# Dynamic Positioning Systems

MANAGING RISK

# Schedule

- Basic definition of a DP vessel
- DNV DP class notations
- Typical operations vs. class notations
- Description of DP Systems
- Failure definitions and Redundancy Concept
- Documentation/Certification
- Environmental Regularity Number (ERN)
- Failure Modes and Effect Analysis (FMEA)
- Tests

# Basic definition

Dynamically positioned vessel:

*A vessel which automatically maintains position and heading (or track) by controlling the three horizontal motions (surge, sway, yaw) exclusive by means of thruster force.*

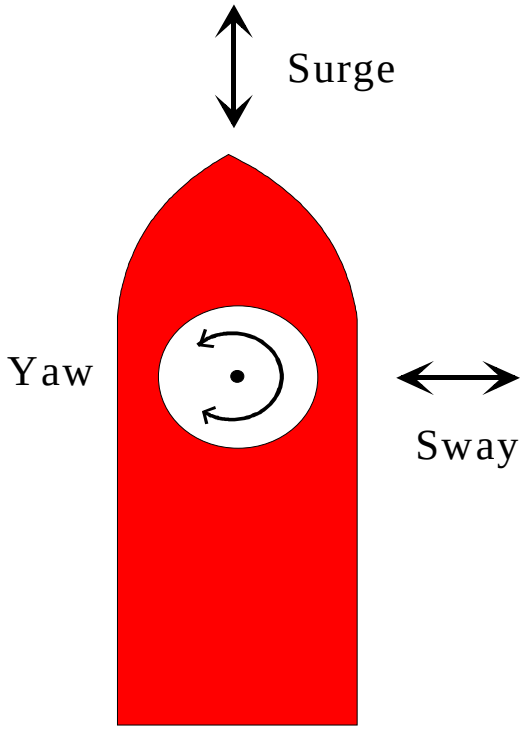


Fig.1 Surge, sway and yaw motions of a vessel

# IMO and class societies DP notations

## Correlation IMO / Class notations

| DNV | IMO | LRS | ABS |
|---|---|---|---|
| AUTS | - | - | - |
| AUT | Class 1 | DP A | DPS-1 |
| AUTR | Class 2 | DP AA | DPS-2 |
| AUTRO | Class 3 | DP AAA | DPS-3 |

# IMO and class societies DP notations

- DYNPOS AUTS:
  - Dynamic positioning without any redundancy
  - Loss of position may occur in the event of a single failure

- DYNPOS AUT (Class 1):

  As for AUTS +
  - Independent joystick backup with auto heading
  - Positioning reference system back-up
  - UPS power supply

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# IMO and class societies DP notations

- DYNPOS AUTR (Class 2):

  As for AUT +

  – Redundancy in technical design = loss of position shall not occur in the event of a single failure in any active component or system.

  – Flooding and fire not considered beyond main class requirements

- DYNPOS AUTRO (Class 3):

  As for AUTR +

  – Single failure definition extended to include flooding in any one watertight compartment and fire in any one fire sub-division

  – Backup DP-control system in a separate compartment, separate engine rooms, separate thruster rooms, separate switchboard rooms etc..

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# Typical operations vs. class notation

DYNPOS-AUT (Class 1):

- Bow loading

- Marine operations
  > 500m from an installation

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# Typical operations vs. class notation

DYNPOS-AUTR (Class 2):

- Marine operations
  < 500 from an installation
- Subsea well stimulation
- Unmanned subsea
  interventions with ROV




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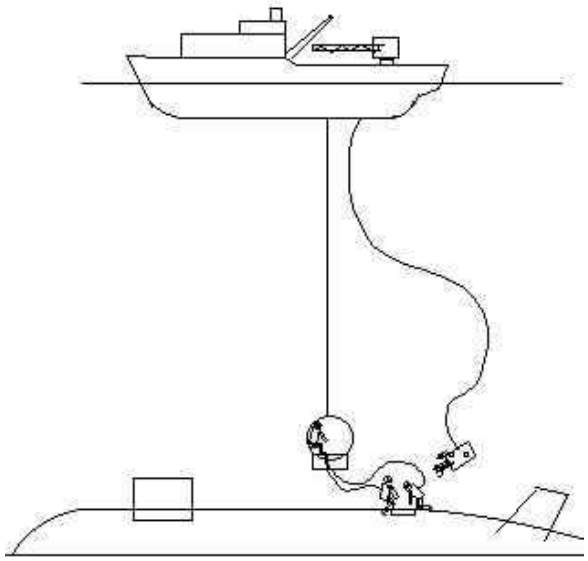
# Typical operations vs. class notation

DYNPOS-AUTRO (Class 3):

- Critical manned subsea interventions (diving)
- Drilling / production of hydrocarbons



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# Dynamic Positioning System

The complete installation on the vessel necessary for dynamically positioning a vessel

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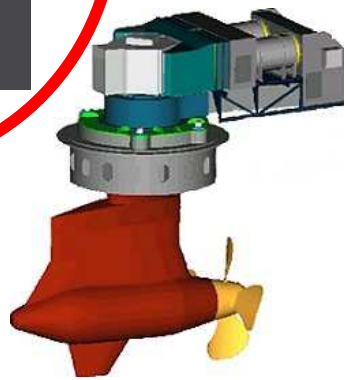
# Dynamic Positioning System

- DP Control System

  All control systems and components, hardware and software necessary to dynamically position the vessel.

- Thruster System

  All components and systems necessary to supply the DP-system with thrust force and direction.



- Power System

  All components and systems necessary to supply the DP-system with power.

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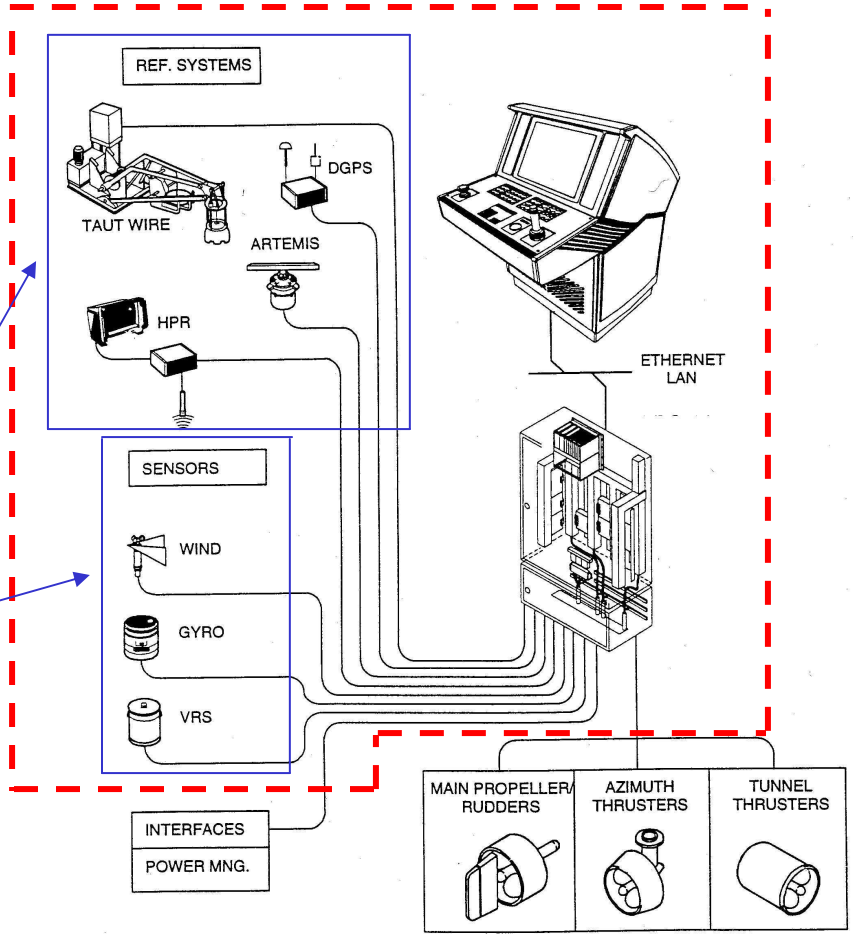
# DP Control System

- Computer system
- Operator system
- Positioning reference system
- Sensor system
- Associated cabling

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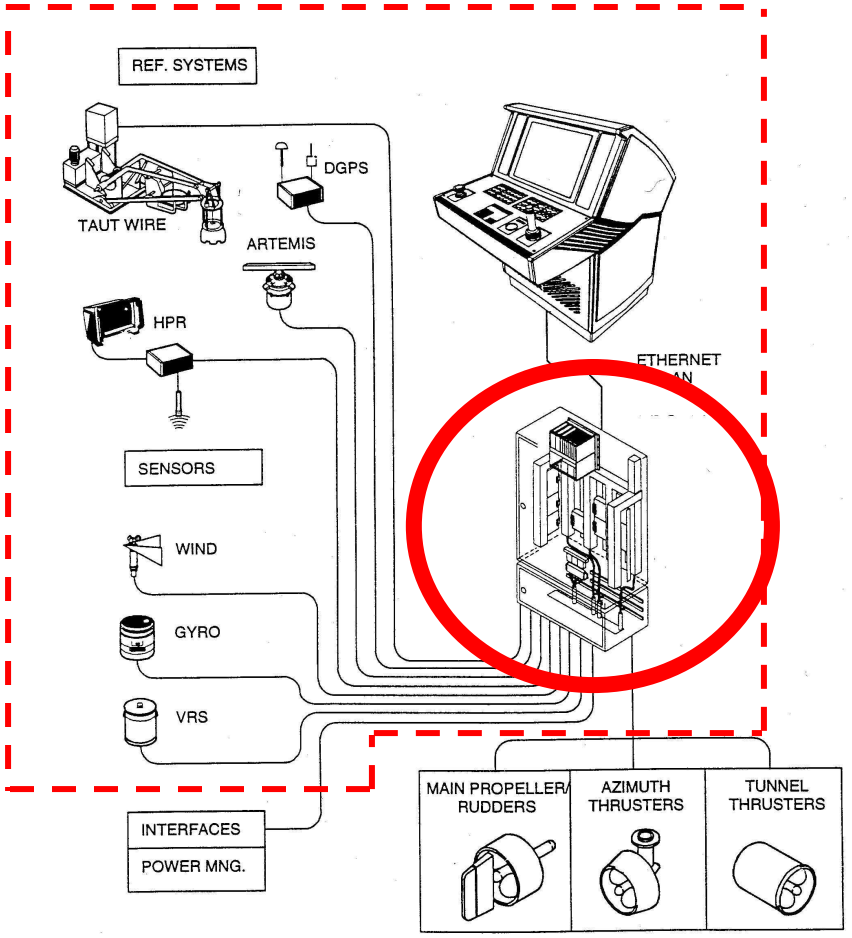
# DP Control System

- Computer system
- Operator station
- Positioning reference system
- Sensor system
- Associated cabling

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# DP Control System

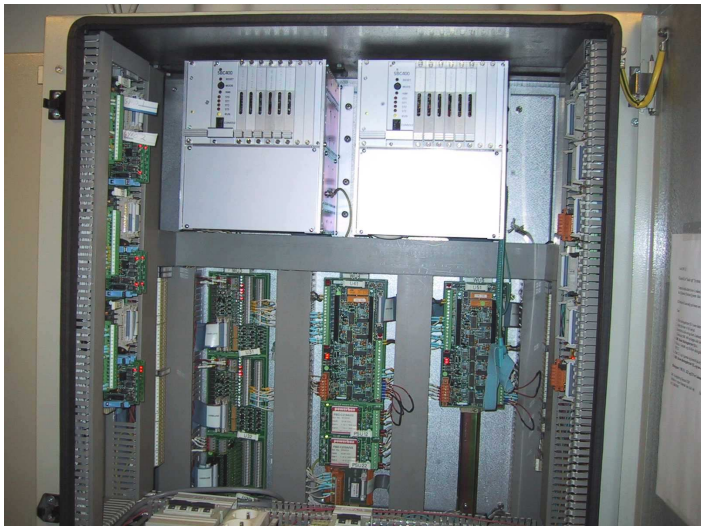
- Computer system, “The brain”

  Gives command signals to thrusters based on:

  - Operator input signals

  - Position input signals

  - Sensor input signals



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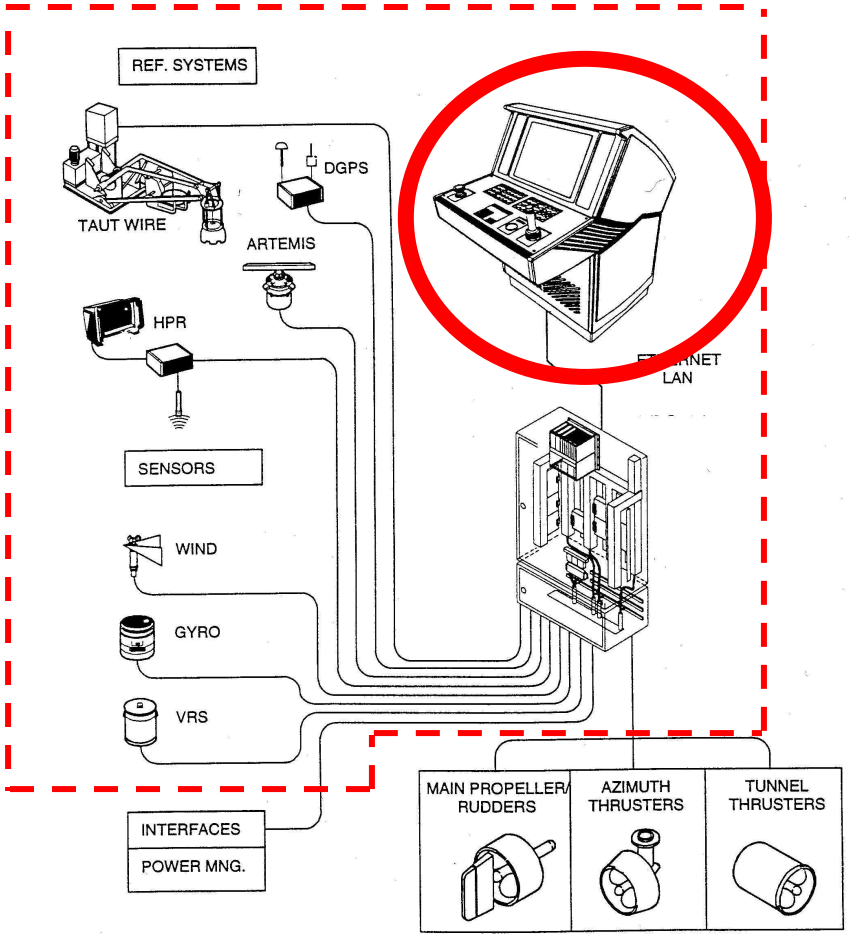


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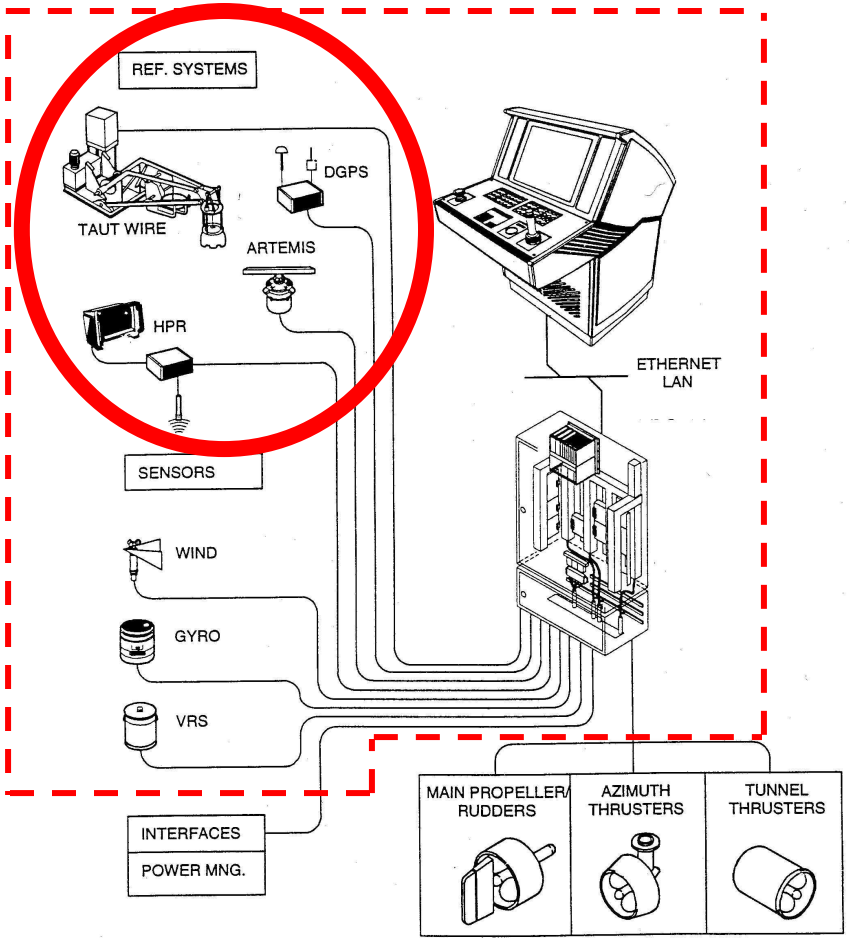
# DP Control System

- Operator station, “Human / Machine Interface”
  - Present the vessels position relative to the reference station
  - Receive operator commands and transfer these to the computer system
  - Present warnings and alarms to the operator


# DP Control System

- Computer system
- Operator station
- Positioning reference system
- Sensor system
- Associated cabling

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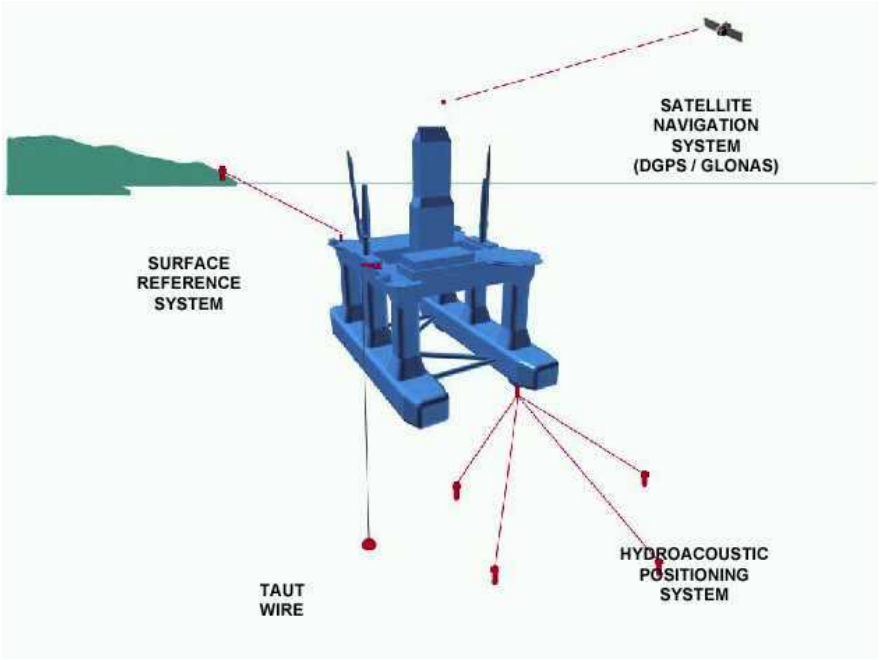
# DP Control System

- Position reference systems
  - Satellite navigation system
  - Hydro acoustic system
  - Taut wire
  - Micro wave system
  - Optical system



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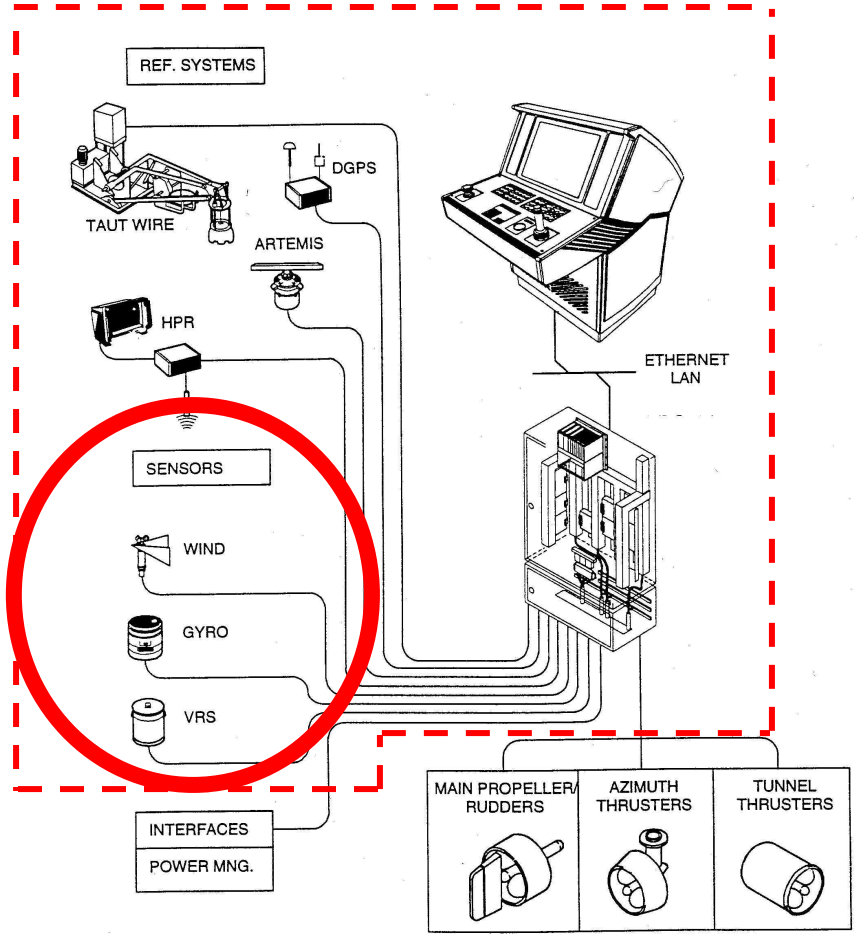

# DP Control System

- Sensor system:

- Gyro compass (heading)


- Motion Reference Unit (MRU), measures pitch, roll and heave in order to compensate for vessel movement

- Wind sensor, used to estimate wind forces on vessel.

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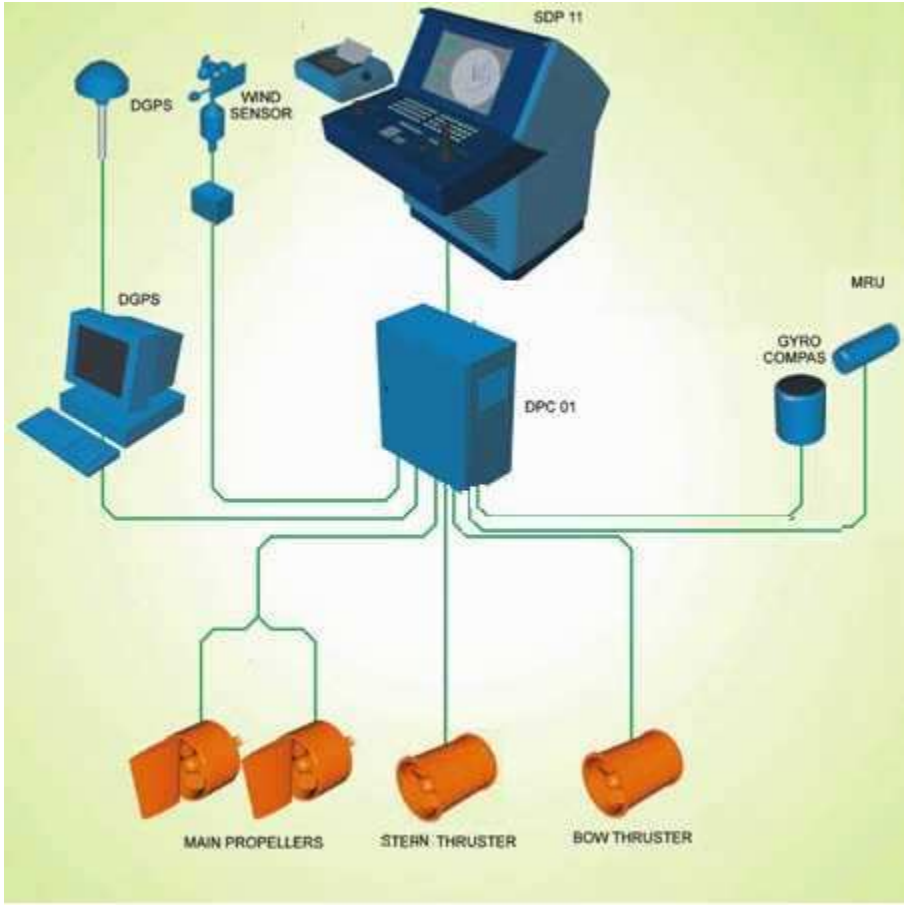
# Class Notation DYNPOS AUTS

Equipment:

- 1 computer system
- 1 position reference system
- 1 wind sensor
- 1 MRU/VRS
- 1 gyro compass
- 1 printer

In addition (not shown):

- Manual levers

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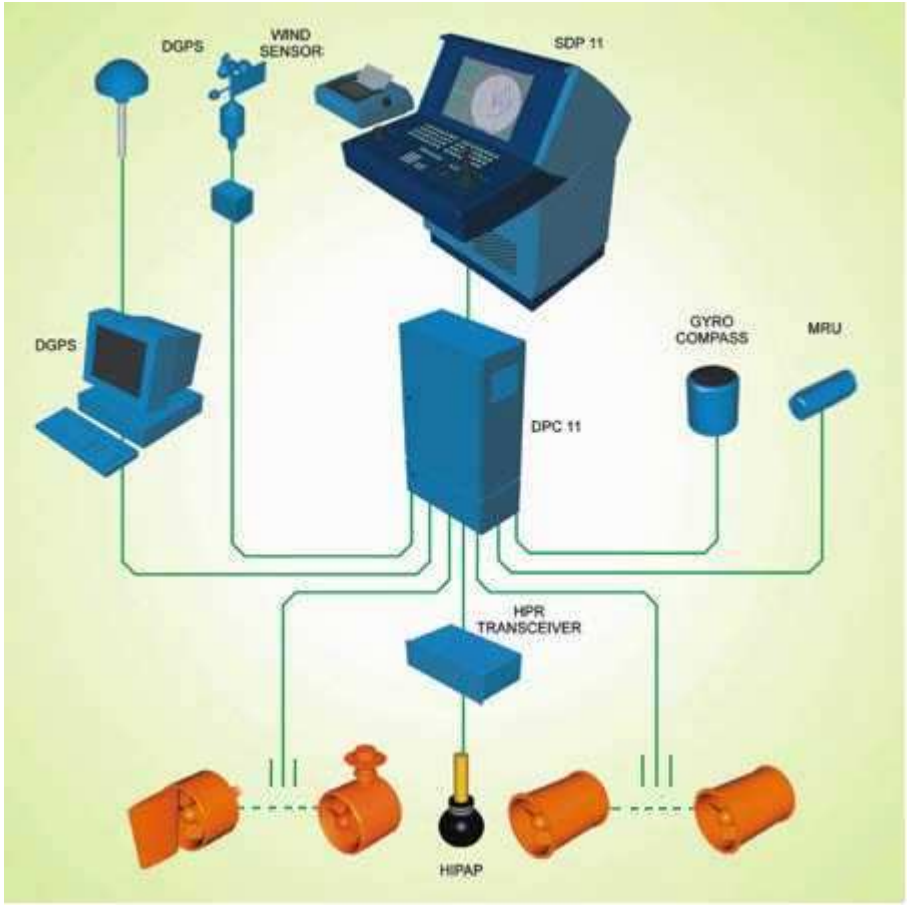
# Class Notation DYNPOS AUT

Minimum equipment:

- 1 computer system
- 2 position reference system
- 1 wind sensor
- 1 MRU/VRS
- 1 Gyro compass
- 1 printer

In addition (not shown):

- 1 Joystick with automatic heading
- Manual levers
- 1 UPS

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# Class Notation DYNPOS AUTR

Minimum equipment:

- 2 computer systems
- 2 operator stations
- 3 position reference systems
- 2 wind sensors
- 2 MRU/VRS
- 3 gyro compass
- 1 printer

In addition (not shown):

- 1 Joystick with automatic heading
- Manual levers
- 2 UPS`s


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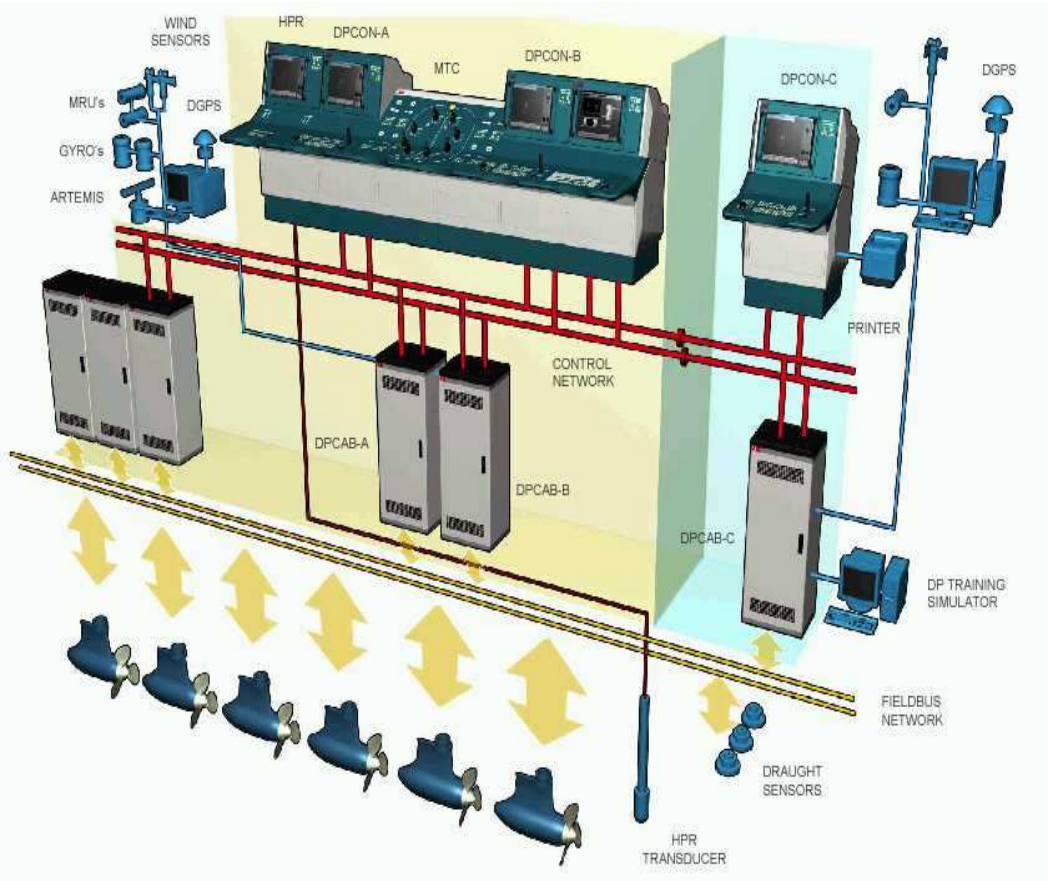
# Class Notation DYNPOS AUTRO

Minimum equipment:

- 2 + 1 computer systems
- 2 + 1 operator stations
- 2 + 1 position reference systems
- 1 + 1 wind sensors
- 2 + 1 MRU/VRS
- 2 + 1 gyro compasss
- 1 printer




In addition (not shown):

- 1 Joystick with automatic heading
- Manual levers
- 3 UPS`s
- Separation is NOT shown for all equipment

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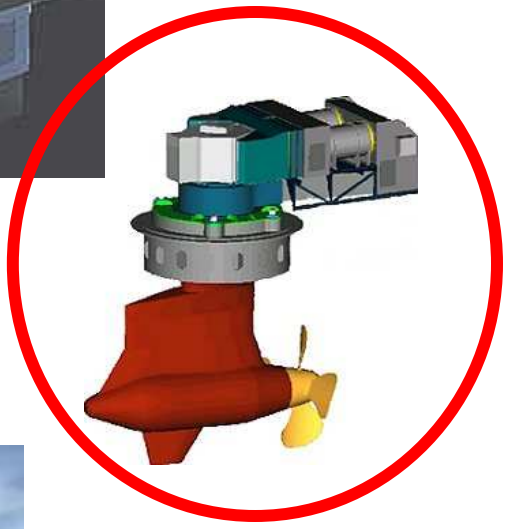
# Dynamic Positioning System

- DP Control System

  All control systems and components, hardware and software necessary to dynamically position the vessel.

- Thruster System

  All components and systems necessary to supply the DP-system with thrust force and direction.



- Power System

  All components and systems necessary to supply the DP-system with power.

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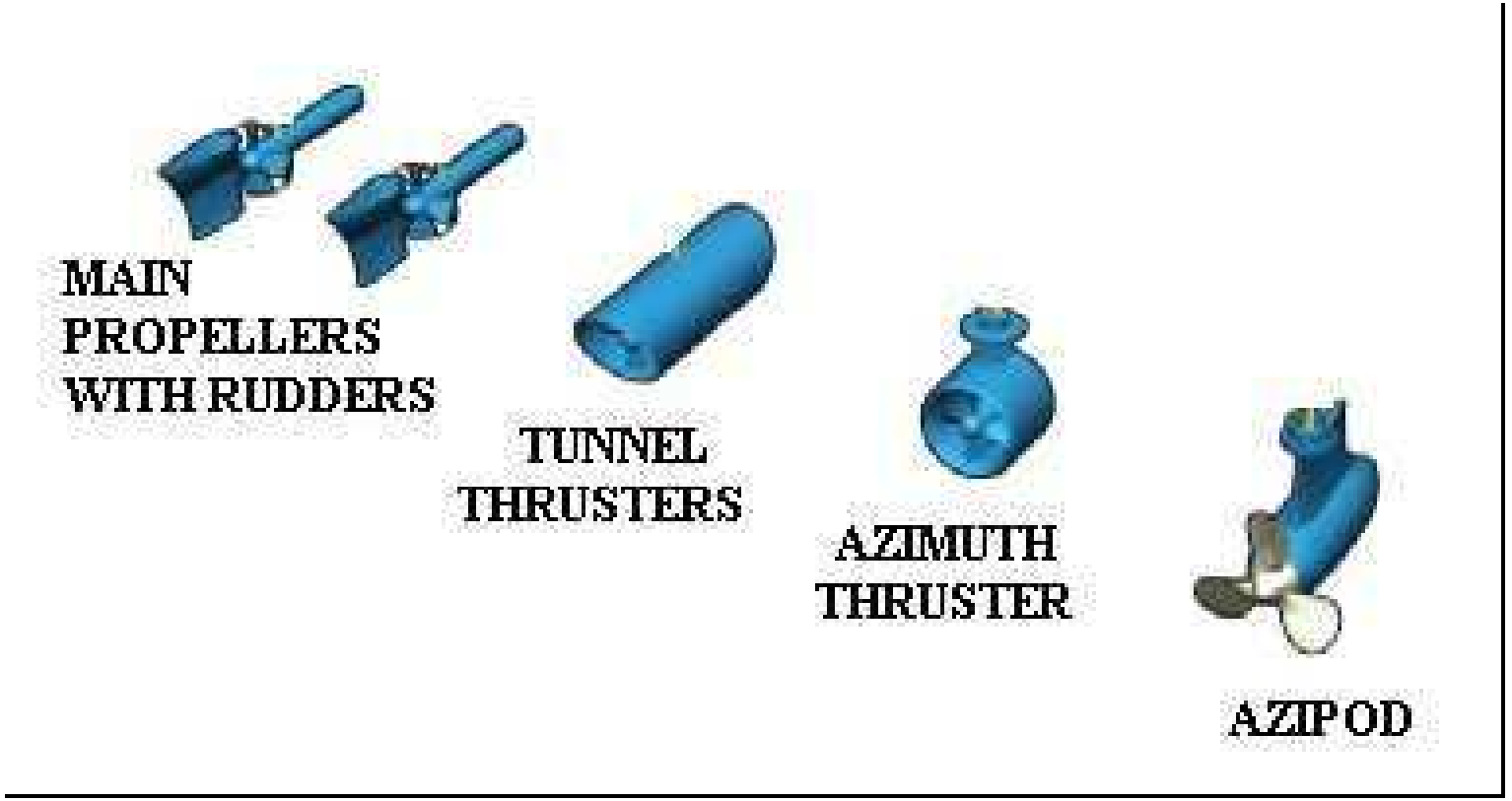
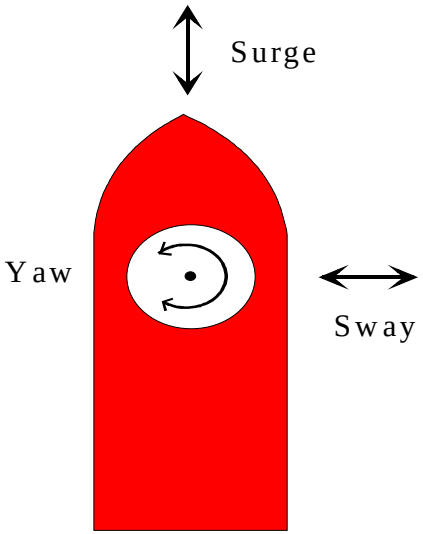
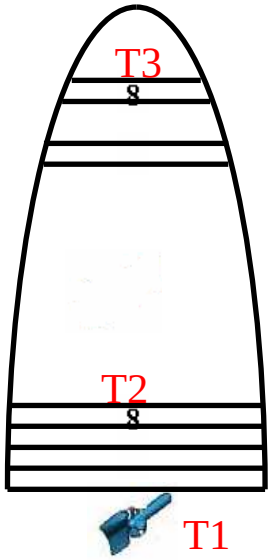
# Thruster system

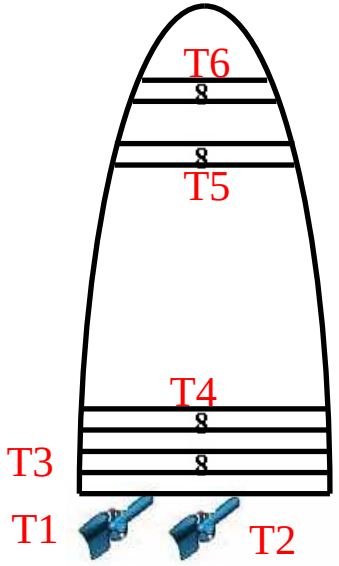


# Thruster Systems

- Configuration
  - Must produce transverse and longitudinal thrust, and a jawing moment
  - For AUTR and AUTRO, transverse and longitudinal thrust, and a yawing moment after any single failure

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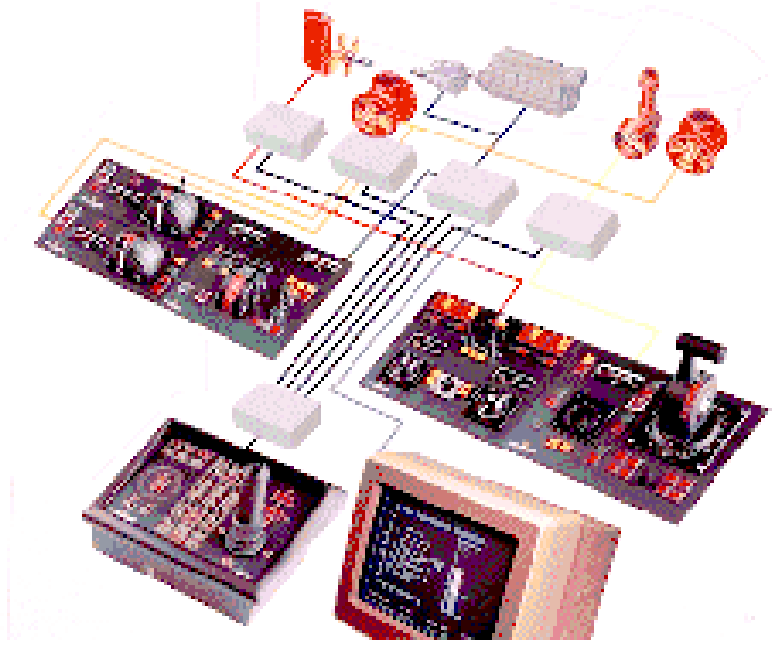
# Thruster System

Covered by DNV Rules:

- Thruster with drive units and necessary auxiliary systems including piping
- Thruster control & monitoring
- Cabling and cabling routing (AUTRO)
- Main propellers and rudders if these are under control of the DP-system

# Thruster System

- Control
  - Individual manual control of each thruster in the DP control centre
  - Emergency stop system at the DP control position
  - Loop monitoring in the emergency stop system (AUTR and AUTRO)



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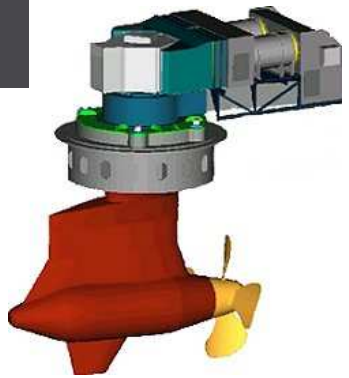

- Power System

  All components and systems necessary to supply the DP-system with power.

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# Power Systems

- General
  - Comply with the relevant rules for main class for all notations
  - For AUTR and AUTRO additional requirements will apply with regard to redundancy and respect to maximum single failure
  - To prevent overloading the power plant, interlocks or thrust limitations are to be arranged

# Power Systems

- Main and Distribution Switchboards
  - For notations AUTR (Class 2) and AUTRO (Class 3) no single failure shall give a total black-out.
  - Single failure includes short-circuit of bus-bars
  - A main bus-bar system consisting of at least two sections, with bus-tie or inter-connector breaker(s), are to be arranged

# Power Systems

- Power Management System
  - Required for AUTR (Class 2) and AUTRO (Class 3)
  - PMS failure not to cause alternations to the power generation, and is to initiate an alarm in the DP-control centre
  - Possible to operate the switchboards in manual as required for the main class, with the PMS disconnected
  - Overload, caused by the stopping of one of or more generators, shall not create a black-out

- PMS functions
  - Load dependent starting of additional generators
  - Block starting of large consumers when there is not adequate running generator capacity, to start up generators as required, and hence to permit requested consumer start to proceed
  - If load dependent stop of running generators is provided, facilities for disconnection of this function is to be arranged

# Power Systems

- Control System Power Supply
  - The controller and measuring system are to be powered from UPS (Uninterruptible Power Supply)
  - The battery for each UPS is to be able to provide output power for 30 minutes after loss of charger input power at actual load.
  - An alarm is to be initiated when the UPS looses charger input

# Failure definitions and Redundancy Concept, AUTR & AUTRO

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# Single Failure

- Failure definition:
  - An occurrence in a component or system causing one or both of the following:
    - Loss of component or system function
    - Deterioration of functional capability to such an extent that safety of the vessel, personnel, or environment is significantly reduced.
- Normally static components will not be considered to fail if adequate protection is provided. Example: Pipes, manual valves. Exceptions for AUTRO.

# Class Notations and Single Failure

- **AUTS and AUT:**

  Loss of position may occur in the event of a single failure

- **AUTR:**

  Loss of position is not to occur in the event of a single failure. Certain exceptions will be allowed in the definition of single failure. Flooding and fire is not to be considered beyond main class requirements and failure of non-moving components, e.g. pipes, manual valves, etc. may not need to be considered.

- **AUTRO:**

  Loss of position is not to occur in the event of a single failure. The definition of single failure has no exceptions, and shall include incidents of fire and flooding. Loss of stability (e.g. as a result of flooding) is not a relevant failure mode for DP.

# Single Failure AUTR

- Any active component or system has to be considered to fail. Examples:

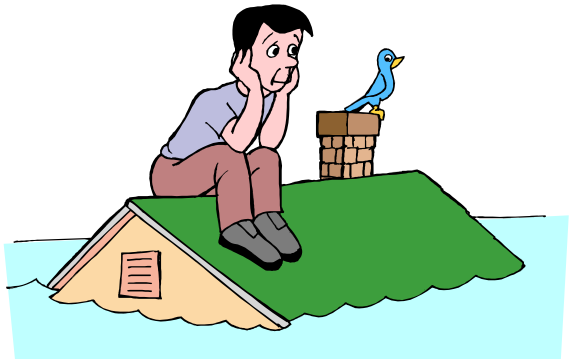
- Components for mechanical transfer of energy, e.g. pumps, fans, electric motors, generators, combustion engines. Short-circuit of switchboard bus-bars considered to be a single failure.
- Coolers, filters, motorised valves, fuel oil tanks, electrical and electronic equipment.

- A single inadvertent act of operation. If such an act is reasonably probable

- Systematic failures or faults that can be hidden until a new fault appears

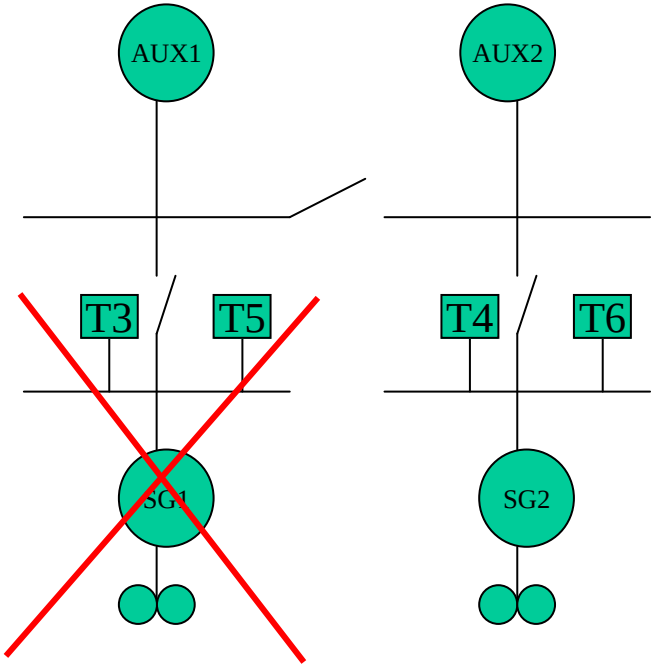
# Single Failure AUTRO

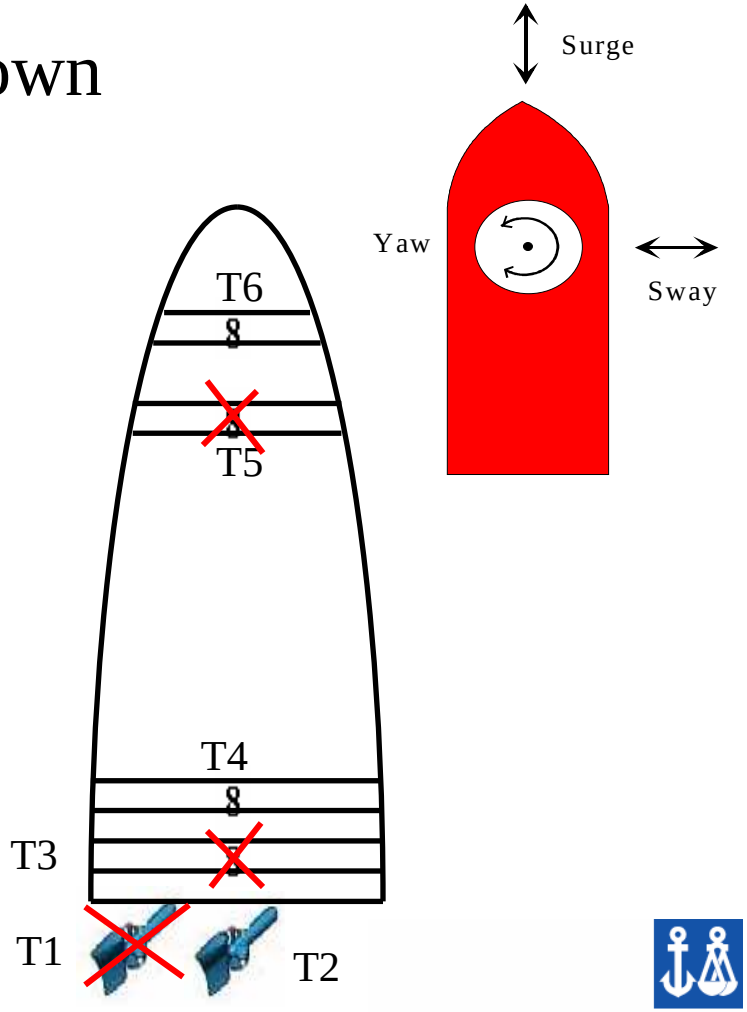
- Items listed for AUTR and failure of static components
- All components in any one watertight compartment, from fire and flooding
- All components in any one fire sub-division, from fire and flooding



# Single failure

- Example ME No.1 shut-down

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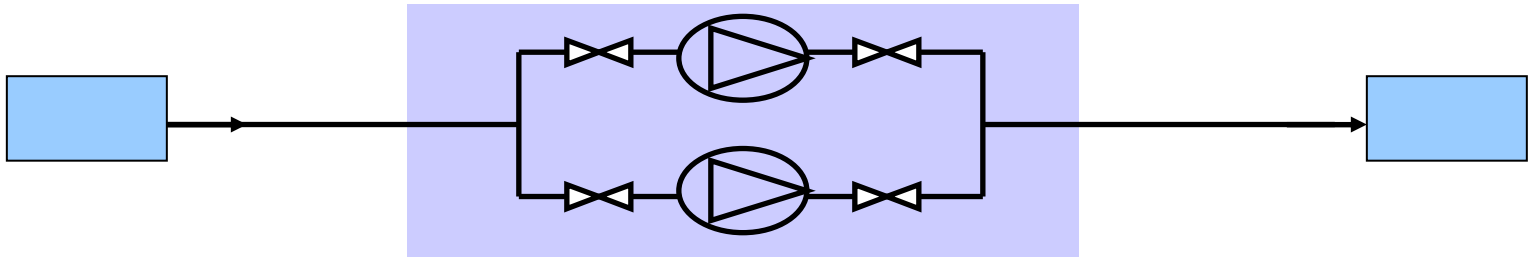
# Redundancy

- The ability of a component or system to maintain or restore its function when one failure has occurred.
- Philosophy: Redundancy can be achieved, for instance, by installation of multiple components, systems or alternative means of performing a function.

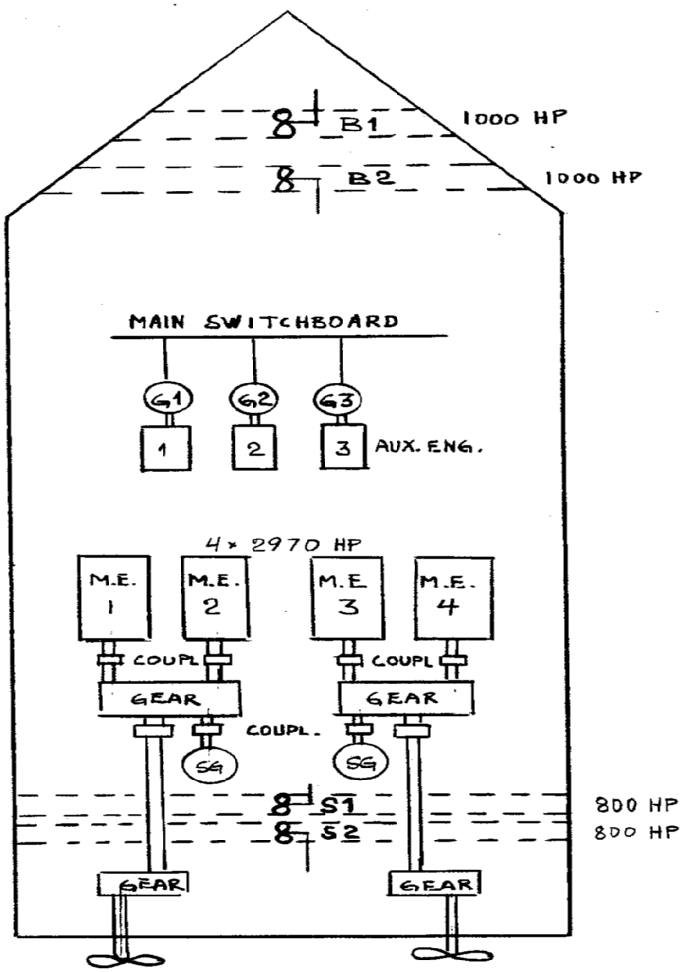


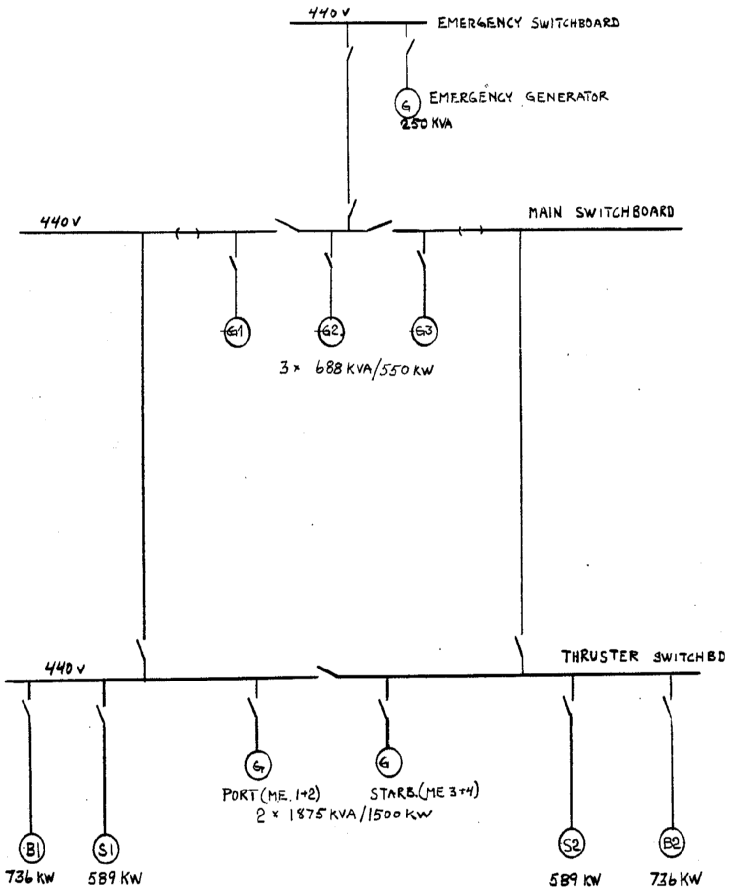
Solutions are not considered to be redundant if they contain single components even if:

- components have proved reliable during the years. 100% availability can never be achieved
- components can be replaced upon failure onboard
- systems can be started after failure. Starting of a generator after black-out is not accepted in this context.

Redundancy is not to reduce the number of failures, but the consequence of failures

# Redundancy example

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# Redundancy

Piping general:

- Fixed piping may be shared by components designed with redundancy for AUTR notation, except for fuel and fresh water piping.
- For AUTRO notation separate piping is to be arranged for systems designed with redundancy

Piping spesial:

– Fuel system
  - Is to be arranged as fully separated systems for AUTR and with separation for AUTRO notation
  - At least one service tank to each dedicated system

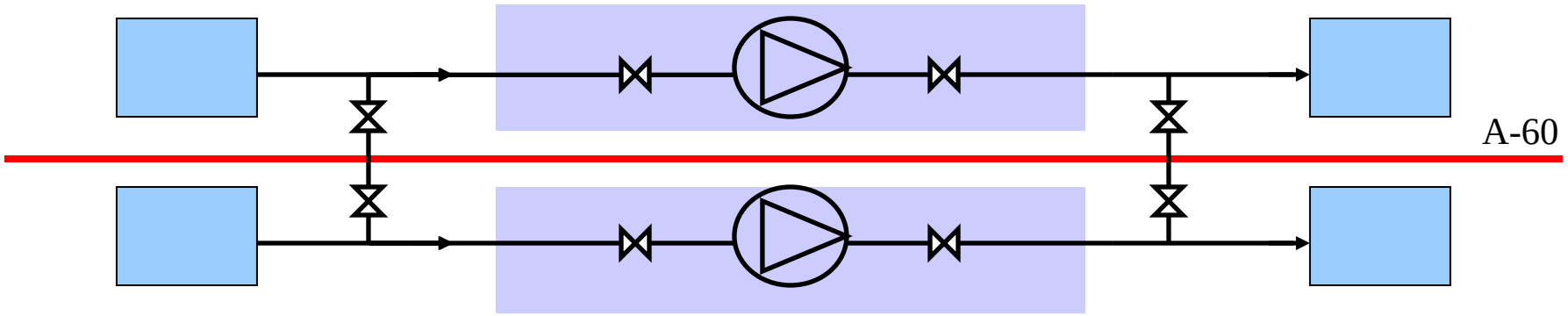
– Cooling water
  - Fresh water cooling systems are to be arranged with full separation between systems designed with redundancy

# Redundancy

- Lubricating oil system
  - Usually no problem since the systems are usually separated
- Compressed air
  - Instrument air may be required redundant if running machinery is dependent of instrument air.
  - A starting air system in compliance with main class will usually be acceptable also for AUTR and AUTRO notation (Starting of an engine is not accepted as a part of the redundancy concept for AUTR and AUTRO notation.)
- Ventilation
  - For AUTRO separate ducting systems is required between systems designed with redundancy

# Separation (AUTRO)

- Physical separation by installation of equipment in two different compartments.
  - Separation by bulkheads which are to be fire-insulated by A60 class division, and in addition are to be watertight if below the damage waterline.




- Normally closed cross over valves on both sides of the bulkhead is accepted.

# Documentation/Certification

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# Documentation/Certification

- Control system must be DNV certified, also independent Joystick system.
- Thrusters must be certified as DP thrusters = propulsion thrusters (100% continuous output)
- Power Management System must be DNV certified. Sometimes included in switchboard certificate.

IMPORTANT DOCUMENTATION:

- Most documentation requirements are usually covered by the manufacturer's document package, submitted in conjunction with certification.
- Electrical load calculation during dynamic positioning operation. For vessels with the notations DYNPOS-AUTR and DYNPOS-AUTRO the load calculations shall also reflect the situation after the maximum single failure(s). Normally part of the power consumption balance document required for main class.
- For vessels with the notation DYNPOS-AUTRO:

— cable routing layout drawing

— fire and flooding separation arrangement

# Documentation

- Drawings showing the physical arrangement and location of all key components in the DP-control centre. GA drawing for bridge can be used. For notation DYNPOS-AUTRO only, drawings showing the physical arrangement and location of all key components in the emergency DP-control centre.
- Failure mode and effect analysis (FMEA), for vessels with the notations DYNPOS-AUTR and DYNPOS-AUTRO. Will be explained on separate sheet.
- ERN calculation = position holding performance. Will be explained on separate slides
- Program(s) for tests and trials
- If external systems such as sensors (gyro's, position reference systems etc.) or thruster control mode switch is not supplied by the DP manufacturer, additional documentation will be required from the Yard.

# ERN

Environmental Regularity Numbers

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# Environmental Regularity Numbers

- Represent
  - The static balance of environmental forces and thruster output
  - The “percentage” chance that the ship will be capable of maintaining its position
- Calculations
  - Based on weather statistics from the North Sea
  - Case situation with regard to direction of the weather (usually at the beam = worst case)
  - Only single failure thruster failures are considered
  - Not related to redundancy
- Represented by three numbers ERN(a, b, c) ranging from 0-99
  - Optimal use of all thrusters (rudders not included) (a)
  - Minimum effect of single thruster failure (b)
  - Maximum effect of single thruster failure (c)

# ERN

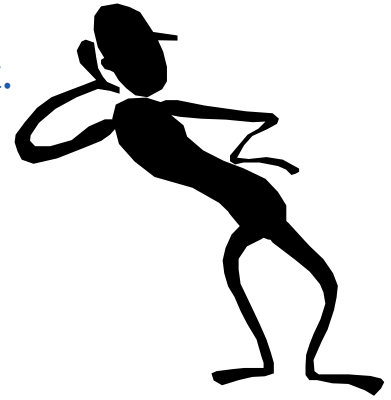
- General information

– The ERN evaluation is restricted to thruster application within the limits of available power; that is one of the ground rules of the ERN concept

– The ERN is to be based upon the thrust output that is under control, in the most efficient mode

– ERN usually submitted by DP manufacturer or external consultant.

– DNV can calculate ERN as consultancy service.



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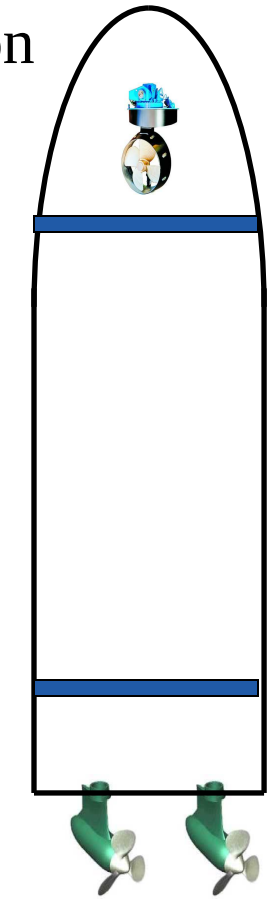
# ERN

- Necessary documentation to do a ERN-calculation
  - Particulars of the vessel
    - $L_{pp}$
    - $L_{oa}$
    - Breadth
    - Depth
    - Front and abeam wind exposed area
    - Front and abeam submerged area

  Can be submitted in form of a GA drawing in scale.

  - Thruster configuration
    - Thruster type, tunnel, azimuth, conventional propeller and rudder
    - Power
    - Maximum thrust
  - Possible power limitations



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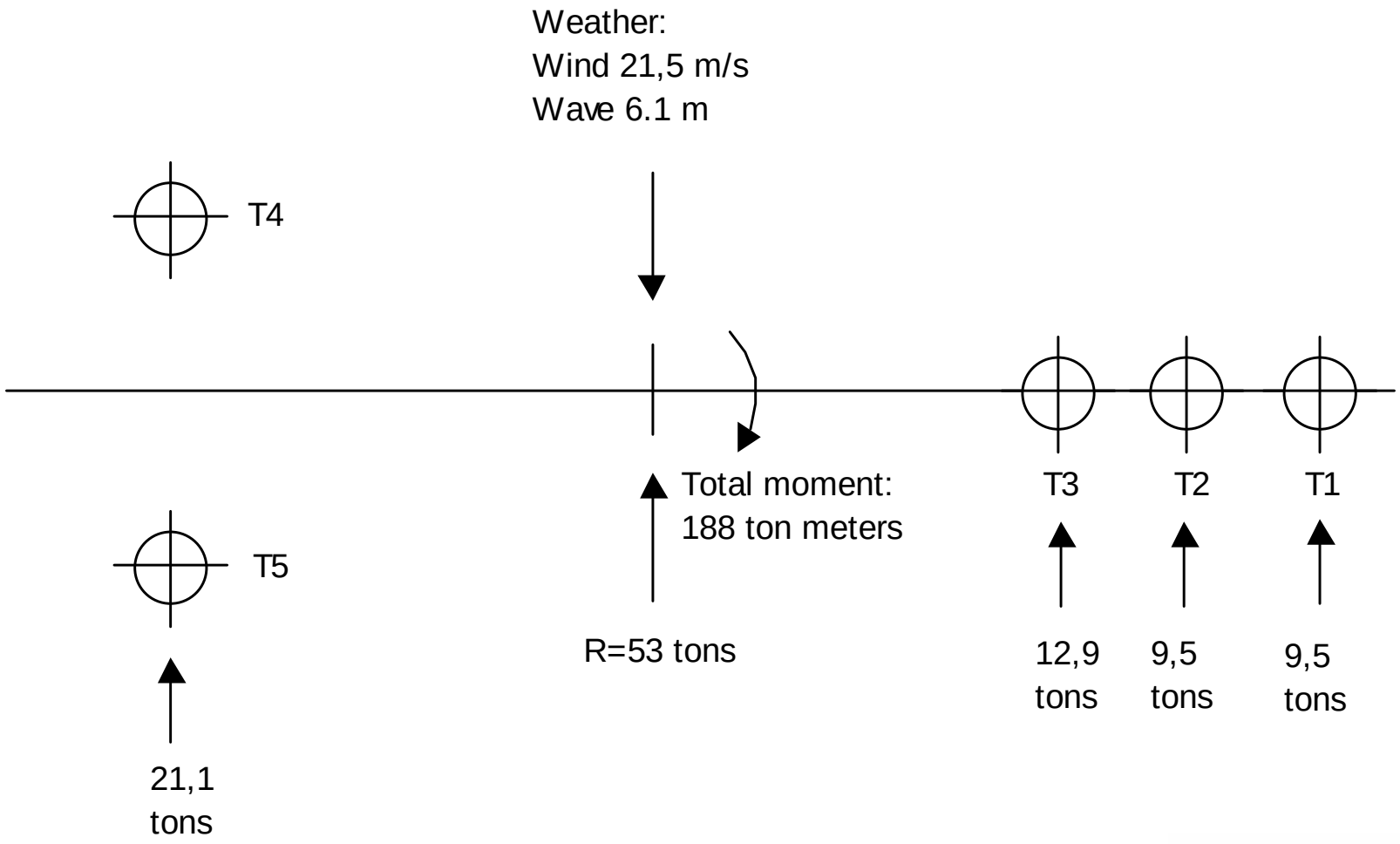
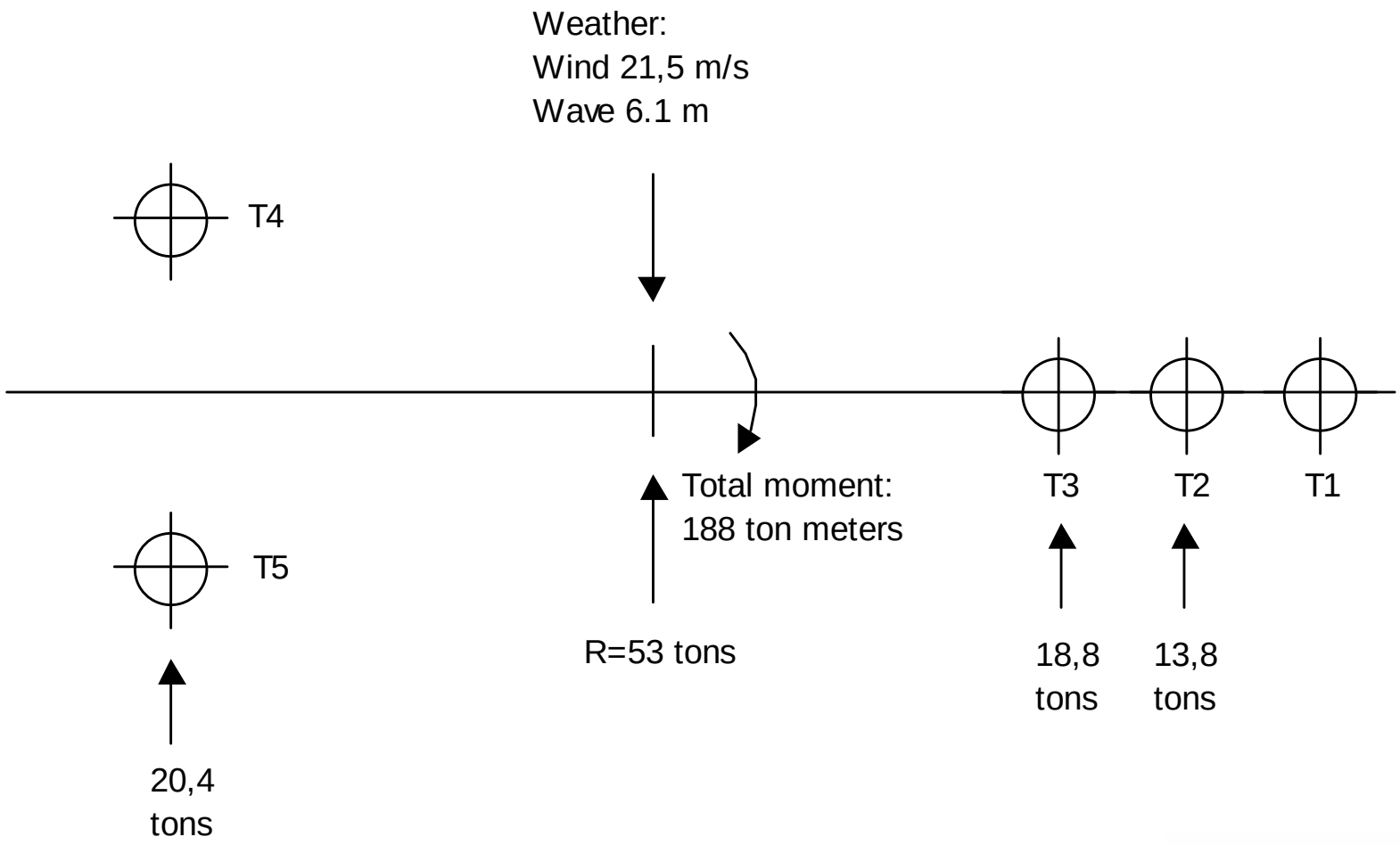
# ERN (first number)




MANAGING RISK

# ERN (third number)




MANAGING RISK

# FMEA

## Failure Mode and Effect Analysis

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# FMEA- Failure Mode and Effect Analysis

- Required for class notations AUTR and AUTRO
- The main purpose is to assist in the assessment of the redundancy of the DP system
- Show that the position keeping ability is maintained after a single failure
- Assumption: Everything that can fail, will fail
- An ongoing process starting at the first design review and continue throughout the lifetime of the ship
- The FMEA should be a complete document including all necessary drawings and descriptions

# FMEA- Failure Mode and Effect Analysis

- Description of FMEA systematic may be found in IEC Publication 60812 and IMO HSC Code, Annex 4.
- FMEA must contain:

– system description
– block diagram of the DP system
– description of each physically and functionally independent item and the associated failure modes
– description of the effects of each failure mode on the overall dynamic positioning system.
– summary, conclusions and recommendations
– corrective actions
– operational restrictions

# FMEA- Failure Mode and Effect Analysis

The FMEA and test program is often submitted by a consultant/designer.

- FMEA work sheets can be very useful:

| Equipment name | Function | Ident. NO | Failure mode | Failure cause | Local failure effect | End failure effect | Failure detection | Alternative provisions | Failure probability | Criticality level | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Azimuth thruster no.1 | Produce thrust in any direction | xxx.xx | Stop | Any mechanical or electrical failure | Stop | Operational | Alarm | Select alternative thruster | | II | Loss of a single thruster will not be critical, assuming all others are available |
| Gyro compass | Heading reference | xxx.xx | Failure of 24V input | 24V bus fault | Loss of heading info | Not operational | Alarm | Switch to manual heading control | | IV | Heading info is essential, loss of power on bus yyyy is a critical fault |

# Testing

# Testing

- Test program submitted by manufacturers of DP & Joystick systems. Accuracy of position keeping.
- Offset inputs for each position reference system and relevant sensors in the dynamic position control system should be verified (spin test).
- The capacity of the UPS batteries shall be tested.
- Manual override, it shall always be possible to gain manual control of the thrusters
- Test of signal failures in thruster control cabling, a single failure in the thruster control system shall neither cause significant increase in thrust output nor make the thruster rotate
- A duration test shall be carried out for at least 8 hours with the complete automatic system in operation
- Redundancy tests for DYNPOS-AUTR and DYNPOS-AUTRO. Specific conclusions of the FMEA for the different systems shall be verified by tests.

# Testing

- Redundancy tests are extensive and will normally imply:
  - Partial black-out of the main- and emergency switchboards
  - Stop of one or more engines at the time
  - Loss of distribution boards or equipment with dual power supply
  - Loss of (black-out) each battery and UPS distribution.
  - Loss of signals (control, feedback, sensors, reference systems, etc)
  - Dependant on the actual design, other tests might be required. For AUTRO, simulated fire or flooding in areas will be tested.

# THE END

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