A numerical DP module
For design and operations

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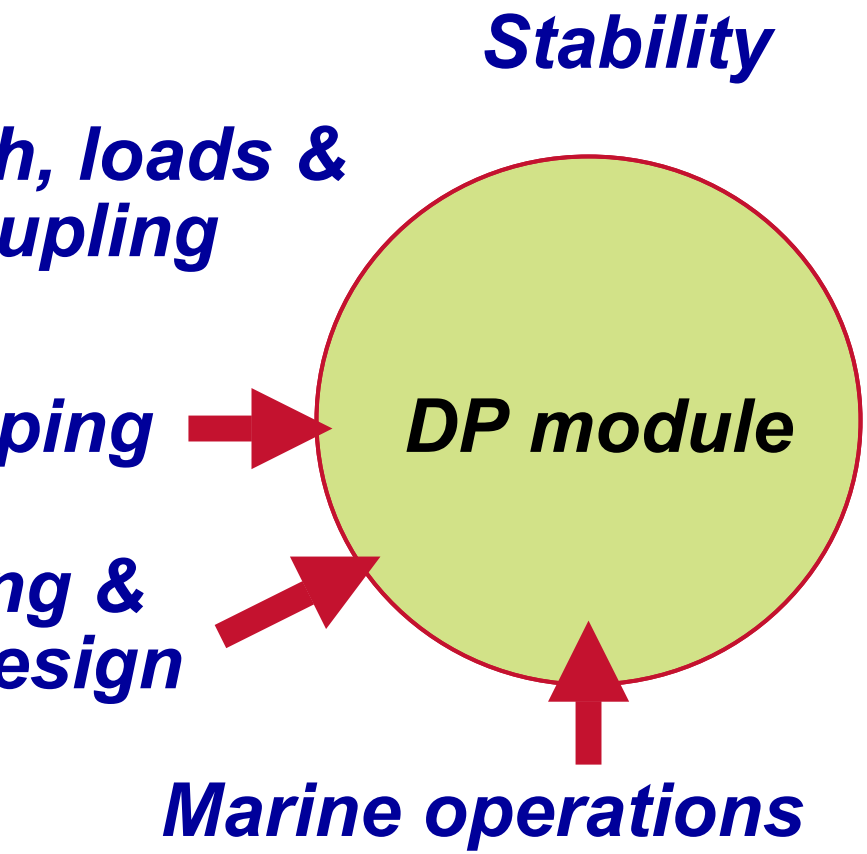
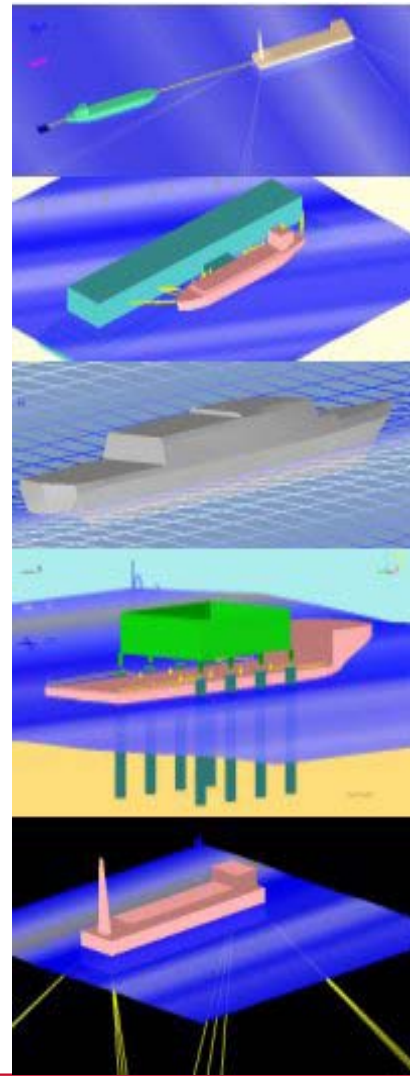
Principia R.D.

Summary

- Numerical Tool: Diodore
  - Modeling of floating structure
  - Modeling of environment
  - Ship simulator
- DP module
  - DP control system
  - Allocation/compensation
  - Type of analyses
- Application: offloading

DIODORE Applications





Software Architecture

PRE

Hydrostatics & mass breakdown

HYDRO

Hydrodynamics loads & pressures

MECA

Frequency/Time domain motion simulation

POST

Post-processing, animations, statistics,plots

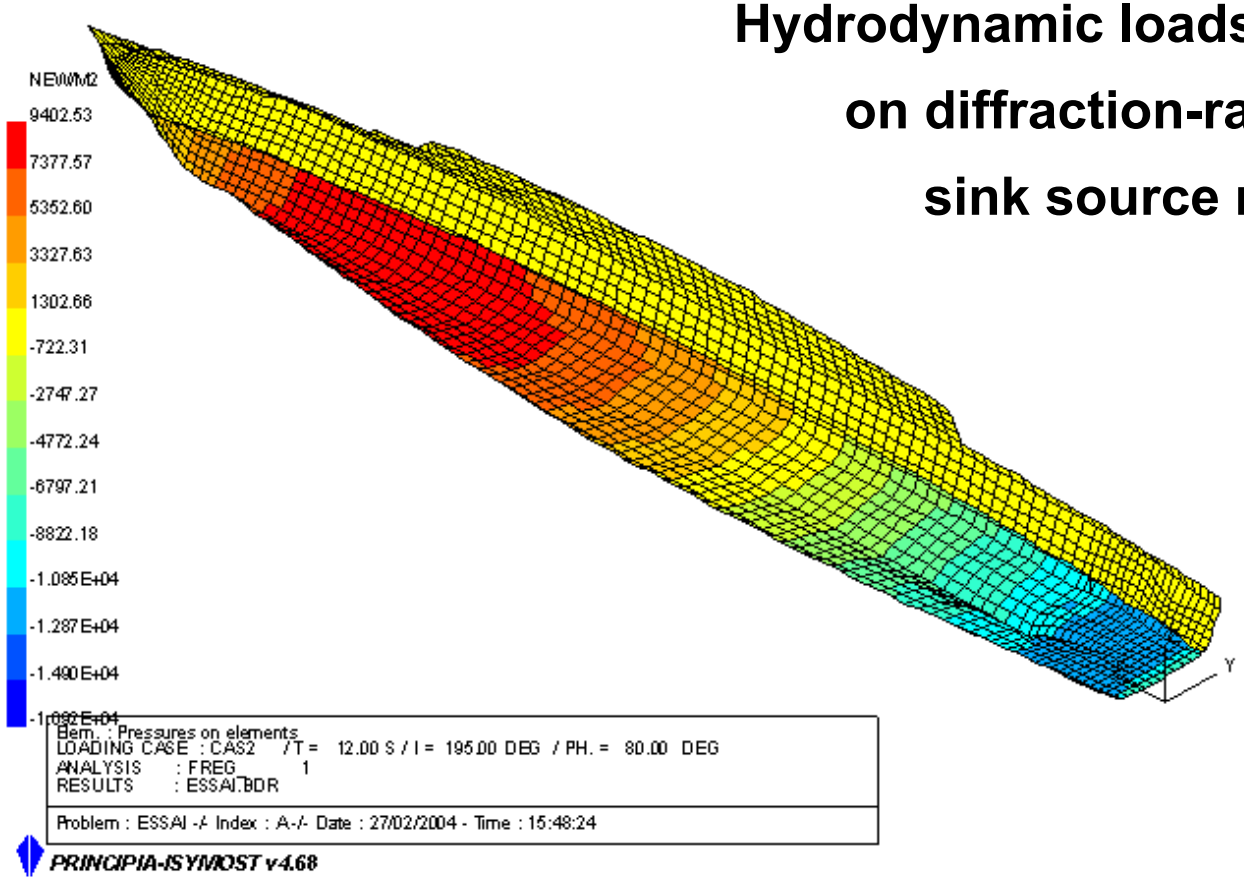
Hydrodynamics

Diffraction-Radiation

- *Source model*
- *Infinite or finite depth*
- *Without or with forward speed*
- *Drift forces*
- *Control point in the fluid (pressure & velocities)*
- *Moonpool & side by side methodologies*

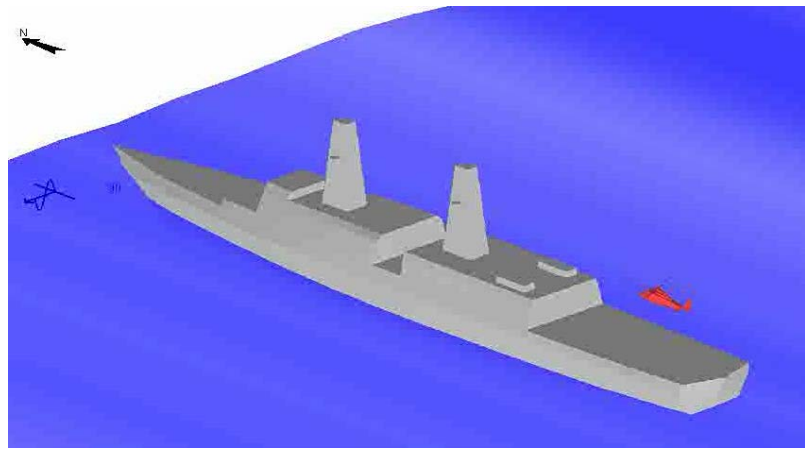
Hydrodynamic model

Hydrodynamic loads based on diffraction-radiation sink source method

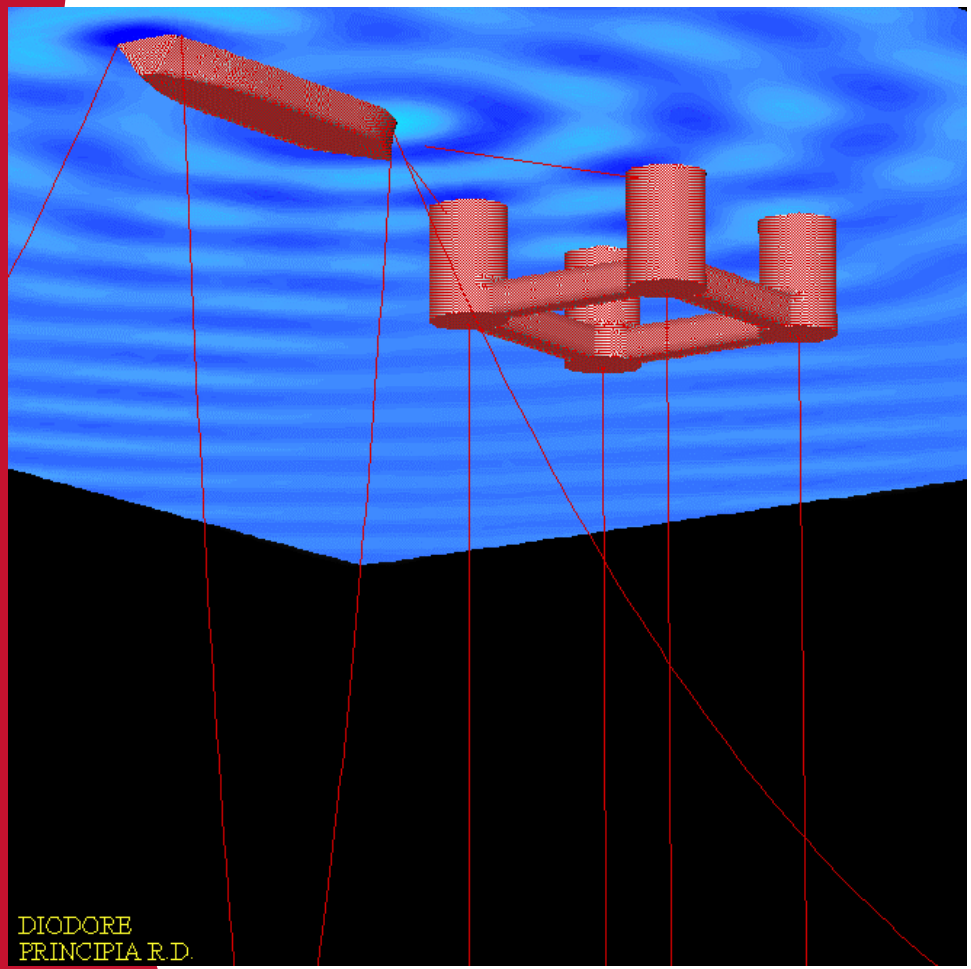


Sea keeping

- *Motions, accelerations at any points*
- *Splash zone, green water, slamming occurrence*
- *Damping formulations*
- *Multi-structures*
- *Long crested & short crested sea states*
- *Advanced features:*
  - *Sloshing/sea-keeping coupling*
  - *Stabilization devices (anti-roll tanks, foils…)*
  - *Multi-peaks multi-directional sea states*
  - *Automatic pilots*



Mooring design

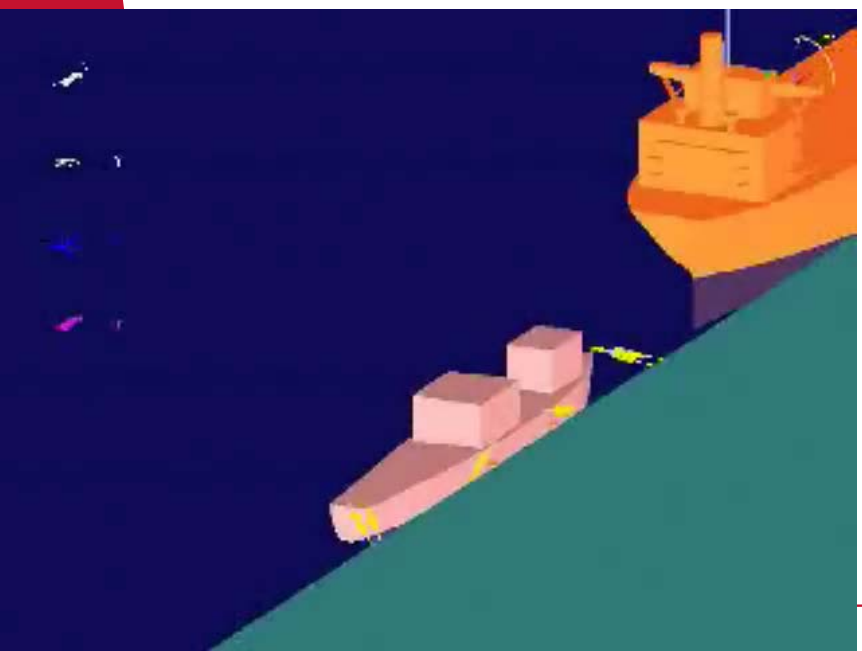


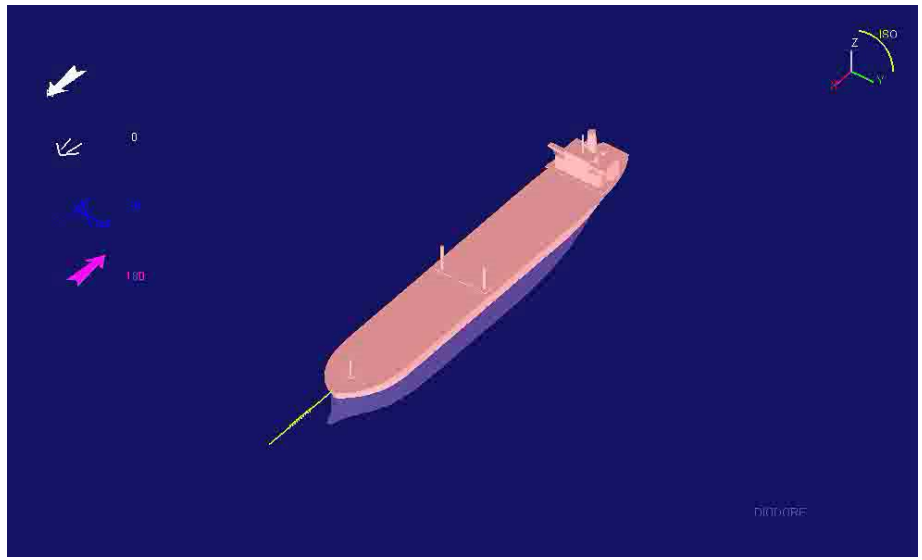
- *Mooring design (extreme & fatigue)*
- *Static, quasi-static simulations*
- *Squall winds*
- *API 2SK rules applications*
- *Compliant to BV rule*

Ship motion

6-dof response assessed from the efforts on the ship, including :

- **environmental loads**
- **mooring**
- **control units**
- **maneuverability**

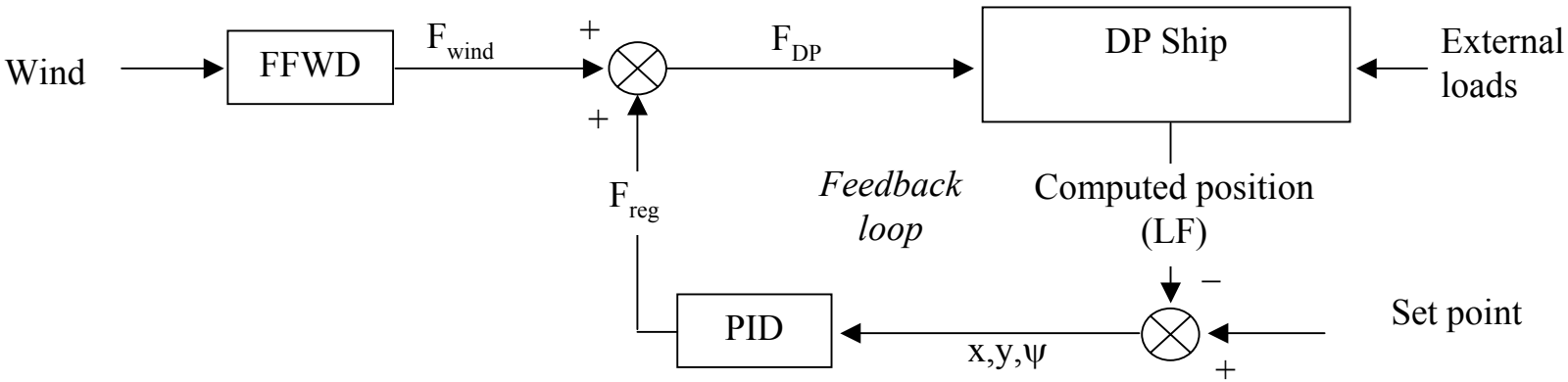




(Speed not at scale)

The DP Module

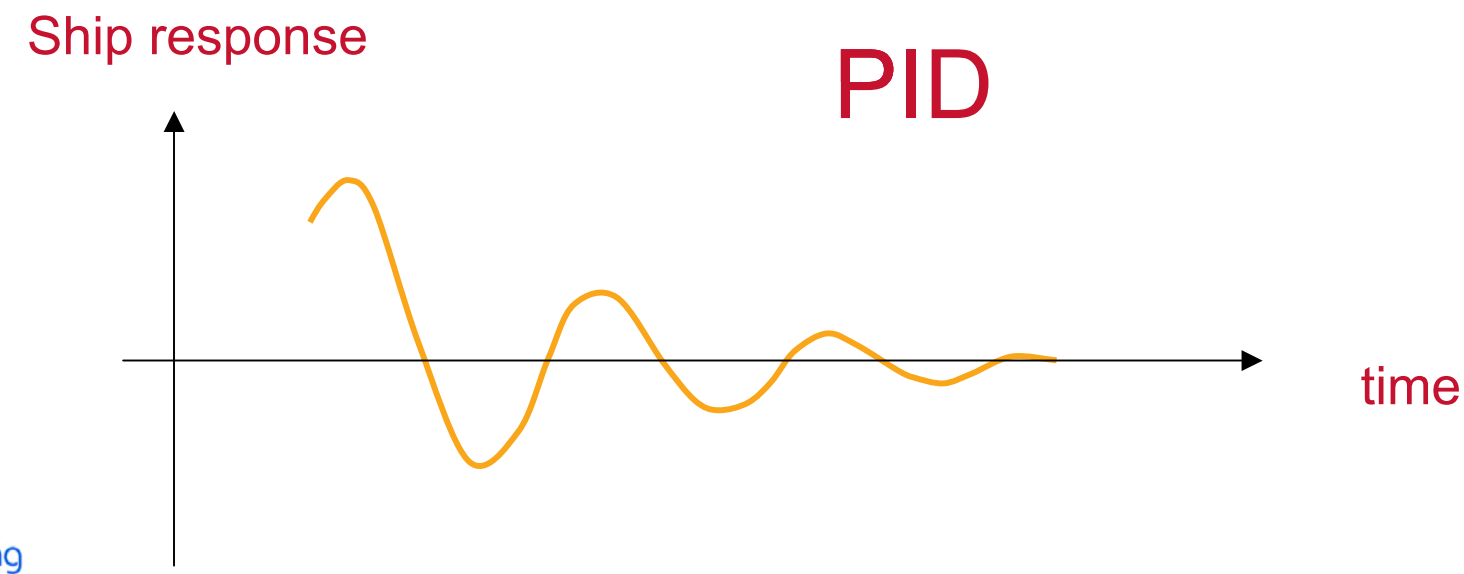
DP CONTROL SYSTEM



- Ideal wind feed forward
- PID corrector
- Anti-reset windup to prevent saturation

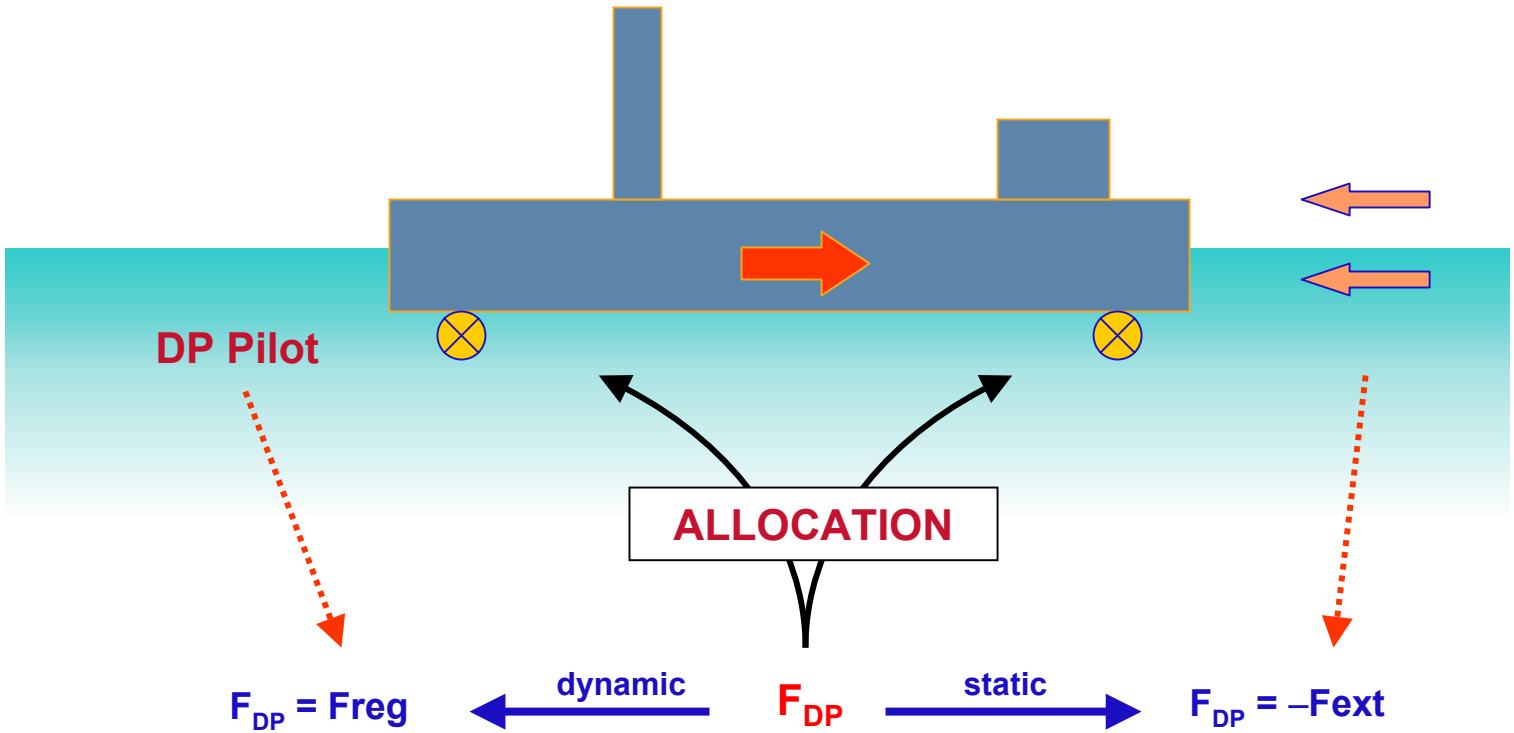
PID regulator

- **DP PILOT : PID REGULATOR**
  - **Proportional = Stiffness**
  - **Integral = Mean offset correction**
  - **Derivative = Damping**

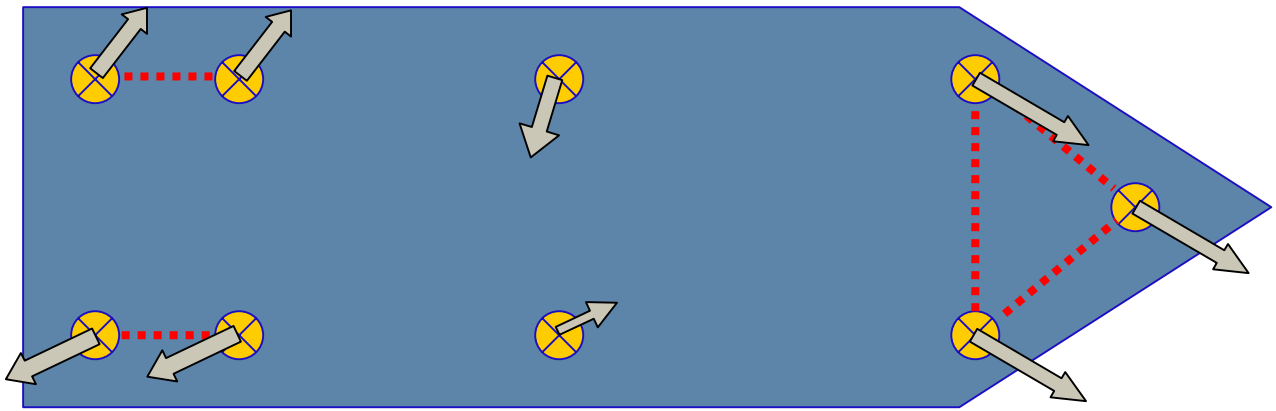


The DP Module

- **THRUSTER ALLOCATION**

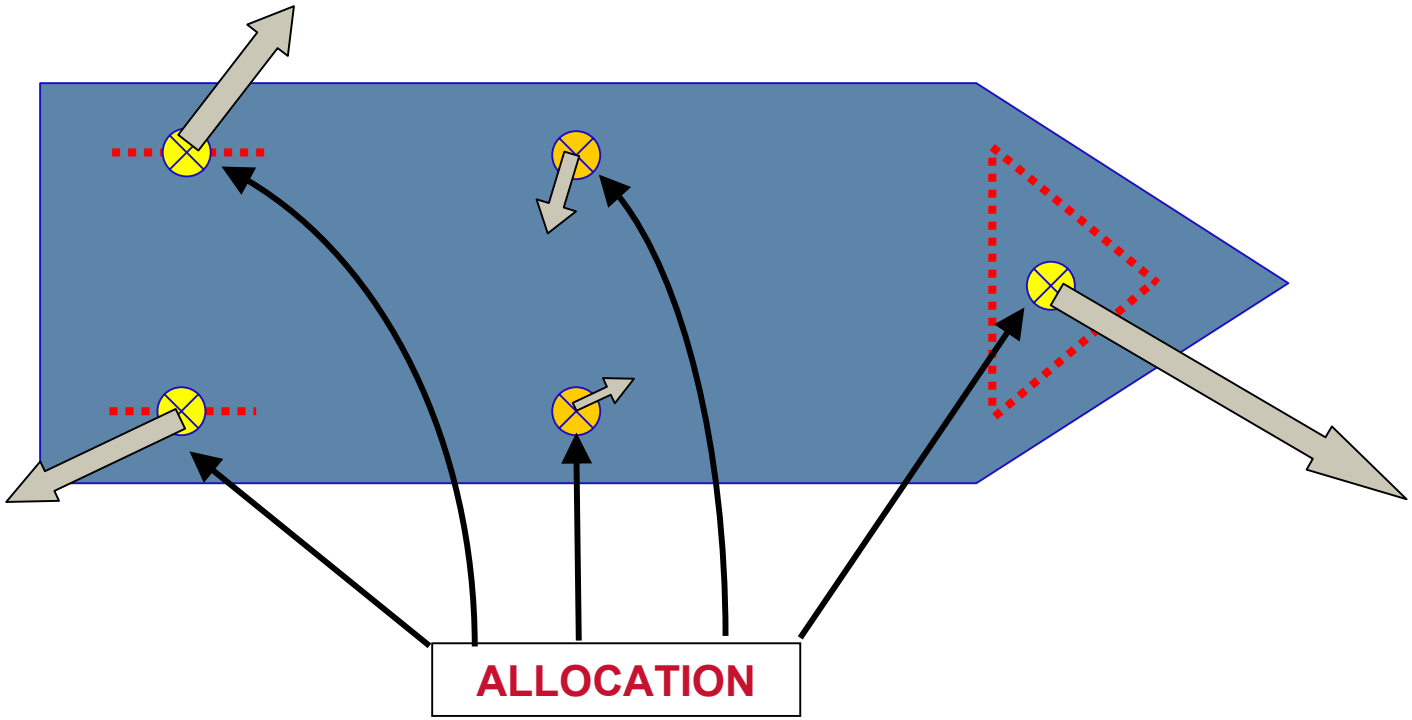


Linking Thrusters



- Should be of the same type
- Will be commanded the same thrust and azimuth

Linking Thrusters

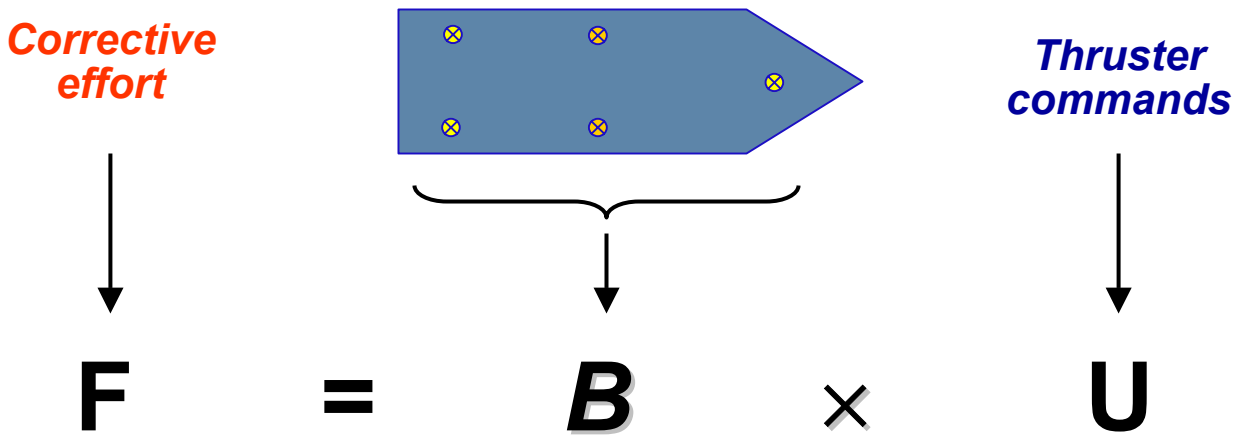


- Will be commanded the same thrust and azimuth
- Allocated as single equivalent thrusters

The DP Module

- **FIRST STEP : LINEAR ALLOCATION**

B **: Allocation matrix based on DP system geometry**

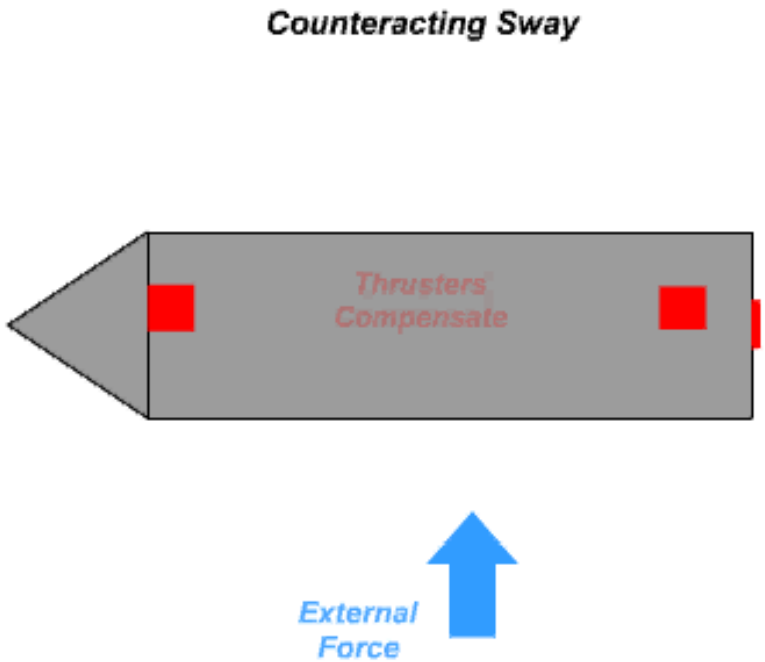


Solved with energy cost-function optimization :

$$U = B^{\dagger} F \quad \text{with} \quad B^{\dagger} = B^{T}.(B.B^{T})^{-1}$$

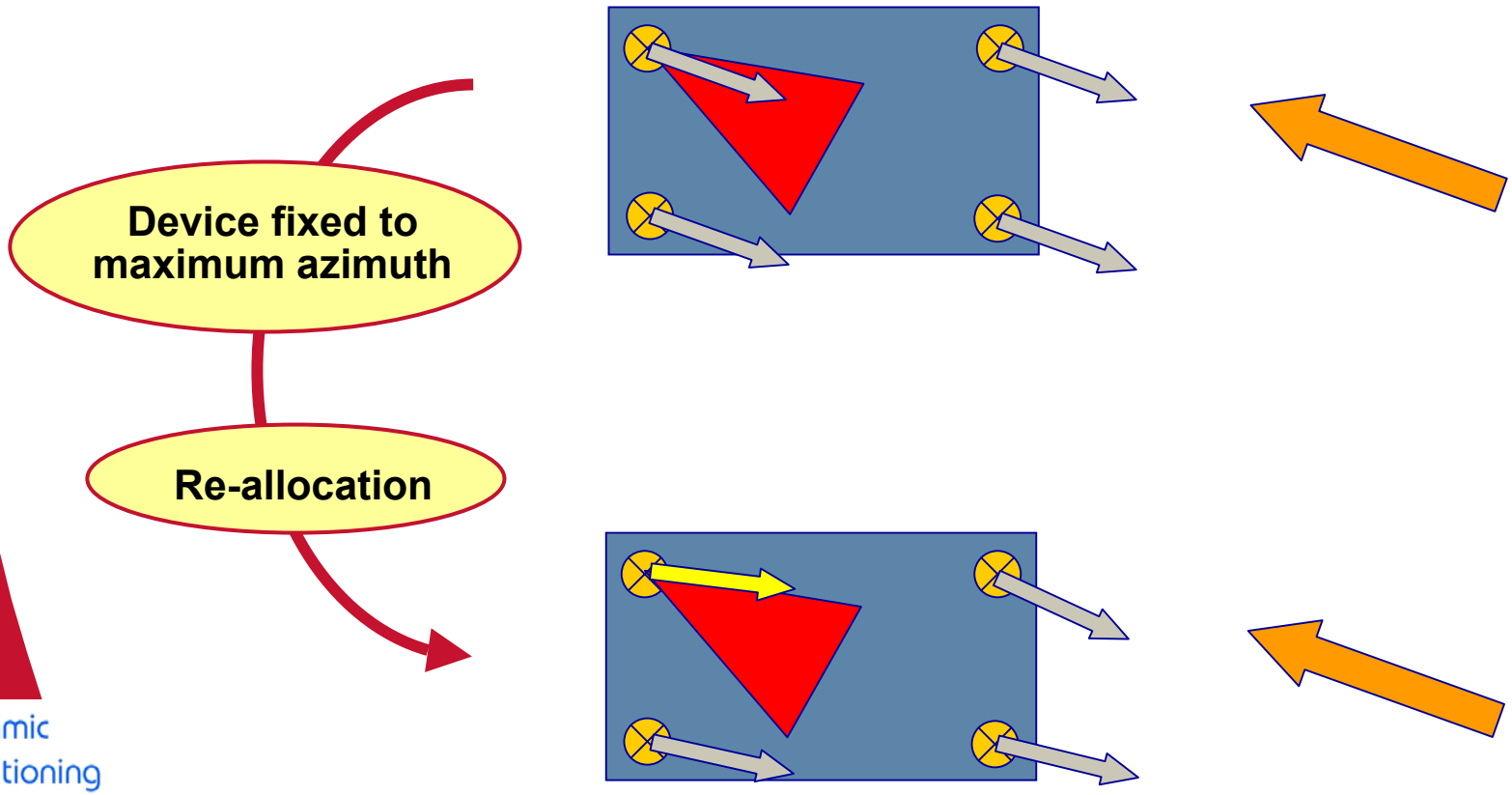
The DP Module

- **THRUSTER ALLOCATION**



The DP Module

- **SECOND STEP : COMPENSATION**
  - **Azimuth compensation**



The DP Module

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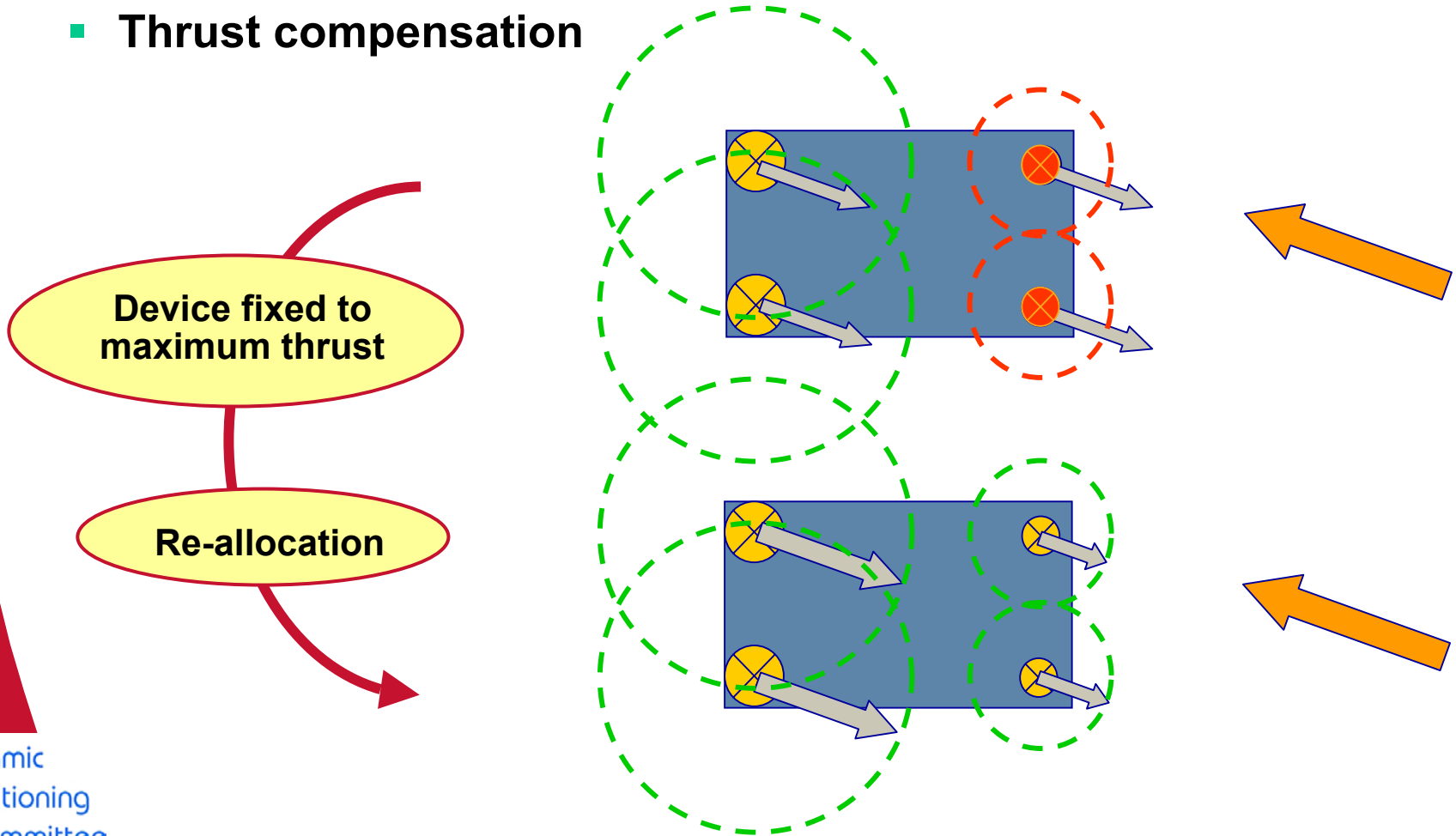
  - **Thrust compensation**



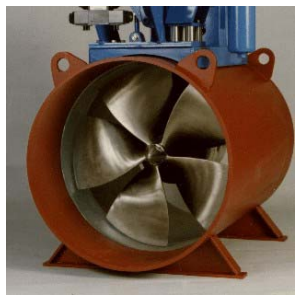
The DP Module

- **STATION KEEPING CAPABILITY ANALYSIS**
  - **Mechanical processor in frequency domain**
  - **Define thrusters + DP system (only static parameters)**
  - **Define environment (API)**
  - **Draw capability plots**

- **TIME SIMULATION**
  - **Mechanical processor in time domain**
  - **Define thrusters + DP system & pilot**
  - **Run LF simulation together with any other mechanical model (mooring, etc)**

The DP Module

- **CONTROL UNITS**
  - **Tunnel thruster**
  - **Directional thruster (reversible or not)**
  - **Screw propeller & rudder**
  - **Azimuth thruster**



The DP Module

CAPABILITY PLOT : IMCA-STANDARD

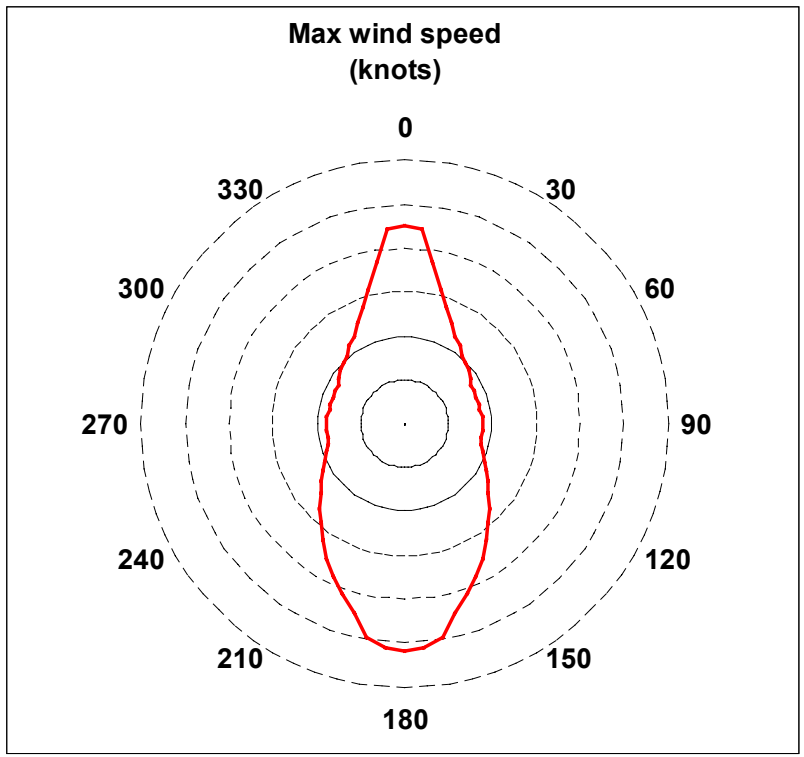
- Overall DP system performance :

Maximum wind speed before system saturation

vs

Incidence of mean environmental forces

- Same direction for wind, wave and current
- Wave and current related to wind speed



The DP Module

CAPABILITY PLOT : API-STANDARD

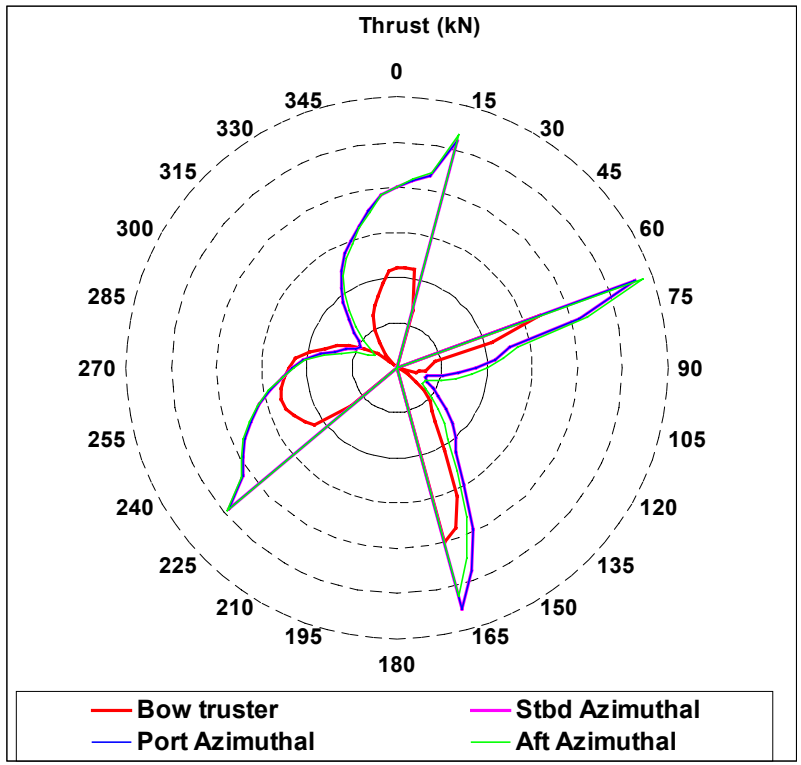
- DP system solicitation in given environment :

Thruster solicitation

vs

Ship heading

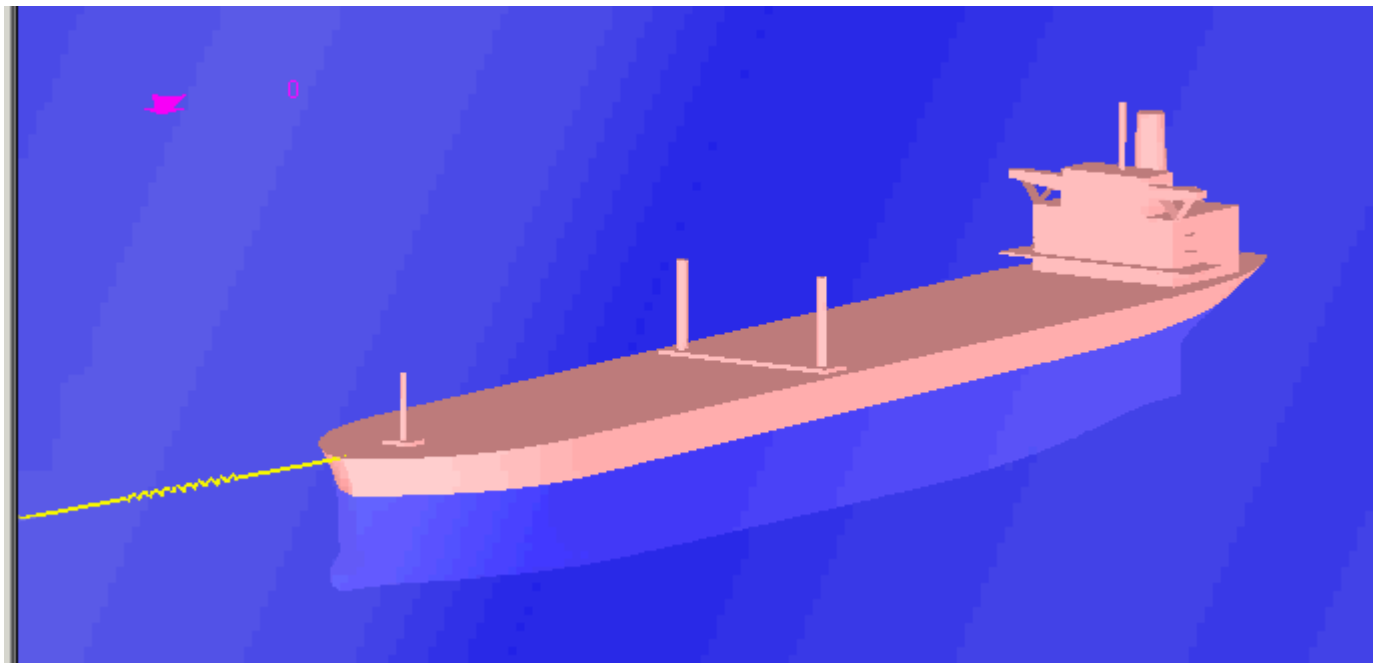
- Optimize ship availability for operations



The DP Module

- **TIME DOMAIN SIMULATIONS**

  Simulate ship response to environment including special events (scenario) or environmental changes (squall winds)

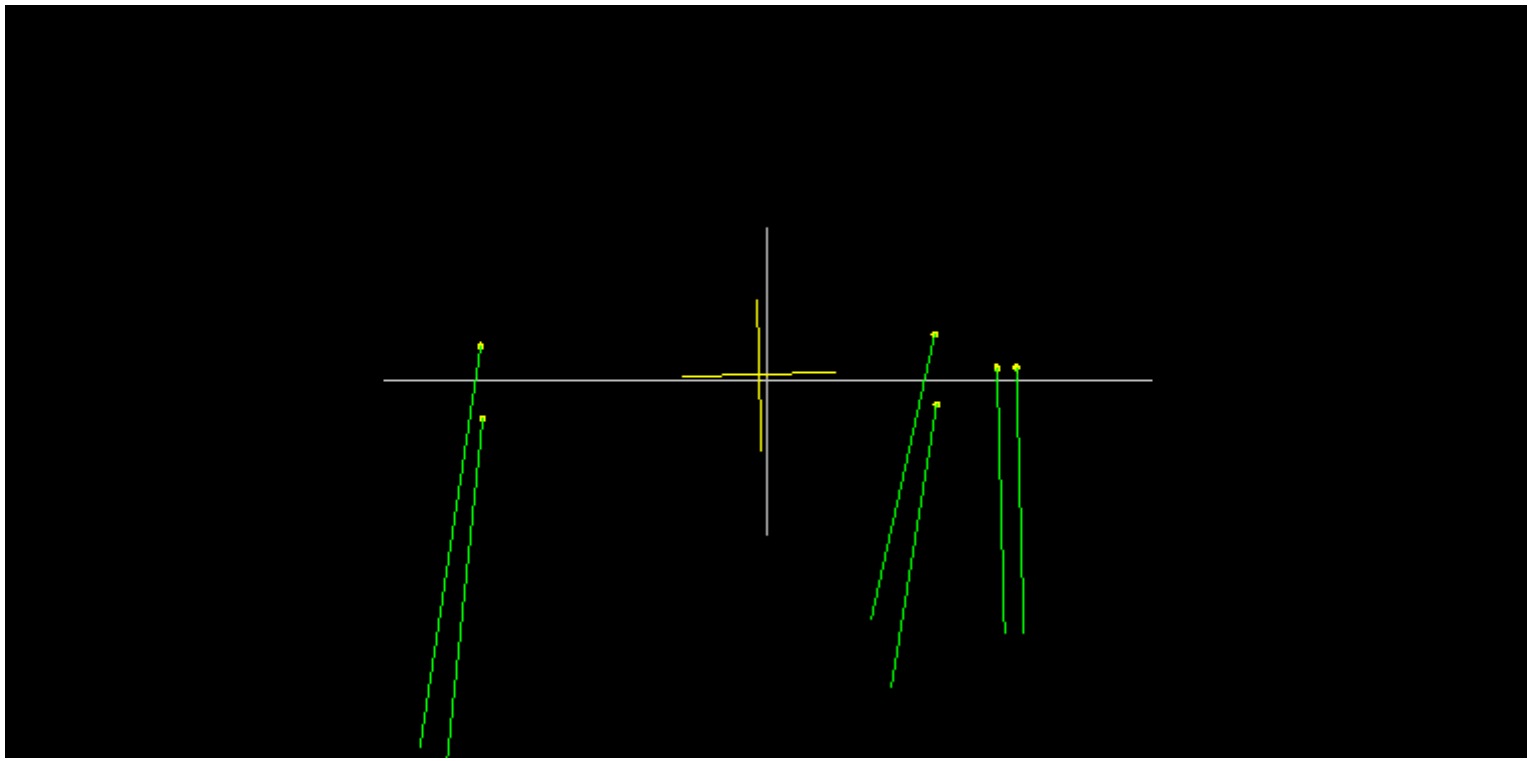


The DP Module

- **TIME DOMAIN SIMULATIONS**
  - **DP pilot parameters :**

    - Gains, thrust saturation, azimuth saturation

    - Set point, actualization time lap



Applications

TANDEM OFF-LOADING

- 110 000 DWT DP-tanker

  L320m x B55m x T8.2m

  2 x 75kN tunnel thrusters + 2 x 100kN azimuth thrusters

  OCIMF coefficients for wind & current polars

- Environment :

  wind : 9.6knots from 75°N

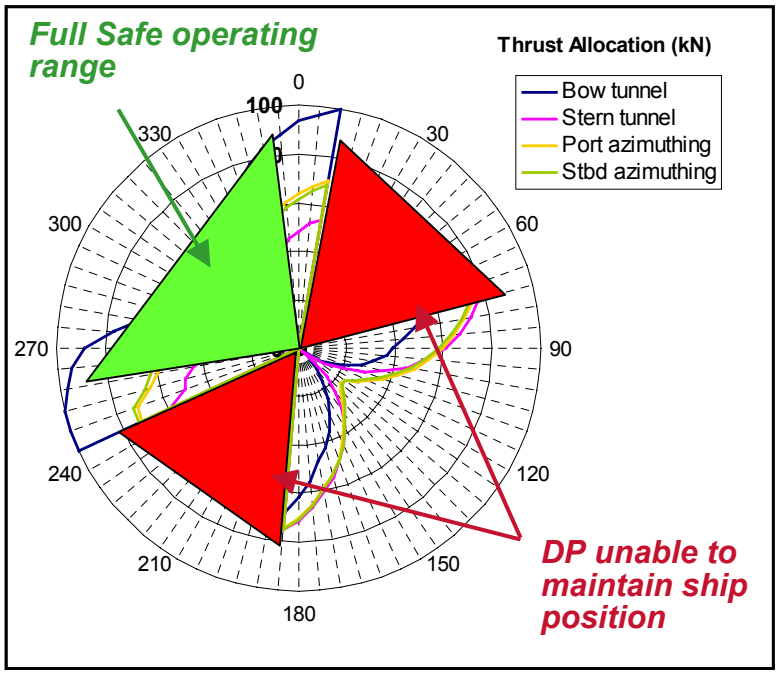
  wave : Hs=2.3m, Tp=12s from 300°N

  current : 0.65m/s to 330°.

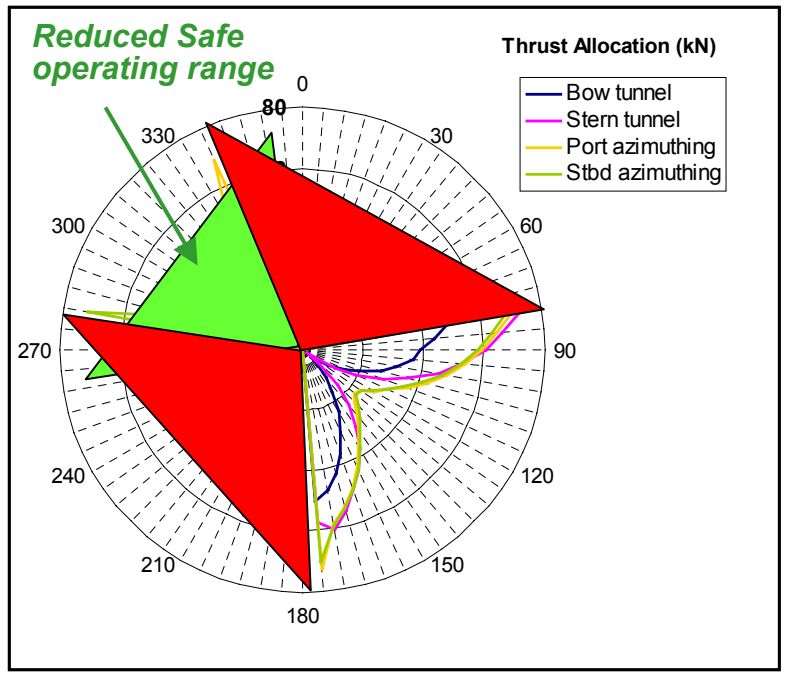
Applications

- **TANDEM OFF-LOADING**
  - **Capability analysis : normal / failure mode**

Normal

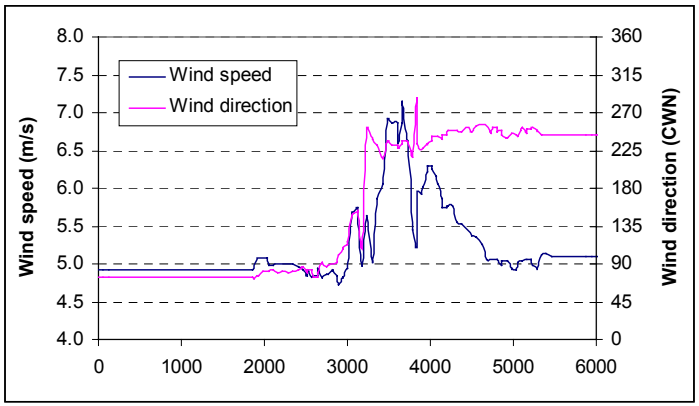


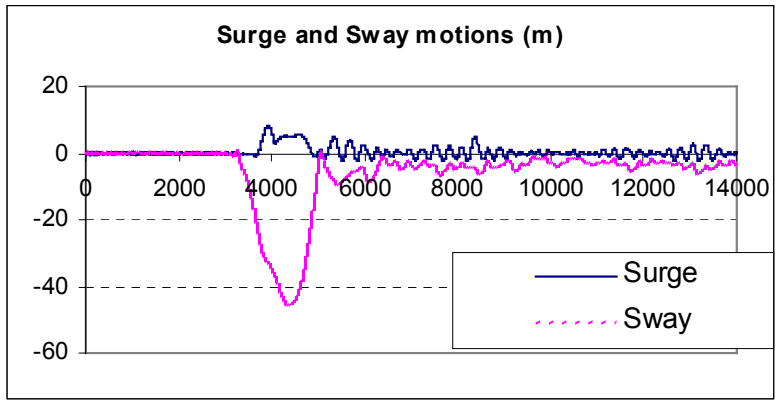
Bow thruster failure

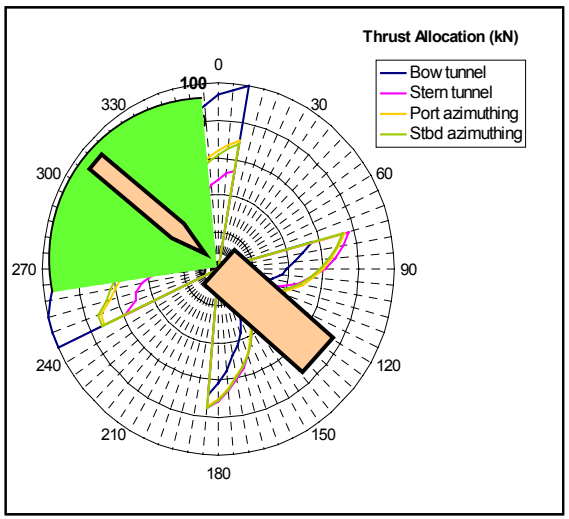


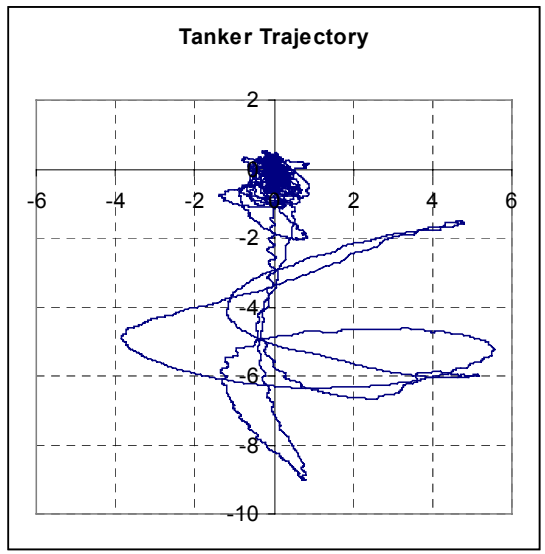
Applications

TANKER RESPONSE TO SQUALL WIND



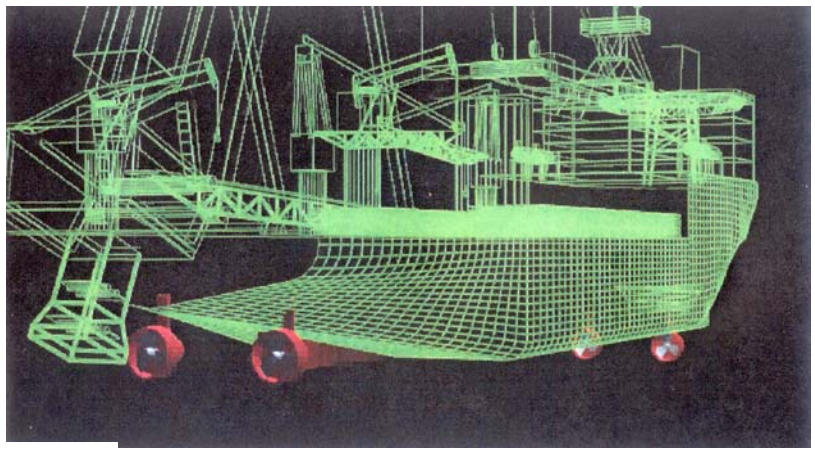






Concluding remarks

- **DP Module Validation : Field Development Ship (SAIBOS)**



Eni Saipem s.a.

- **Development : frequency domain**