Cybersecurity in Smart Ship

2024.11.12

Korean Register
Park Kaemyoung
(kaemyoung@krs.co.kr)

Contents

I. The Concept of Smart Ship

I. Concept of Smart Ship

Definition of Smart Ship

- A next-generation digital ship that enables autonomous operation, economic operation, and safe operation by applying cutting-edge information technology to ships built based on information and communication technology (ICT).
- Smart vessel that utilizes information and communication technology (ICT) to operate easily and safely at minimum cost

Concept of Smart Ship

- Vessel capable of monitoring in-ship/exterior information and operation information
- Vessels capable of safe cargo transport and tracking
- Vessels that are easy to repair and maintain -> Ships that can be operated economically
- Vessels that can be controlled and controlled remotely (on land) while satisfying tightened environmental regulations
- (Future-Final Goal) Future ships capable of autonomous operation

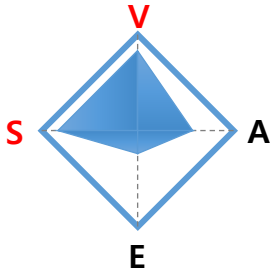
Comprehensive technology that applies advanced equipment and ICT to ships of meaning

I. Concept of Smart Ship

Development of Smart Ship

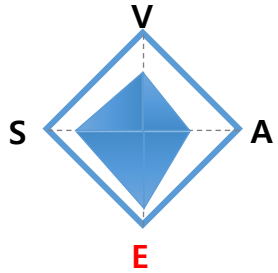
Ref. : ISTOCK

Conventional Ship
(~ Early 2000)



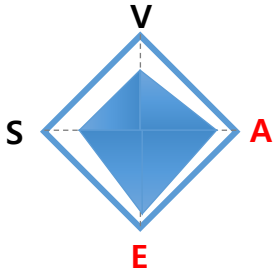
Ref. : Japan Marine United Corporation

Eco Ship
(2012~2017)



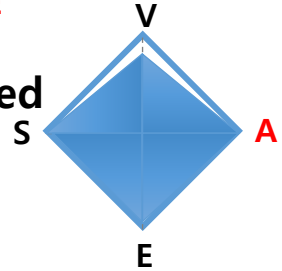
Ref. : DNVGL

Smart Ship
(2017~2030)

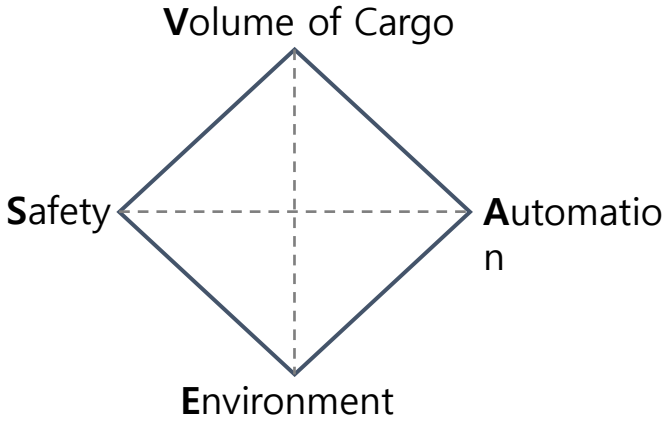


Ref. : Rolls-Royce

Unmanned Ship
(2030~)



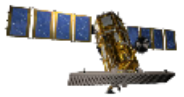
Information &
Communication
Technology
to the ship



Refer : Korean Maritime Institute

I. Concept of Smart Ship

Core Technology of Smart Ship



[Communication]

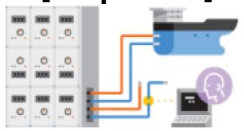
Remote Maintenance

[Cybersecurity]

Remote Control	Monitoring
Marine Env, Onboard Info ▪ Wave, Current ▪ Vessel Info ▪ CCTV info	**Voyage Info** ▪ Equip Status ▪ Failure Prediction Info.

Engine Info.

[Propulsion]

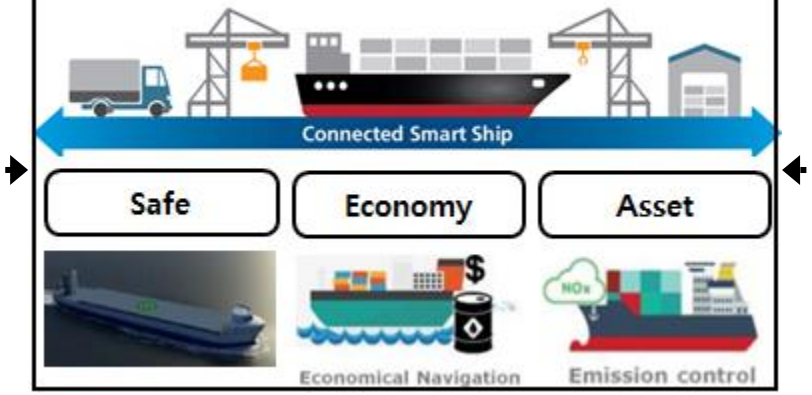


[Electric]

Voyage Info.

Cargo Info

Hull Info



[Autonomous Ship]

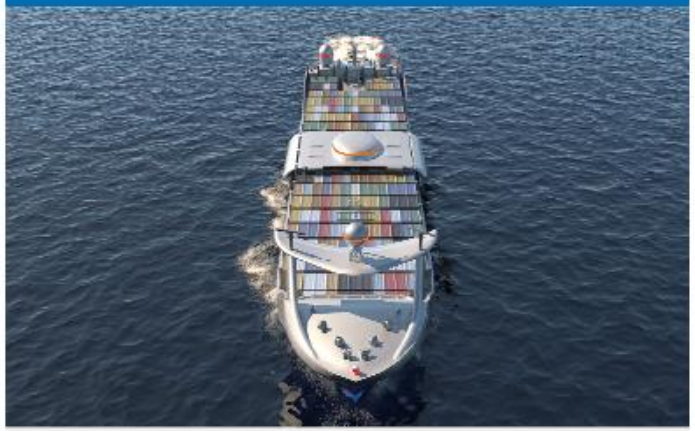
I. Concept of Smart Ship

Future of Smart Ship

Smart Ship

Comprehensive technology that applies advanced equipment and ICT to ships of meaning

Partial Autonomous Ship



Integrating IOT, platform, and control technology into existing ships The system replaces the role the crew was playing Vessels that can be operated with only minimum crew

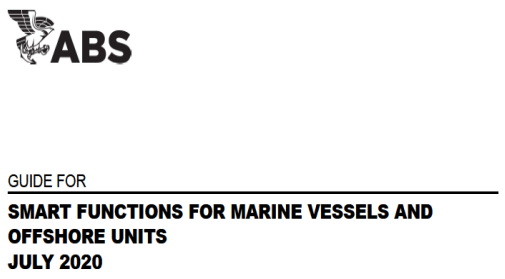
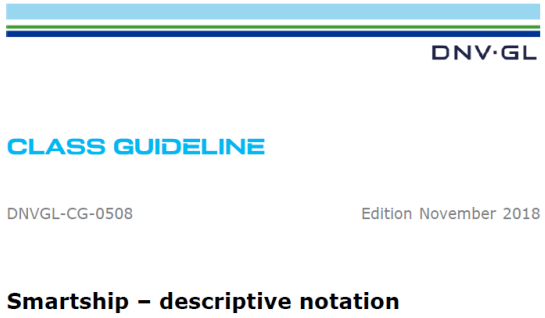
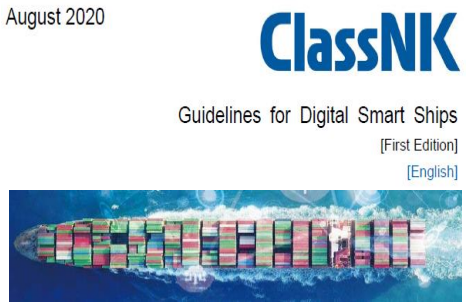
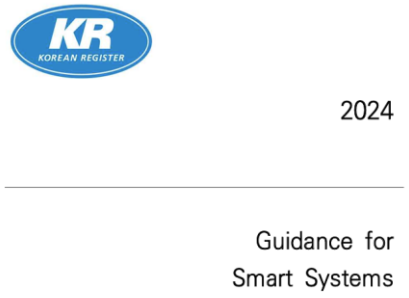
Fully Autonomous Ship

Fully autonomous operation that can be operated without human intervention Ship

Refer : Korea Autonomous Surface Ship Project

I. Concept of Smart Ship

Smart Ship from Class

ABS [Guidance]	DNV [Guideline]	ClassNK [Guideline]	Korean Register [Guidance]
Smart Functions for Marine Vessels and Offshore Units (3rd Edit 2020)	Smart ship – descriptive notation (DNVGL-CG-0508, 2018)	Digital Smart Ships (1st Edit 2020)	Guidance for Smart System (2024)
			
SMART(XX, YY, etc,)	Smartship(XX, YY, etc,)	DSS(XX, YY, etc,)	Smart(XX, YY, etc)

II. International trends in maritime cybersecurity

II. International trends in maritime cybersecurity

Analysis for cyber incidents in maritime domain

* Since 2000, more than 142 cyber incidents was reported in the maritime domain

[Shipping Company]

- Ransomware 21 cases
- Phishing 8 cases
- Malware 7 cases
- Hacking 5 cases
- Other cyber attacks 3 cases

[Ship]

- Spoofing 15 cases
- Ransomware 4 cases
- Jamming 8 cases
- Hacking 3 cases
- Other cyber attack 3 cases

[Port Facility]

- Ransomware 9 cases
- DDoS Attack 8 cases
- Hacking 4 cases
- Other cyber attacks 3 cases

[Shipyards, etc.]

- Ransomware 12 cases
- Malware 7 cases
- DDoS attack 3 cases
- Other cyber attacks 7 cases

Ref : MCAD Maritime Cyber Attack Database https://maritimecybersecurity.nl/

II. International trends in maritime cybersecurity

Since 2017, International regulations on ship cyber security have been strengthen

1. IMO and Administrations

2017 MSC-FAL.1/Circ.3 - GUIDELINES ON MARITIME CYBER RISK MANAGEMENT.
* Include UR E26 rev.1 and E27 Rev.1 at MSC 108

2017 Res. MSC.428(98)* - MARITIME CYBER RISK MANAGEMENT IN SAFETY MANAGEMENT SYSTEMS.
* Mandatory for more than 24 flag states (USCG, Marshall Island, Singapore, Australia, Cyprus, Vanuatu, etc.)

2020 USCG CVC-WI-027(1) - Vessel Cyber Risk Management Work Instruction

2. Shipping Association

2016 Guidelines on Cyber Security Onboard Ships

2020 4th Version of Guidelines on Cyber Security Onboard Ships

2019 Implementation Guide for Cyber Security on Vessels v1.0.

3. Shippers Association

2017 TMSA 3 13 Maritime Security 1.2, 2.3, 2.4, 3.2 and 4.5

2018 SIRE VIQ 7 7 Cyber Security 7.14, 15, 16 and 17

2022 SIRE 2.0 7.5 Cyber Security

2017 Inspection and Assessment Report for Dry Cargo Ships / 4.7 Cybersecurity

2021 Inspection Ship Questionnaire (RISQ) / 12 Security 12.2, 12.7 and 12.8

4. Classification Societies

2020 Rec.166 – Recommendation on Cyber Resilience

2020 Rec.171 - Recommendation on incorporating cyber risk management into Safety Management Systems

2022 UR E26 – Cyber Resilience of Ships

UR E27 – Cyber Resilience of on-board systems and equipment

2023 UR E26 Rev.1 & E27 Rev.1 : Mandatory for SOLAS ships contracted for construction on and after 1 July 2024

IMO : International Maritime Organization
IACS : International Association of Classification Societies
BIMCO : Baltic and International Maritime Council,
OCIMF : The Oil Company International Marine Forum
DCSA : Digital Container Shipping Association,
USCG : US Coast Guard

II. International trends in maritime cybersecurity

IMO : International Maritime Organization

MSC-FAL.1/Circ.3 – Guidelines on Maritime Cyber Risk Management

- Urgent need to raise awareness on cyber risk threats and vulnerabilities
- **High-level recommendations on maritime cyber risk management** to safeguard shipping from current and emerging cyber threats and vulnerabilities
- **Five Functional elements** that support effective cyber risk management.

Resolution 428(98)

The resolution encourages administrations to ensure that cyber risks are appropriately addressed in existing **safety management systems (as defined in the ISM Code)** no later than the first annual verification of the company's Document of Compliance **after 1 January 2021**.

IMO continues to express interest in cyber risk management for ships. Currently, resolution MSC.428(98) is recommended as non-mandatory by each flag state, but it is highly likely that it will develop into a mandatory requirement in the future. Currently, it is a mandatory requirement in the United States, Marshall Island, Singapore, Australia, Cyprus, and Vanuatu.

II. International trends in maritime cybersecurity

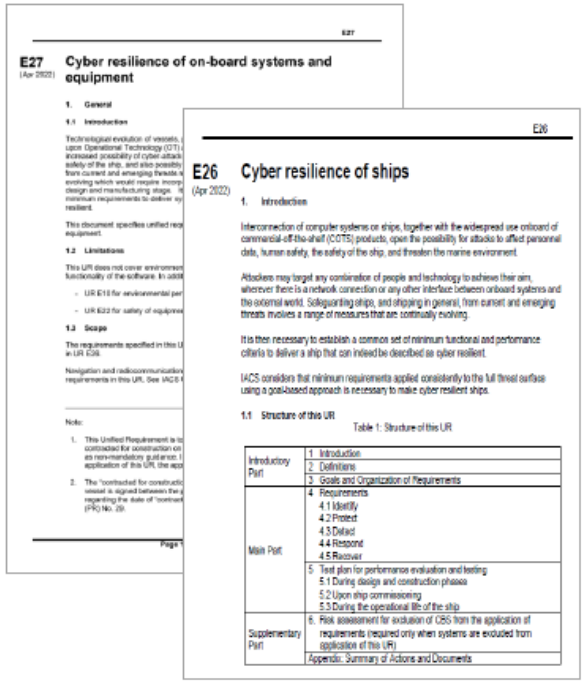
IMO : International Maritime Organization

(Goal) To support safe and secure shipping, which is operationally resilient to cyber risks

Identification	• Define personnel roles and responsibilities for cyber risk management and identify the systems, assets, data and capabilities that, when disrupted, pose risks to ship operations
Protect	• Implement risk control processes and measures, and contingency planning to protect against a cyber-event and ensure continuity of shipping operations
Detect	• Develop and implement activities necessary to detect a cyber-event in a timely manner
Respond	• Develop and implement activities and plans to provide resilience and to restore systems necessary for shipping operations or services impaired due to a cyber-event
Recover	• Identify measures to back-up and restore cyber systems necessary for shipping operations impacted by a cyber-event

II. International trends in maritime cybersecurity

IACS Requirements for cyber resilience


E27 Cyber resilience of on-board systems and equipment

E26 Cyber resilience of ships

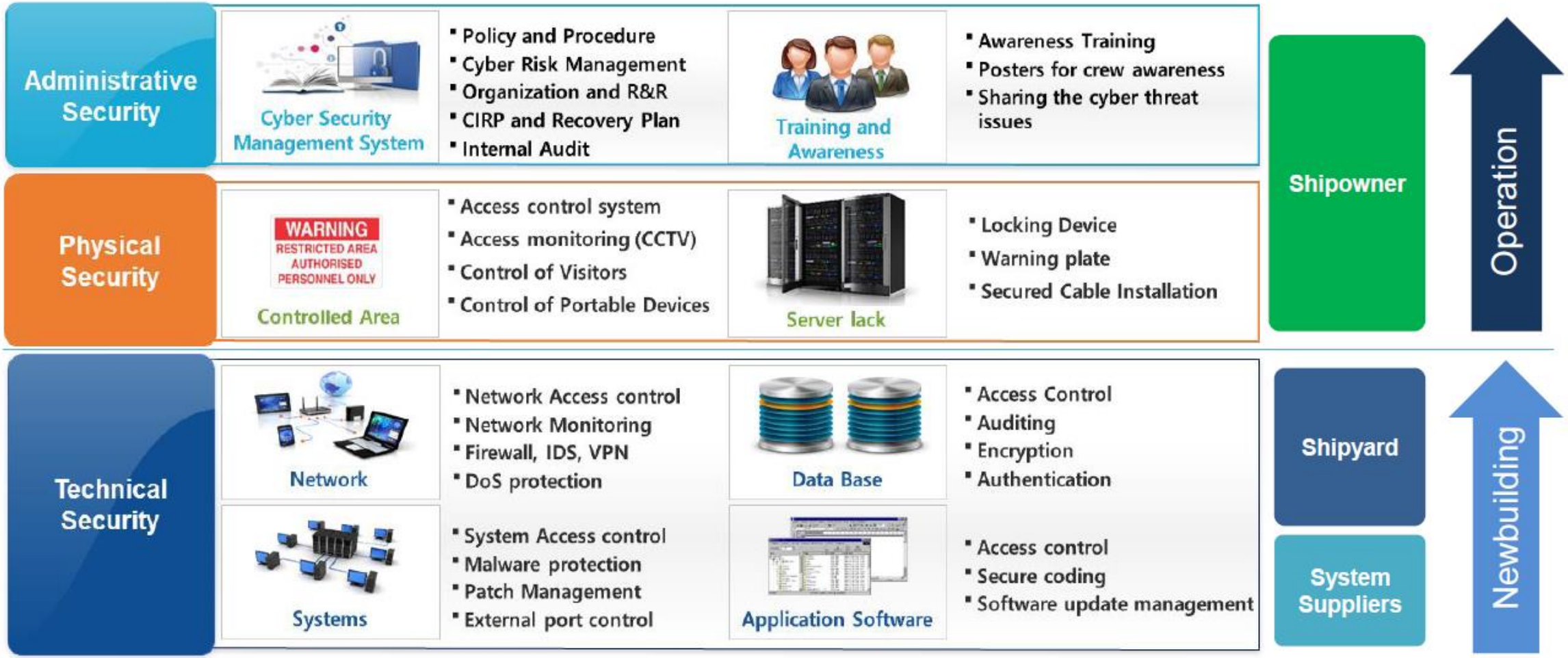
- **IACS Unified Requirements(URs)**
  - **UR E26 rev.1: Cyber Resilience of Ships**
  - **UR E27 rev.1: Cyber Resilience of Systems**
- **Applied ships**
  - **Cargo ships of 500GT and upwards engaged in international voyages, which contracts for newbuilding on or after 1 July 2024**
- **Organization of URs and stakeholders**

UR	Requirements	Phase	Stakeholder
UR E27 rev.1	Cyber security functions for systems	Newbuilding	Suppliers
UR E26 rev.1	Design, integration and testing for cyber resilience of ships	Newbuilding	Shipyards*
UR E26 rev.1	Management and operation of cyber resilience of ships	Operation	Shipowner

* Shipyards may delegate the role of cyber resilience design, integration, and testing to external systems integrators.

II. International trends in maritime cybersecurity

Concept of Implementation on Ship Cyber Resilience



II. International trends in maritime cybersecurity

Framework of Cyber Resilience of Ships

Identify (4.1)	• Inventory of CBSs and networks onboard	Document
Protect (4.2)	• Security zone • Network protection safeguards • Antivirus, antimalware, antispam and other protections from malicious code • Access control • Wireless communication • Remote access control and communication with untrusted networks • Use of Mobile and Portable Devices	Network design and item configuration
Detect (4.3)	• Network operation monitoring • Diagnostic functions of CBS and networks	Install solution (NMS & SIEM)
Respond (4.4)	• Incident response plan • Local, independent and/or manual operation • Network isolation • Fallback to a minimal risk condition	
Recovery (4.5)	• Recovery plan • Backup and restore capability • Controlled shutdown, reset, roll-back and restart	Document, set up system configuration

II. International trends in maritime cybersecurity

UR E26 rev.1 : Cyber Resilience of Ships

No.	Document (E26)	Systems integrator			Shipowner			
		Design	Construction	Commissioning	Operation	1st AS	AS	SS
1	Approved supplier documentation		Maintain	Maintain	Maintain			
2	Zones and conduit diagram	Submit	Maintain	Maintain	Maintain			
3	Cyber security design description	Submit	Maintain	Maintain	Maintain			
4	Vessel asset inventory	Submit	Maintain	Maintain	Maintain			
5	Risk assessment for the exclusion of CBSs	Submit	Maintain	Maintain	Maintain			
6	Description of compensating countermeasures	Submit	Maintain	Maintain	Maintain			
7	Ship cyber resilience test procedure		Submit	Demonstrate	Maintain			Demonstrate
8	Ship cyber security and resilience program - Management of change (MoC) - Management of software updates - Management of firewalls - Management of malware protection - Management of access control - Management of confidential information - Management of remote access - Management of mobile and portable devices - Detection of security anomalies - Verification of security functions - Incident response plans - Recovery plans				Maintain	Submit	Demonstrate	

II. Cybersecurity in Smart Ship

III. Cybersecurity in Smart Ship

System Design and Type Approval → Ship Design and Integration → Onboard Test → Ship Delivery → Ship Operation

Type Approval of Security functions for OT* Systems

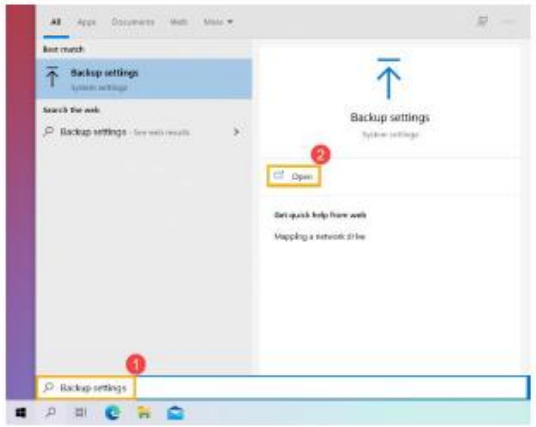
* OT: Operational Technology

- **Security function requirements: IACS UR E27 rev.1 Sec.4**
- **Implement basic 30 Security functions**
  - (e.g.) ID & Password, Malware Protection, Use control for portable devices, System backup, system recovery, etc.
- **Implement additional 11 Security functions in case of remote connection use**
  - (e.g.) Multifactor Authentication, Limit the number of login attempts, secure communication, etc.

[ID and password authentication]

[Anti-virus program]

[Installation of USB Port Blocker]



[System backup function]

III. Cybersecurity in Smart Ship

System Design and Certification | **Ship Design and Integration** | Onboard Test | Ship Delivery | Ship Operation

Identify OT systems in the scope (1/3)

- **Identify essential OT systems to be managed in the scope of cyber resilience**
- **Development of Vessel Asset Inventory**
  - List of OT systems onboard in the scope
  - Hardware and software information, network devices and security devices(Firewall, IDS, etc)

dcsa

Asset List

Example asset list which can be populated with a list of critical assets including type (hardware/software), owner (shore), custodian (on vessel) and criticality based on existing impact assessments within the SMS.

Asset Serial	Asset	Type/Description	Version	Owner	Custodian	Location	Date of Last Check	Criticality
1	Dell Inspiron 17 Laptop	Hardware	Windows 10	J Doe	A Smith	Bridge	01/11/2019	Low
2								
3								
4								
5								
6								
7								
8								
9								
10								

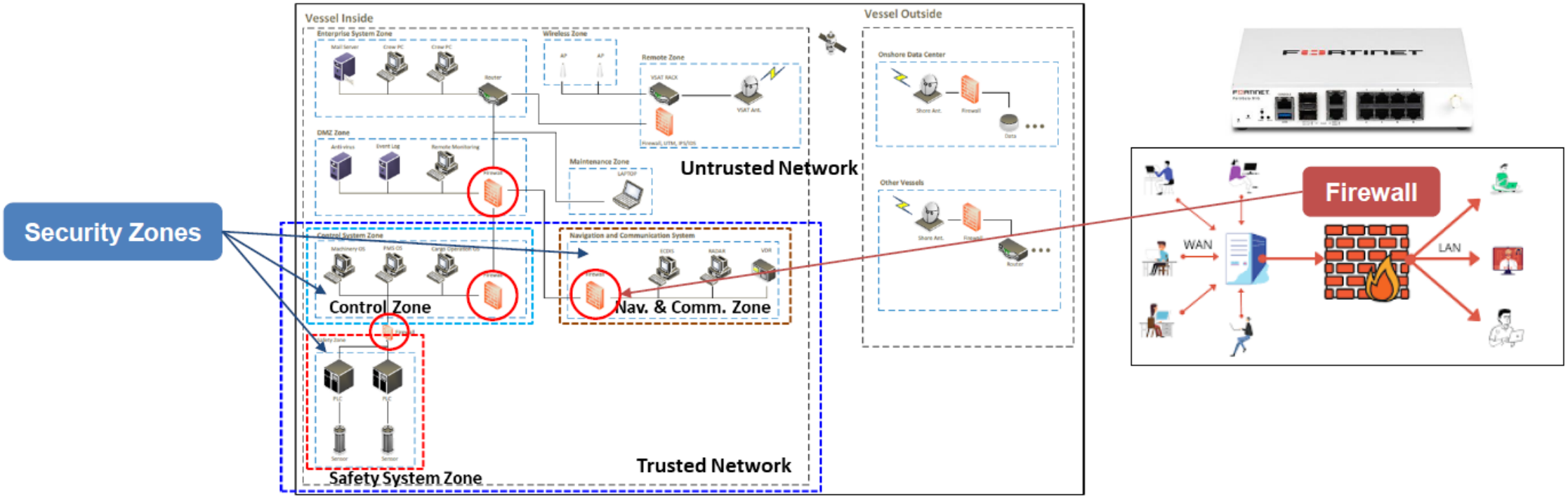
[Example of Vessel Asset Inventory]

III. Cybersecurity in Smart Ship

System Design and Certification | **Ship Design and Integration** | Onboard Test | Ship Delivery | Ship Operation

Network Segmentation and Safeguard (2/3)

- **Step 1: Define security zones for protection**
  - (e.g.) Machinery control system zone, navigation and communication zone, safety zone, DMZ zone, etc.
- **Step 2: Network segmentation based on security zones**
- **Step 3: Implement safeguards such as firewalls and DoS protection**

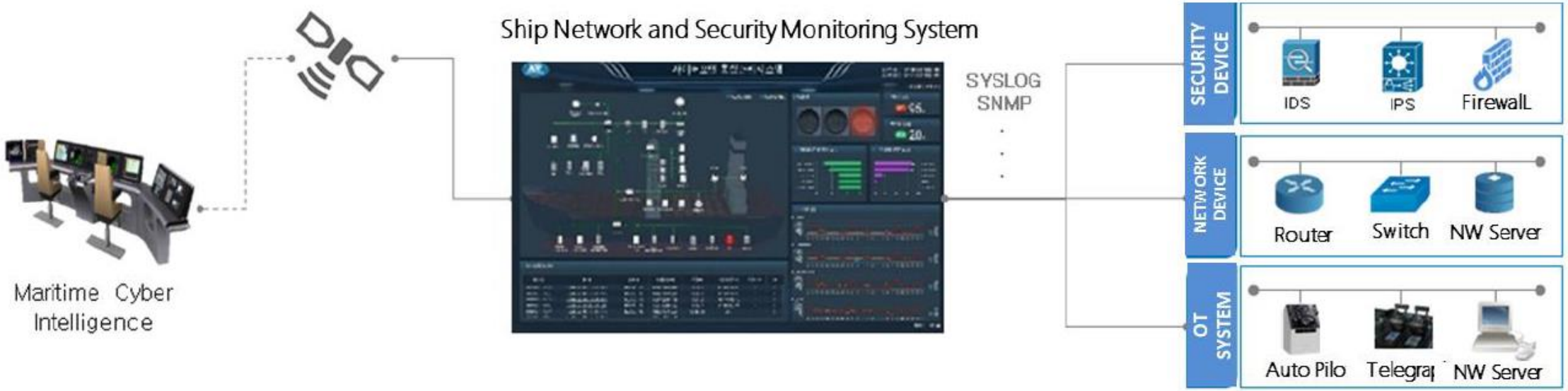


III. Cybersecurity in Smart Ship

System Design and Certification | **Ship Design and Integration** | Onboard Test | Ship Delivery | Ship Operation

Network Monitoring System (3/3)

- **Monitor and alarms any malfunction or abnormal condition in network system**
- **Network system: Firewall, Router, Switch(Managed)**

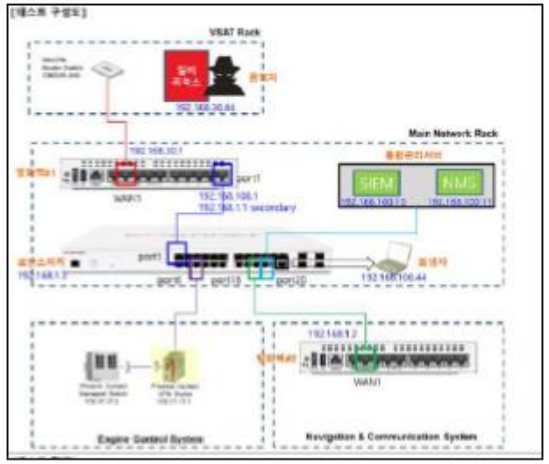


III. Cybersecurity in Smart Ship

System Design and Certification → Ship Design and Integration → **Onboard Test** → Ship Delivery → Ship Operation

Onboard test for cyber resilience

- **Carry out onboard test for cyber resilience of ship**
- **Examples of check points**
  - System inspection (Security configuration, SW update status, etc.)
  - Network test (network segregation, network protection, network monitoring, etc)
  - Access control test (Management of ID and Password, remote connection, control of exposed USB ports, etc)



[Test setup]

[On-board test]

[Test tool(e.g. Kali Linux)]

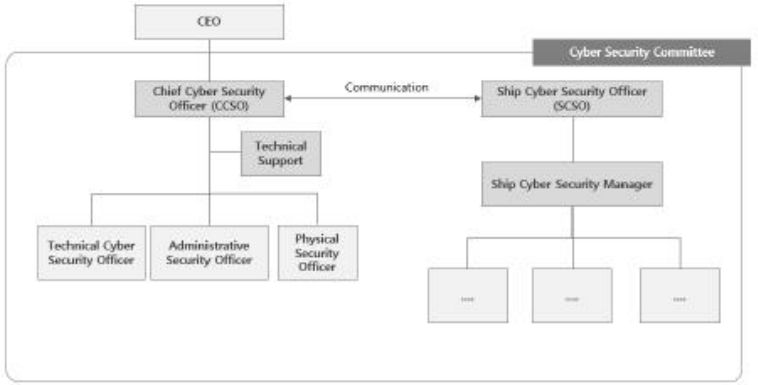
[Network monitoring system]

III. Cybersecurity in Smart Ship

System Design and Certification → Ship Design and Integration → Onboard Test → Ship Delivery → **Ship Operation**

Establishment of Ship Cyber Security Management System (CSMS)

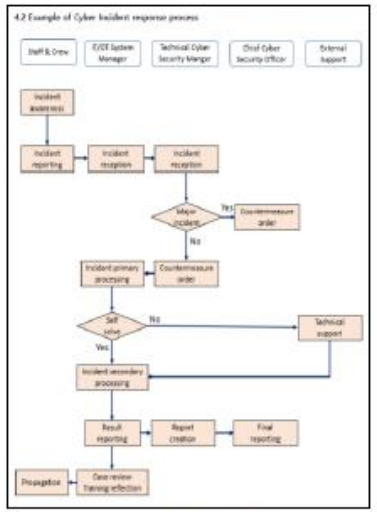
- **Policy and Procedures for CSMS (i.e. Cyber Security and Resilience Programme(CSRP) in UR E26)**
  - Management Process for Ship Cyber Resilience (UR E26 rev.1)
  - Cyber Risk Management Process (Covered by Res.MSC.428(98))
  - Organization and R&R (Covered by Res.MSC.428(98))
  - Crew awareness training (Covered by Res.MSC.428(98))
- **Cyber Incident Response Plan**
- **Recovery plans**



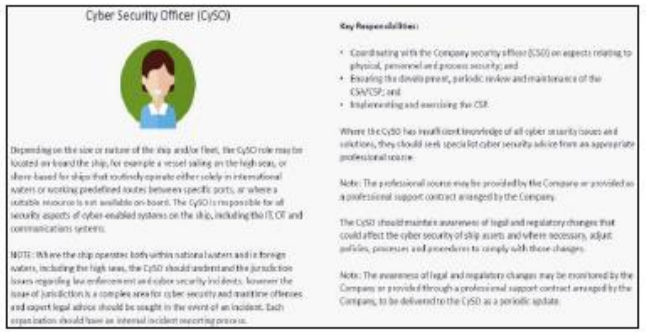
[Organization for CSMS]

[CSMS Policy]

[CSMS Procedure]



[CIRP]



[Roles and Responsibility]

III. Cybersecurity in Smart Ship

System Design and Certification → Ship Design and Integration → Onboard Test → Ship Delivery → **Ship Operation**

Operation of Ship Cyber Security Management System (CSMS)

- **Update of documents and manuals**
  - CSMS procedure, CIRP, Recovery Plan, etc.
- **Ship Cyber Risk Management**
  - Cyber Risk Assessment in annual basis
  - Adopt mitigation controls for high cyber risks
- **Awareness Training**
  - Crew training plan and training record
- **Management of Changes of OT systems**
  - SW update and HW changes
  - Update Vessel Asset Inventory
- **Network system management**
  - Firewall management, network monitoring status
- **Patch update**
  - Update of Antivirus program or security patch
- **Access control**
  - Management of ID and Password for systems
  - Access control for Visitors
  - Control of Mobile or Portable Device including USB media

[Cyber Risk Assessment Report]

[Crew training plan]

[Update of antivirus program]

[Installation of USB Port Blocker]

III. Cybersecurity in Smart Ship

Risk-based Cybersecurity Approach – Smart System

CONTENTS

Section 1 Smart Infrastructure

101. General

1. The purpose of smart infrastructure is to perform smart system functions through hardware and software installed to implement smart system functions.
2. The smart infrastructure includes the necessary components to collect, manage and relay data.
3. The smart infrastructure shall be capable of collecting and storing information received from one or more source systems.
4. The smart infrastructure shall meet the relevant requirements for data quality management in this guidance.
5. Electrical and electronic equipment on the bridge shall be installed so that electromagnetic interference does not affect the proper function of navigational systems and equipment.
6. Screen displays and indications installed on the bridge shall be installed so as not to obstruct the navigator's view even at night. *(2024)*

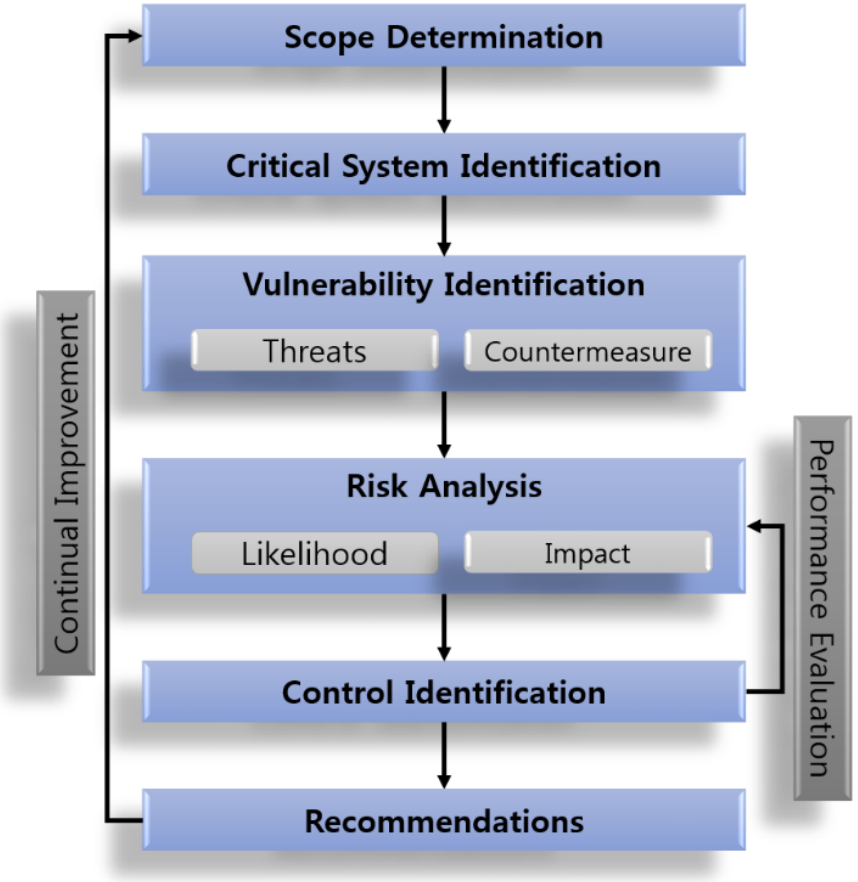
102. Configuration and functional requirements of smart systems

The infrastructure for implementing the functions of a smart system may include the following configurations and functions, but is not limited to.

1. Sensor for smart system functions
   (1) Internal and external data are received through sensors installed to implement smart system functions.
   (2) Hardware and software installed to interface with the on-board system shall have the following functions:
      (A) Data interface to support certain number and type of input/output channels;
      (B) Configurable and expandable input/output channels, in terms of number and type of channels;
      (C) Connection to the data network and communication function when smart system function is implemented;
      (D) Time stamping and time synchronization for the data collected; and
      (E) Monitoring and alarming for data transmission

III. Cybersecurity in Smart Ship

Risk-based Cybersecurity Approach – Risk Assessment



* **Scope Determination**

01 Communication System

- Starlink
- 6G Satellite

02 Smart Equipment

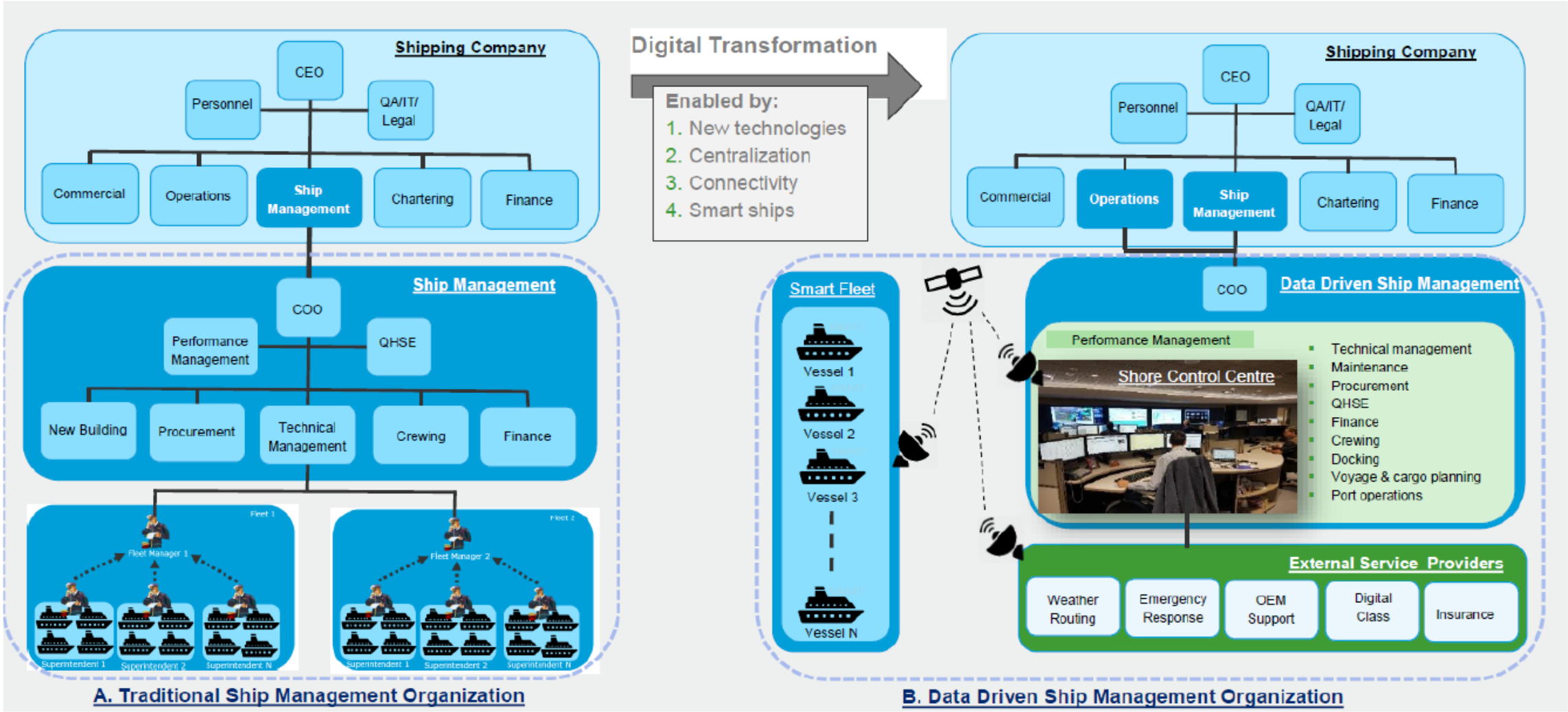
- Autonomous Navigation Control System
- Smart Safe Navigation System
- Smart Economic Navigation System
- Smart Eco-friendly navigation system

03 On shore

- Remote Vessel Navigation System

III. Cybersecurity in Smart Ship

Data-Driven Ship Operation in Smart ship



Ref. : DNV, Data driven ship management benefit cases

III. Cybersecurity in Smart Ship

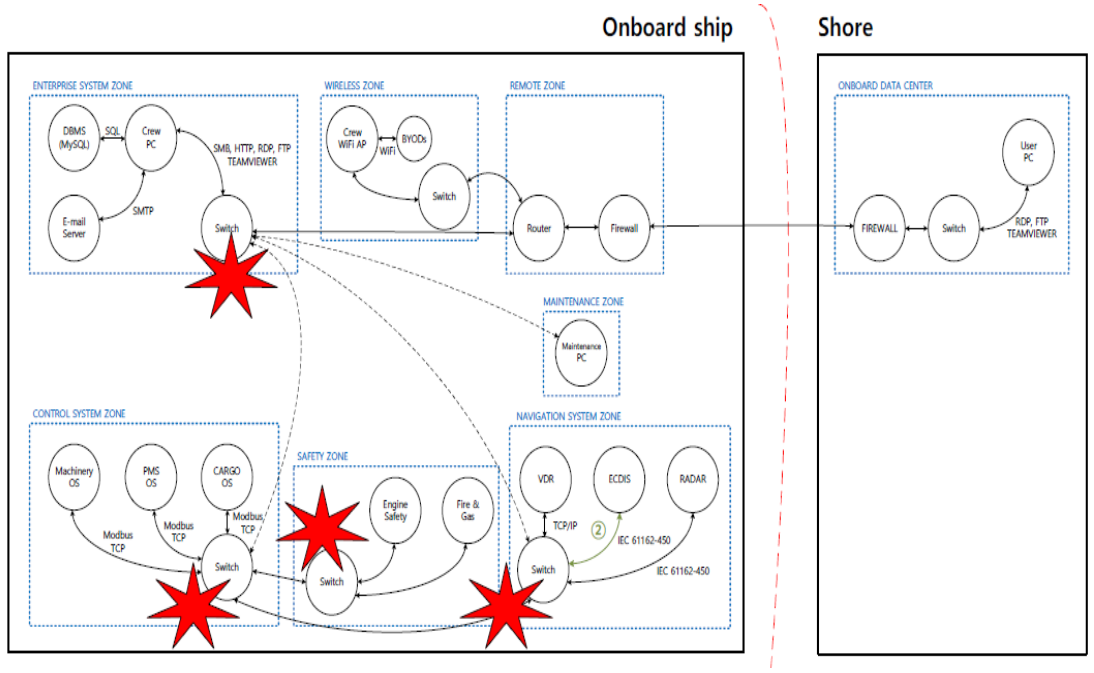
Risk-based Cybersecurity Approach – Asset List Including Data & Data Flow

2.2. Alarm Monitoring System

No.	Component Name	Type	Manufacturer	Model	Location	Port (of the Asset equipment)			
						USB	LAN	Serial	CAN
1	SPOWS1	Operation Station	HP		ECC	2	2	-	-
2	SPOWS2	Operation Station	HP		ECC	2	2	-	-
3	SPOWS3	Operation Station	HP		C/E's RM	2	2	-	-
4	SPOWS4	Operation Station	HP		BCC	2	2	-	-

No.	Component Name	IP Address	Subnet Mask	Malware Protection Means	Interface to other Systems	Interface Method	OS		
							Name	Version	Last update
1	SPOWS1			-	-		Windows 10	Professional or Higher Ver	-
2	SPOWS2			-	VDR	Serial	Windows 10	Professional or Higher Ver	-
3	SPOWS3			-	-		Windows 10	Professional or Higher Ver	-
4	SPOWS4			-	-		Windows 10	Professional or Higher Ver	-

No.	Component Name	Software			Firmware			Access Control	Maintenance Method	Scope of E26
		Name	Version	Last update	Name	Version	Last update			
1	SPOWS1				N/A	N/A	N/A	P	L	O
2	SPOWS2				N/A	N/A	N/A	P	L	O
3	SPOWS3				N/A	N/A	N/A	P	L	O
4	SPOWS4				N/A	N/A	N/A	P	L	O



New Asset List : Including Data & Information

Data Flow Diagram

III. Cybersecurity in Smart Ship

Data-Driven Ship, Data-Driven Treats

Ship

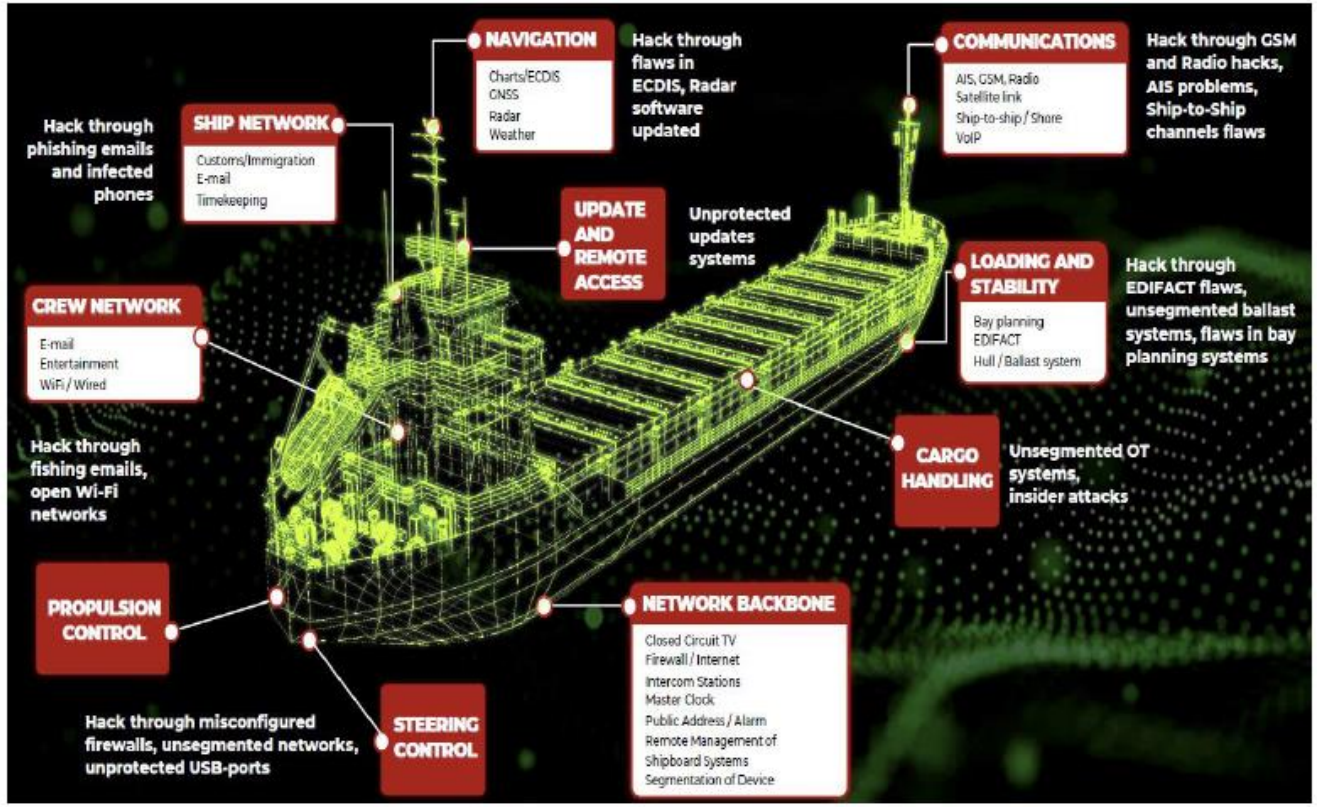


Image source : Reperion

Data-Driven Ships

Voyage Planning

Machinery Maintenance

Energy Efficiency Management

Shore Center

III. Cybersecurity in Smart Ship

Data-Driven Ship, Data-Driven Treats

Ship

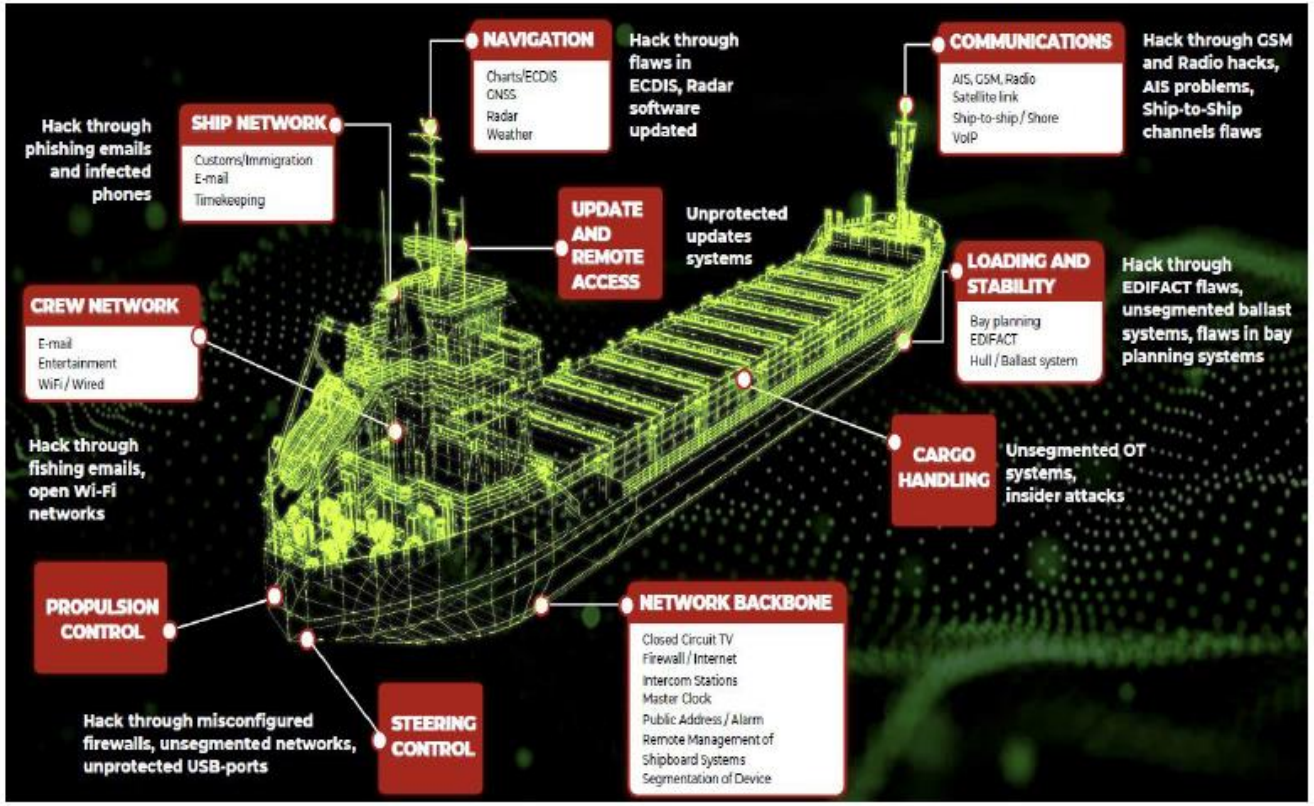


Image source : Reperion

Data-Driven Threats

Unauthorized Alteration of Voyage Plans

Exploiting IoT Devices

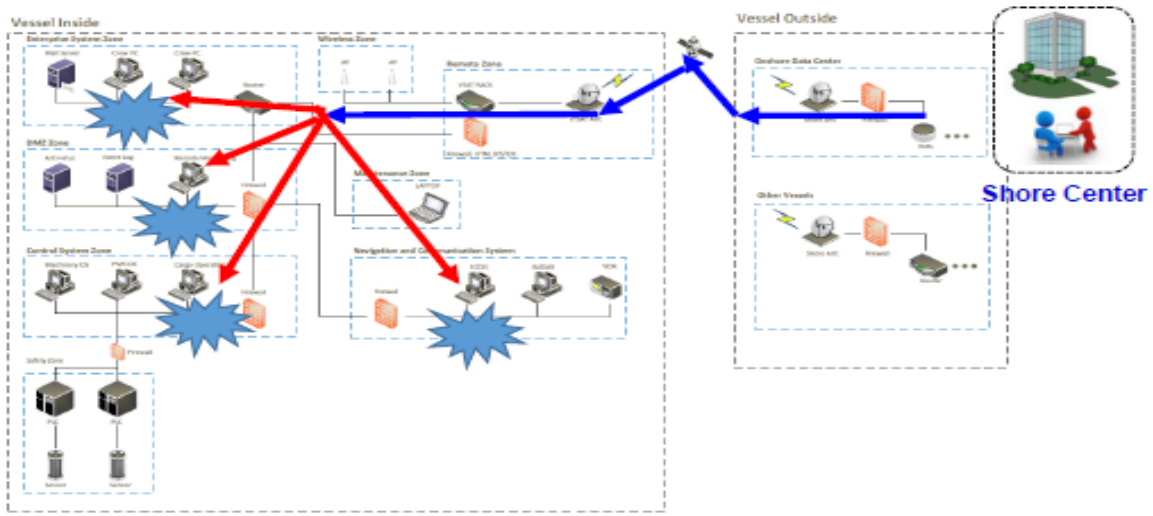
Theft of Sensitive Data Management

Shore Center

III. Cybersecurity in Smart Ship

Data-Driven Ship, Data-Driven Treats – Cyberattack Scenarios

Threat	Cause	Agent	Consequence
Malware	Remote update and maintenance	External	System malfunction / network infection



Identify cyber threats

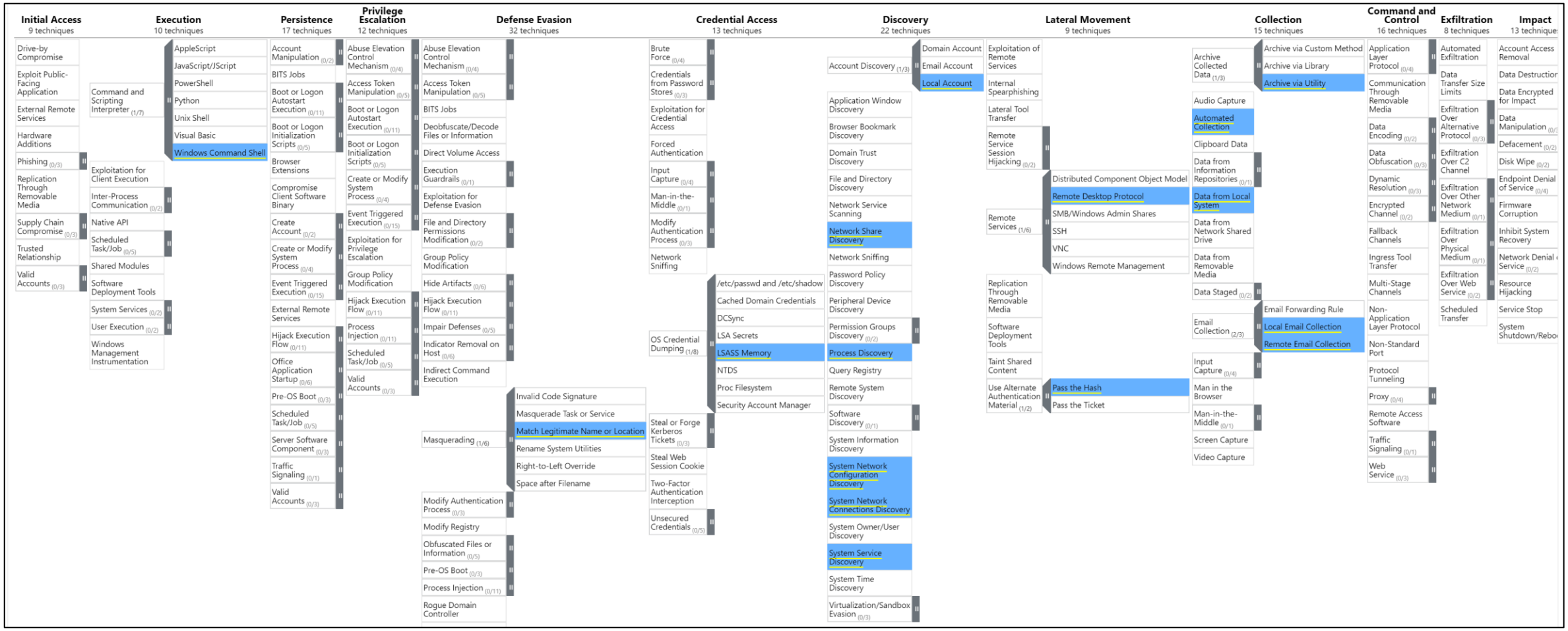
No. (old No.)	Top 10 2016	Top 10 2014
1 (3)	Social Engineering and Phishing†	Malware Infection via Internet and Intranet
2 (2)	Infiltration of Malware via Removable Media and External Hardware	Infiltration of Malware via Removable Media and External Hardware
3 (1)	Malware Infection via Internet and Intranet	Social Engineering
4 (5)	Intrusion via Remote Access	Human Error and Sabotage
5 (4)	Human Error and Sabotage	Intrusion via Remote Access
6 (6)	Control Components Connected to the Internet	Control Components Connected to the Internet
7 (7)	Technical Malfunctions and Force Majeure	Technical Malfunctions and Force Majeure
8 (9)	Compromising of Extranet and Cloud Components	Compromising of Smartphones in the Production Environment
9 (10)	(D)DoS Attacks	Compromising of Extranet and Cloud Components
10 (8)	Compromising of Smartphones in the Production Environment	(D)DoS Attacks

Ref. : BSI Industrial Control System Security – Top 10 Threats and Countermeasures 2016

III. Cybersecurity in Smart Ship

Data-Driven Ship, Data-Driven Treats – Cyberattack Scenarios

MITRE ATT&CK summarizes cyber threat cases in the form of a kill chain

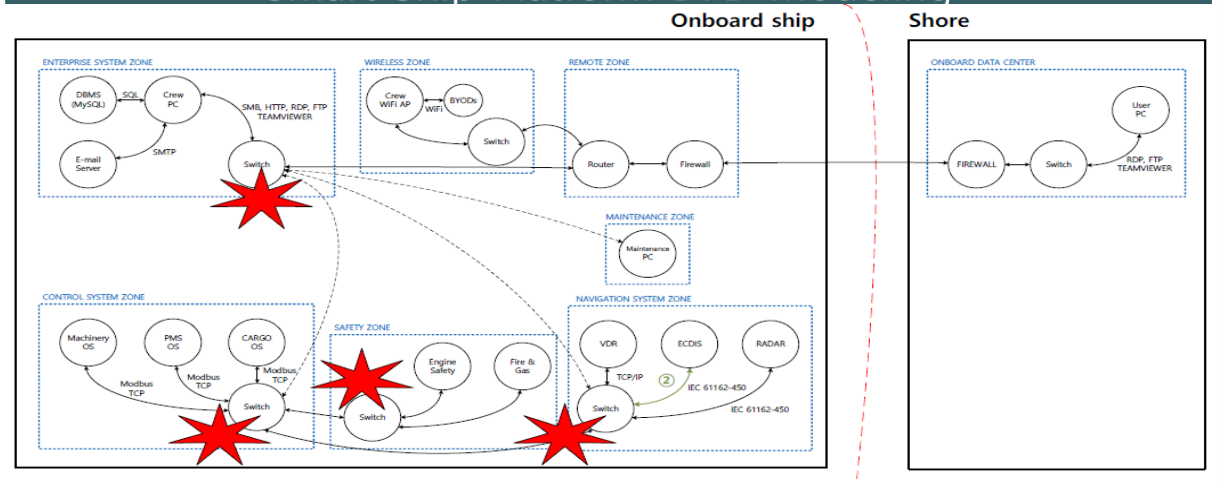


Threat scenarios used by APT 1 in its attack

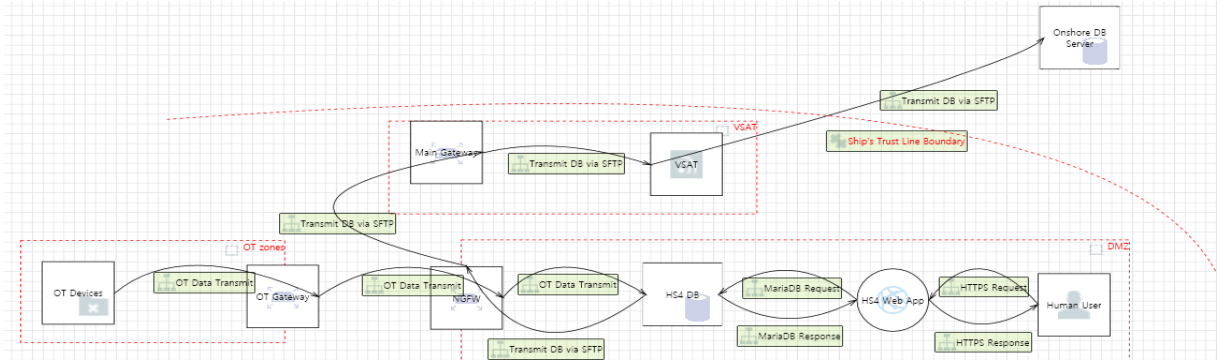
III. Cybersecurity in Smart Ship

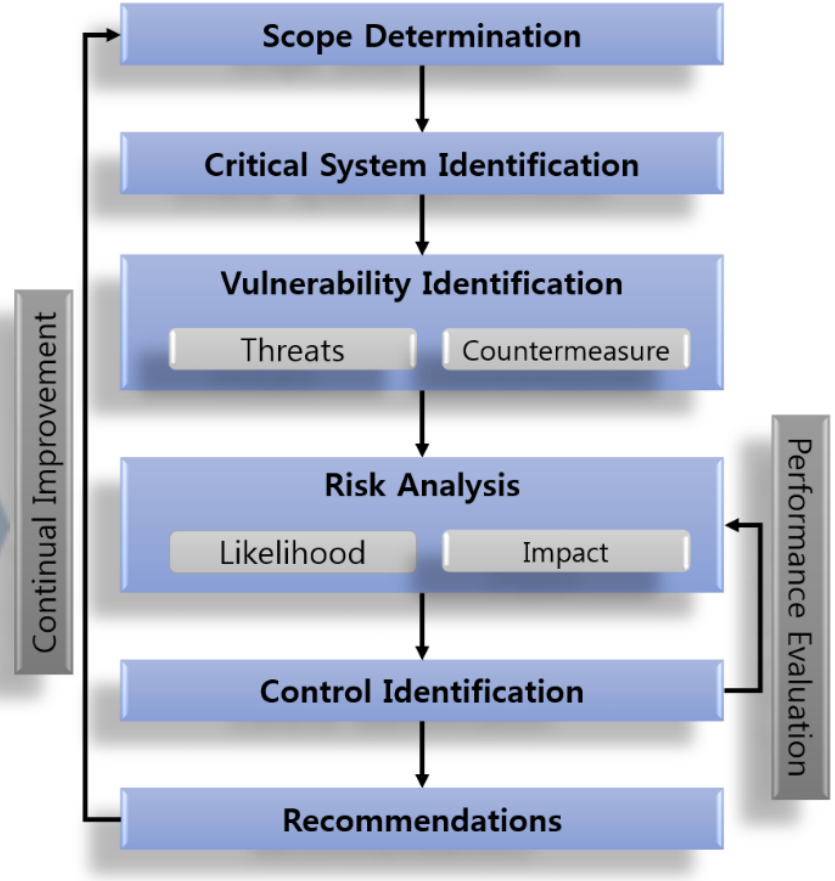
Cybersecurity Risk Modeling

Smart Ship Platform DFD Modeling



Threat Modeling Tool

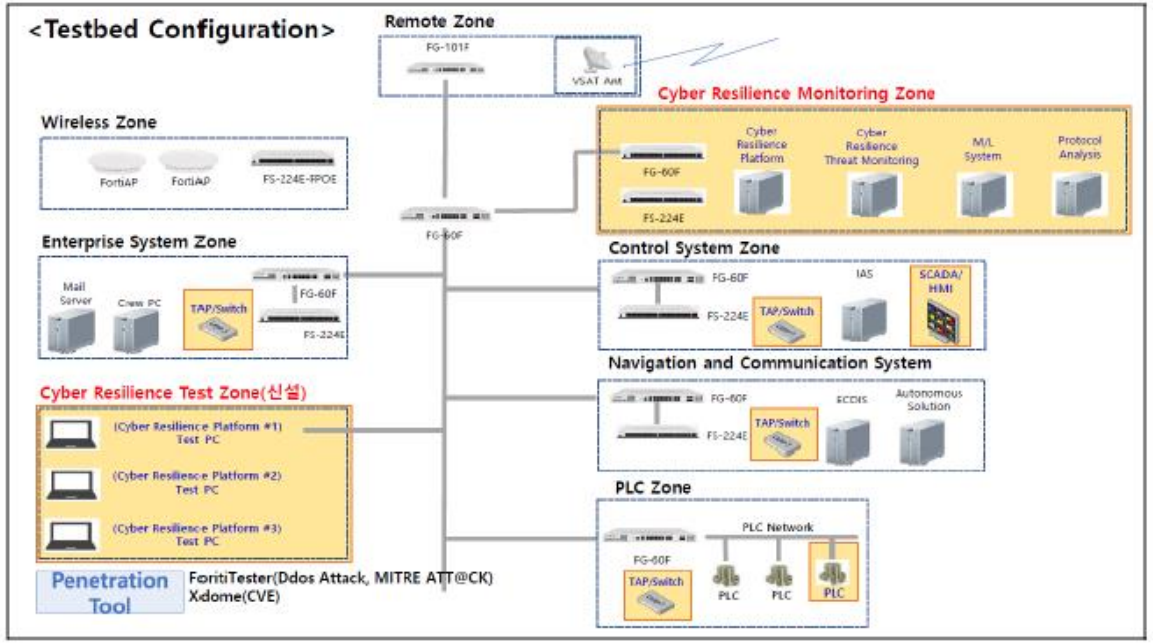




III. Cybersecurity in Smart Ship

Smart Ship Cybersecurity Testbed

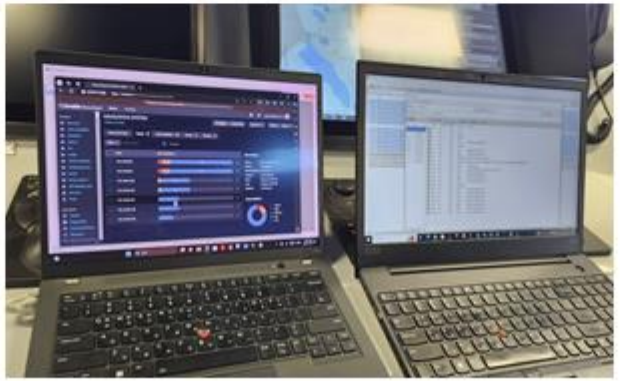
Smartship Cyber Security Testbed Operation ('23~'27.12) + **Technical verification through testbed**



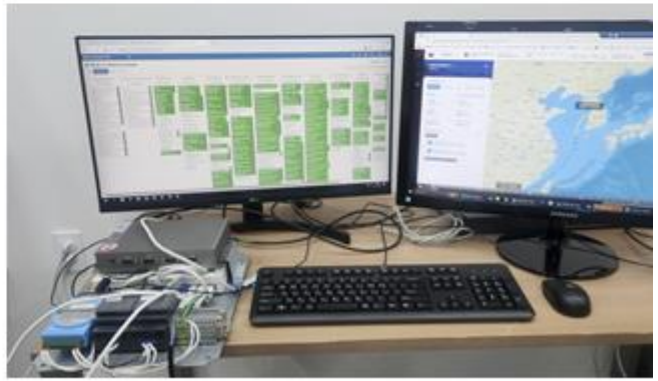
III. Cybersecurity in Smart Ship

Smart Ship Cybersecurity Testbed

Vulnerability diagnostics and penetration testing tools



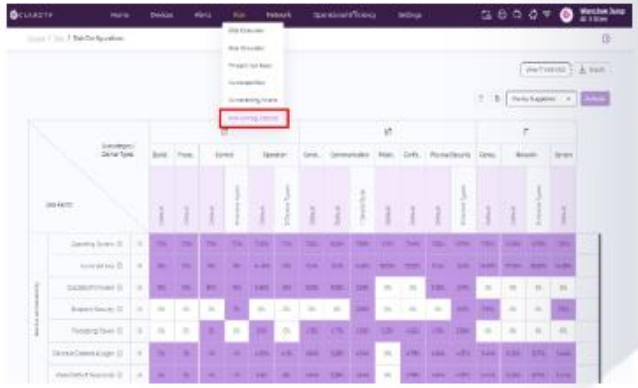
Ship Equipment Testing Equipment



III. Cybersecurity in Smart Ship

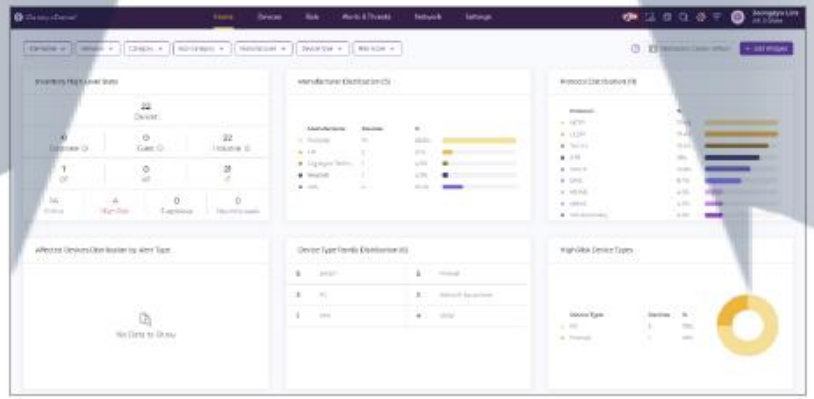
Smart Ship Cybersecurity Testbed

Vulnerability Analysis Tool

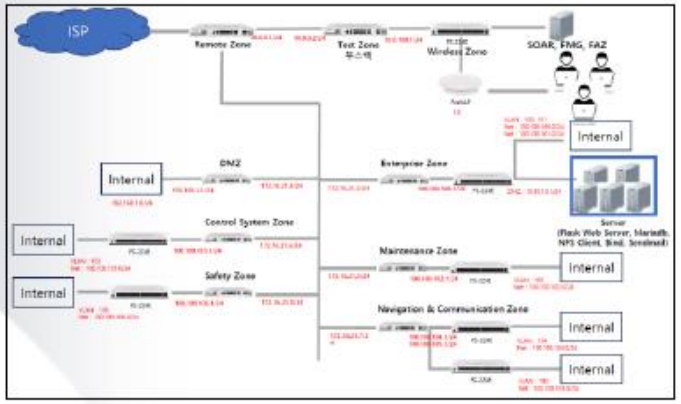


Ship Cyber Resilience Document Control & Design Platform

Ship Cyber Resilience Onboard Platform (SIEM, IDS, etc)



Cyber Security Testbed



Thank you

Contact

ADD
- 36, Myeongji ocean city 9-ro, Gangseo-gu, Busan 46762 Republic of Korea

E-mail
- kaemyoung@krs.co.kr