0x12 - KEEP_ALIVE: Keep alive message
0x20 - READ_MEMORY_BLOCK: Read a memory block from PLC
0x22 - READ_VARIABLES: Read System bits, Words and variables
0x23 - WRITE_VARIABLES: Write System bits, Words and variables
0x24 - READ_COILS_REGISTERS: Read coils and holding registers
0x25 - WRITE_COILS_REGISTERS: Write coils and holding registers

0x30 - INITIALIZE_UPLOAD: Initialize upload
0x31 - UPLOAD_BLOCK: Upload a block to the PLC
0x32 - END_STRATEGY_UPLOAD: Finish Upload
0x33 - INITIALIZE_DOWNLOAD: Initialize download
0x34 - DOWNLOAD_BLOCK: Download a block
0x35 - END_STRATEGY_DOWNLOAD: Finish download
0x39 - READ_ETH_MASTER_DATA: Read Ethernet Master Data
0x40 - START_PLC: Starts the PLC
0x41 - STOP_PLC: Stops the PLC
0x50 - MONITOR_PLC: Monitors variables, Systems bits and words
0x58 - CHECK_PLC: Check PLC Connection status
0x70 - READ_IO_OBJECT: Read IO Object
0x71 - WRITE_IO_OBJECT: Write IO Object
0x73 - GET_STATUS_MODULE: Get Status Module

Source: lirasenlared.xyz

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

Unity's Function Codes

0x01 - INIT_COMM: Initialize a UMAS communication
0x02 - READ_ID: Request a PLC ID
0x03 - READ_PROJECT_INFO: Read Project Information
0x04 - READ_PLC_INFO: Get internal PLC Info
0x06 - READ_CARD_INFO: Get internal PLC SD-Card Info
0x0A - REPEAT: Sends back data sent to the PLC (used for sync)
0x10 - TAKE_PLC_RESERVATION: Reserve the PLC to a station
0x11 - RELEASE_PLC_RESERVATION: Release the reservation
0x12 - KEEP_ALIVE: Keep alive message
0x20 - READ_MEMORY_BLOCK: Read a memory block from PLC
0x22 - READ_VARIABLES: Read System bits, Words and variables
0x23 - WRITE_VARIABLES: Write System bits, Words and variables
0x24 - READ_COILS_REGISTERS: Read coils and holding registers
0x25 - WRITE_COILS_REGISTERS: Write coils and holding registers
0x30 - INITIALIZE_UPLOAD: Initialize upload
0x31 - UPLOAD_BLOCK: Upload a block to the PLC
0x32 - END_STRATEGY_UPLOAD: Finish Upload
0x33 - INITIALIZE_DOWNLOAD: Initialize download
0x34 - DOWNLOAD_BLOCK: Download a block
0x35 - END_STRATEGY_DOWNLOAD: Finish download
0x39 - READ_ETH_MASTER_DATA: Read Ethernet Master Data
0x40 - START_PLC: Starts the PLC
0x41 - STOP_PLC: Stops the PLC
0x50 - MONITOR_PLC: Monitors variables, Systems bits and words
0x58 - CHECK_PLC: Check PLC Connection status
0x70 - READ_IO_OBJECT: Read IO Object
0x71 - WRITE_IO_OBJECT: Write IO Object
0x73 - GET_STATUS_MODULE: Get Status Module

Source: lirasenlared.xyz

Demo: Exploiting the Unity Protocol

THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE

Schneider Recommended Mitigations

- Disable Unity Protocol
- Store project files in secure, access-restricted locations
- Encrypt project files with reputable third party file encryption tools.



Thanks!



Thiago Alves

thiagoralves@gmail.com

www.openplcproject.com

www.github.com/thiagoralves/defcon26

THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE