# How Cybersecurity or the Lack of Impact Functional Safety

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# Disclaimer

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# Biography

**David Ong,**

Entrepreneur and Founder of Excel Marco Group, a successful Industrial Automation Integrator and Attila Cybertech, a Operational Technology (OT) cyber security firm. With over 25 years of professional experience and is widely recognized as an active professional in process automation safety industries.

# Evolution of Safety PLC

- Relay based Interlocking Panel
- Solid-state Safety System
- PLC with redundant Processor, Fail-safe design
- Third party certified Safety PLC: FS, DMR, QMR, TMR

Siemens

Schneider Electric

Mitsubishi Electric

Allen Bradley

ABB

# Standards

***Functional Safety***

- DIN V VDE 0801
- DIN V 19250
- ISA SP84
- IEC 61508/61511

***Cybersecurity***

- ISO/IEC 27000 (Information Security)
- ISA/IEC 62443 (Industrial Security)
- NIST 800-53 Appendix
- NIST 800-82

61508-life.jpg

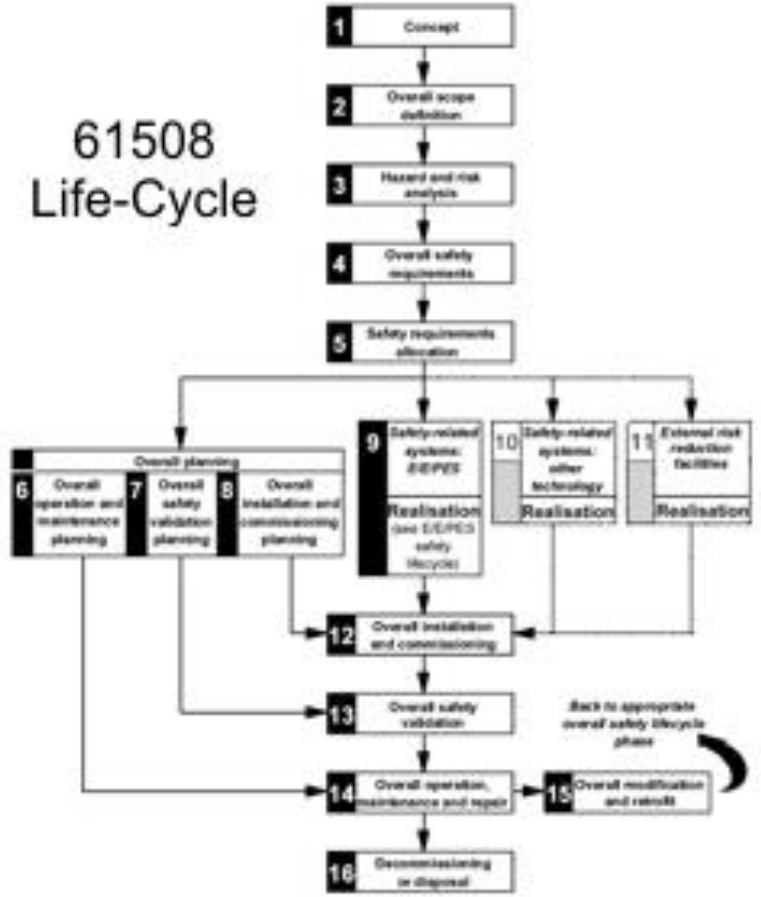
# Standards for Functional Safety

**Fundamental change from Qualitative to Quantitative:**

Safety Life Cycle Model

Safety Integrity Level

Third party certification, e.g. TUV

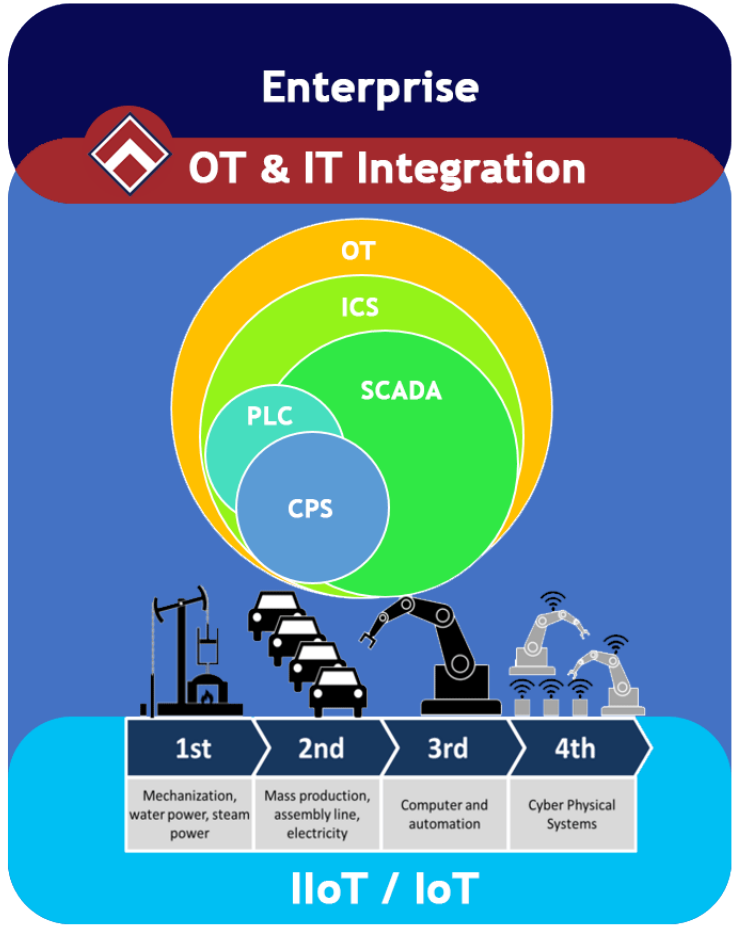


# Connectivity … Hello World

- Communications capability
  - interface to EWS, DCS, HMI, Peer to Peer
- Uni-directional communication, read-only
- Bi-directional communication, read-write
- Integrated Control & Safety Systems

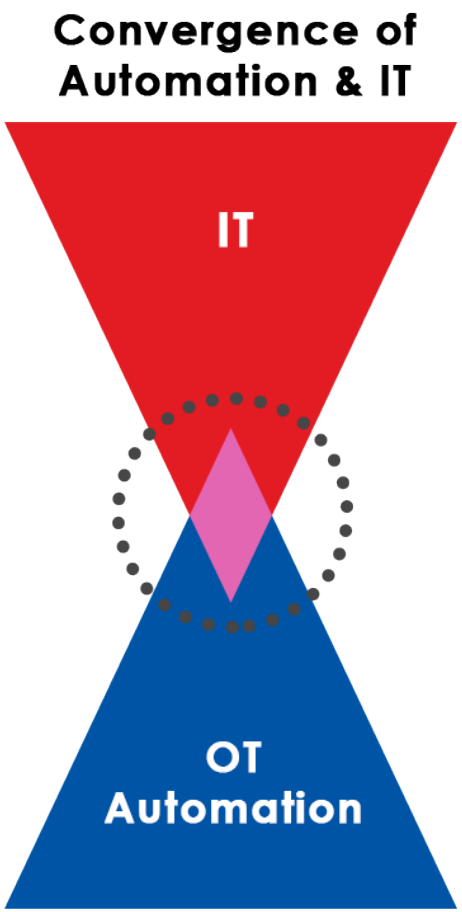
# Convergence of IT and OT

- Historically, IT and OT have had fairly separate roles and were managed separately within an organization
- ICS were traditionally developed using specialized hardware and proprietary software
- Deployed as standalone platforms using vendor proprietary communication protocols to communicate with similar systems



# Convergence of IT and OT

- Reduce manufacturing and operational costs.
- Increase productivity.
- Provide access to real-time information.
- Utilize modern networking systems to interconnect ICS with business and external networks.
- ICS makers switched to commercial-off-the-shelf equipment and software



# Convergence of IT and OT

- Whatever Windows is vulnerable to exploitation, so is ICS?
- Can you Hack an SIS?
- Can you Hijack a plane?
- Now can you Cyber hack an SIS?

# Top 10 Cybersecurity attacks of ICS

| FY 2014-2016 TOP SIX WEAKNESS CATEGORIES IN ORDER OF PREVALENCE | | |
|---|---|---|
| **FY 2014** | **FY 2015** | **FY 2016** |
| 1. Boundary Protection | 1. Boundary Protection | 1. Boundary Protection |
| 2. Information Flow Enforcement | 2. Least Functionality | 2. Least Functionality |
| 3. Remote Access | 3. Authenticator Management | 3. Identification and Authentication |
| 4. Least Privilege | 4. Identification and Authentication | 4. Physical Access Control |
| 5. Physical Access Control | 5. Least Privilege | 5. Audit Review, Analysis and Reporting |
| 6. Security Function Isolation | 6. Allocation of Resources | 6. Authenticator Management |

Table 1: FY 2014-2016 Top Six Weaknesses

| FY 2016 MOST PREVALENT WEAKNESSES | | |
|---|---|---|
| **Area of Weakness** | **Rank** | **Risk** |
| Boundary Protection | 1 | • Undetected unauthorized activity in critical systems<br>• Weaker boundaries between ICS and enterprise networks |
| Least Functionality | 2 | • Increased vectors for malicious party access to critical systems<br>• Rogue internal access established |
| Identification and Authentication | 3 | • Lack of accountability and traceability for user actions if an account is compromised<br>• Increased difficulty in securing accounts as personnel leave the organization, especially sensitive for users with administrator access |
| Physical Access Control | 4 | • Unauthorized physical access to field equipment and locations provides increased opportunity to<br>o Maliciously modify, delete, or copy device programs and firmware<br>o Access the ICS network<br>o Steal or vandalize cyber assets<br>o Add rogue devices to capture and retransmit network traffic |
| Audit Review, Analysis and Reporting | 5 | • Without formalized review and validation of logs, unauthorized users, applications, or other unauthorized events may operate in the ICS network undetected detection |
| Authenticator Management | 6 | • Compromised unsecured password communications.<br>• Password compromise could allow trusted unauthorized access to systems |

Table 2: Risk Associated with FY2016 Most Prevalent Weaknesses

***Source: ICS-CERT Annual Assessment Report FY2016***

# Top 10 Cybersecurity attacks of ICS

**#10:** Cell-phone WIFI

**#9:** Sophisticated Market Manipulation

**#8:** Market manipulation

**#7:** Ukraine Attack

**#6:** Sophisticated Ukraine Attack

**#5:** Zero-day ransom ware

**#4:** Targeted ransom ware

**#3:** Common ransom ware

**#2:** IT insider

Source: https://ics-cert.us-cert.gov/sites/default/files/ICSJWG-Archive/QNL_DEC_17/Waterfall_top-20-attacks-article-d2%20-%20Article_S508NC.pdf

# Top 10 Cybersecurity attacks of ICS

**#1: ICS Insider** – A disgruntled insider with access to ICS equipment uses social engineering to steal passwords able to trigger a partial plant shutdown.

Source: https://ics-cert.us-cert.gov/sites/default/files/ICSJWG-Archive/QNL_DEC_17/Waterfall_top-20-attacks-article-d2%20-%20Article_S508NC.pdf

# ICS Cybersecurity Attacks

Some infamous ICS Cybersecurity Attacks :

- Stuxnet
- Black Energy (Ukraine)
- Maroochy Shire sewage

# Overview of Stuxnet

- A malicious computer worm, first uncovered in 2010 by Kaspersky Lab
- Specifically targets – only Siemens PLC
- Brought down 1/5 of Iran's nuclear centrifuges by causing them to rotate unusually fast and then slowing down abruptly – with no indication on HMI
- Alleged state sponsored attacked by the US/Israel

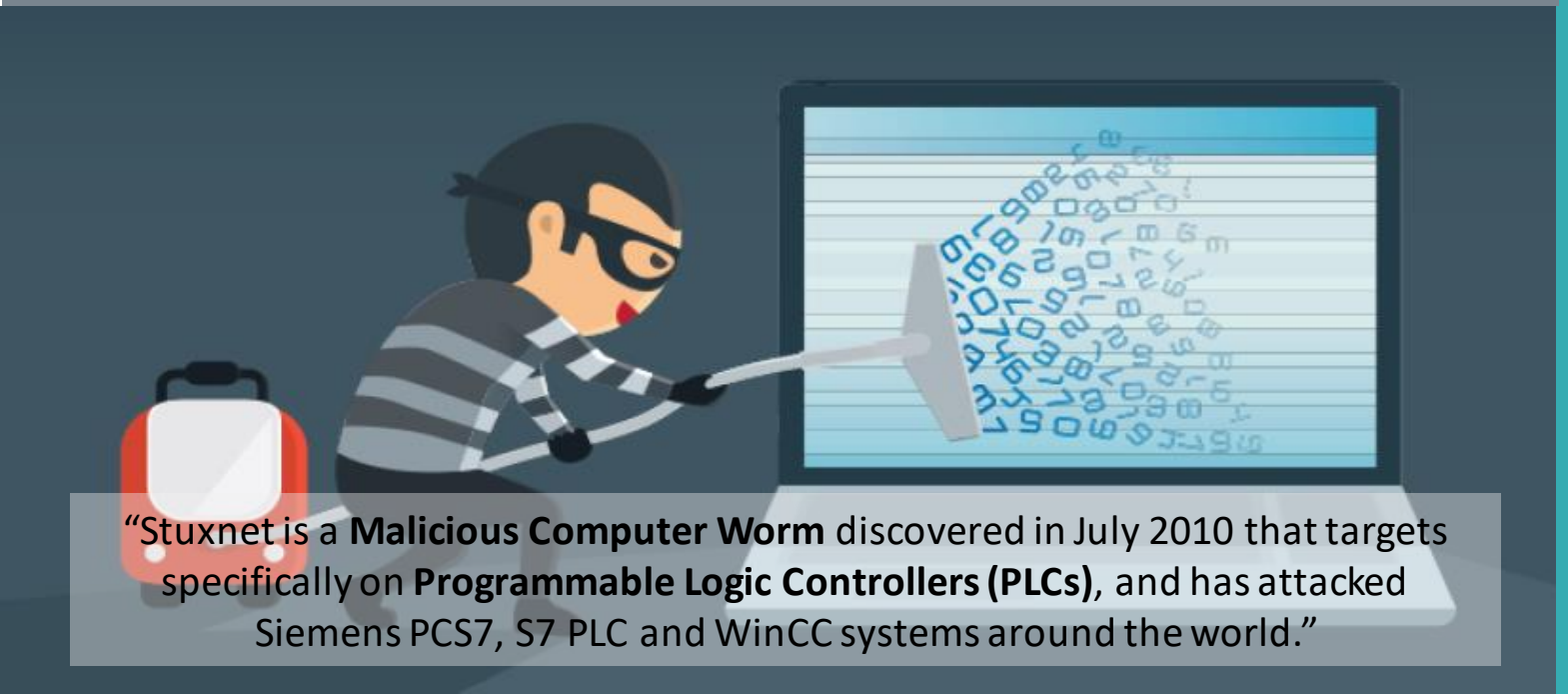
# How Stuxnet works

**Infection**

Stuxnet enters a system via a USB stick and proceed to infect all machines running Microsoft Windows.

**Search**

Stuxnet checks whether a given machines is part of the targeted Industrial Control Systems made by Siemens



"Stuxnet is a **Malicious Computer Worm** discovered in July 2010 that targets specifically on **Programmable Logic Controllers (PLCs)**, and has attacked Siemens PCS7, S7 PLC and WinCC systems around the world."

**Update**

Stuxnet attempt to access the internet and download a more recent version of itself.

**Compromise**

Stuxnet compromises the targeted system's logic controllers exploiting zero-day vulnerabilities that hasn't been identified by security experts.

**Control**

Stuxnet spies on the Operations of the targeted system and use the information it has gathered to take control of centrifuges, making them spin themselves to failure.

**Man-In-The-Middle**

Stuxnet provides false feedback to outside controllers, ensuring that they wont know what's wrong until it is too late to rectify.

# Black Energy (Ukraine)

- Prior compromise of corporate networks using spear-phishing emails with BlackEnergy malware
- Seizing SCADA under control, remotely switching substations off
- Disabling/destroying IT infrastructure components (uninterruptible power supplies, modems, RTUs, commutators)
- Destruction of files stored on servers and workstations with the KillDisk malware
- Denial-of-service attack on call-center to deny consumers up-to-date information on the blackout.

# Maroochy Shire Sewage Attack

- More than 1,000,000 litres of sewage fluid released into local parks
- Insider ICS attack (listed as no.1) – disgruntled ex employee
- Stole configuration program and control equipment, “impersonated” a pump to cause malfunction

# ICS/SIS Vulnerability

**ICS**

- USB Drive malware
- DOS/DDOS

Common Mode Failure

- Human factor
- Power Source
- Environment

**SIS**

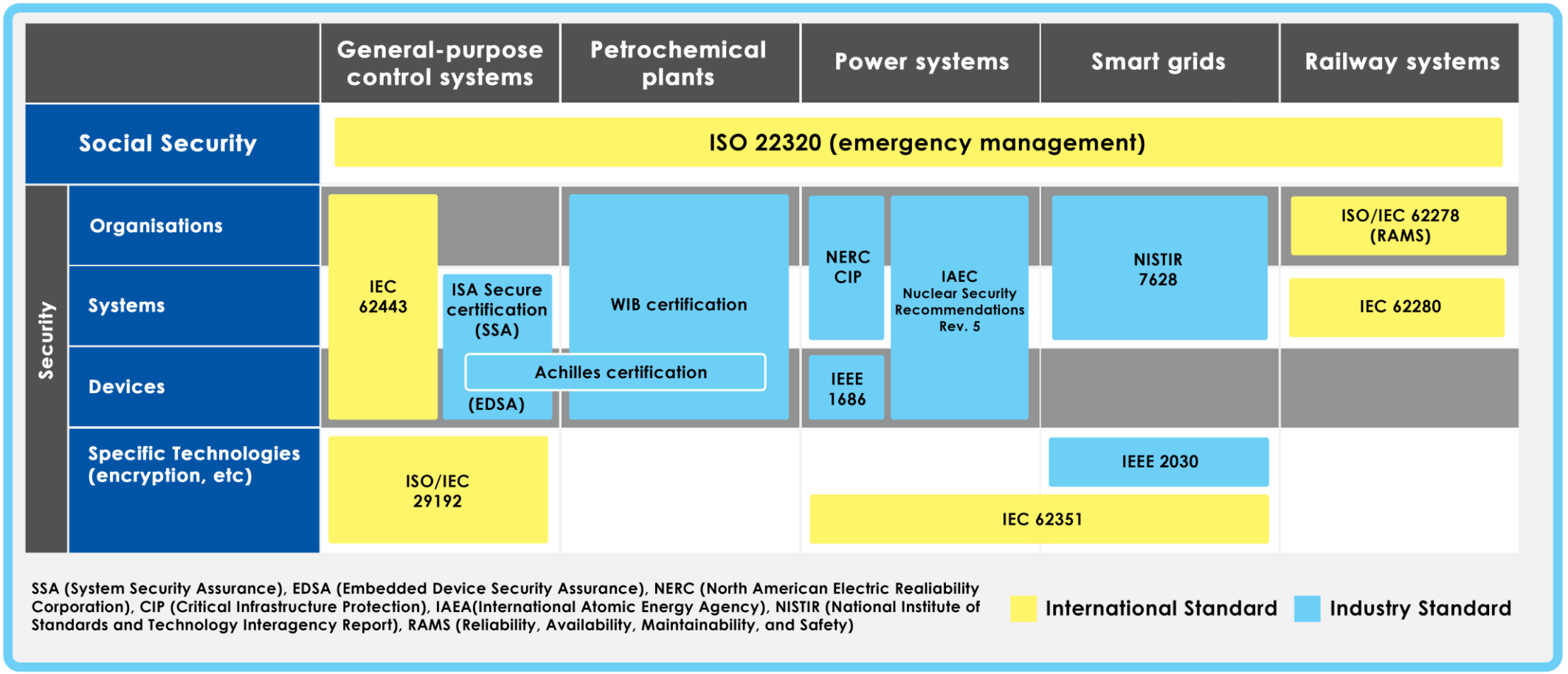
- USB drive on EWS

# Information Security Standards

- ISO27001 / 27002 / 15408
- NIST 800-82
- IEC62443/ISA99
- CISQ
- NERC 1300
- RFC 2196
- ISA/IEC 62443 (previously ISA-99)

Source: https://ics-cert.us-cert.gov/sites/default/files/ICSJWG-Archive/QNL_DEC_17/Waterfall_top-20-attacks-article-d2%20-%20Article_S508NC.pdf

# Standards and Best Practices for ICS




Source: Hitachi Review Vol. 63 (2014)

# Standards and Best Practices for ICS

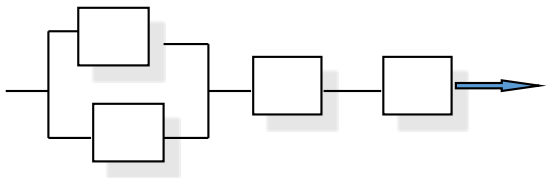

- American Petroleum Institute (API): API-1164 - Pipeline SCADA Security, 2nd ed.
- National ICS Security Standard (Qatar), v3, Mar 2014
- Australian Signals Directorate (ASD): Strategies to Mitigate Cyber Security Incidents – Mitigation Details, Feb 2017 (Note: It claims implementing the Top 4 can mitigate over 85% of intrusions)

# Functional Safety vs Cyber Security

**Functional Safety**

- Risk Assessment
- Quantitative Risk Analysis (QRA)
- Layer of Protection Analysis (LOPA)
- SIL Determination
- Safety Requirement Specification (SRS)

*Reliability Block Diagrams*

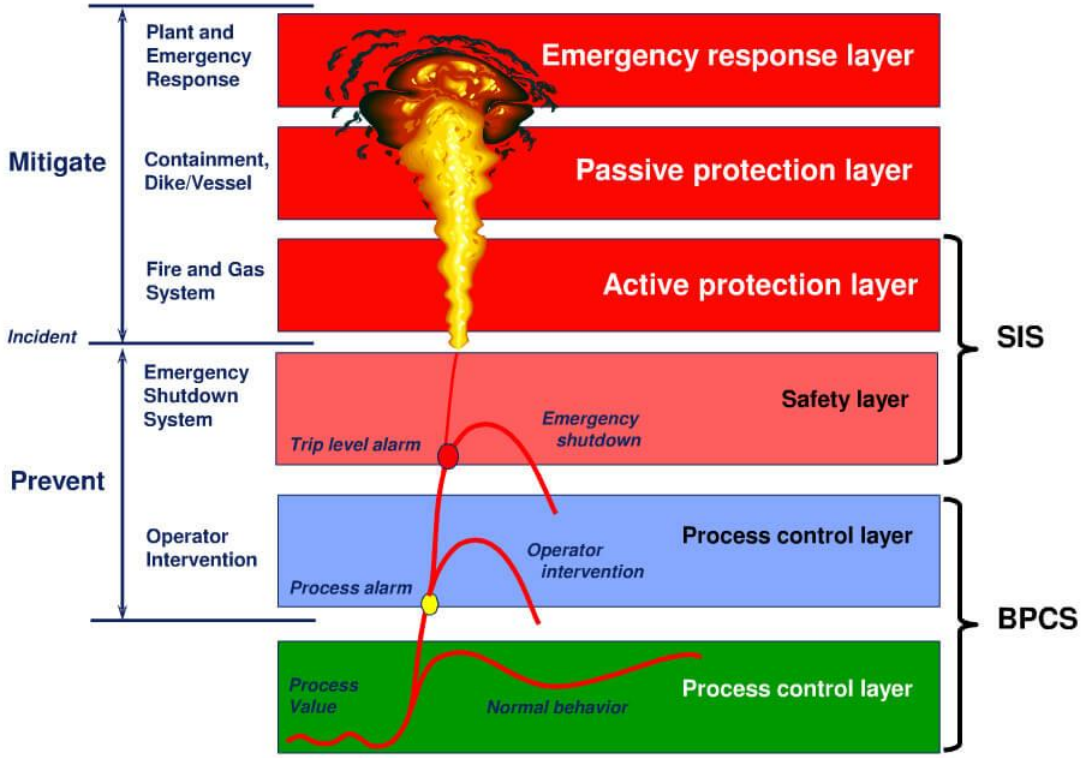


**Cyber Security**

- Risk Assessment
- Threat, Vulnerability & Risk Assessment (TVRA)
- Defense-in-Depth
- Security Level (SL)
- Security by Design

# LOPA vs Defense-in-Depth

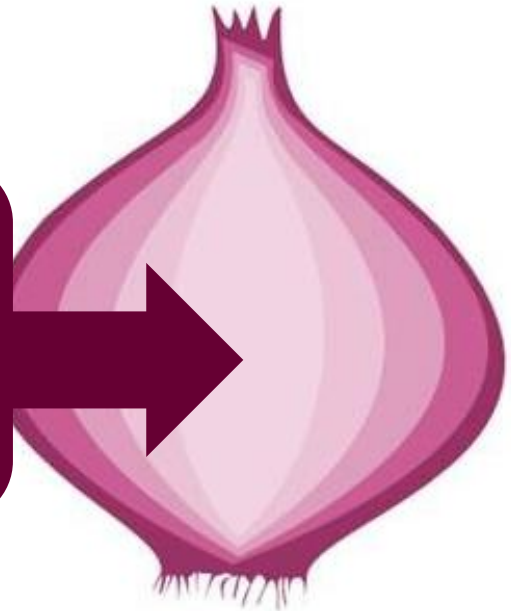
## Layer of Protection Analysis (LOPA)




## Defense-In-Depth (DiD)

- Defense-in-depth approach: Employs multiple layers of defense (physical, procedural and electronic) at separate levels. The layers are:

- Policies, Procedures and Awareness
- Physical Security
- Network Security
- Computer Hardening
- Application Security
- Device Hardening



# Challenges: What are the problems…?

**Functional Safety**

- SIL is quantitative
- It is derive from PFD(avg)

**Cybersecurity**

- SL not widely used yet
- Not “quantifiable”, based on qualitative judgement

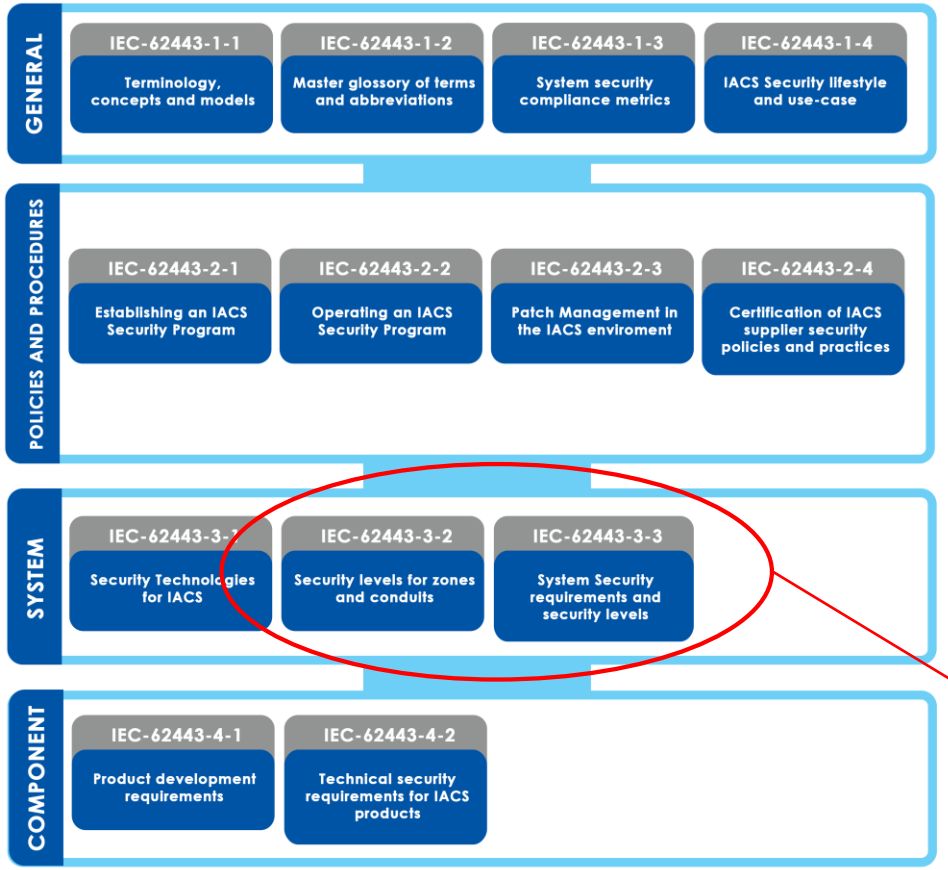
? “There are unknown unknown …. things that we don’t know what we don’t know” (Donald Rumsfield)

? What is the Probability of a Hacker attacking an ICS using a particular attack vector?
  - Depends on human behavior?
  - Can we based on historical data of attacks?

? Can we quantify what is the likelihood of a terrorist attack?

# Rating Cyber Security Risk: Security Level

**Cybersecurity Risk can be rated via Security Level or Common Vulnerability Scoring System (CVSS)**

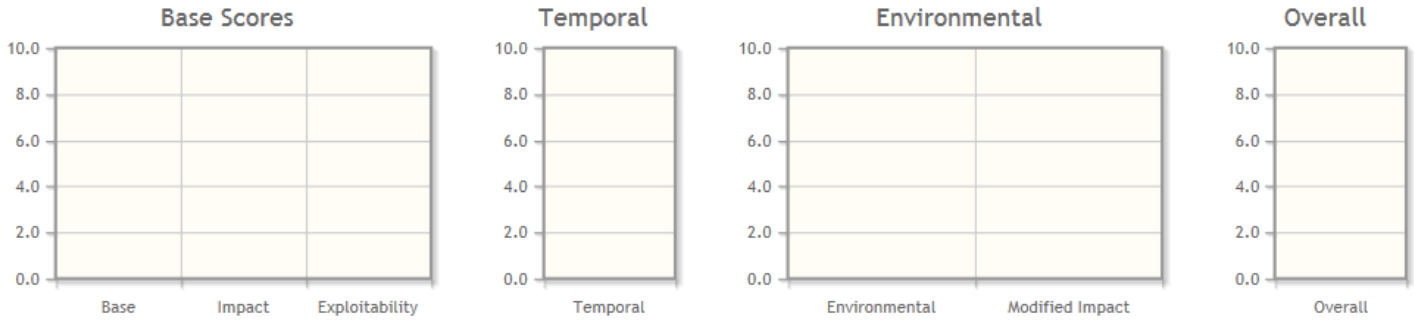



| Security Level Definition | |
|---|---|
| SL 1 | Protection against casual or coincidental violation |
| SL 2 | Protection against intentional violation using simple means with low resources, generic skills and low motivation |
| SL 3 | Protection against intentional violation using sophisticated means with moderate resources, IACS specific skills and moderate motivation |
| SL 4 | Protection against intentional violation using sophisticated means with extended resources, IACS specific skills and high motivation |

Part 3-2: asset owner / system integrator define zones and conduits with target SLs
Part 3-3: product supplier provides system features according to capability SLs

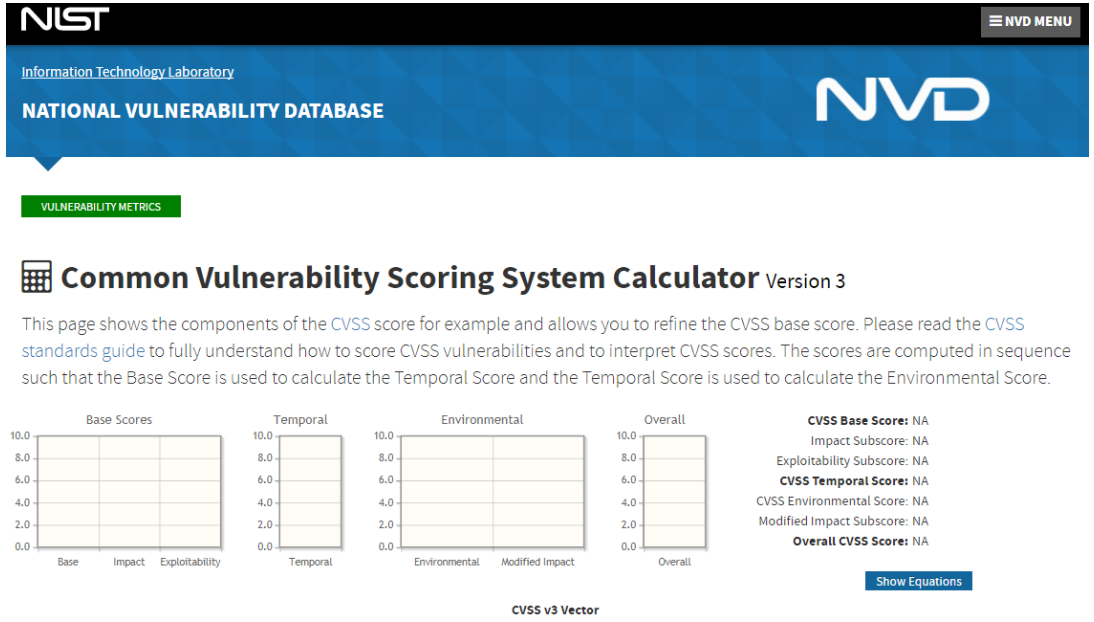
# Rating Cyber Security Risk: CVSS

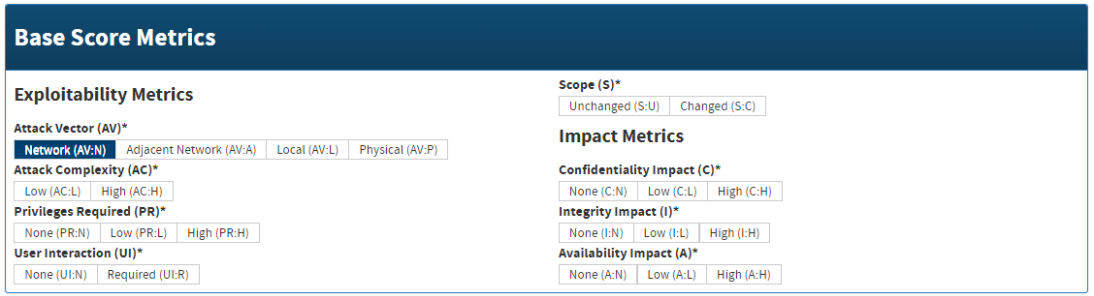
- The Common Vulnerability Scoring System (CVSS) is an open framework for communicating the characteristics and severity of software vulnerabilities.
- CVSS consists of three metric groups: Base, Temporal, and Environmental.
  - The Base group represents the intrinsic qualities of a vulnerability,
  - The Temporal group reflects the characteristics of a vulnerability that change over time.
  - The Environmental group represents the characteristics of a vulnerability that are unique to a user's environment.

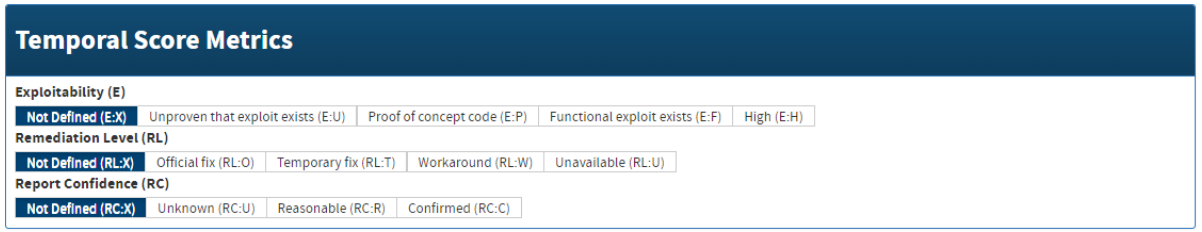


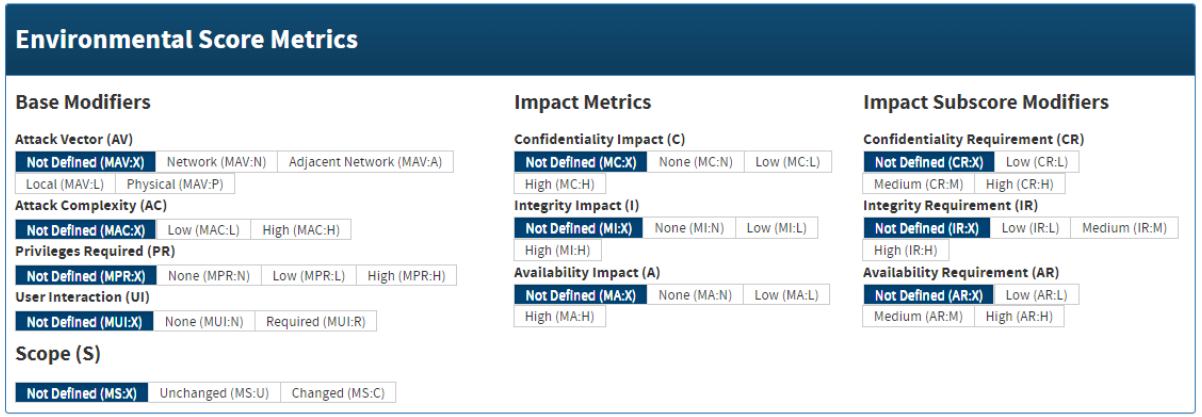

Source : https://nvd.nist.gov/vuln-metrics/cvss/v3-calculator

# Rating Cyber Security Risk: CVSS




**Source :** https://nvd.nist.gov/vuln-metrics/cvss/v3-calculator

# Solutions

- Are we able to apply IT Cybersecurity to OT (ICS)?

- Why not?

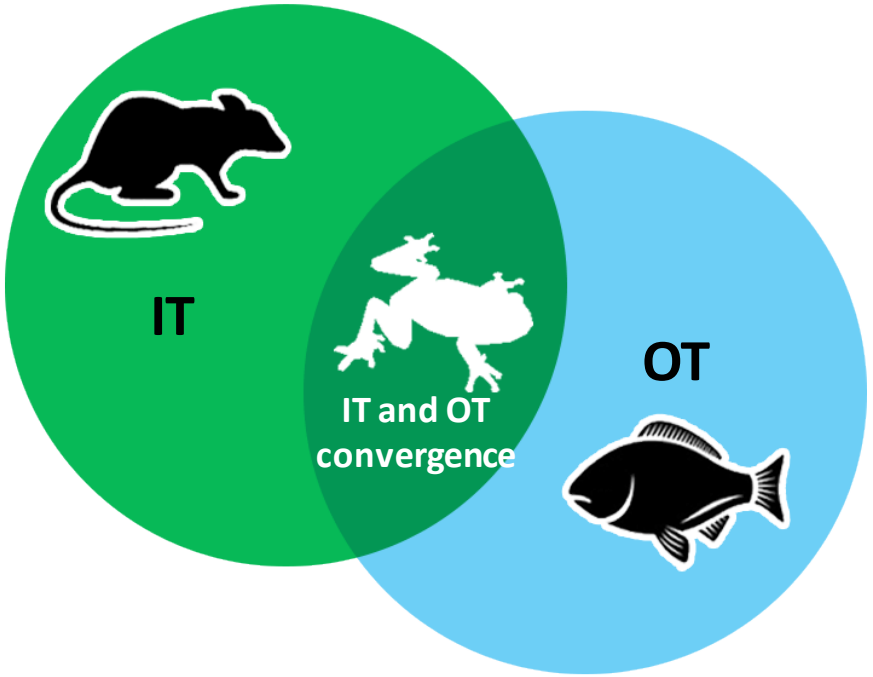
  IT Protocol: TCP/IP
  Secured by: HTTPS, DNNSEC, AES128 etc…

  Industrial Protocol: Modbus, Industrial Fieldbus, Industrial Ethernet (Ethernet/IP, Profinet)
  Secured by: Threat modelling, risk mitigation, signature-based and anomaly detections

  Tapping in to OT networking!

# Understanding IT and OT

- **Operational Technology (OT)**
  - ICS, PLC, DCS, SCADA, IACS synonymously used terms
- The Difference between **IT vs OT**
  - Modus Operandi
  - External Inputs
  - CIA and AIC
  - Latency issues
  - False Positives
  - Functional Safety
  - Proofing

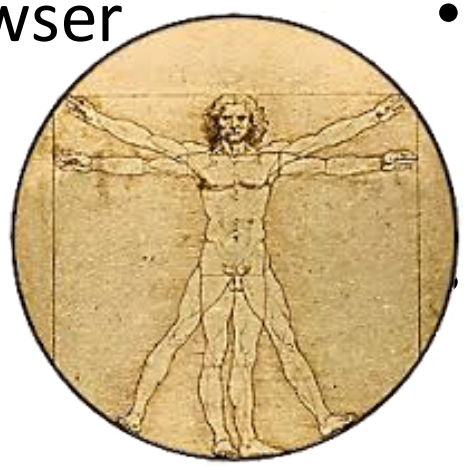


# Differences between IT vs OT

## External Inputs – Human initiated vs Sensor triggered

**Source of Input to IT**

- PC user: keys, mouse, trackball etc.
- Internet / Intranet download, web browser
- Emails
- ERP



**Source of Input to OT**

- Sensors e.g. Pressure, Flow, Level, Position, Limit, Smoke, Gas etc
- Operator action such as alarm acknowledgement, auto/manual mode selection
- Set-point entry

# Differences between IT vs OT

## False Positives

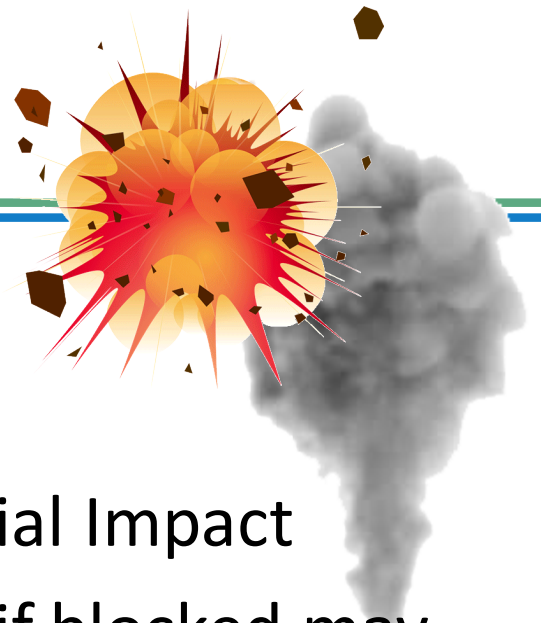
### IT

- Suspicious Packets may be blocked, rejected or quarantine

### OT

- Suspicious Packets may **trigger alerts**
- Unless determined unambiguously as malicious packets, it may not be blocked
- False Positives leads to indifference, which leads to "**switching off**"

# Differences between IT vs OT



## Functional Safety

### IT

- Low Consequential Impact
- Blocking a email or Approval of legitimate online payment may be inconvenient but not life - threatening

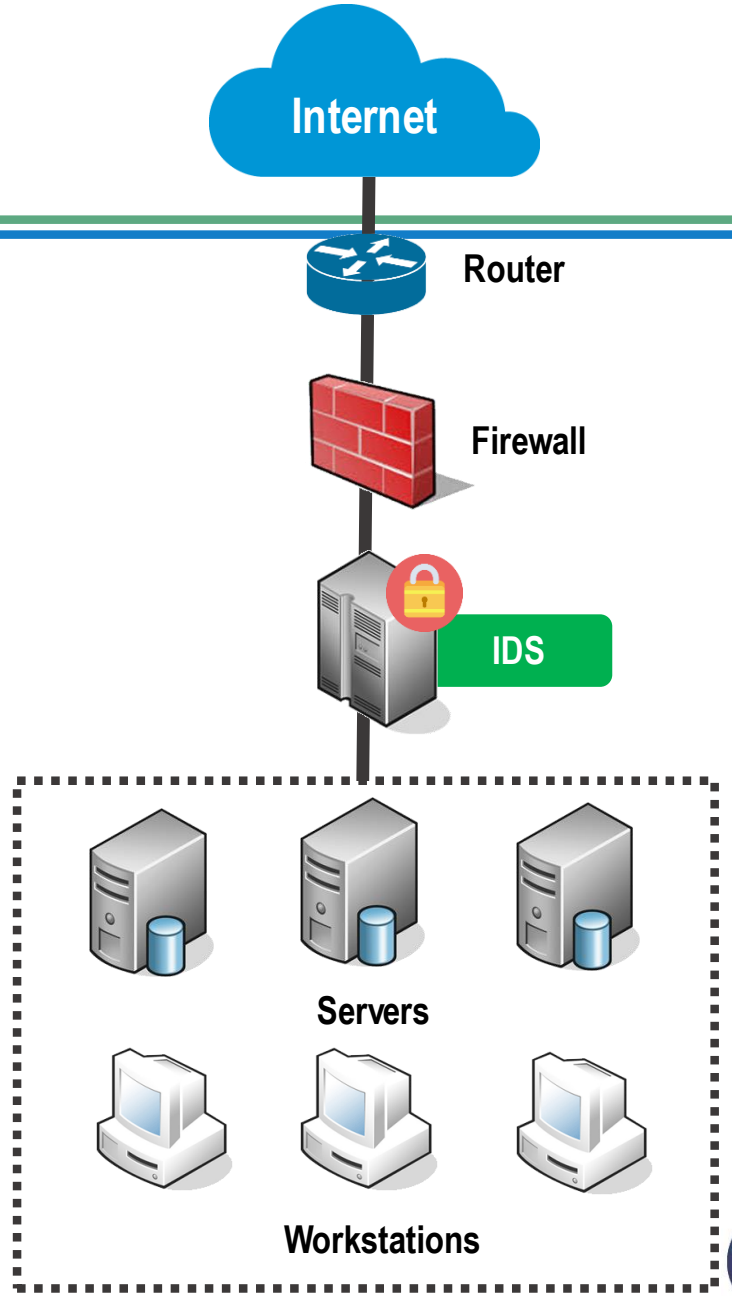
### OT

- High Consequential Impact
- Shutdown signal if blocked may prevent bringing Process to a “Safe State”, could be life threatening

# Solutions

- Industrial firewall
- Intrusion Detection System (IDS)
- Whitelisting
- Hardening
  - Active directory

**Don’t throw away common sense, use it!**



# Cyber Security Law - Regulatory Compliance Standards

## Regulatory Compliance Standards

- NERC Critical Infrastructure Protection (CIP) Version 6, July 2016, USA.
- DHS Chemical Facility Anti-Terrorism Standards (CFATS), 9 April 2007 and the CFATS Act 2014, USA.
- Cyber Security Programs for Nuclear Facilities, NRC Regulation 5.71 (Jan 2010), USA.
- German IT Security Law (IT-Sicherheitsgesetz), 25 July 2015, Germany.
- The Directive on Security of Network and Information Systems (NIS Directive), (EU) 2016/1148, European Union.
- Military Programming Law (LPM), Article 22, 1 July 2016.
- The Cybersecurity Law of the People's Republic of China, 1 June 2017, China.
- Security of Critical Infrastructure Bill 2017, 7 December 2017, Australia.

# Conclusion

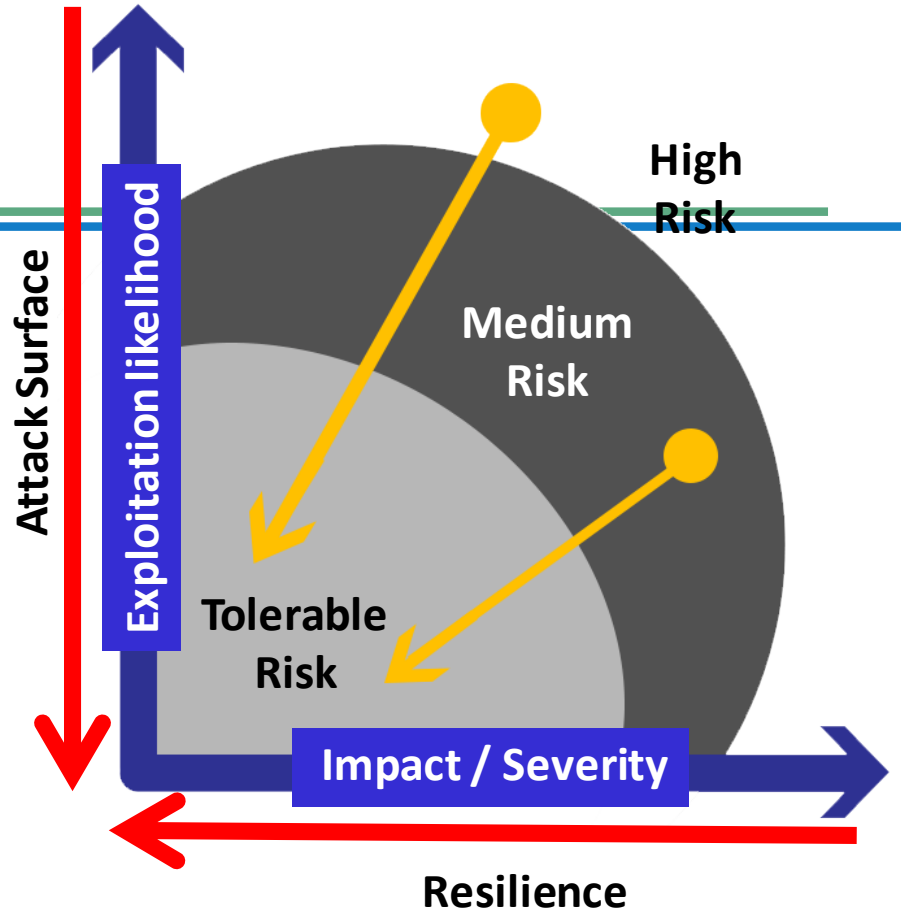
- SIS – no such thing as zero risk
- Cybersecurity – no such thing as zero risk

**Functional Safety**

- No zero risk
- Risk Reduction
- ALARP

**Cyber Security**

- No zero risk
- Risk Reduction
- ALARP




**Zero Risk is non existent!**

**We have to be Cybersecurity Resilient!**

# Conclusion

**Common Mode Failure**

- Human Factor (During Operation)
- Wrong Assumption (At Design Stage)
- Exploring “New” Technology
- HVAC / Chiller
- Power

# References


https://ics-cert.us-cert.gov/sites/default/files/ICSJWG-Archive/QNL_DEC_17/Waterfall_top-20-attacks-article-d2%20-%20Article_S508NC.pdf

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