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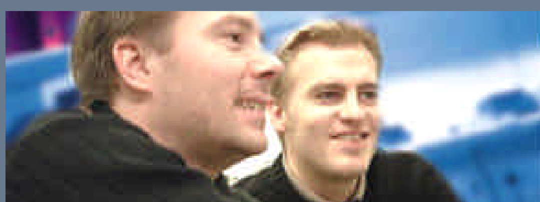
WORLD CLASS —

through people, technology and dedication



A network of ideas

Technology — inspired by nature

Kongsberg — at your command

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DP Design Studies

Arild Gonsholt and Bjørn Nygård

Kongsberg Simrad AS

‘Design’ in this context

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- Thruster configurations
  - Types, sizes, locations
  - Dynamic capabilities
- Power system configurations
  - Generator sizes and dynamic capabilities
  - Switchboard layout
- Sensor specifications
  - Accuracy
  - Update rate
- DP control system and thrust allocation strategies

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DP Design Studies

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- DP Capability Analyses
- Performance simulations
- Drift-off and drive-off simulations

DP Capability analyses

- Purpose
  - Establish the limiting weather conditions
  - Determine thrust utilisation for a 'design sea state'
- Basic procedure
  - For a given weather condition calculate thruster forces needed
  - Increase the wind/waves/current until thrusters are fully utilised
  - Repeat for all wind angles-of-attack

DP Capability analyses

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- Configuration
  - Main particulars
  - Load coefficients
  - Thruster and rudder types, sizes, locations
- Setup per case
  - Wind/wave/current relationships
  - Wind and wave spectra
  - 'Spare' thrust required
  - Thrusters and rudders to use

DP Capability analyses

- Characteristics:

  + Fairly easy configuration
  + Uses thruster allocation algorithm from DP control system
  + Frequency domain (wind/wave forces)
  + Low turn-around time

  — Power limitations are not taken into account

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DP Capability Plot

EXAMPLE

Case number	:	1
Case description	:	DP Design 1
Thrusters active	:	T1-T4
Rudders active	:	

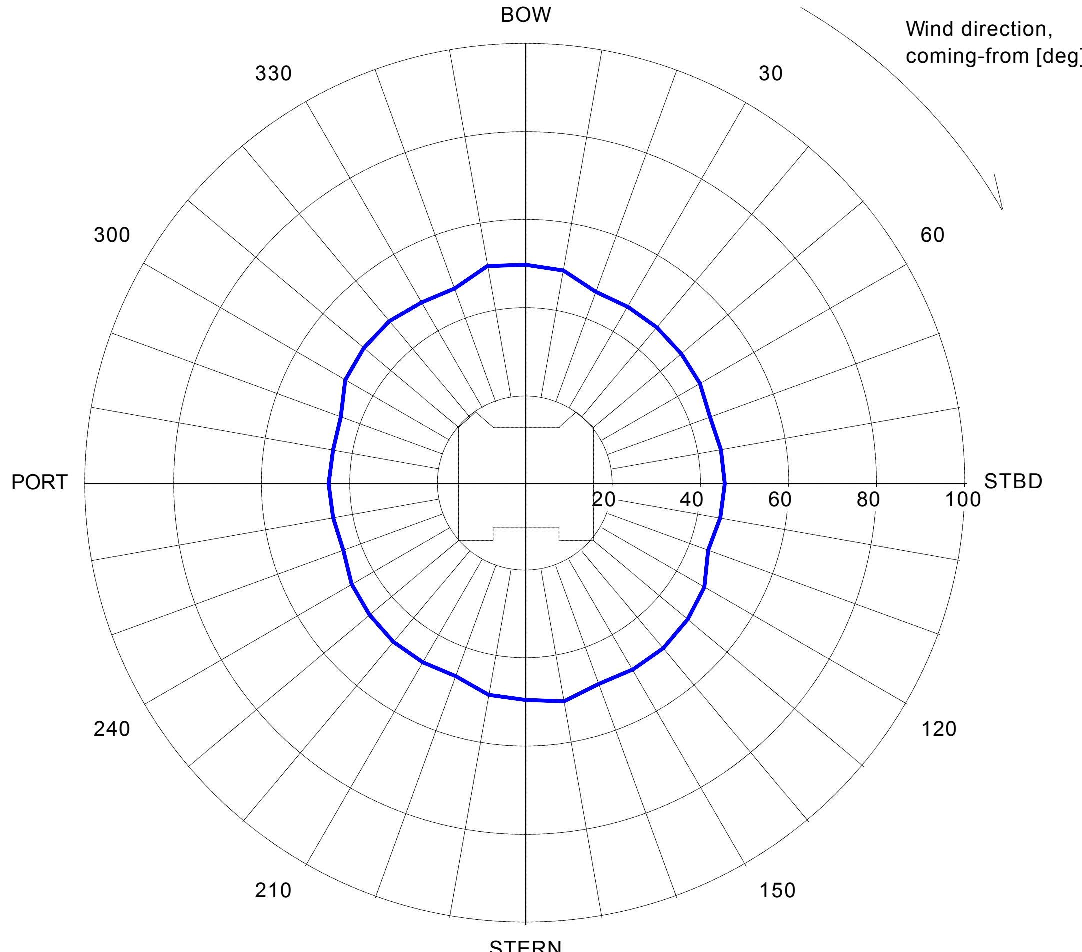
Input file reference	:	Example.scp
Last modified	:	2002-08-09 13.57 (v. 1.3.0)

Length overall	:	100.0 m
Length between perpendiculars	:	100.0 m
Breadth	:	100.0 m
Draught	:	20.0 m
Displacement	:	50000.0 t
Longitudinal radius of inertia	:	25.0 m (= 0.25 * Lpp)
Pos. of origo ahead of Lpp/2 (Xo)	:	0.0 m
Wind load coefficients	:	From file (Scaled by Area)
Current load coefficients	:	From file (Scaled by Displacement)
Wave drift load coefficients	:	From file (Scaled by Displacement)

Tidal current direction offset	:	0.0 deg
Wave direction offset	:	0.0 deg
Wave spectrum type	:	Pierson-Moskowitz
Wind spectrum type	:	NPD
Current-wave drift interaction	:	OFF
Load dynamics allowance	:	1.0 * STD of thrust demand
Additional surge force	:	0.0 tf
Additional sway force	:	0.0 tf
Additional yawing moment	:	0.0 tf.m
Additional force direction	:	Fixed
Density of salt water	:	1026.0 kg/m³
Density of air	:	1.23 kg/m³

#	Thruster	X [m]	Y [m]	F+ [tf]	F- [tf]	Max [%]	Pe [kW]	Rudder
1	AZIMUTH	45.0	-45.0	50.0	-29.1	100	3000	
2	AZIMUTH	45.0	45.0	50.0	-29.1	100	3000	
3	AZIMUTH	-45.0	-45.0	50.0	-29.1	100	3000	
4	AZIMUTH	-45.0	45.0	50.0	-29.1	100	3000	

Limiting 1 minute mean wind speed in knots
at 10 m above sea level



Wind speed: Automatic
Significant wave height: IMCA (North Sea)
Mean zero up-crossing period: IMCA (North Sea)

Rotating tidal current: 1.5 knots
Rotating wind induced current: 0.000*Uwi knots

Performance simulations

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- Purpose:
  - Assess station keeping accuracy and power consumption for given sea state when the vessel is controlled by a DP system
  - Comparing different control and thruster allocation strategies
  - Comparing different thruster and power configurations
- Basic procedure
  - Specify setup
  - Record vessel states
    - thruster response
    - power consumption
    - position and heading (combined LF+WF motions)
  - Post-process recorded signals to obtain statistical results

Performance simulations

- Configuration
  - As for DP Capability analysis
  - Response Amplitude Operators (RAOs)
  - Thruster dynamic characteristics
  - Thruster open water diagrams
  - Power system configuration and dynamic characteristics
- Setup per simulation case
  - Sea state (fixed or changing with time)
  - DP Control system
    - Sensors
    - Thrusters, generators, bus ties
    - Operating modes
  - Sensor/actuator noise

Performance simulations

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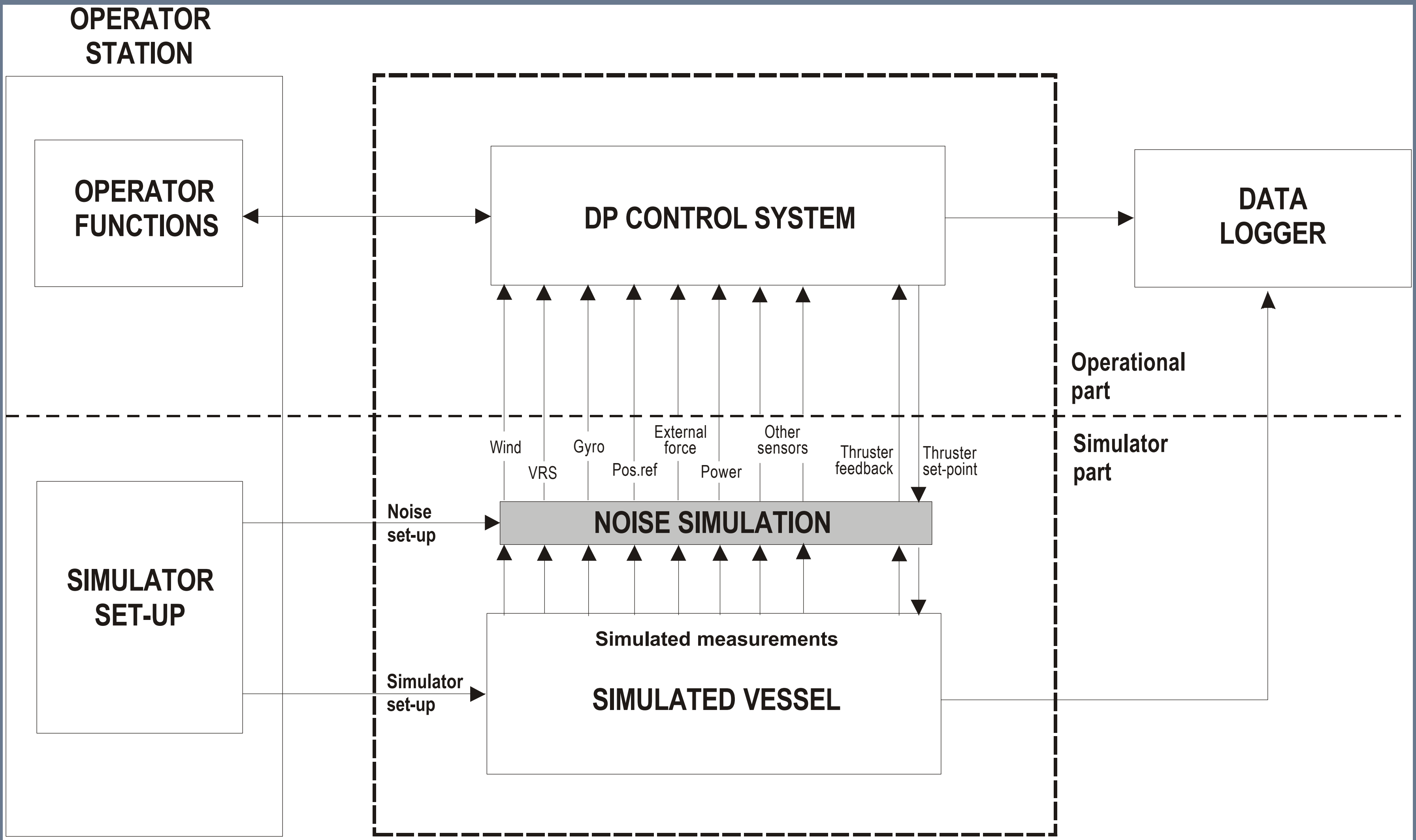
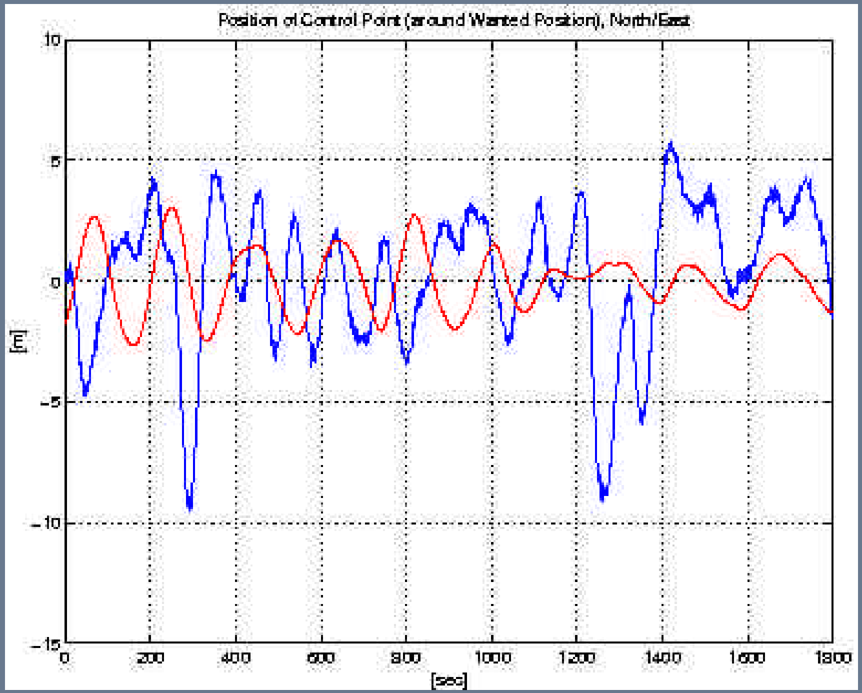
- Characteristics
  - + Time domain
    - + Simulates vessel response to wind, waves and current
    - + Simulates thruster response to DP system orders
    - + Simulates power consumed by the thrusters
  - + DP Control system in the loop including thrust allocation algorithm
  - + Power limitations are taken into account
  - + Output is time-series for statistical analysis
  - + Non-linearities may be modelled

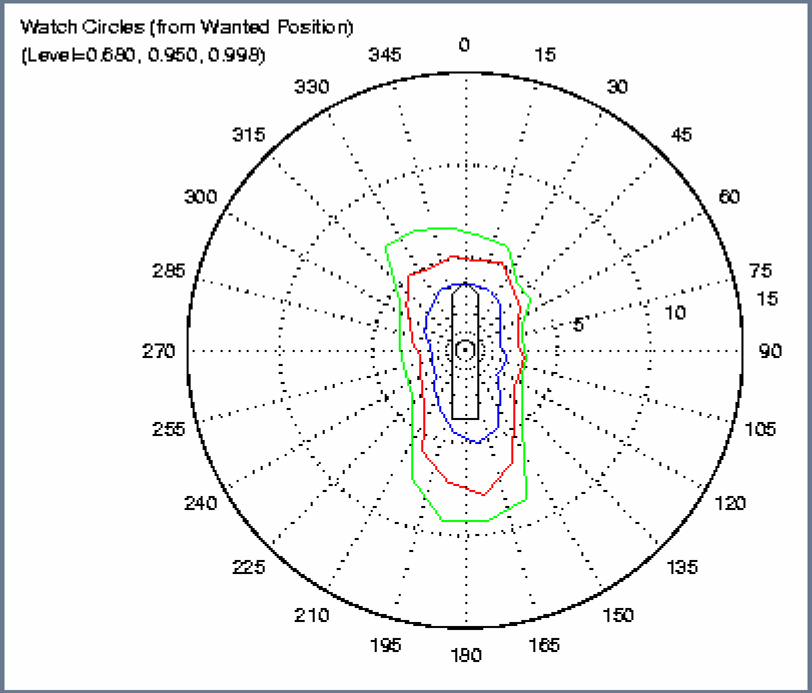
  - — More complex configuration, more input data required
  - — Longer turn-around time

Performance simulations



Performance simulations





Drift-off and drive-off simulations

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- Purpose:
  - Assess Time-to-go after failure
- Basic procedure
  - Vessel is on station in a given sea state
  - Introduce failure in
    - thrusters (setpoint/feedback, local thruster control, trip)
    - generators (trip)
    - power system (bus failure, switch opens/closes)
    - position reference systems (freeze, drift, sudden jump)
    - other sensors (increased noise, general failure)
  - Measure time until limits are exceeded

Drift-off and drive-off simulations

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Problem:

- Environmental dynamics will cause different results for different time-of-failure

Qualitative procedure to find span in results:

- Determine statistics of environment and positioning
- Using average environmental loads and position, introduce failure(s)
- Using high env. loads and down-weather position, introduce same failure(s)
- Using low env. loads and up-weather position, introduce same failure(s)

		Start position		
		Watch circle 0.950 up weather	Average	Watch circle 0.950 down weather
Environmental forces	Average – two standard deviations	Longest		
	Average		Average	
	Average + two standard deviations			Shortest

Drift-off and drive-off simulations

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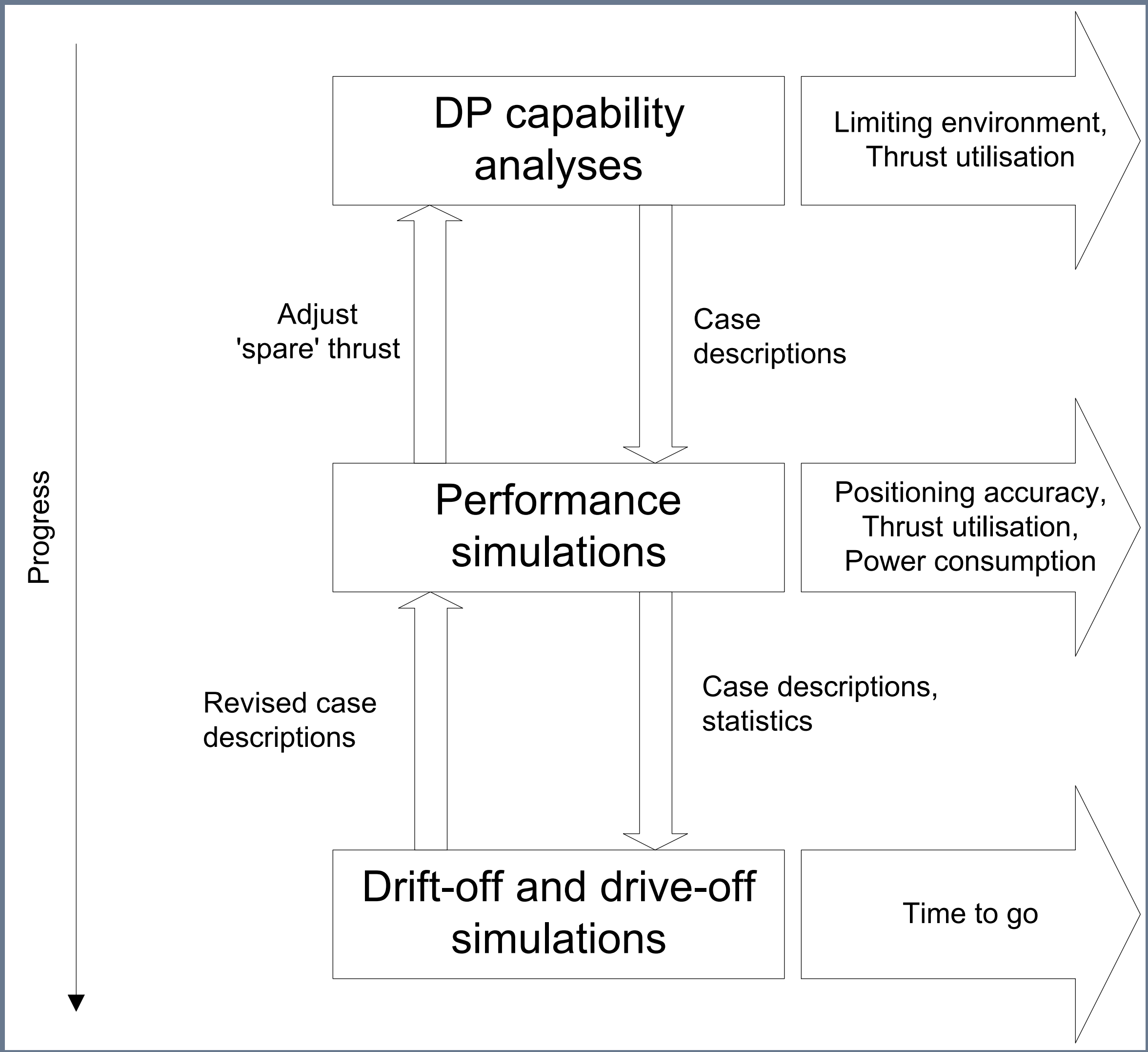
- Configuration
  - As for Performance simulations
- Setup per case
  - As for Performance simulations (sea state is fixed)
  - Failure(s)
- Characteristics
  - \+ Based on the performance simulator structure
  - \+ Qualitative approach to randomness
  - \+ Simulates single or multiple failure(s)
  - — Does not provide significance levels of the results (no Monte-Carlo simulations)

Relationship between the simulation types



Concluding remarks

- Simulations
  - valuable for investigating and comparing different designs
  - complement to model tests or full-scale tests
  - theoretical exercises
  - relies on adequate mathematical modelling and input data
- Thorough hydrodynamic analysis will also be beneficial for installed DP system