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Practical Considerations for Autonomous Vessels

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CISMaRT Online Workshop
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OUR LOCATIONS.

4 office locations worldwide:

- Vancouver, BC
- Ottawa, ON
- Houston, TX
- Vung Tau, Vietnam

Part of Vard Group, headquartered in Norway

Majority owned by Fincantieri in Italy

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Ocean Infinity Marine Robotics

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- 8x 78 m multi-role robotic vessels, 2022-2023 delivery
- Onshore remote control, light crewed or uncrewed operations
- Green ammonia, fuel cell, battery technology
- ROV & robotic systems deployment/recovery/operation

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Autonomy Levels

SAMPLE DEFINITIONS (Bureau Veritas)

Level	Description	Example
0	Human operated	Crewed vessel, manual operation
1	Human directed	Automated Bridge & platform management
2	Human delegated	Limited autonomous decision making & control
3	Human supervised	Full autonomy with high level oversight
4	Fully autonomous	Full autonomy

- Small vessels already at Level 4
  - Mayflower 2
  - Numerous UxV
- Larger vessels currently at approx. Level 2
  - Safety
  - Machinery and systems
  - Regulatory regime
- Some approaching level 3, targeting level 4

Considerations for Larger Vessels

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- Implications of reduced or non-existent onboard presence
  - Situational awareness
  - Systems management
  - Routine maintenance
  - Fault/Failure identification & recovery
  - Security
- Related imperatives
  - Communications
  - Observability & Controllability
  - Reliability
- System impacts

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Observability, Controllability

- Vessel control
  - Perception & Situational Awareness (PSA) systems
  - Similar to C4IS element of naval combat systems in principle
    - Sense environment
      - All-weather
      - Relatively short range
      - All available means (Radar, AIS, LRIT, EOIR…)
    - Interpret
    - Determine response actions
    - Implement
    - Observe & repeat
  - Primary time scales O(hours to seconds)
  - Primary parameters O(10's to 100's)
  - SOLAS/ColRegs Compliant!

Observability, Controllability

- Machinery Control
  - Similar to IPMS with operator roles automated
    - Primary time scales O(10's of seconds to 10s of milliseconds)
  - Dense information requirements
    - Today 5-20 k IO points
    - Future 10-50k points
  - Information reliability & interpretation
    - Information redundancy
      - Ex: 737 Max
    - Physics-based validity checks
    - Interpretation challenge
      - Ex: Qantas QF 32
- Seen as the most challenging aspect of full autonomy
- AI application layered over expanded IPMS
- Must coordinate with Vessel Control function

Communications

- Human involvement up to Level 3 will begin onboard and transition to fully remote with experience & confidence
- Onboard autonomy even at Level 4 unlikely to remove requirement for real-time remote situational awareness & management at a land-based control centre
  - Requires high data rate, low latency data links that are robust to failures and weather
  - Favours LEO Satcom (Starlink, Iridium etc)
- Must remain operable through all failures including dark ship
- Multiple redundancy (antennas, channels)

Reliability

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- Statistically 63% of items will fail before MTBF
    - Commercial: Large fleets, shorter unmanned durations
    - Naval: Small fleets, larger unmanned durations
    - Research vessels & arctic voyages: Small numbers, extended durations
- No onboard maintenance -> reduced MTBF
- Remove least reliable elements from critical functional paths
    - Ex: IEP, Diesel-electric
- Remove auxiliary system complications altogether
    - Ex: Gas Turbine vs diesel (where reasonable)
- Implement redundancy as flexibly as possible
    - Ex: IEP vs CODAD
- Eliminate correlated failures & failure propagation paths across transverse systems
    - Electrical power distribution
    - Fuel system
    - Compressed air system
    - Lube oil system
- Autonomous machinery control & auxiliary systems remain the most challenging reliability aspects
- Simulation is key

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Reliability – Basic Propulsion System

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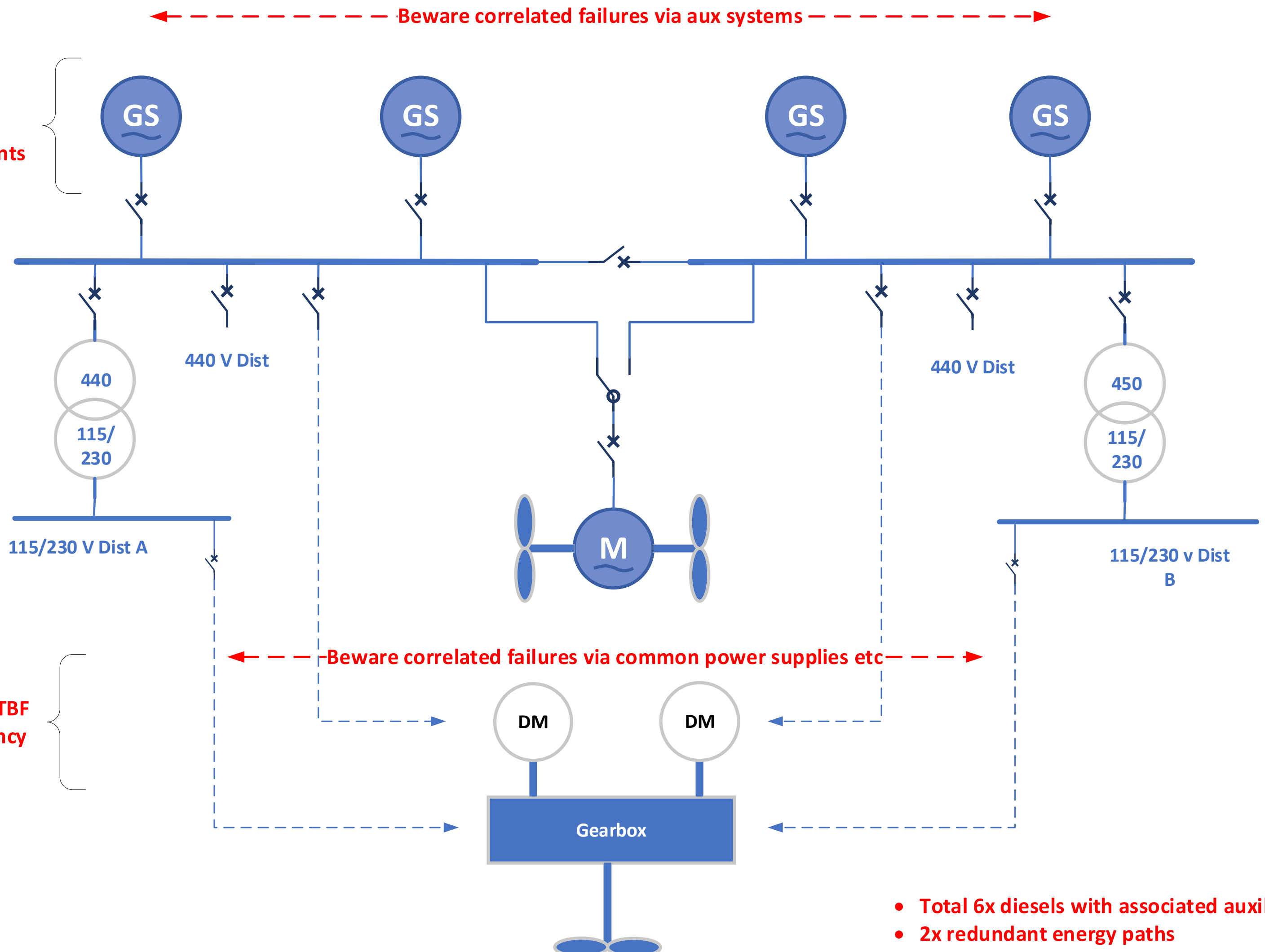
- Low intrinsic MTBF
- Redundancy
- Independent segments



- Low intrinsic MTBF
- Apply Redundancy

- Total 6x diesels with associated auxiliary systems
- 2x redundant energy paths
- Max 2x fully independent service buses
- 50% propulsion loss on one DM failure

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Reliability – IEP/CODLAG/CODLOG Propulsion Systems

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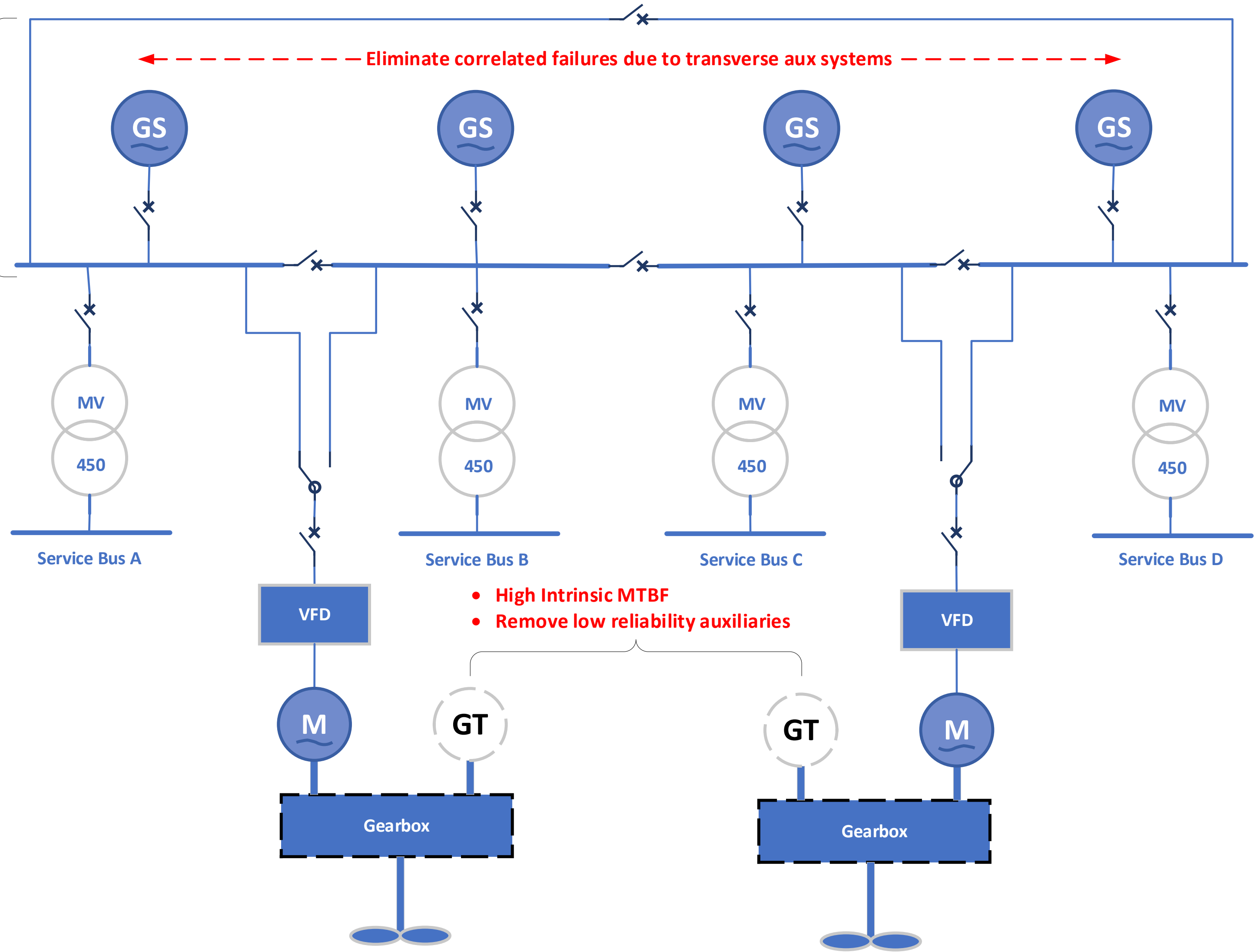
- Low-Med individual MTBF
- High system-level MTBF
- Multiple redundancy in gensets & paths
- Homogeneity & symmetry simplifies autonomous control

- High intrinsic MTBF
- Independent segments

- High intrinsic MTBF



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Security

- General
  - Minimize & control interior access points
  - Impede unauthorized boarding
    - Manoeuvring
    - Structure
    - Slippery foam
    - Electric razor fence
  - Disable boats (foul poropellers)
  - Provide non-lethal deterrents
    - Laser dazzlers
    - High intensity sound
    - Water cannons
    - High intensity microwaves
  - Requires
    - Local or remote human involvement
    - Triggered real-time broadband EOIR to remote centres
- Naval & anti-piracy
  - Provide force escalation options
  - Kinetic weapons less useful against sustained assault (cannot remotely reload, etc.)

High-Intensity Sound

Water Cannon

Millimetre Wave

Laser Dazzler