INDUSTRIAL CONTROL SYSTEMS

Pentesting PLCs 101

WHO AM I?

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Senior security auditor

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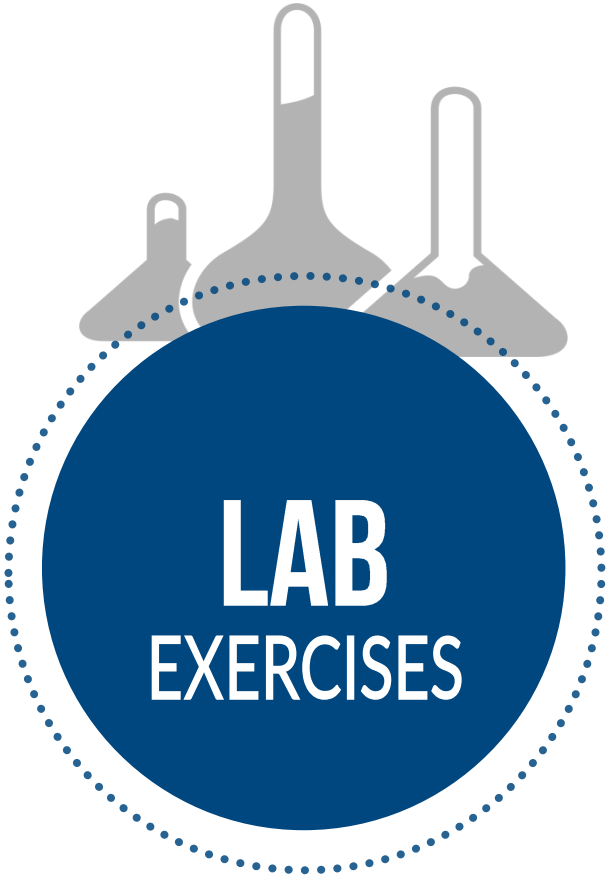
INTERESTS

- Windows Active Directory
  Can a Windows AD be secured ? JSSI 2013
  (French, sorry)
- SCADA stuff
- Wine tasting
  (we're not going to talk about it today)

solucom
management & IT consulting



LAB PREREQUISITE
WHAT'S IN THE LAB VM?

KALI LINUX

ADDITIONAL TOOLS

- MODBUSPAL
- MBTGET
- PLCSCAN
- SNAP7
- ...

SCRIPTS AND FILE EXAMPLES

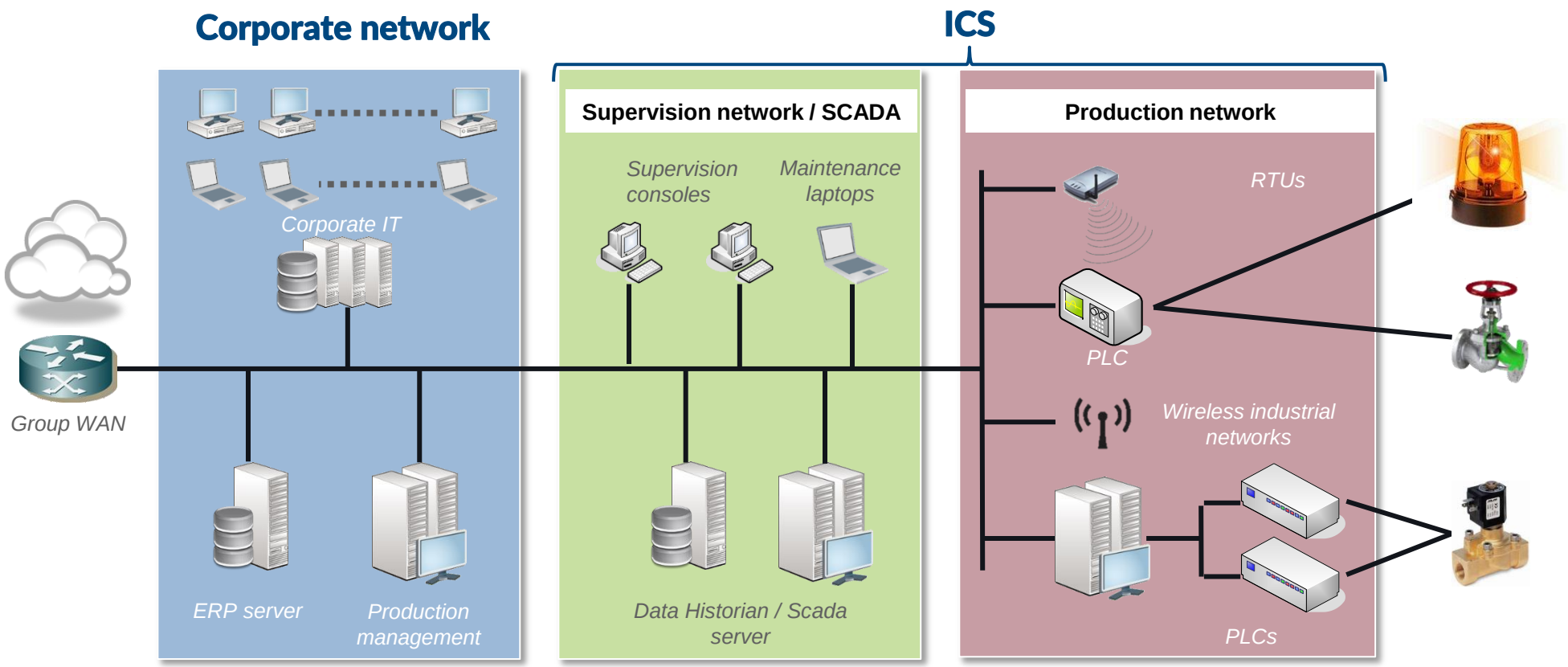
- PCAP SAMPLES
- SCRIPTS SKELETONS
- ...

AGENDA

1. ICS INTRODUCTION
2. MODBUS PROTOCOL
3. ATTACKING PLCS

ICS INTRODUCTION

WHAT IS AN INDUSTRIAL CONTROL SYSTEM (ICS)?



Corporate IS handle data

≠

ICS handle interfaces data with physical world

A BIT OF VOCABULARY

ICS (*Industrial Control System)*

=

IACS (*Industrial Automation and Control Systems)*

~=

SCADA (*Supervisory Control And Data Acquisition*)

~=

DCS (Distributed Control System)

Nowadays, people tend to say "SCADA" for anything related to ICS

ICS COMPONENTS

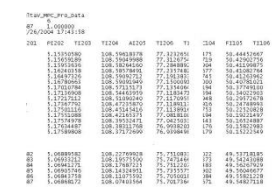
- **Sensors and actuators**: allow interaction with the physical world (pressure sensor, valves, motors, ...)

- **Local HMI**: Human-Machine Interface, permits the supervision and control of a subprocess

- **PLC**: Programmable Logic Controller : manages the sensors and actuators

- **Supervision screen**: remote supervision of the industrial process

- **Data historian**: Records all the data from the production and Scada networks and allows exporting to the corporate IS (to the ERP for instance)



SCADA SECURITY AWARENESS TIMELINE (SIMPLIFIED)

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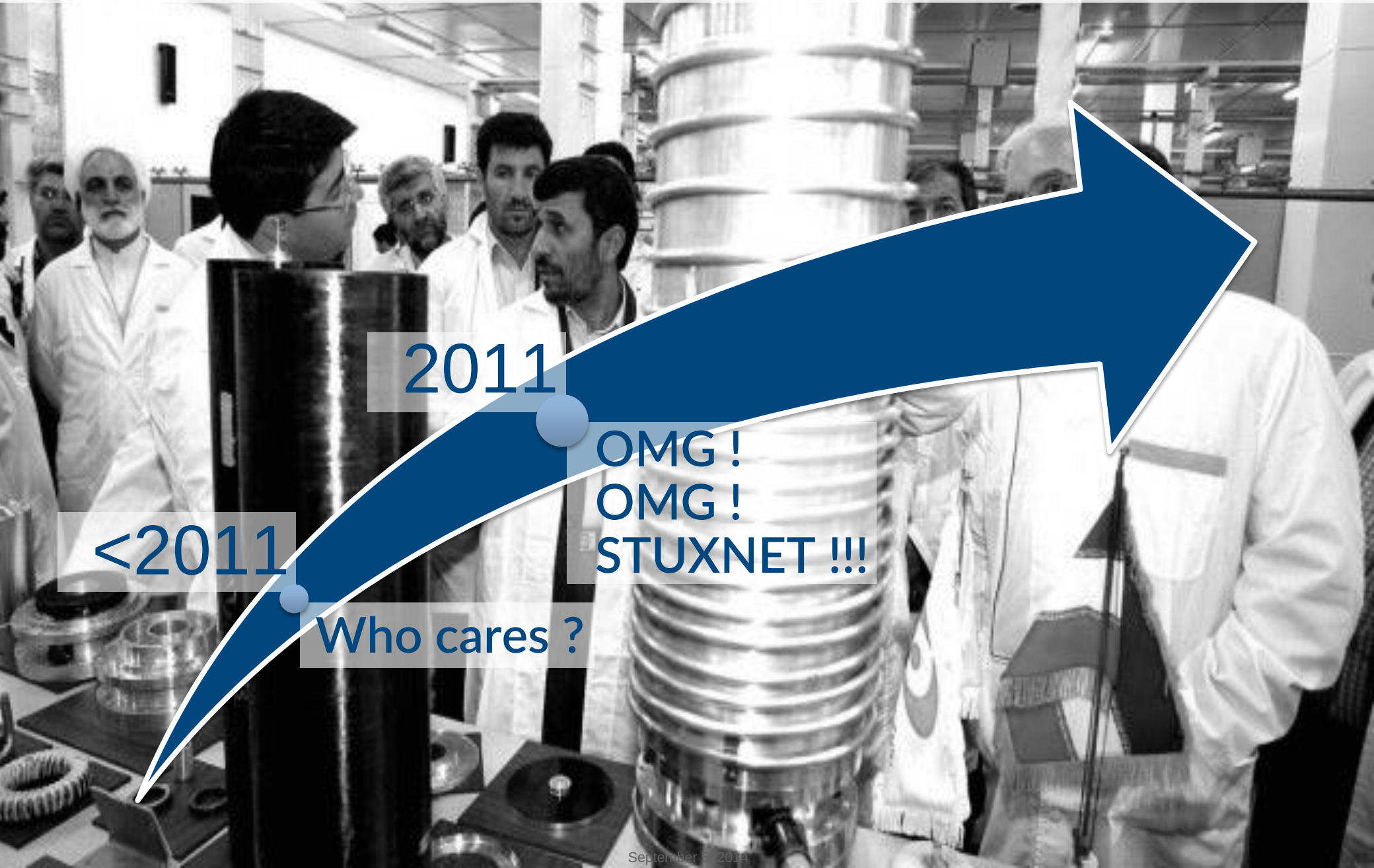
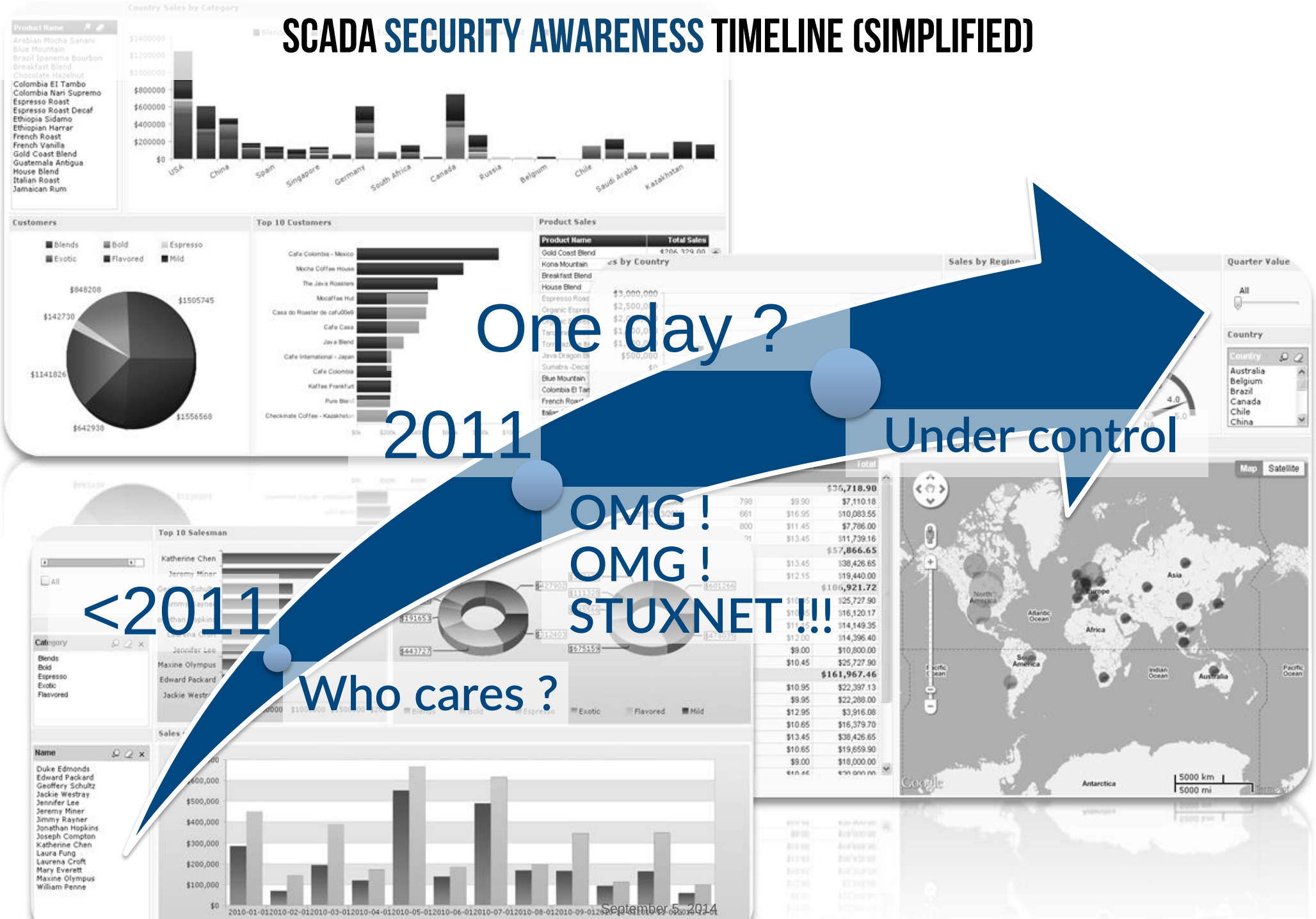


SCADA SECURITY AWARENESS TIMELINE (SIMPLIFIED)



WHAT IS WRONG WITH CURRENT ICS SECURITY?

- ORGANIZATION & AWARENESS
- NETWORK SEGMENTATION
- VULNERABILITY MANAGEMENT
- SECURITY IN PROTOCOLS
- THIRD PARTY MANAGEMENT
- SECURITY SUPERVISION

ICS-CERT

INDUSTRIAL CONTROL SYSTEMS CYBER EMERGENCY RESPONSE TEAM

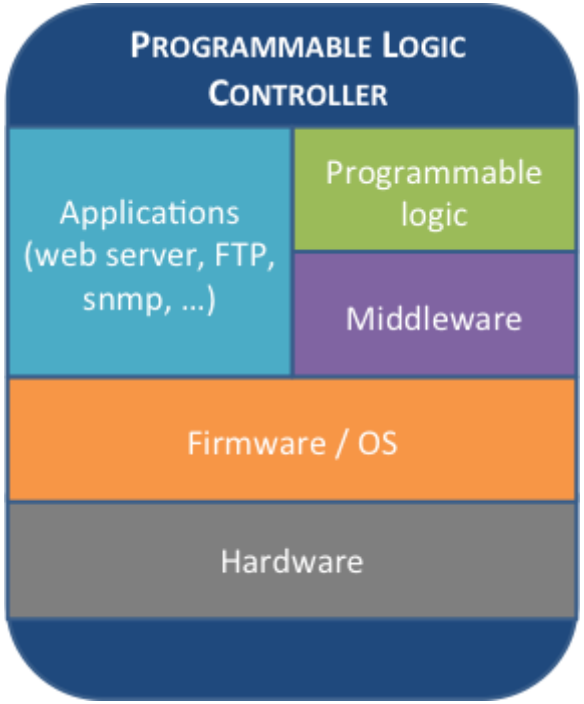
ICS-CERT listed over **250 attacks** on ICS in 2013

- **59%** of attacks targeted the energy sector
- **79** attacks successfully compromised the target
- **57** attacks did not succeed in compromising the target
- **120** attacks were not identified/investigated

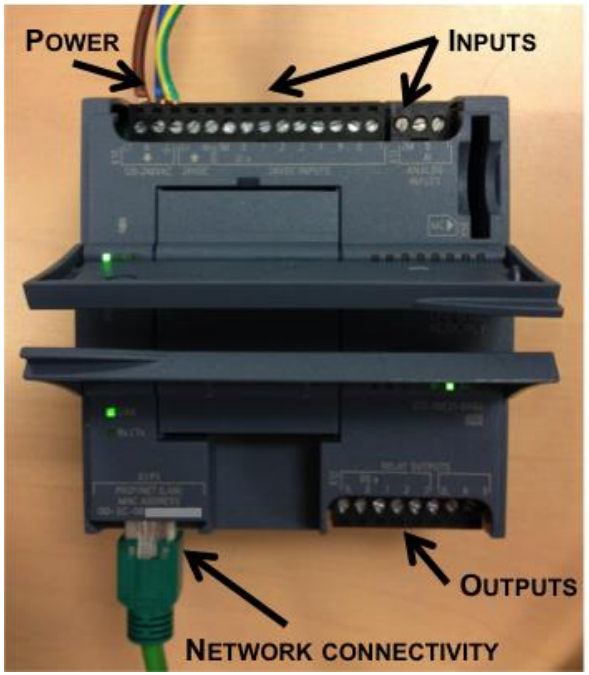
WHAT IS A PLC?

- Real-time digital computer used for automation
- Replaces electrical relays
- Lots of analogue or digital inputs & outputs
- Rugged devices (immune to vibration, electrical noise, temperature, dust, ...)

WHAT'S INSIDE ?



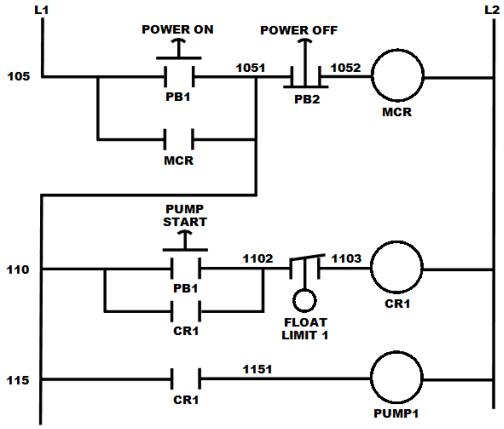
SIEMENS S7-1200



PLC
PROGRAMMING

- "*Ladder Logic*" was the first programming language for PLC, as it mimics the real-life circuits
- IEC 61131-3 defines 5 programming languages for PLCs
  - LD: Ladder Diagram
  - FBD: Function Block Diagram
  - ST: Structured Text
  - IL: Instruction List
  - SFC: Sequential Function Chart

LADDER DIAGRAM EXAMPLE



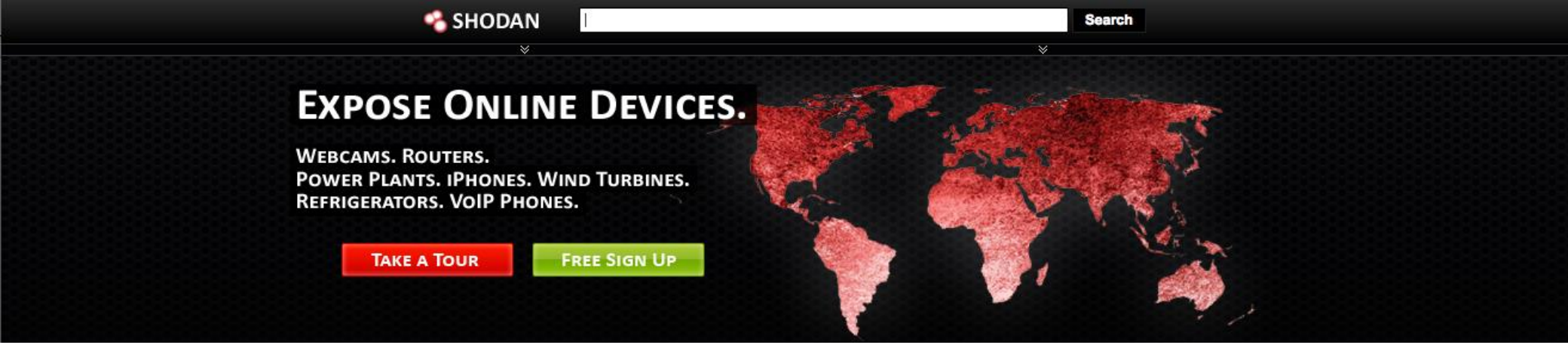
STRUCTURED TEXT EXAMPLE

```
(* simple state machine *)
TxtState := STATES[StateMachine];

CASE StateMachine OF
   1: ClosingValve();
ELSE
    ;; BadCase();
END_CASE;
```

INSTRUCTION LIST EXAMPLE

```
LD      Speed
          GT      1000
          JMPCN   VOLTS_OK
          LD      Volts
VOLTS_OK  LD      1
          ST      %Q75
```



- Shodan is a search engine dedicated to find devices exposed to the Internet
- It regularly scans the whole Internet IPV4 range (~4,3 billions IPs)
- Results are partially free (you have to pay to export the results)

WHAT CAN YOU FIND?

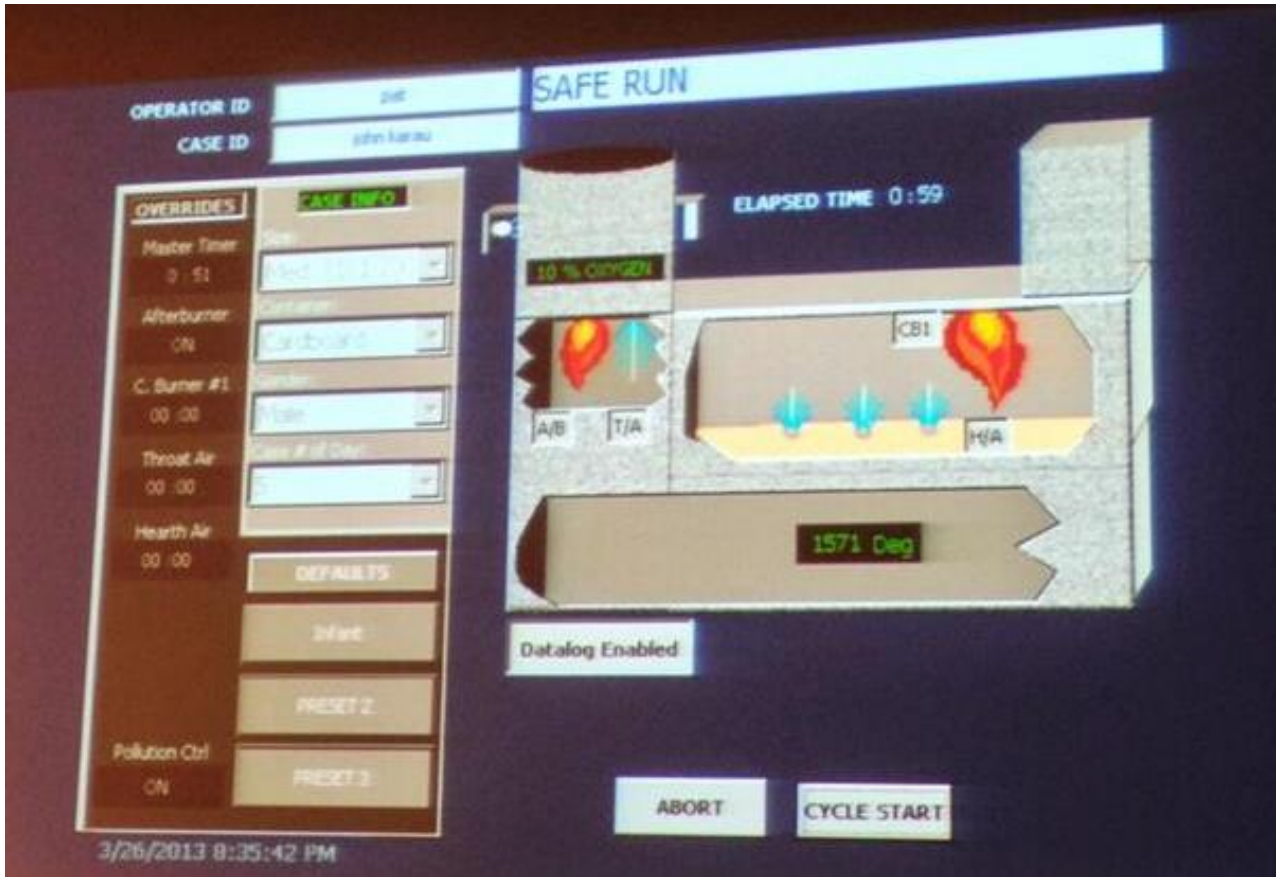
- All kinds of connected devices
  - PLCs
  - Webcams
  - Smart-things (fridge, TV, ...)
- Things you can't even imagine...
- Example ICS report : https://www.shodan.io/report/l7VjfVKc

ALTERNATIVES?

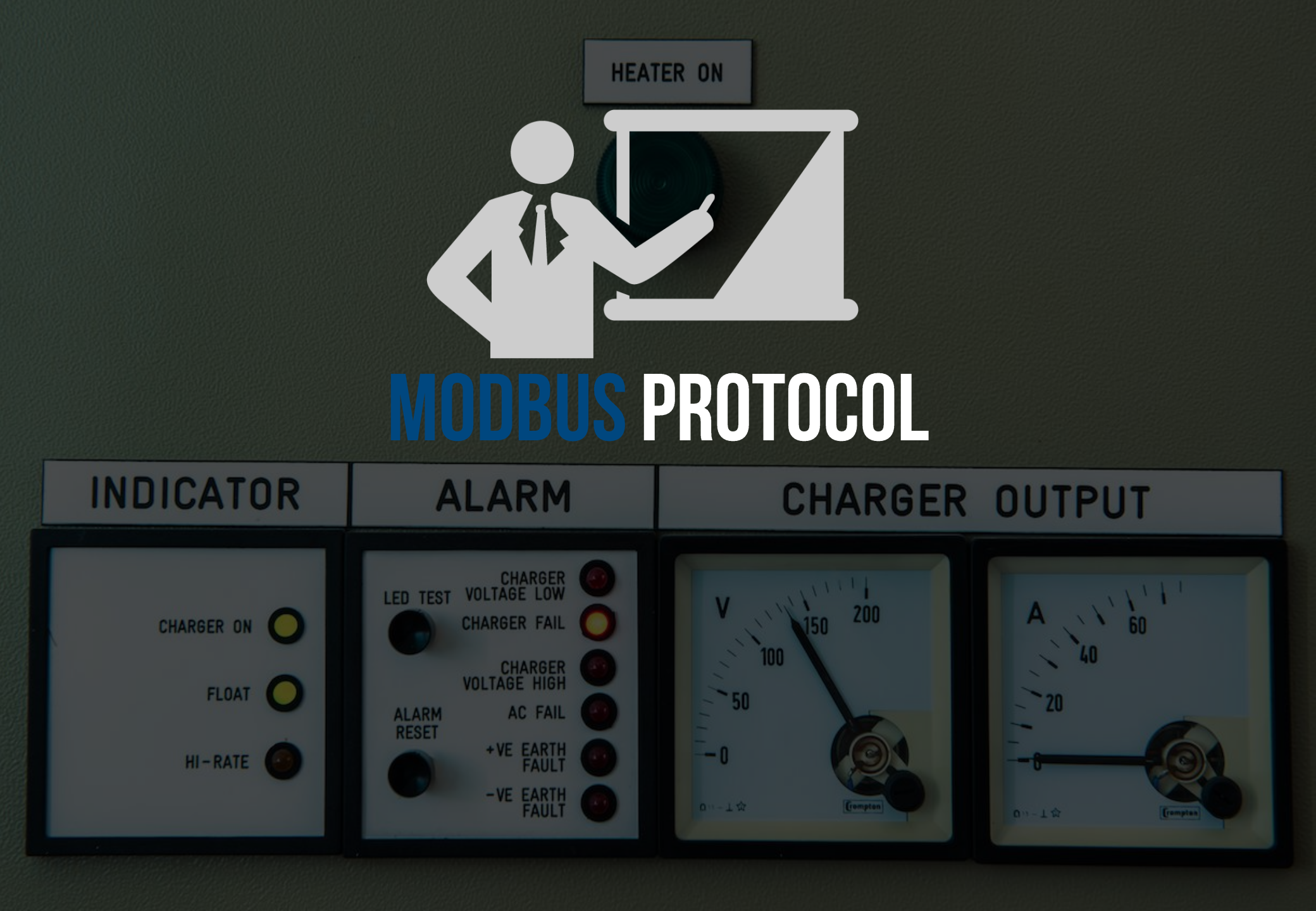
- Scan the Internet yourself (Zmap, Massscan)
- Other online services/surveys

FUNNY THINGS YOU CAN FIND ON TEH INTERWEBS

It's not just webcams.



THIS IS A CREMATORIUM.
ON THE INTERNET.


HEATER ON
MODBUS PROTOCOL
INDICATOR
ALARM
CHARGER OUTPUT
CHARGER ON
FLOAT
HI-RATE
LED TEST
CHARGER VOLTAGE LOW
CHARGER FAIL
CHARGER VOLTAGE HIGH
ALARM RESET
AC FAIL
+VE EARTH FAULT
-VE EARTH FAULT
V
0
50
100
150
200
A
0
20
40
60

MODBUS PROTOCOL

- Serial communication protocol invented in 1979 by Schneider Electric
- Developed for industrial application
- Royalty-free
- Now one of the standards for industrial communications

HOW IT WORKS

- Master / Slave protocol
- Master must regularly poll the slaves to get information
- Modbus addresses are 8 bits long, so only 247 slaves per master
- There is no object description: a request returns a value, without any context or unit

SECURITY ANYONE?

- Clear-text
- No authentication

MODBUS PROTOCOL

- Modbus was originally made for serial communications
- However it is now often used over TCP

MODBUS/TCP FRAME FORMAT

Name	Length	Function
Transaction identifier	2	For synchronization between server & client
Protocol identifier	2	Zero for Modbus/TCP
Length field	2	Number of remaining bytes in this frame
Unit identifier	1	Slave address (255 if not used)
Function code	1	Function codes as in other variants
Data bytes or command	n	Data as response or commands

MODBUS PROTOCOL

- The most common Modbus functions allow to read and write data from/to a PLC
- Other functions, such as file read and diagnostics functions also exist
- Undocumented Modbus function codes can also be used to perform specific actions

COMMONLY USED MODBUS FUNCTION CODES

Function name	Function code
Read coils	1
Write single coil	5
Read holding registers	3
Write single register	6
Write multiple registers	16
Read/Write multiple registers	23

MODBUS PROTOCOL

ALL DOCUMENTED MODBUS FUNCTION CODES (FROM WIKIPEDIA)

http://en.wikipedia.org/wiki/Modbus

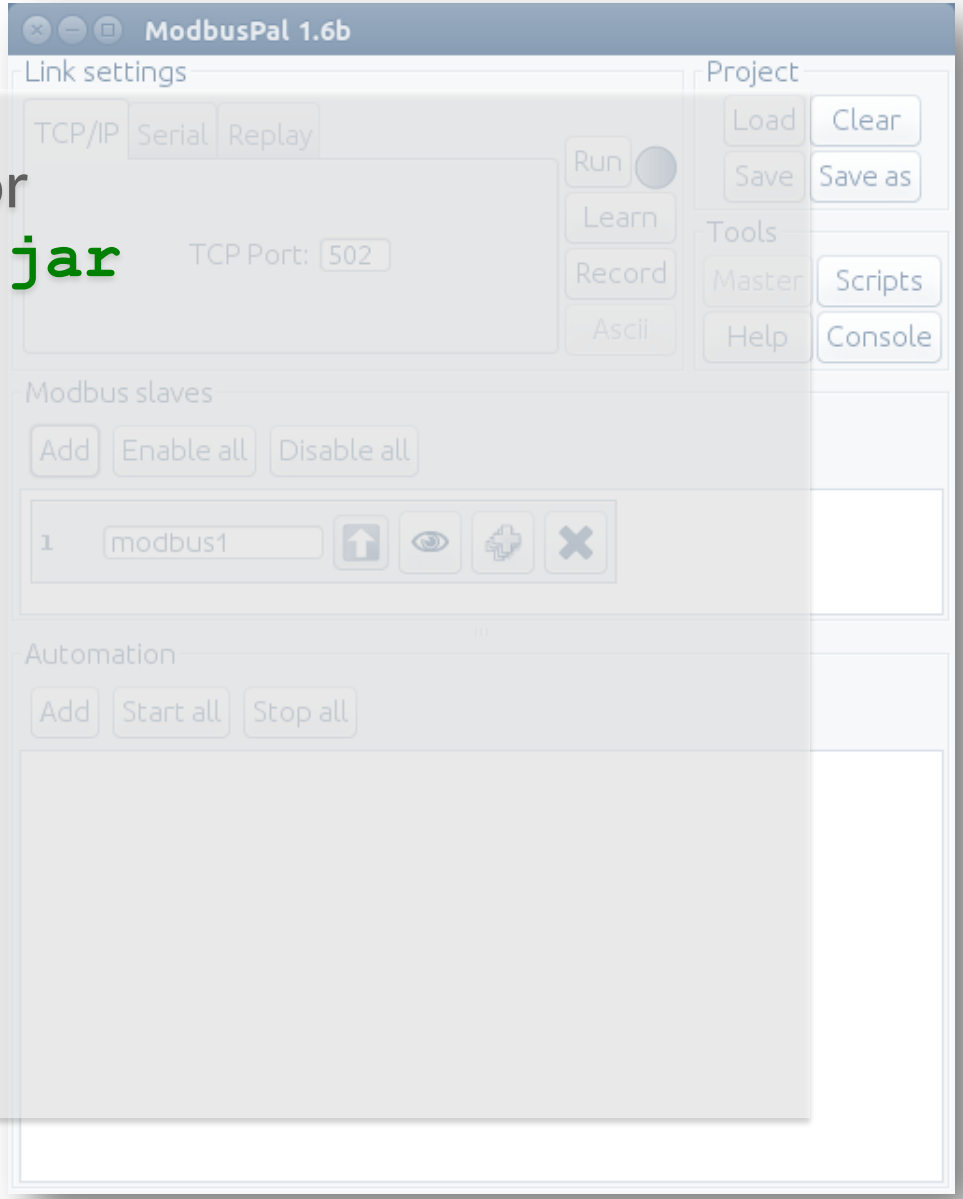
Function type			Function name	Function code
Data Access	Bit access	Physical Discrete Inputs	**Read Discrete Inputs**	2
		Internal Bits or Physical Coils	**Read Coils**	1
			Write Single Coil	5
			Write Multiple Coils	15
	16-bit access	Physical Input Registers	**Read Input Registers**	4
		Internal Registers or Physical Output Registers	**Read Holding Registers**	3
			Write Single Register	6
			Write Multiple Registers	16
			Read/Write Multiple Registers	23
			Mask Write Register	22
			Read FIFO Queue	24
	File Record Access		Read File Record	20
			Write File Record	21
Diagnostics			Read Exception Status	7
			Diagnostic	8
			Get Com Event Counter	11
			Get Com Event Log	12
			Report Slave ID	17
			Read Device Identification	43
Other			Encapsulated Interface Transport	43

LAB SESSION #1: ANALYZING A MODBUS COMMUNICATION WITH WIRESHARK

- Launch Wireshark
- Open "`modbus1.pcap`"
- Try to understand what's going on
- What's the value of register #123 at the end?

LAB SESSION #2: MODBUSPAL

- Modbuspal is a modbus simulator
  `$ > java -jar ModbusPal.jar`
- Add a modbus slave
- Set some register values
- Query it with:
  - MBTGET Perl script
  - Metasploit module
- Analyze traffic with Wireshark



LAB SESSION #2: MODBUSPAL + MBTGET

- Mbtget is a perl script to perform Modbus/tcp queries

```
$ > cd toolz
$ > ./mbtget -h
```

- Read requests
  - Coils (1 bit)

```
$ > ./mbtget -r1 -a 0 -n 8 127.0.0.1
```

  - Words (8 bits)

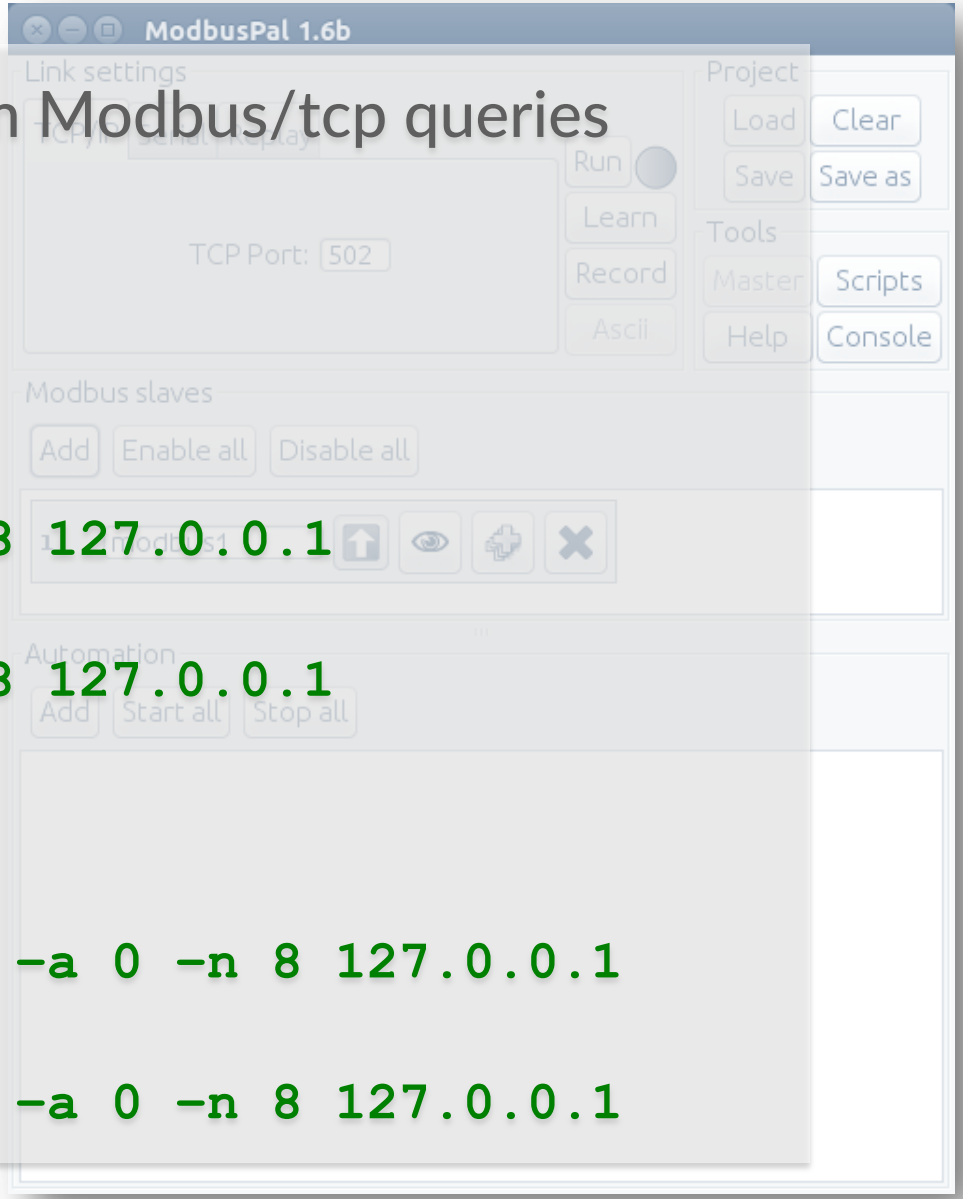
```
$ > ./mbtget -r3 -a 0 -n 8 127.0.0.1
```

- Write requests
  - Coils (1 bit)

```
$ > ./mbtget -w3 #{VALUE} -a 0 -n 8 127.0.0.1
```

  - Words (8 bits)

```
$ > ./mbtget -w6 #{VALUE} -a 0 -n 8 127.0.0.1
```



LAB SESSION #2: MODBUSPAL + METASPLOIT

- A simple modbus client that I developed
- Can perform read and write operations on coils and registers
- Included in msf's trunk so you already have it ☺

- Launch msf console

```
$ > msfconsole
msf > use auxiliary/scanner/scada/modbusclient
msf auxiliary(modbusclient) > info
```

- Play!

```
msf auxiliary(modbusclient) > set ACTION
```


WARNING
The following show features stunts
performed either by professionals or
under supervision of professionals.
performed on this show.
ATTACKING PLCS
NEVER DO THIS
ON LIVE PRODUCTION SYSTEMS

LAB SESSION #3 : RECONNAISSANCE

- Objective : Identify all exposed services on a device or a range of devices
- Often the first step in a pentest

- We will use two tools
  - Nmap: The world's finest port scanner
  - PLCSCAN: A reconnaissance tool dedicated to PLCs

- PLCs IP addresses
  - 192.168.0.50: Siemens S7-1200
  - 192.168.0.5: Schneider m340

LAB SESSION #3 : RECONNAISSANCE (NMAP)

- The de-facto tool for port scanning
- Can be really dangerous on ICS

- Two stories from NIST SP800-82
  - *A ping sweep broke for over 50 000$ in product at a semi-conductor factory*
  - *The blocking of gas distribution for several hours after a pentester went slightly off-perimeter during an assessment for a gas company*

- Nmap useful setup for ICS scanning
  - Reduce scanning speed! Use « `--scan-delay=1` » to scan one port at a time
  - Perform a TCP scan instead of a SYN scan
  - Do not perform UDP scan
  - Do not use fingerprinting functions, and manually select scripts (do not use "`-sC`")

LAB SESSION #3 : RECONNAISSANCE (PLCSCAN)

Siemens PLC

```
127.0.0.1:102 S7comm (src_tsap=0x100, dst_tsap=0x102)
  Module                    : 6ES7 151-8AB01-0AB0  v.0.2        (36455337203135312d38414230312d304142302000c000020001)
  Basic Hardware            : 6ES7 151-8AB01-0AB0  v.0.2        (36455337203135312d38414230312d304142302000c000020001)
  Basic Firmware            :                      v.3.2.6      (202020202020202020202020202020202020202000c056030206)
  Unknown (129)             : [illegible]                       (2020202020202020202020202020202020000041200909)
  Name of the PLC           : SIMATIC 300(xxxxxxxxx)            (53494d41544943203330302800000000000000000029000000000000000000)
  Name of the module        : IM151-8 PN/DP CPU                 (494d3135312d3820504e2f44502043505500000000000000000000000000)
  Plant identification      :                                   (202020202020202020202020202020202020202020202020202020202020)
  Copyright                 : Original Siemens Equipment        (4f726967696e616c205369656d656e73204571756970656e74000000000000)
  Serial number of module   : S C-BOUVxxxxxxxx                  (5320432d424f5556xxxxxxxxxx000000000000000000000000000000000000)
  Module type name          : IM151-8 PN/DP CPU                 (494d3135312d3820504e2f44502043505500000000000000000000000000)
```

Modbus device

```
127.0.0.1:502 Modbus/TCP
  Unit ID: 0
    Response error: ILLEGAL FUNCTION
    Device info error: ILLEGAL FUNCTION
  Unit ID: 255
    Response error: GATEWAY TARGET DEVICE FAILED TO RESPOND
    Device: Lantronix [illegible]
```

- https://code.google.com/p/plcscan/ by SCADAStrangeLove (http://scadastrangelove.org/)
- Scans for ports `102` (Siemens) and `502` (Modbus) and tries to pull information about the PLC (modules, firmware version,…)
- Not exhaustive since not all PLCs use Modbus or are Siemens

LAB SESSION #4 : ATTACKING STANDARD SERVICES

- Most PLCs have standard interfaces, such as HTTP and FTP
- Lets' say security was not the first thing in mind when introducing these features …

- Schneider M340
  - Connect to the webserver
  - Default password
  - Hardcoded password ?
  - Take a look at Java applets !

LAB SESSION #5 : ATTACKING ICS PROTOCOLS

- Modbus
  - Scan for registry values using `mbtget`
  - Python / Ruby / Perl / PHP, your call !

- Unauthenticated actions

  - STOP/RUN
    `msf > use auxiliary/admin/scada/modicon_command`

  - Logic download/upload
    `msf > use auxiliary/admin/scada/modicon_stux_transfer`

Reading program instruction

little endian counter

Modbus Function Code

WHAT CAN WE DO ABOUT IT ?

It's difficult, but not all hope is lost.

NETWORK SEGMENTATION

- Do not expose your ICS on the Internet
- Do not expose all of your ICS on your internal network
- Use DMZ / Data diodes to export data from ICS to corporate network

PATCH WHEN YOU CAN

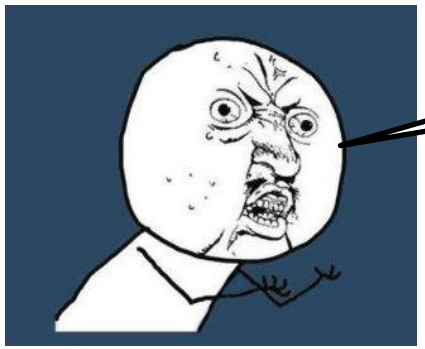
- Patching once a year during plant maintenance is better than doing nothing

APPLY CORPORATE BEST PRACTICES

- Change default passwords
- Disable unused services

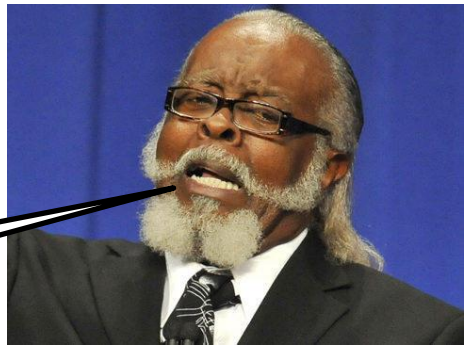
SECURITY SUPERVISION

- IPS have signatures for ICS
- Create your own signatures, it is not that difficult



Y U NO SECURE ICS ?

THE COST IS TOO DAMN HIGH !



The power of simplicity

«Ce qui est simple est fort»

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