



T6.2.3 Hybrid ship control system

Session 02 Digital Twins as Tools for Operational Support

09/07/2025

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FLEXSHIP



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1. Training 1: Digital twins for green shipping
2. Training 2: Enhancing safety and maintenance planning with digital models
3. Training 3: Digital Twin best practices from power electronics side



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1. **Training 1: Digital twins for green shipping**
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1. Training 1: Digital twins for green shipping
by Austin Kana/TU DELFT



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Digital models are virtual representations of physical assets, systems, or processes. In maritime maintenance, they allow real-time analysis of propulsion, battery, and hybrid systems. These models mirror actual behavior through sensor data, system parameters, and operational feedback—enabling smarter decisions and predictive diagnostics.



Model Types Used in Marine Engineering

Content:

- **Digital Twin:** A real-time, continuously updated replica of onboard systems
- **Simulation Model:** Physics-based or AI-enhanced scenario analysis
- **System Emulator:** Real-time testing environment for control systems
- **Data-Driven Model:** Built from historical logs and sensor analytics

These models help engineers simulate failures, test interventions, and verify system response before real-world deployment.



How Digital Models Improve Operational Safety

Content:

- Simulate hazardous conditions without exposing the vessel or crew
- Forecast thermal, electrical, or mechanical anomalies before they occur
- Analyze emergency procedures and containment strategies virtually
- Increase crew readiness with scenario-based training from model outputs
- Reduce human error through automated decision-support systems

Digital twins allow safety scenarios to be evaluated frequently without operational interruption.



Predictive Maintenance Enabled by Modeling

Content:

- Monitor wear, stress, and charge-discharge cycles of battery systems
- Generate maintenance schedules based on actual degradation, not fixed time
- Use model feedback to prioritize high-risk components
- Integrate historical maintenance logs for trend prediction
- Improve planning for spare parts and labor, reducing downtime

Models help move from calendar-based to condition-based maintenance, improving efficiency and reducing cost.



Real Application: FLEXSHIP's Use of Digital Models

Content:

FLEXSHIP employed digital twins to model hybrid energy systems on demonstration vessels. By integrating BMS data and PMS control logic, they could:

- Predict system imbalance or overloading risks
- Adjust energy dispatch based on real-time demand
- Run safety drills virtually to validate emergency strategies
- Refine maintenance intervals dynamically using live performance feedback

The result: safer, more resilient, and better-optimized marine energy systems.



The Path Forward

Content:

- Integration of AI/ML for autonomous diagnostics
- Cloud-based fleet-level digital twins
- Real-time coordination with port infrastructure and shore control
- Cyber-physical simulation for full-system safety analysis
- Crew training systems integrated with operational data streams

As digital modeling evolves, vessels will become safer, smarter, and more efficient.



3. Safety

3.1 Safety protocols

Ensure that all crew members are fully equipped with the necessary knowledge and practical skills to respond to

- various safety and emergency scenarios
- proactive risk assessment, hazard identification, and mitigation measures

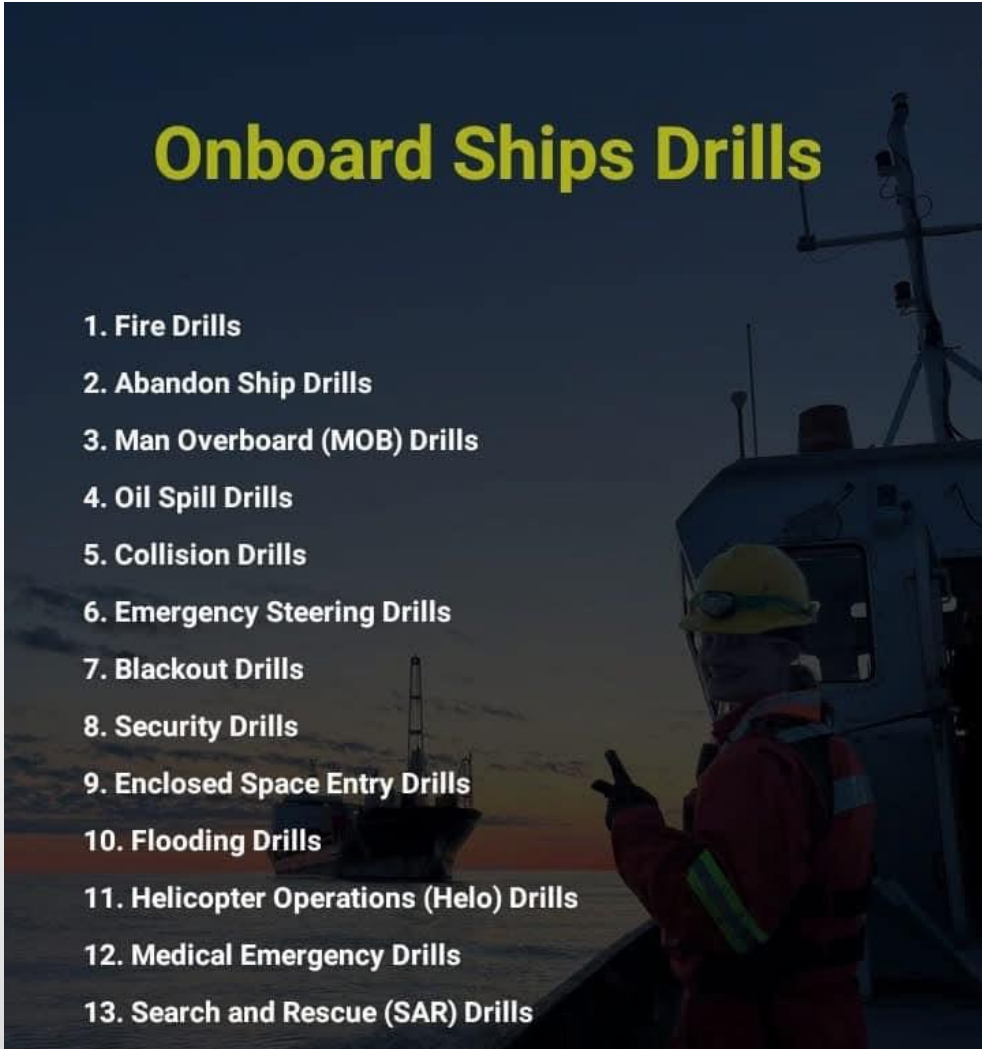
International Maritime Organization (IMO)
 International Labor Organization (ILO)
 Code
 International Safety Management (ISM)
 International Ship and Port Facility Security (ISPS) Code
 SOLAS (Safety of Life at Sea) Convention
 MARPOL (Marine Pollution)
 Ballast Water Management Convention



Types of Emergencies

- Fire
 - determine the most effective firefighting methods
 - execute evacuation procedures
 - fire emergency procedures
 - fire suppression equipment
 - management of crew members' safety
- Flooding
 - immediate actions to stop or slow water ingress
 - closing watertight doors
 - using pumps to remove water
 - deploying flood barriers or seals
- Medical Emergencies
 - initial first aid
 - severity of a medical emergency
 - victim's condition
 - effectively communicate with medical professionals

Onboard Ships Drills

- 
1. Fire Drills
 2. Abandon Ship Drills
 3. Man Overboard (MOB) Drills
 4. Oil Spill Drills
 5. Collision Drills
 6. Emergency Steering Drills
 7. Blackout Drills
 8. Security Drills
 9. Enclosed Space Entry Drills
 10. Flooding Drills
 11. Helicopter Operations (Helo) Drills
 12. Medical Emergency Drills
 13. Search and Rescue (SAR) Drills



3. Safety

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3.3 Use of safety equipment

Personal Protective Equipment (PPE)

- safety helmets
- life jackets
- gloves
- safety boots
- hearing protection
- respirators
- eye protection

Firefighting and Rescue Equipment

- fire extinguishers and powder extinguishers for batteries
 - fire hoses
 - fixed fire suppression systems (such as sprinklers or CO2 systems)
 - portable firefighting equipment
-
- rafts, lifeboats and life-saving appliances (LSAs)



Reporting and Documentation

- reporting and documentation following any emergency or safety incident
- in improving future safety protocols
- identifying areas for improvement
- maintaining regulatory compliance

Psychological Support for Crew Members

- maintaining the mental health and well-being of crew members
- involved in or affected by an emergency situation
- experiencing an emergency or witnessing a traumatic event
- long-lasting emotional effects

Key issues raised by gender, Yacht Crew Help, 2022

Percentages of total issues raised by gender

● Female ● Male

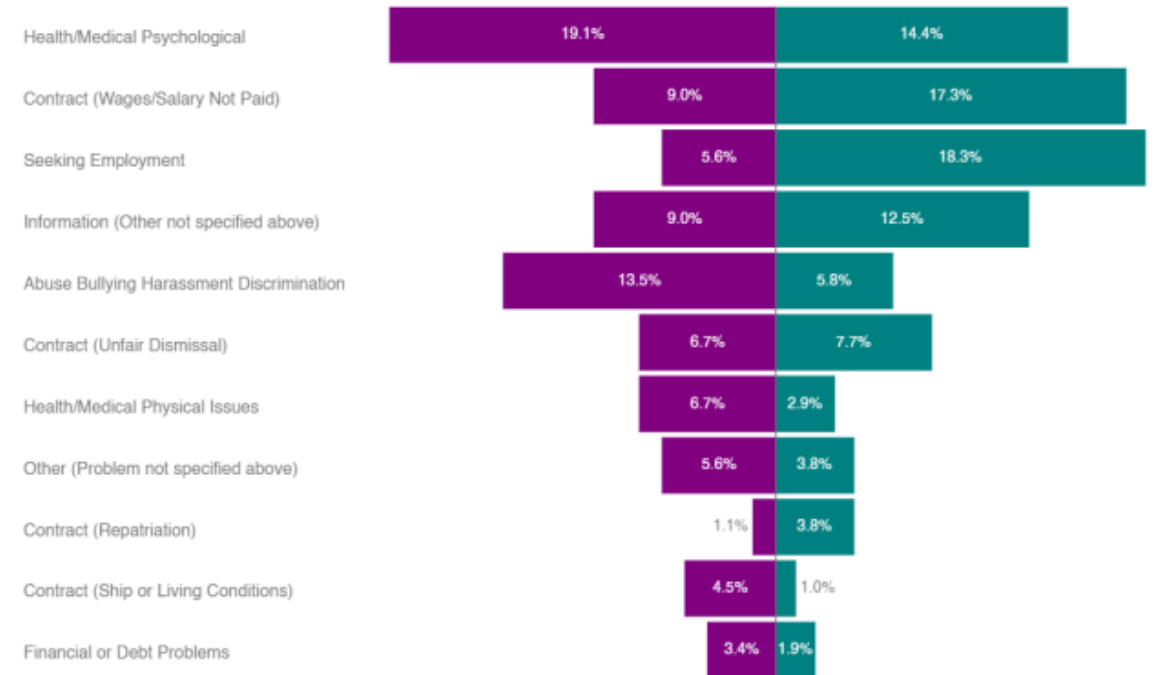




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2.3.1. Generators: Maintenance Procedures

- **1. Generator**

Purpose

- To ensure continuity and reliability in electricity generation.

Maintenance Procedure

- **Daily / Weekly**

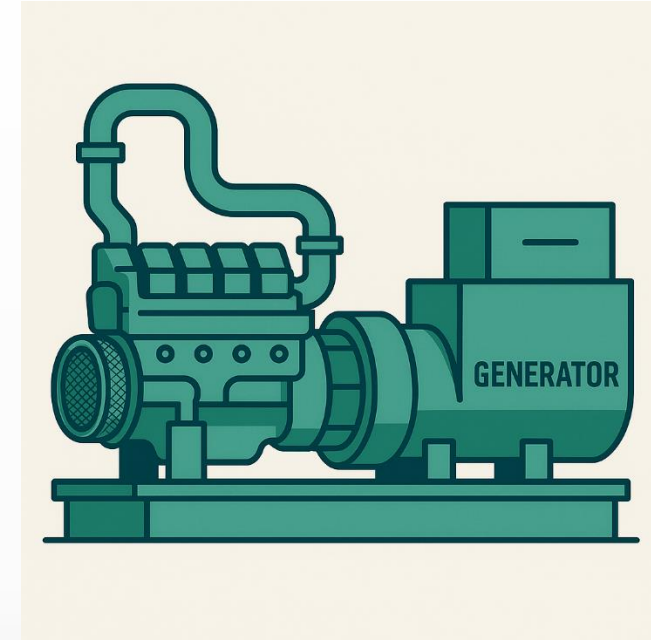
- Check oil level and quality.
- Inspect coolant and air filter.
- Perform visual checks for leaks, loose connections.
- Listen for unusual noise or vibration.

- **Every 3 to 6 Months**

- Replace oil and filters.
- Check battery condition and charging system.
- Measure electrical output (voltage and frequency).
- Inspect exhaust system.

- **Annually**

- Measure insulation resistance.
- Clean rotor and stator.
- Inspect/replace bearings.
- Check grounding connections.



2.3.2. Inverter: Maintenance Procedures

Fault Condition

Insufficient voltage

Overheating

Sudden shutdown

Possible Cause

Worn brushes, weak excitation

Low coolant, clogged filter

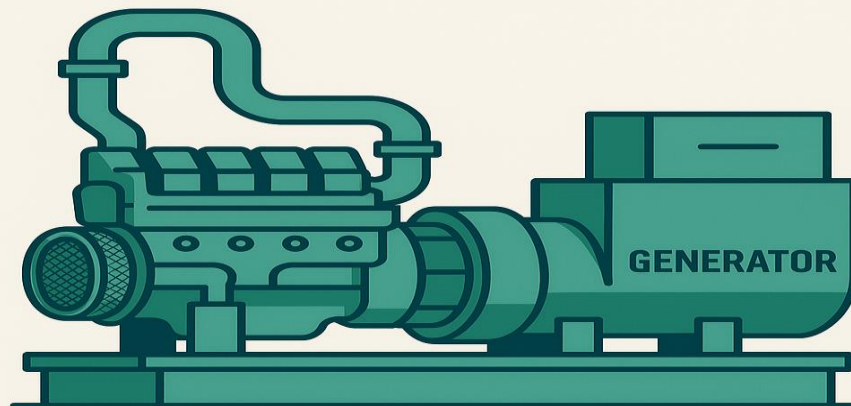
Fuel cut-off, ECU failure

Preventive Action

Check brushes and windings

Maintain cooling system, clean filters

Inspect fuel system and ECU



2.3.2. Inverter : Maintenance Procedures

- **Maintenance Procedure**

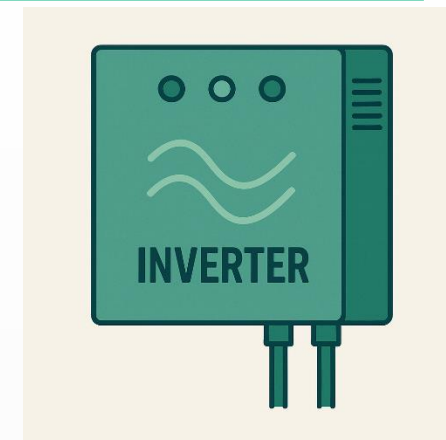
- **Monthly**

- Clean fans and ventilation ducts.
- Check LEDs, alarms, and monitor temperature.

- **Every 6 Months**

- Measure input/output voltage.
- Conduct load test.
- Test protection circuits.
- Inspect terminal and cable tightness.

- **Annually**
- Renew thermal paste.
- Measure insulation resistance.
- Update firmware if available.



Possible Faults and Preventive Measures

Fault Condition	Possible Cause	Preventive Action
Unstable output voltage	Overload, faulty IGBT	Load monitoring, test IGBTs
Overheat warning	Fan failure, dust buildup	Fan testing and regular cleaning
Inverter won't start	Low input voltage, blown fuse	Check DC input and fuses

- **Converter**

Purpose

- To maintain reliable voltage or frequency conversion.

Maintenance Procedure

- **Monthly**

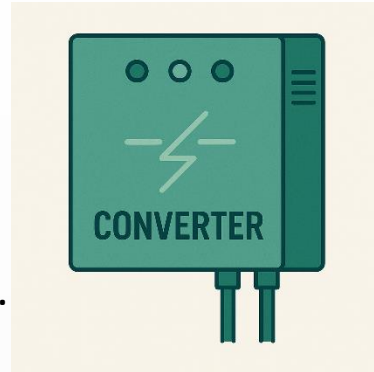
- Inspect and clean fan/ventilation.
- Check LED indicators, alarms, and monitor temperature.

- **Every 6 Months**

- Perform voltage and current output tests.
- Test protection circuits.
- Inspect cable connections.

- **Annually**

- Test capacitors and power semiconductors.
- Clean heat sinks and coolers.
- Conduct insulation and grounding tests.



Possible Faults and Preventive Measures

Fault Condition	Possible Cause	Preventive Action
Low output power	Aged capacitors	ESR testing, replace faulty capacitors
Unstable voltage	Overheating, internal fault	Thermal monitoring, test internal circuits
Triggering failure	Control signal issue	Inspect control board

Purpose

- To ensure safe and efficient conversion from AC to DC.

Maintenance Procedure

• Monthly

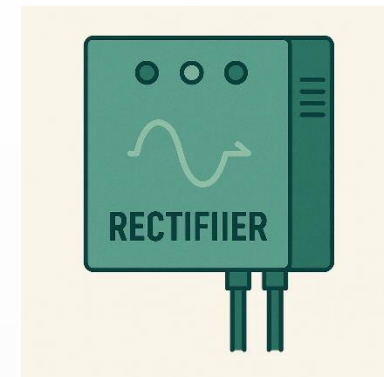
- Check DC output voltage.
- Clean fans and air channels.
- Inspect LED and error display.

• Every 6 Months

- Measure ripple voltage.
- Conduct thermal inspection.
- Test protection features.

• Annually

- Test diodes and semiconductors.
- Inspect fuses and relays.
- Conduct grounding and insulation testing.



Possible Faults and Preventive Measures

Fault Condition	Possible Cause	Preventive Action
Increased ripple voltage	Faulty filter capacitors	Test/replace capacitors
Overheating / blown fuse	Shorted diode	Diode testing, thermal monitoring
Low DC output voltage	Weak AC input, loose terminals	Inspect input lines and connections

2.3.5. General Procedures and Preventive Measures

- **Cleaning:** Keep all PCBs, fans, and ducts free from dust.
- **Record Keeping:** Log all measurements and maintenance actions.
- **Safety:** Always isolate power and use PPE before servicing.
- **Spare Parts:** Keep critical parts (fans, filters, fuses) in stock.
- **Power Quality Monitoring:** Track harmonic distortion, voltage fluctuations.
- **Vibration Monitoring:** Routinely check and tighten mechanical joints.

GENERAL PROCEDURES AND PREVENTIVE MEASURES



Cleaning

Keep all PCBs, fans, and ducts free from dust



Record Keeping

Log all measurements and maintenance actions



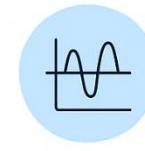
Safety

Always isolate power and use PPE before servicing



Spare Parts

Keep critical parts (fans, filters, fuses) in stock



Power Quality Monitoring

Track harmonic distortion, voltage fluctuations



Vibration Monitoring

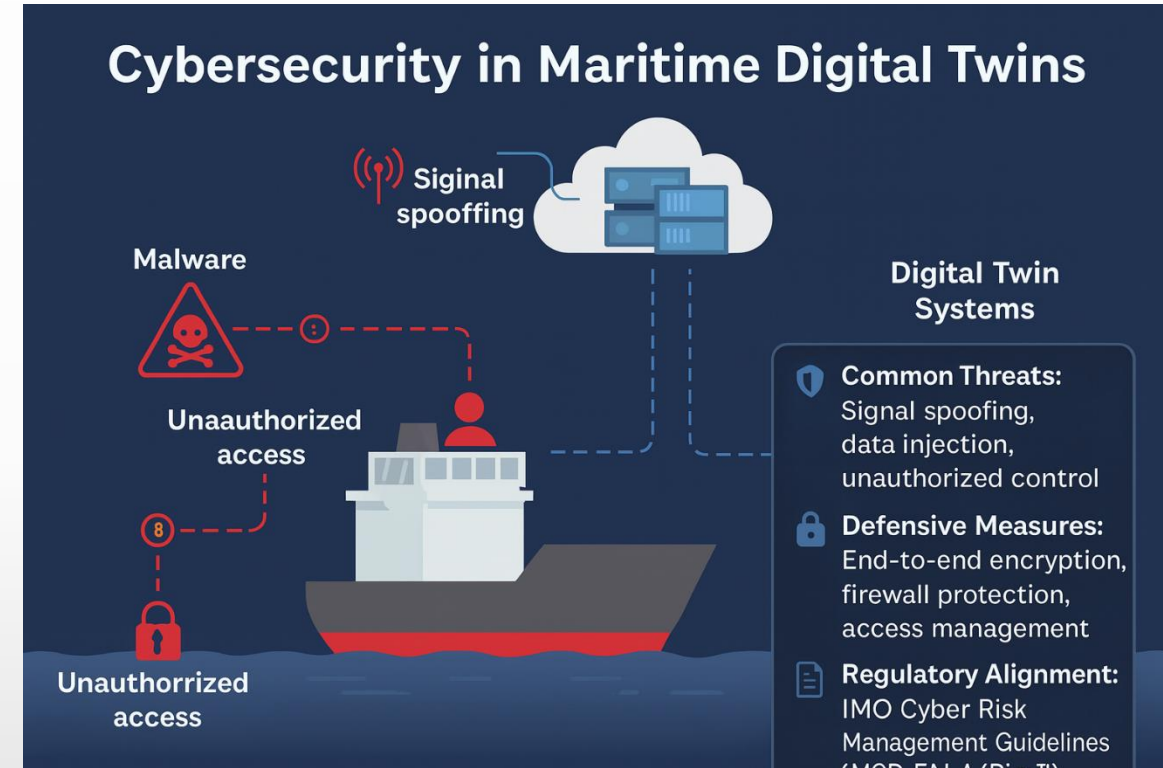
Routinely check and tighten mechanical joints

Vibration Monitoring

Routinely check and tighten mechanical joints

2.3.6. Cybersecurity in Digital Twin Systems

- As vessels increasingly rely on interconnected digital twin systems, cybersecurity becomes a critical concern. It is recommended to add a dedicated subsection that addresses potential cyber threats, such as unauthorized access, data manipulation, or system spoofing. This can include:
- Common maritime cybersecurity risks
- Protection strategies (e.g., encryption, access control, anomaly detection)
- Regulatory frameworks (e.g., IMO Cyber Risk Management Guidelines)

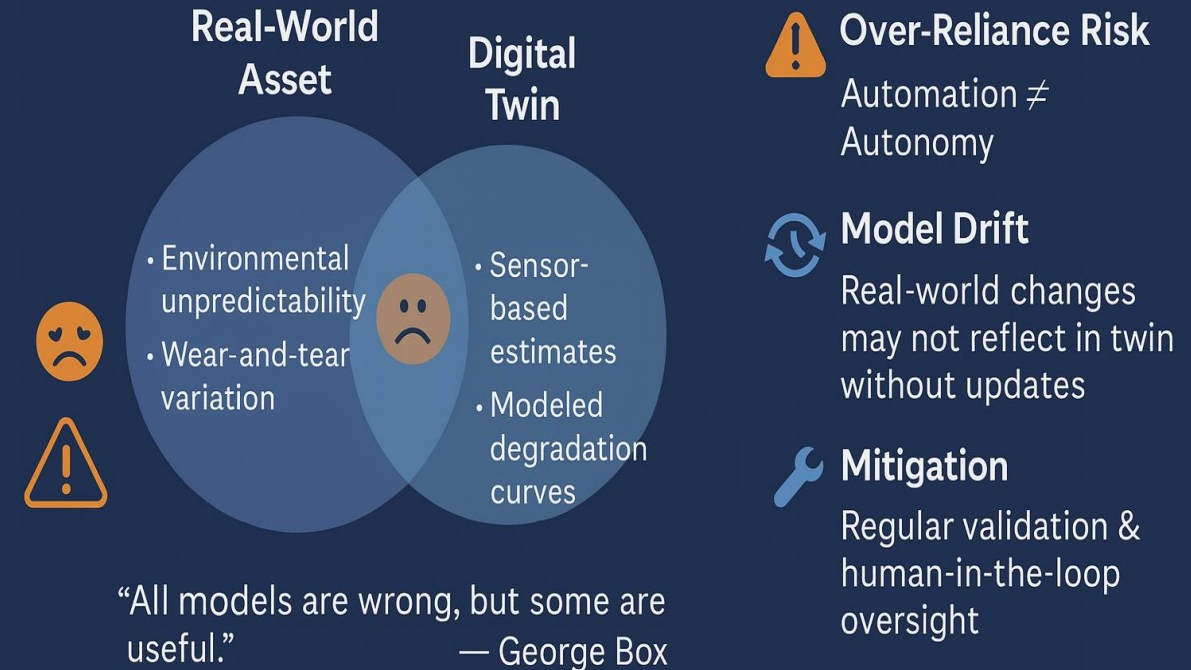


2.3.7. Limitations of Digital Models

While digital twins are powerful tools, they are still approximations of reality and may not capture all edge cases or unexpected scenarios. A short segment discussing model limitations would be valuable, highlighting:

- The importance of maintaining manual backup procedures
- The risks of over-reliance on automated systems
- Situations where real-world conditions deviate from model assumptions

Understanding the Limitations of Digital Models



Thanks for your attention!