Dynamic positioning

Literatura:

Jan Babicz - Encyclopedia Of Ship Technology
IMO - Guidelines For Vessels And Units With Dynamic Positioning (DP) Systems
IMCA - Guidelines for The Design and Operation of Dynamically Positioned Vessels

Encyclopedia Of Ship Technology

Dynamic positioning is a capability of a vessel to maintain its position automatically using its propulsion system.

Dynamic positioning system – A hydrodynamic system which controls or maintains the position and heading of the vessel by centralized manual control or by automatic response to the variations of the environmental conditions within the specified limits.

MSC.1/Circ. 1580 *Guidelines for Vessels with Dynamic Positioning Systems*

Dynamically positioned vessel (DP vessel) means a unit or a vessel which automatically maintains its position and/or heading (fixed location, relative location or predetermined track) by means of thruster force.

History

The development of DP systems is strongly linked to the development of the oil industry in sea areas.

- Beginning of the 19th century - the Caspian Sea - the first well in the seabed about 30m from the shore using a wooden pier
- Further drillings from from piers with lengths up to 400m
- 1925 - Caspian Sea - the first self-elevating drilling and production platforms of the "Jack up" type. These platforms could carry out drilling and mining operations on waters with depths up to approx. 60 m.

Historia

- Vessels, stabilizing their position by appropriate selection of tension forces on anchor ropes (chains) attached to anchors, which were previously appropriately arranged and dropped. This solution enabled drilling and exploitation of wells at depths up to around 600m.

History

- 1960 – California USA – CUSS (Continental, Union, Shell & Superior oil consortium)

Core drilling

- Goal 180m
- Water depth up to 3500m

Equipment:

- Four azimuth thrusters
- Manual control
- Visual observations
- Sonar tracking

Historia

- 1961 – USA – launching the first drilling vessel with a fully functional (automatic) dynamic positioning system. EUREKA ship built for Shell. Drilling at depths up to 1300m (wave up to 6m wind up to 21 m / s)

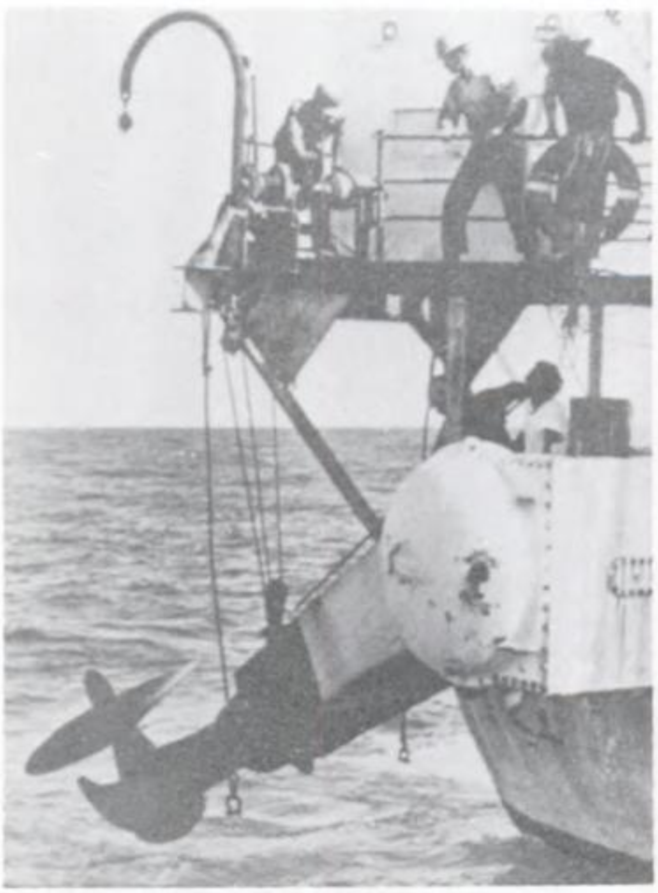
The Eureka

Historia

- 1963 – France - launching two DP ships (Salvor and Terebel) intended for laying pipelines on the seabed and securing underwater works.

History

- 1964 – USA – launching of DP vessel Caldrill (Caldrill Offshore Company). Drills up to 2000m.



History

- 1971 – United Kingdom – first DP systems constructed by British GEC Electrical Projects Ltd.
- 1974 – United Kingdom - conversion of the commercial ship Wimpey Sealab into a drilling vessel for exploring hard coal deposits
- 1977 – United Kingdom - launching the first semi-submersible drilling rig Uncle John

Historia

- 1975 – Norway – first research on DP systems at the request of Stolt Nielsen by Kongsberg Vapenfabrikk (KV)
- 1977 – Norway – launching (Seaway Eagle) of the first vessel with the Norwegian DP system.

The Kongsberg systems were highly appreciated, which made the company one of the largest producers of DP systems. According to an advertising folder from 2012, it covered over 75% of the world market of DP systems

Applications of DP systems

Diving Support Vessels

Applications of DP systems

Pipelay Vessels

Applications of DP systems

ROV Support Vessels

ROV - remotely operated underwater vehicle

Applications of DP systems

Crane Vessels

Applications of DP systems

Float-over Vessels

Applications of DP systems

Accommodation Vessels

Applications of DP systems

Drilling Vessels

Applications of DP systems

FPSO Vessels

floating production storage and offloading

Applications of DP systems

Shuttle Tankers

Applications of DP systems

Trenching Vessels

Applications of DP systems

Cable Lay/Repair Vessels

Applications of DP systems

Jack-up Vessels

Applications of DP systems

Offshore Supply Vessels

Applications of DP systems

Anchor Handling Vessels/Tug

Applications of DP systems

Well Stimulation Vessels

Applications of DP systems

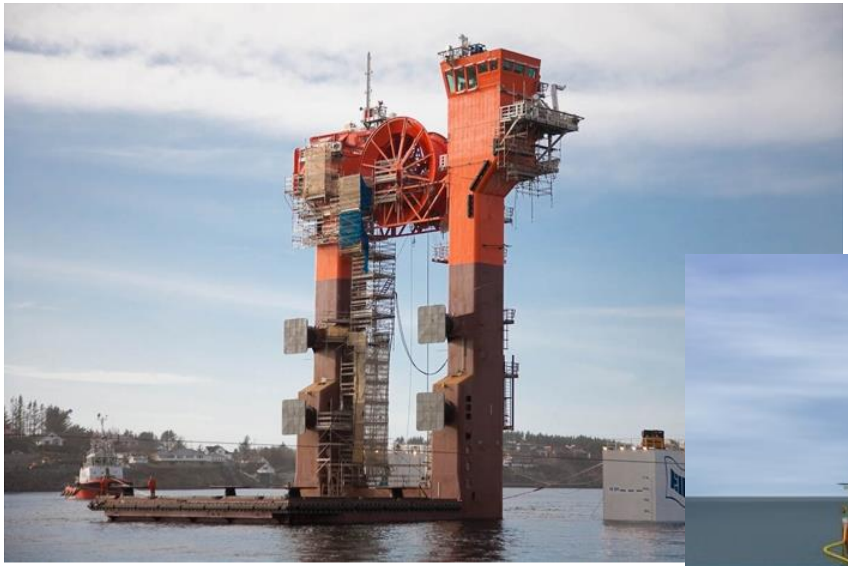
Rock Placement Vessels

Applications of DP systems

Dredging Vessels

Applications of DP systems

Other applications



Classes of DP systems

A DP system consists of components and systems acting together to achieve sufficiently reliable position keeping capability. The necessary redundancy level for components and systems is determined by the consequence of a loss of position and/or heading keeping capability. To achieve this philosophy the requirements have been grouped into three equipment classes. For each equipment class, the associated worst-case failure should be defined as in below. The equipment class of the vessel required for a particular operation should be agreed between the company and the customer based on a risk analysis of the consequence of a loss of position and/or heading. Otherwise, the Administration or coastal State may decide the equipment class for the particular operation.

For equipment **class 1**, a loss of position and/or heading may occur in the event of a single fault.

For equipment **class 2**, a loss of position and/or heading will not occur in the event of a single fault in any active component or system. Common static components may be accepted in systems which will not immediately affect position keeping capabilities upon failure (e.g. ventilation and seawater systems not directly cooling running machinery). Normally such static components will not be considered to fail where adequate protection from damage is demonstrated to the satisfaction of the Administration. Single failure criteria include, but are not limited to:

- any active component or system (generators, thrusters, switchboards, communication networks, remote-controlled valves, etc.); and
- any normally static component (cables, pipes, manual valves, etc.) that may immediately affect position keeping capabilities upon failure or is not properly documented with respect to protection.

For equipment **class 3**, a loss of position and/or heading will not occur in the event of a single fault or failure. A single failure includes:

- items listed above for class 2, and any normally static component assumed to fail;
- all components in any one watertight compartment, from fire or flooding; and
- all components in any one fire sub-division, from fire or flooding

For equipment classes 2 and 3, a single inadvertent act should be considered as a single fault if such an act is reasonably probable.

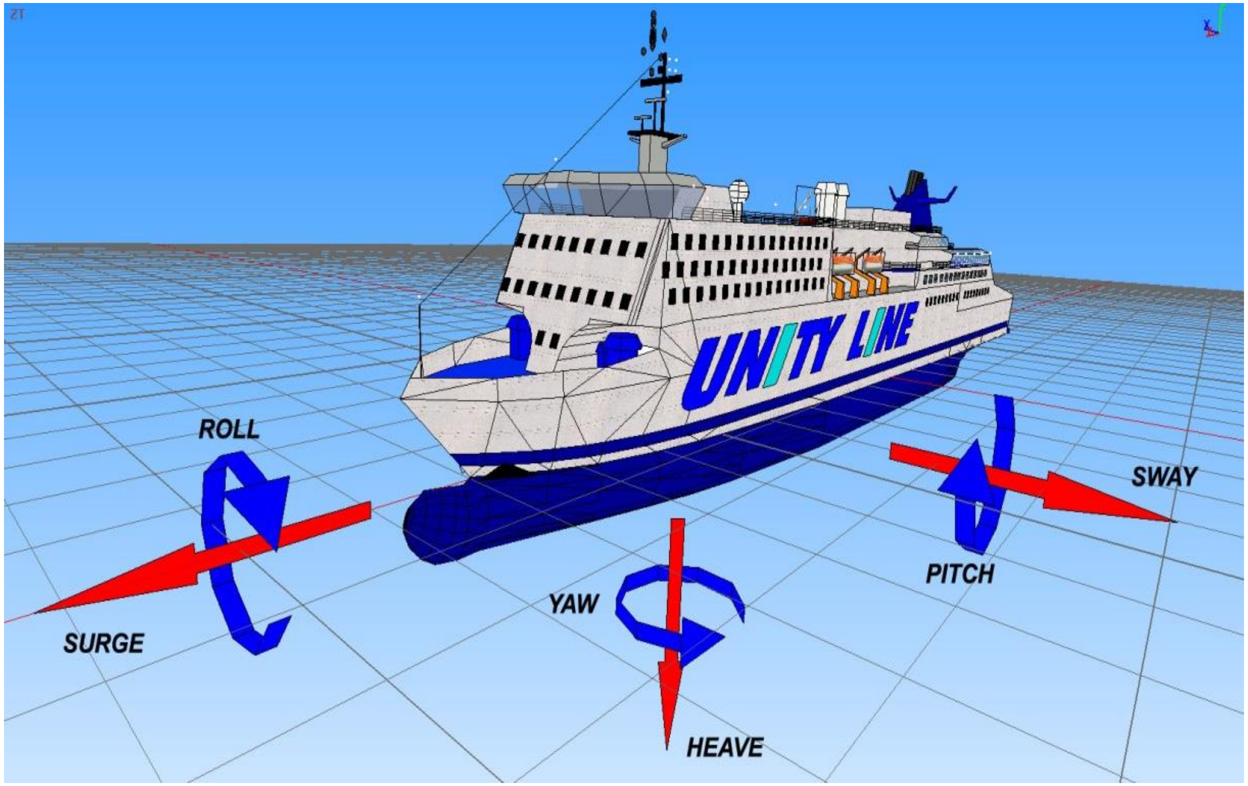
Degrees of freedom

An example of six degree of freedom movement is the motion of a ship at sea. It is described as:

Translations:
Moving forward and backward on the X-axis. (Surging)
Moving left and right on the Y-axis. (Swaying)
Moving up and down on the Z-axis. (Heaving)

Rotations:
Tilting side to side on the X-axis. (Rolling)
Tilting forward and backward on the Y-axis. (Pitching)
Turning left and right on the Z-axis. (Yawing)

Degrees of freedom



Main Principles of Operation

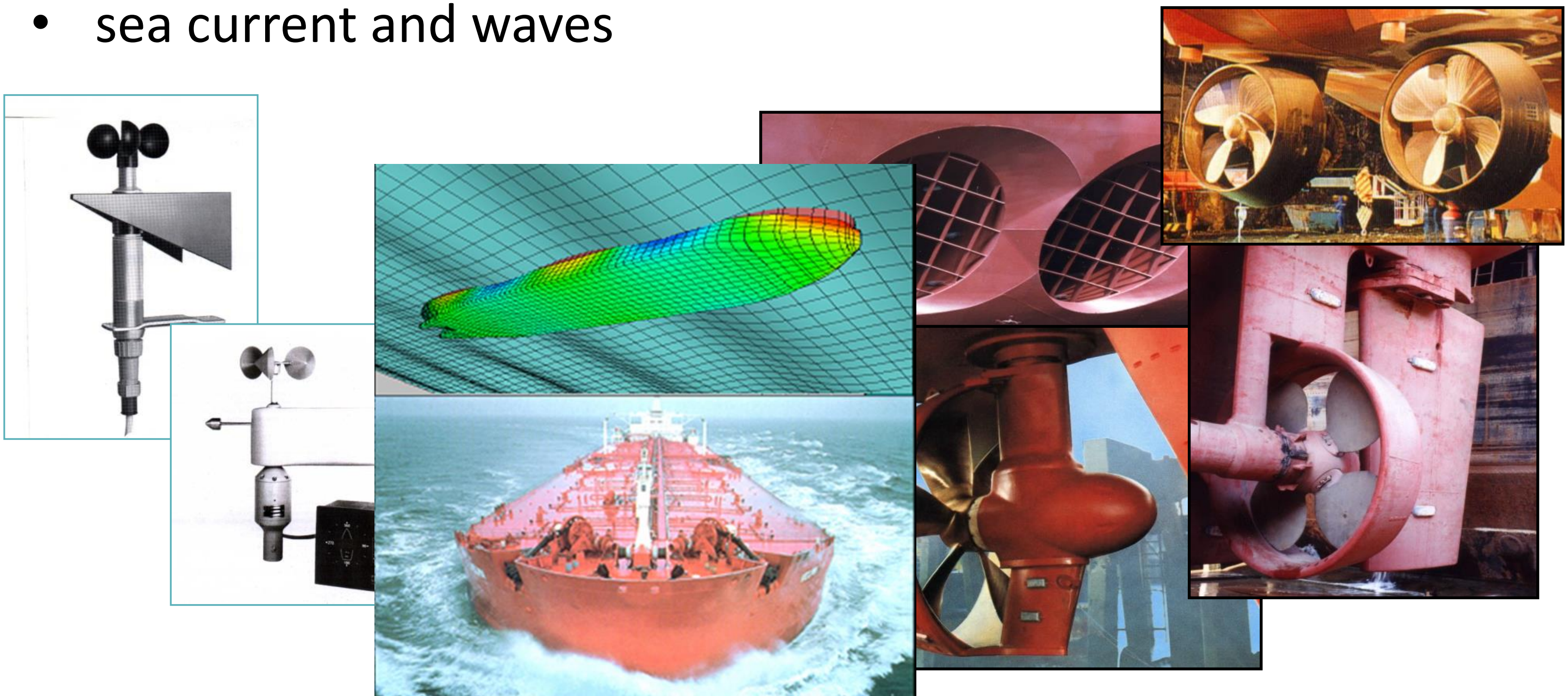
A seagoing vessel is subjected to forces from wind, waves and currents as well as from forces generated by the propulsion system. The vessel's response to these forces, i.e. its changes in position, heading and speed, is measured by the position-reference systems, the gyrocompass and the vertical reference sensors.

Wind speed and direction are measured by the wind sensors. The system calculates the deviation between the measured (actual) position of the vessel and the required position, and then calculates the forces that the thrusters must produce in order to make the deviation as small as possible. In addition, the system calculates the forces of wind, wave and water current which act upon the vessel and the thrust required to counteract them. Normally the system controls the vessel's motion in three horizontal degrees of freedom - surge, sway and yaw

Main Principles of Operation

Traditional DP systems are based on the mathematical model which requaries following data:

- wind speed and direction
- thruster/propeller pitch/rpm and direction
- sea current and waves

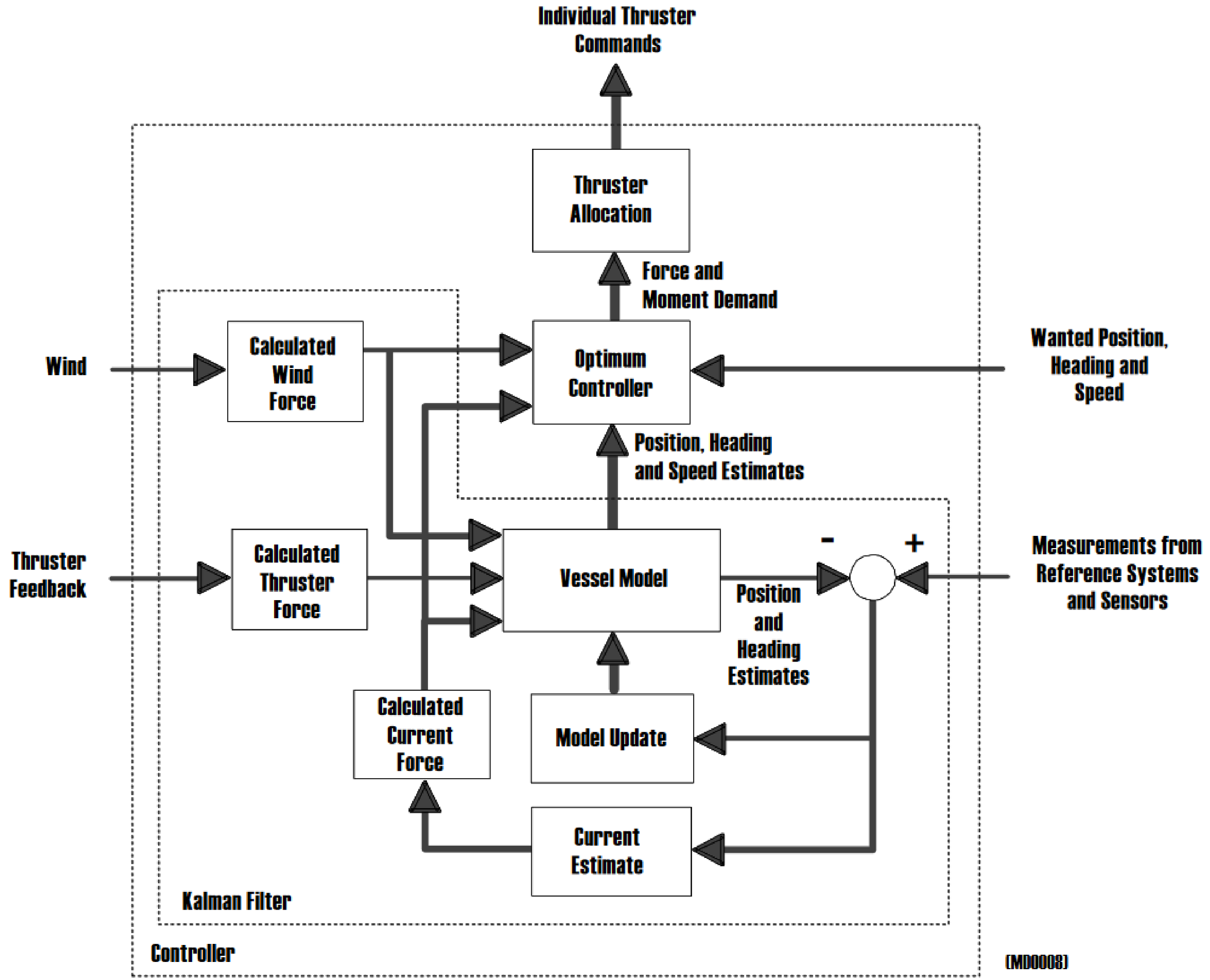


Main Principles of Operation

The model is a mathematical description of how the vessel reacts or moves as a function of the forces acting upon it. The model is a hydrodynamic description, i.e. it involves the vessel's characteristics such as mass and drag. The design criterion for the model is an as accurate as possible description of the vessel's motions and reaction to any external forces.

The mathematical model is affected by the same forces as the vessel itself. Wind forces are calculated as a function of measured wind speed and direction, while thruster forces are calculated as a function of thruster/propeller pitch/rpm and direction.

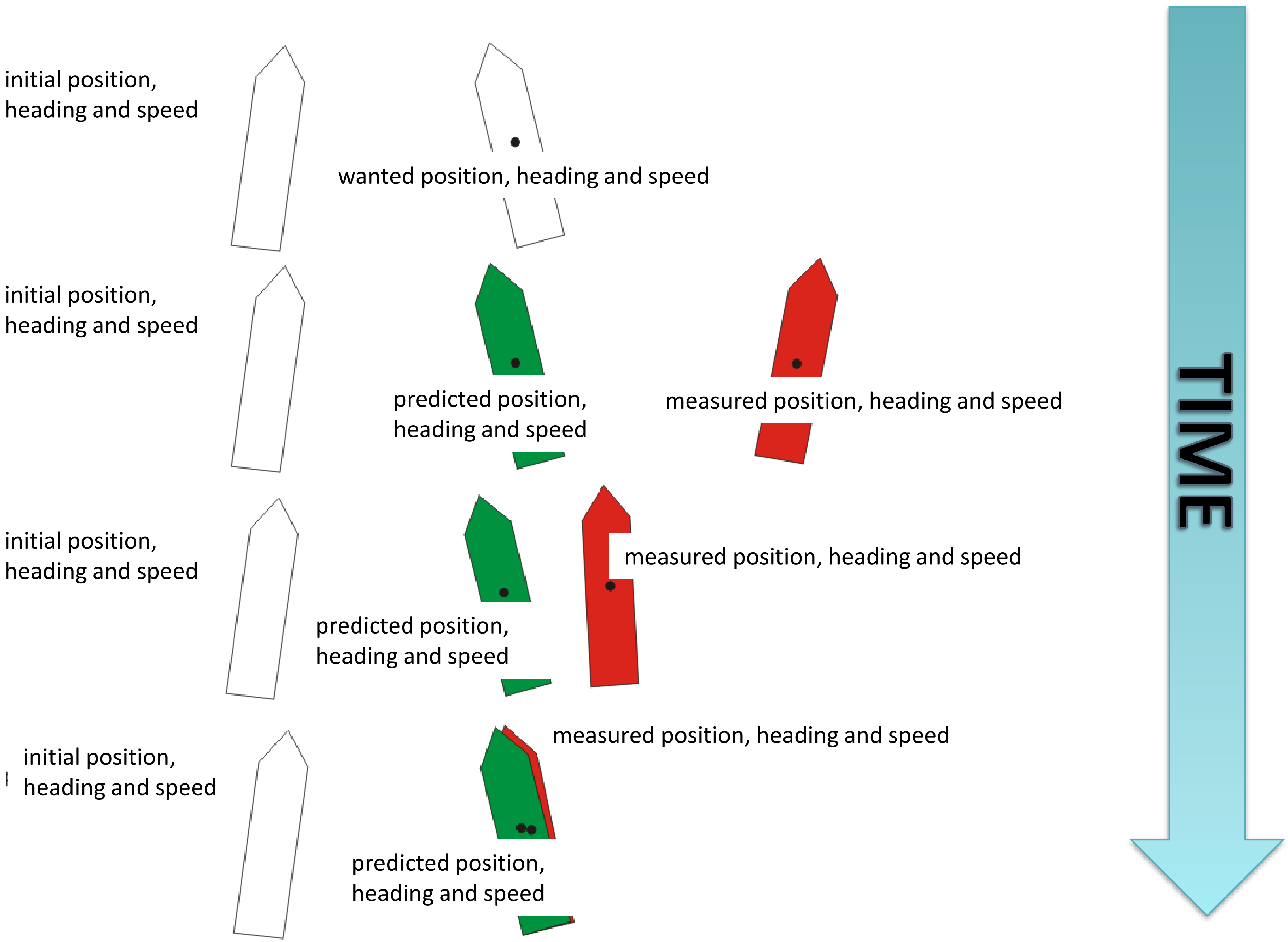
The system incorporates algorithms for the estimation of sea current and waves, and the forces caused by these.


Individual Thruster Commands
Thruster Allocation
Force and Moment Demand
Wind
Calculated Wind Force
Optimum Controller
Wanted Position, Heading and Speed
Position, Heading and Speed Estimates
Thruster Feedback
Calculated Thruster Force
Vessel Model
-
+
Measurements from Reference Systems and Sensors
Position and Heading Estimates
Calculated Current Force
Model Update
Current Estimate
Kalman Filter
Controller
(MD0008)

Main Principles of Operation

The main outputs from the mathematical model are filtered estimates of the vessel's heading, position and speed in each of the three degrees of freedom - surge, sway and yaw.
The mathematical model itself is never a 100% accurate representation of the real vessel. However, by using the Kalman filtering technique, the model can be continuously corrected. The vessel's heading and position are measured using the gyrocompasses and position-reference systems, and are used as the input data to the DP system. This data is compared to the predicted or estimated data produced by the mathematical model, and the differences are calculated. These differences are then used to update the mathematical model to the actual situation.

Main Principles of Operation



DP construction

The following components can be distinguished in the DP system :

- Power supply system
- Thruster system
- Reference systems
- Sensors
- Control system
- Steering console
- System operator

DP construction - Power supply system

All subsystems of the DP system use this system. This system must therefore be characterized by high flexibility of work, due to the possibility of sudden changes in the power demand caused by, for example, irregular operation of thruster system.

The control system, control console, displays and alarm systems and reference systems of the DP system, even in the event of failure of the main power system, must be able to operate for at least 30 minutes.

DP construction - Thruster system

- Propeller – one or more, in most cases Controllable Pitch Propeller (CPP)

DP construction - Thruster system

- Rudder – usually modified steering gear, eg Becker rudder, Schilling rudder, Kort nozzle



DP construction - Thruster system

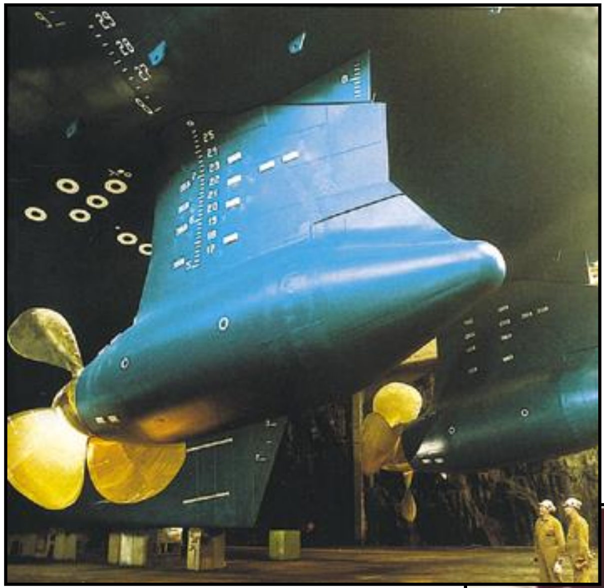
- Manoeuvring thrusters – transversal propulsion device built into, or mounted to, either the bow or stern, of a ship

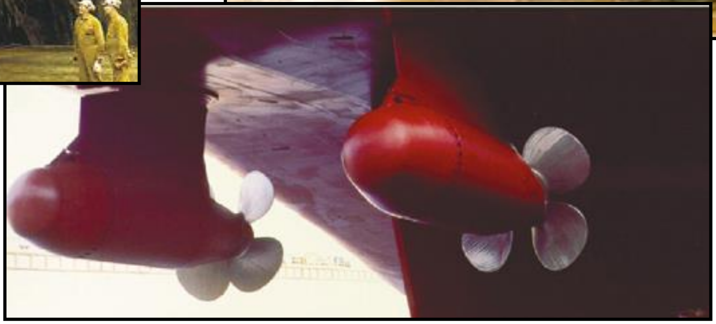
DP construction - Thruster system

- Azimuth thrusters

DP construction - Thruster system

- Azipod thrusters





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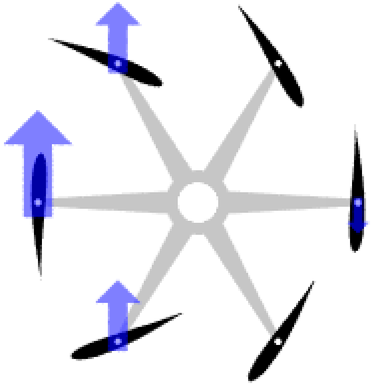
DP construction - Thruster system

- Voit-Schneider thrusters



DP construction - Reference systems

The reference systems included in the DP system must be characterized by high accuracy, high reliability and continuity of work.

The number and type of reference systems used depends on:

- The level of risk associated with the operation being performed
- Required level of redundancy
- Availability of reference systems
- The effects of losing one or more reference systems

DP construction - Reference systems

Traditional navigation systems (GPS, Glonass) do not meet the requirements for reference systems used in DP systems

The most commonly used systems are:

- Mechanical
  - taut wire
- Microwave
  - Artemis, RADius, RadaScan, Miniranger, Trispondeur
- Laser
  - Fanbeam, CyScan
- differential satellite
- hydroacoustic

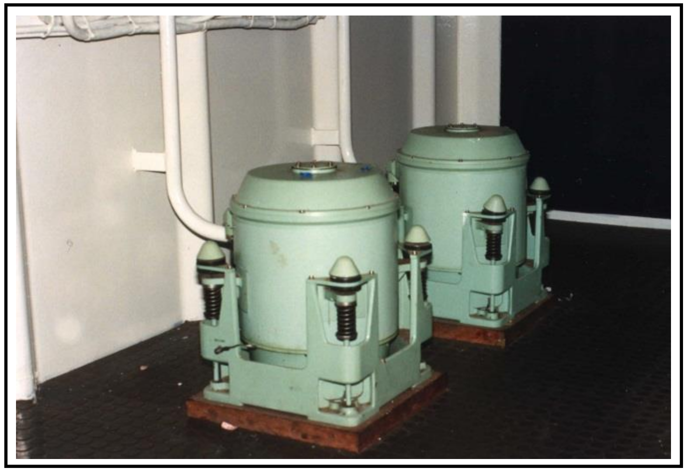
DP construction – Sensors

A system of sensors and other measuring devices used to determine the ship's motion parameters, its course, estimation of external disturbances and measurement of other parameters or factors required in the dynamic positioning process.

DP construction – Sensors

Heading sensors - gyrocompasses

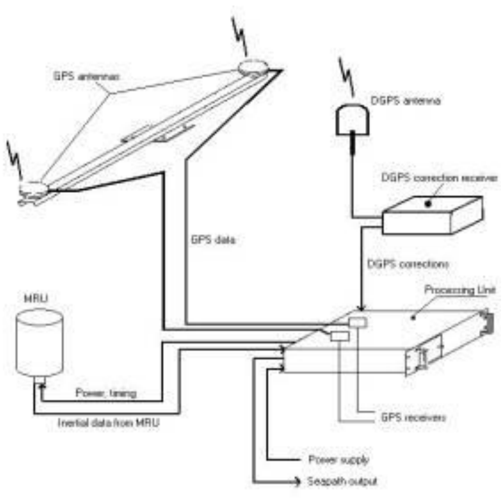
Depending on the required level of redundancy, two, three or more gyrocompasses are the main source of heading



DP construction – Sensors

Heading sensors – satellite compasses

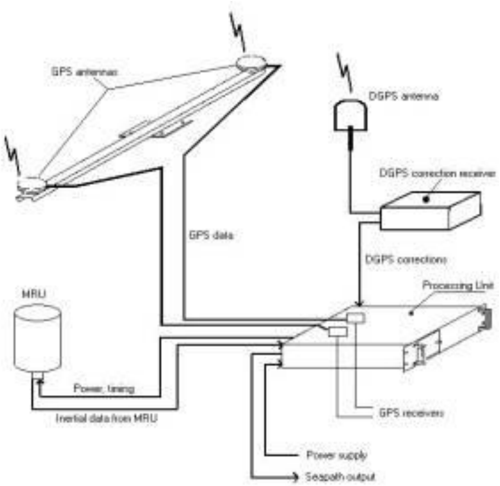
Satellite compasses can be used as a additional source of heading



DP construction – Sensors

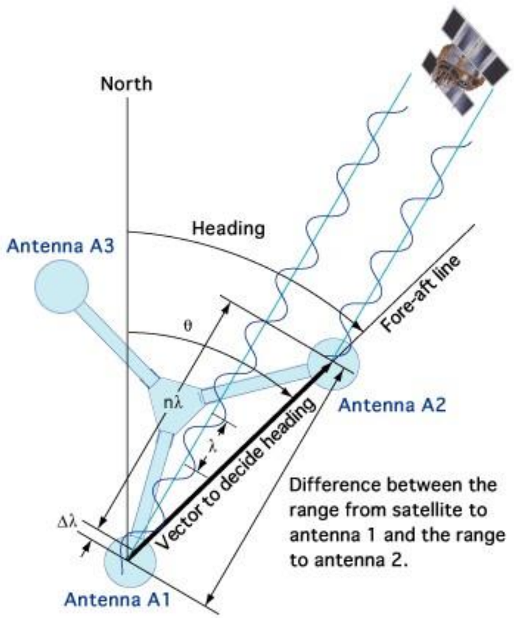
Heading sensors – satellite compasses

Satellite compasses can be used as a additional source of heading



DP construction – Sensors

Heading sensors – satellite compasses



DP construction - Sensors

Attitude sensors

Movements in the vertical plane (roll, pitch and heave) are not compensated, knowledge of their current values is necessary in the stabilization proces.

Possible types of motion sensors:

- Pendulum devices
- Fluid Stabilized Devices
- VRU
- VRU / GPS
- Aided Inertial sensors

DP construction – Attitude sensors

Pendulum devices, or inclinometers, are normally applied to DP systems as a solid state unit with two sensors mounted fore/aft and port/starboard. By measuring the component of gravity in each of these axes we can derive roll and pitch. Although solid state the effect under marine dynamics can be similar to that experienced by a mechanical pendulum, i.e. follow-up errors, low accuracy and inability to cope with short term accelerations.

Advantages:

- Low cost
- Good performance in static conditions

Disadvantages:

- Low Performance
- Poor performance in Dynamics
- Low update rate and Latency

DP construction – Attitude sensors

Fluid Stabilized Devices

The next stage is to put the pendulum type of device into a dampened environment to counter the vessel dynamics. Such units use a pick up coil that floats in a oil bath to sense rotation about primary coils that are fixed in the roll and pitch axes. Although fairly accurate and reliable, such units have disadvantages in terms of size and handling restrictions and cost of routine maintenance.

Advantages:

- Relatively accurate and reliable
- Tried and trusted

Disadvantages:

- Size and Handling
- Life Cycle Costs
- Installation difficulties
- Latency

DP construction – Attitude sensors

VRU - Vertical Reference Units

Advances in and the availability of solid state inertial sensors heralded the development of strapdown motion sensors . Such sensors use an orthogonal array of 3 accelerometers and 3 angular rate sensors (gyros) and deploy a vertical reference algorithm to compute Roll and Pitch.

Advantages:

- Good accuracy for GPS and Acoustic Stabilization
- Range of performance / price sensors available
- Relatively low cost

Disadvantages:

- No heading information

DP construction – Attitude sensors

VRU / GPS

Advantages:

- Heading and Position Information
- Good Accuracy

Disadvantages:

- Relatively High Cost
- Heading and Position GPS dependent

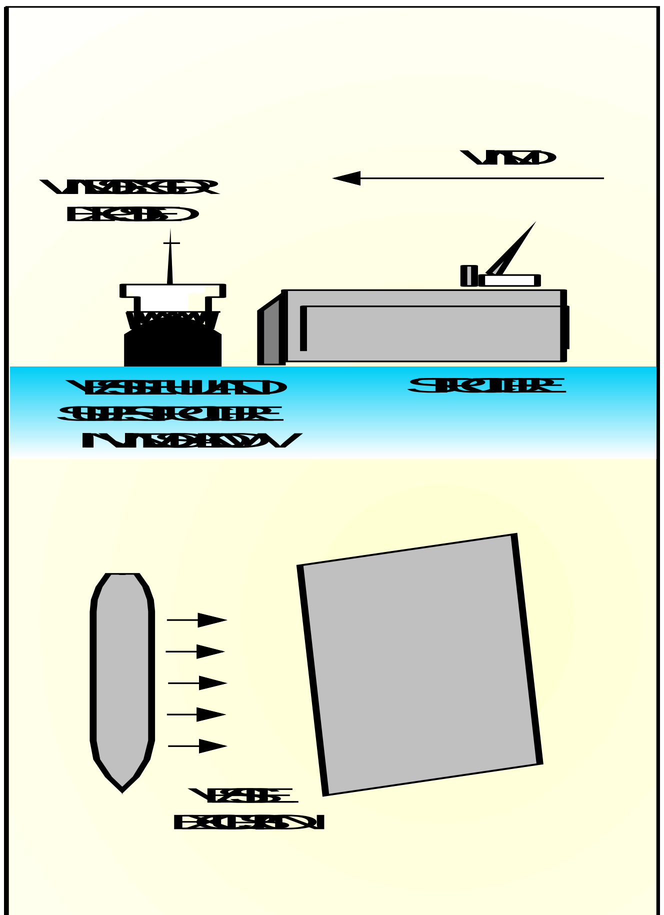
DP construction – Sensors

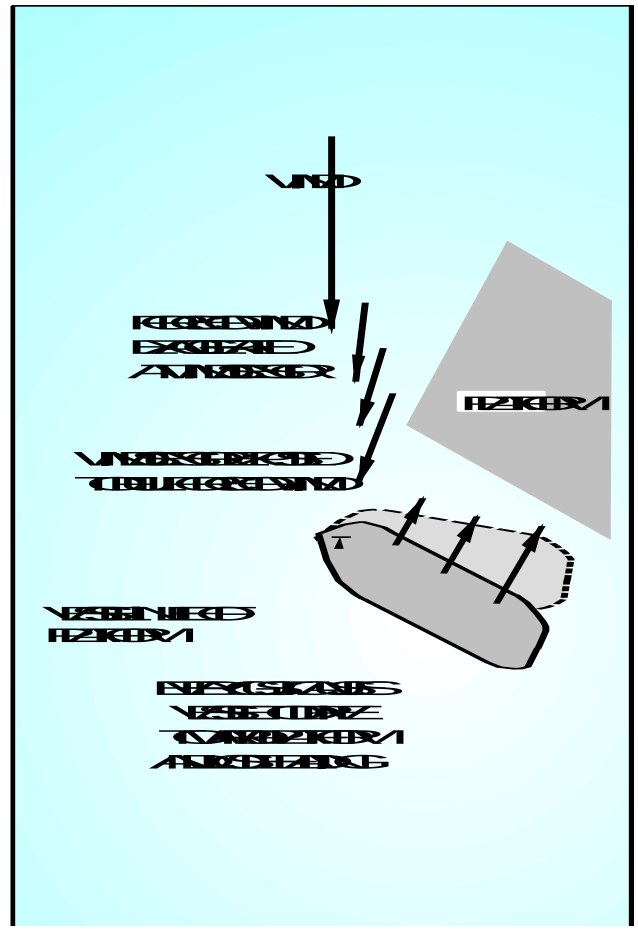
Anemometers:

- Mechanical anemometers (cup, vane)
- Ultrasonic

DP construction – Sensors

Anemometers:



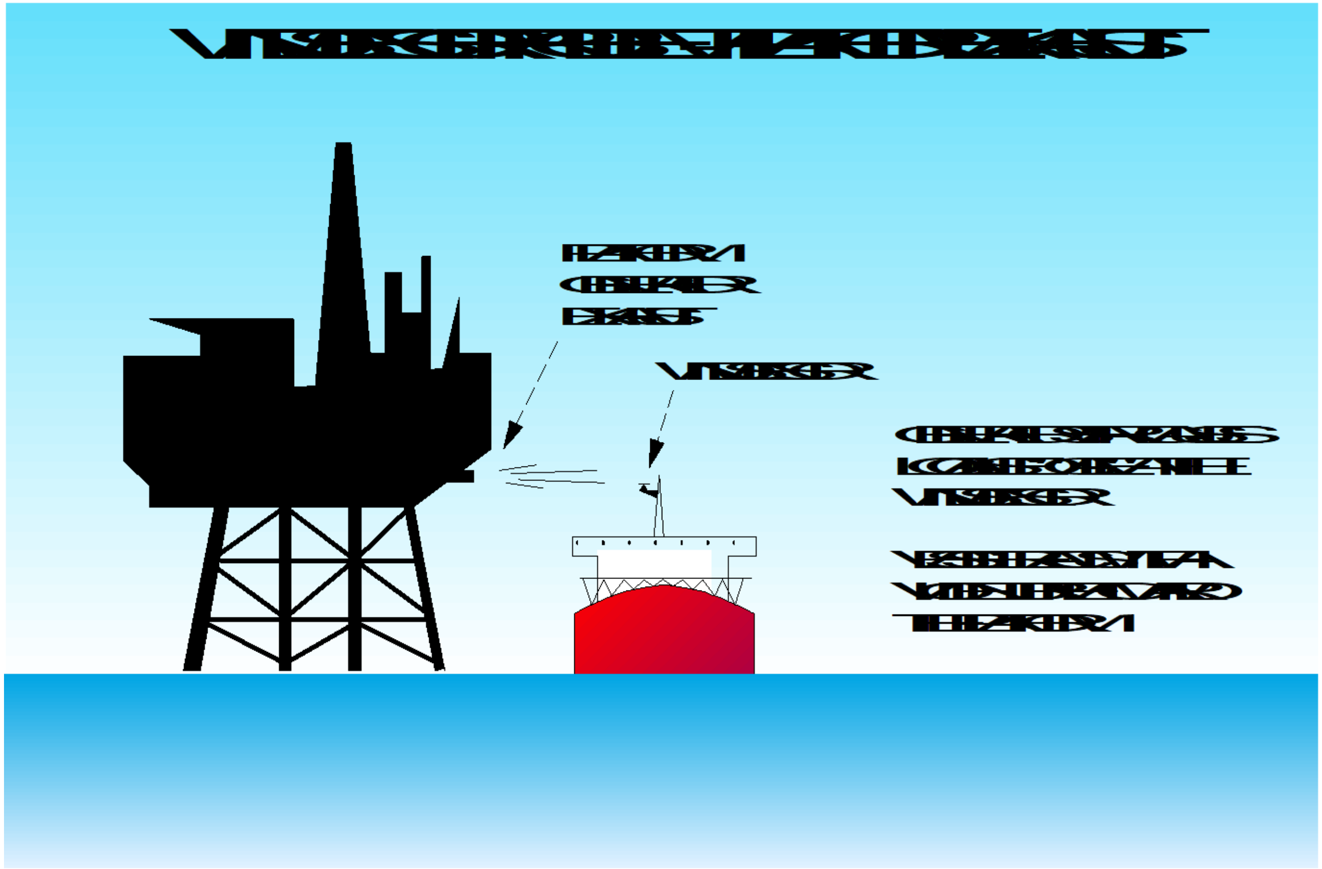


DP construction – Sensors

Anemometers:

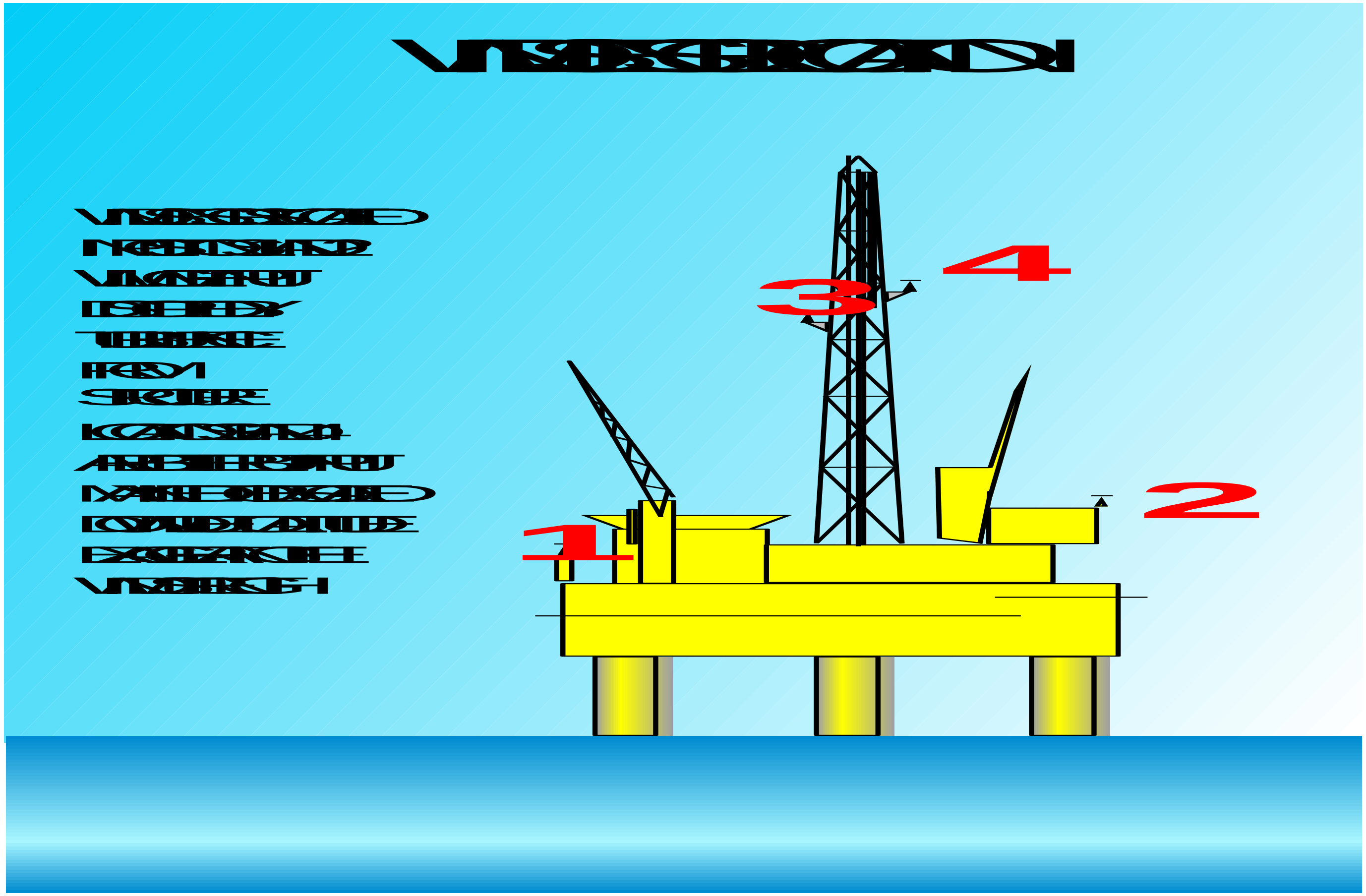
DP construction – Sensors

Anemometers:



DP construction – Sensors

Anemometers:



DP construction – Sensors

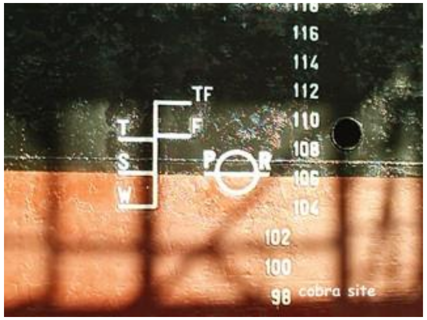
Waves sensors - Hydrometeorological buoys

DP construction – Sensors

Current sensors – logs

DP construction – Sensors

Draft sensors



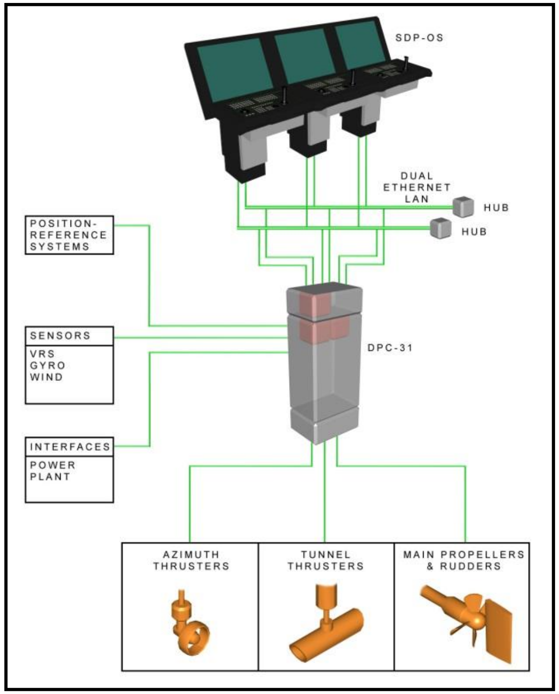
Ships' speed sensors – main source - reference (positioning) systems, additional supporting sensors (logs)

Depth sensors

Additional sensors (loading)

DP construction - Control system

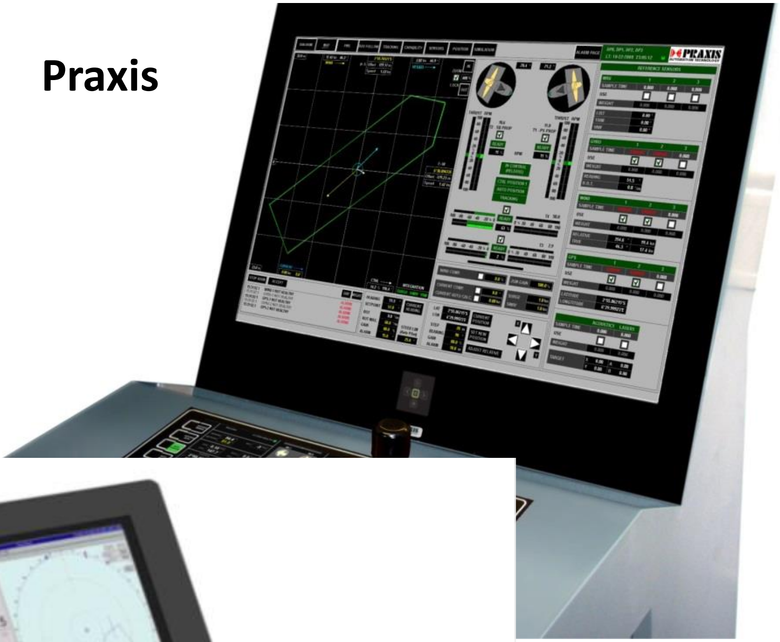
The first DP systems used analogue techniques, digital techniques have been used since 1968 and microprocessors since 1980.



DP construction

Steering console:

Praxis



Kongsberg

DP construction