Wave Response
Under design conditions

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Mathematics & Water
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Outline

- BMT ARGOSS
- Waves & wave spectra
- Ship response applications

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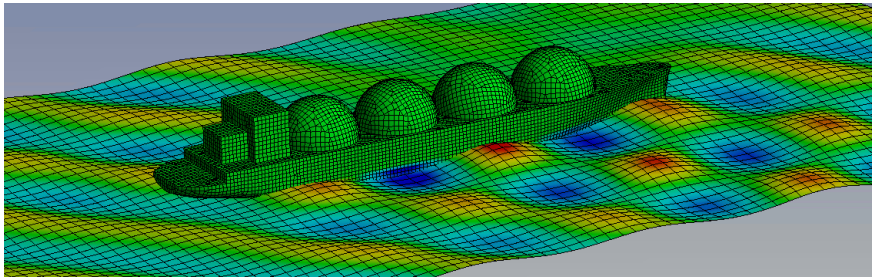
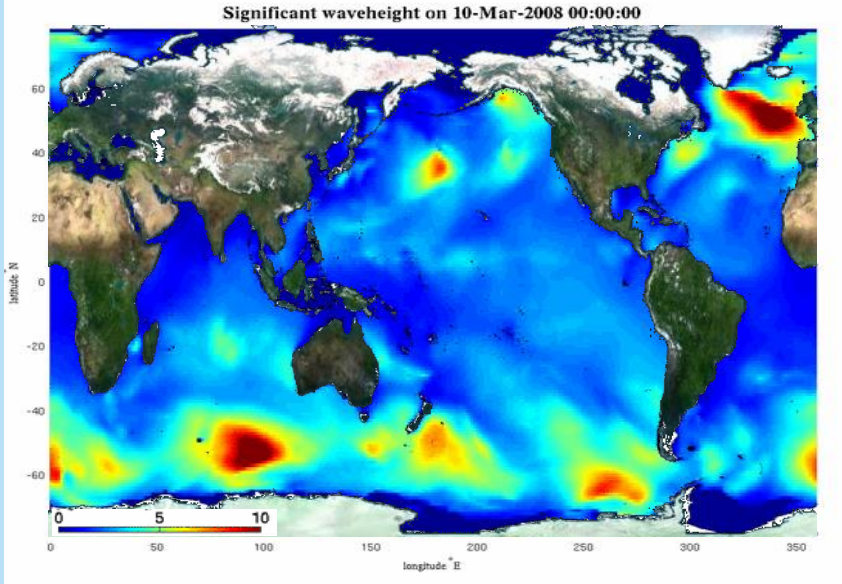
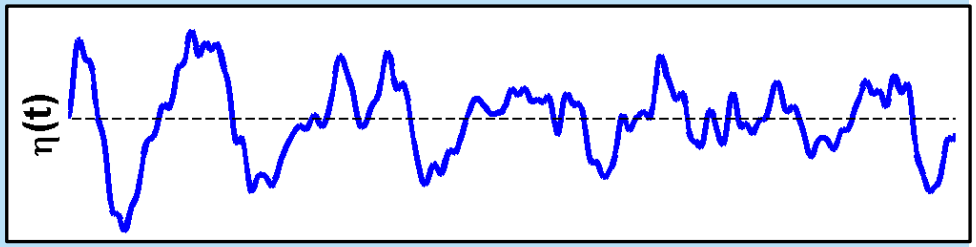
- Operational Maritime Forecast
- Metocean
- Vessel response
- REMBRANDT
- SARIS





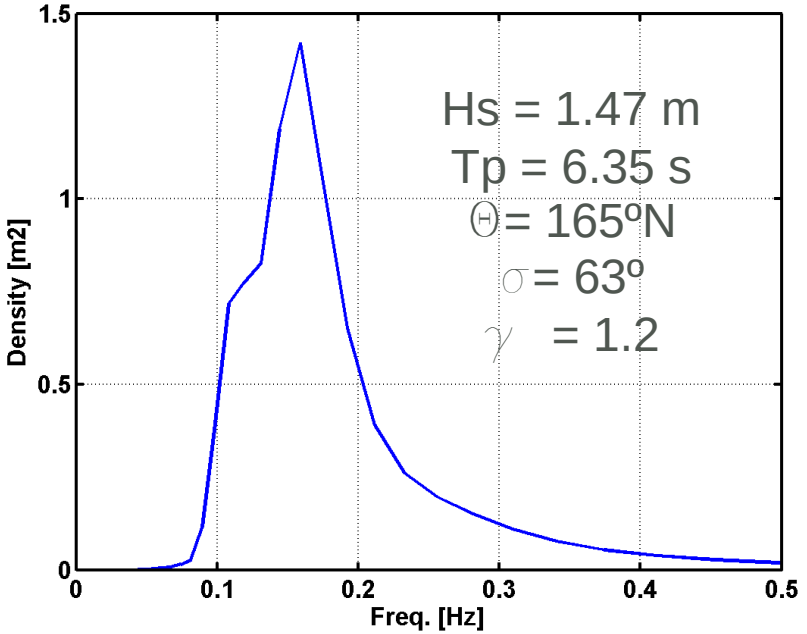
Wave spectra

Signal (t)



FFT

Quasi 1D



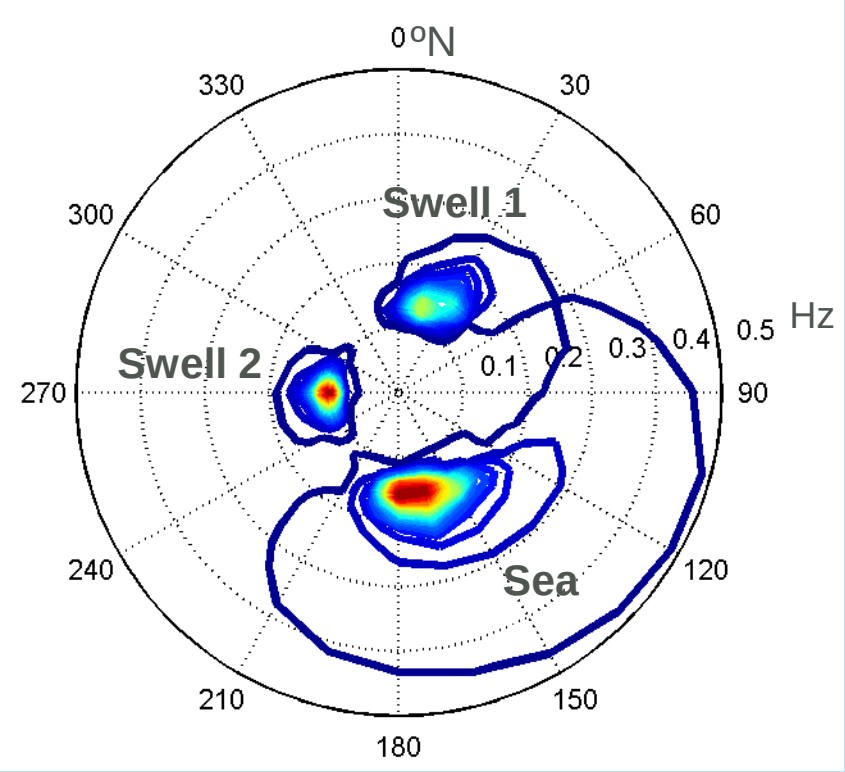
Irregular waves in the field

- **Measure surface elevation & wave direction (or a derivative)**
- **Process to obtain spectra**
- **Sensors can not produce 2D (directional) spectra**

2D wave spectra: multiple wave systems

Client question:

What wave conditions to expect at the site



Integrated wave parameters

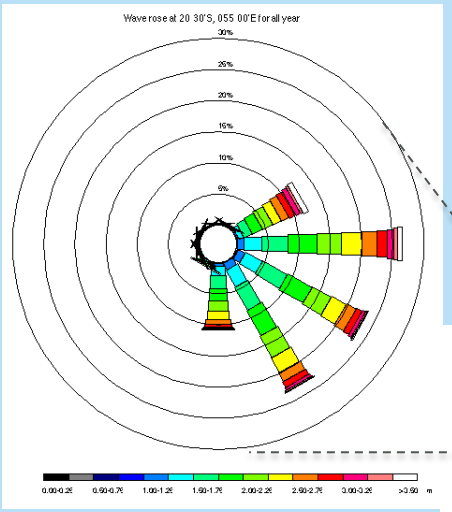
	Hs [m]	Tp [s]	Dir [°N]
'Sea'	1.18	6.2	168
'Swell 1'	0.64	7.1	19
'Swell 2'	0.60	9.1	269

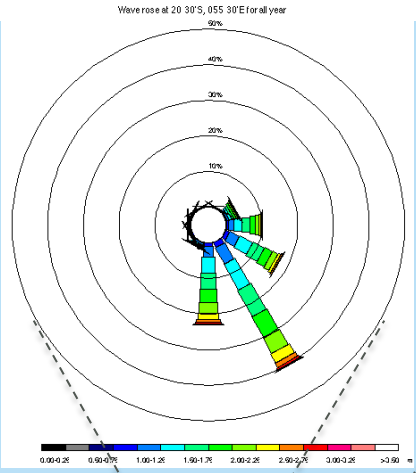
Relevant for:

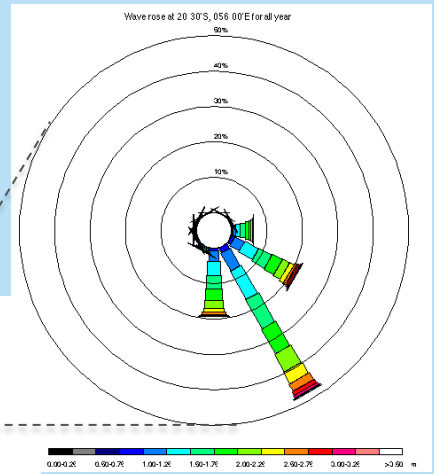
- **Dikes**
- **Breakwaters**
- **Ports**
- **Shipping**
- **Oil platforms**
- **FSRU**
- **Dredging**
- **Pipelines**
- **Wind & wave energy**

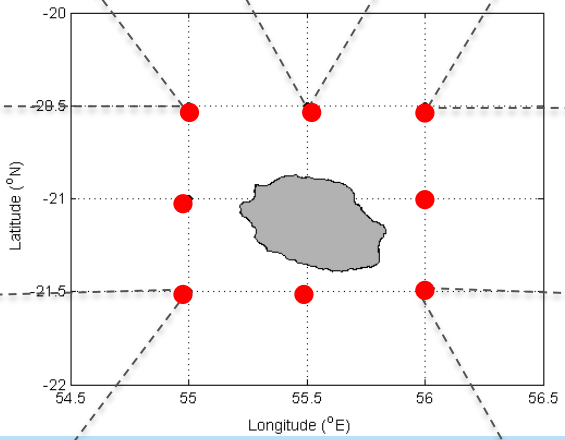
Wave Hindcast

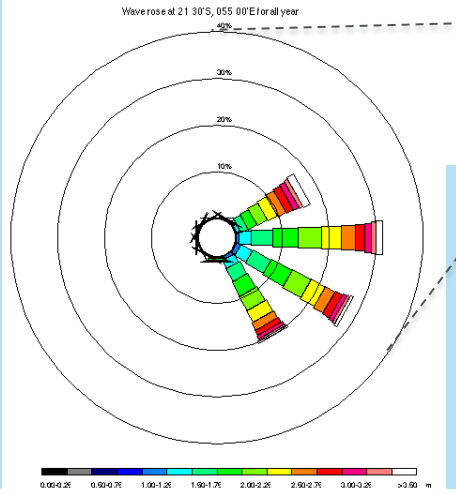
- **Offshore: Numerical Models**
- **Establish offshore climate**
- **Nest Nearshore Models**

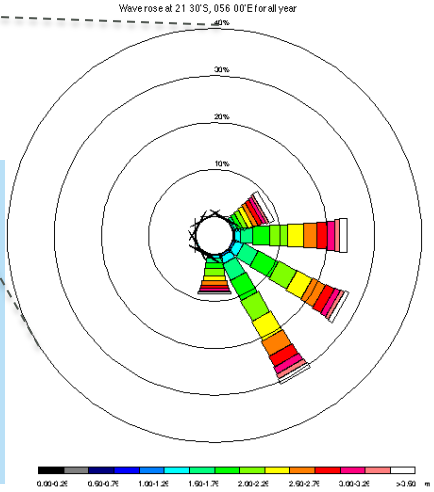












35 years!

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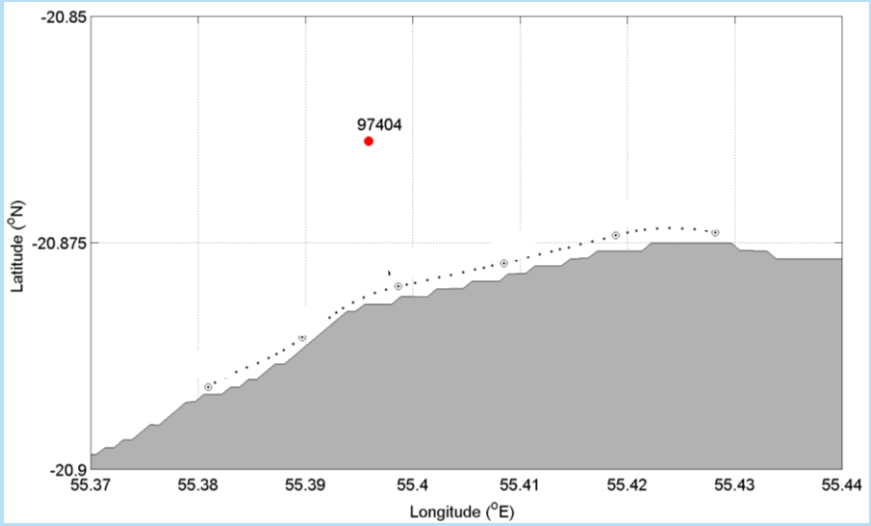
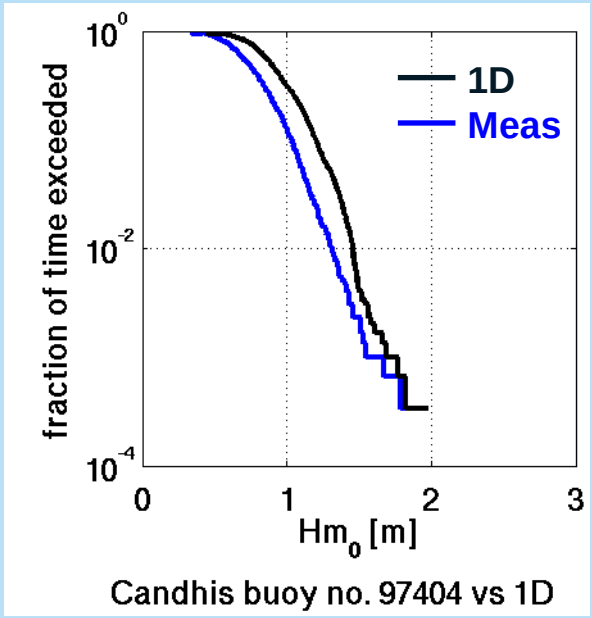
In situ conditions

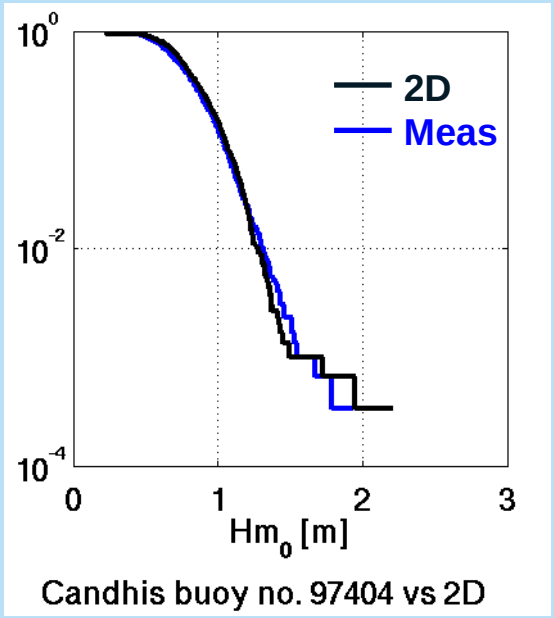
- Propagate waves from offshore to nearshore
- Validate against available data
  - Satellite observations;
  - In-situ sensors (buoys)



Project analysis:

- Persistency
- Workability
- Down time
- Extreme conditions (design)

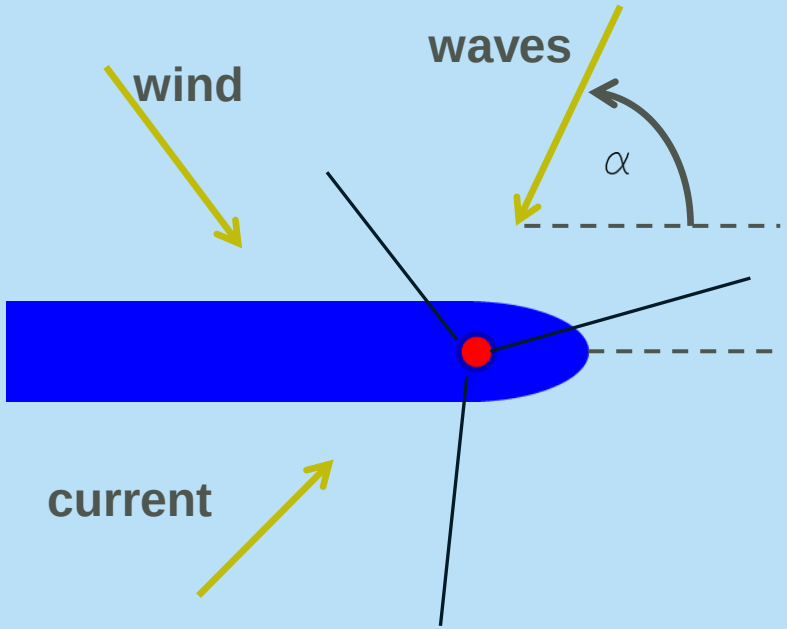




Heading analysis

Weather vaning ship

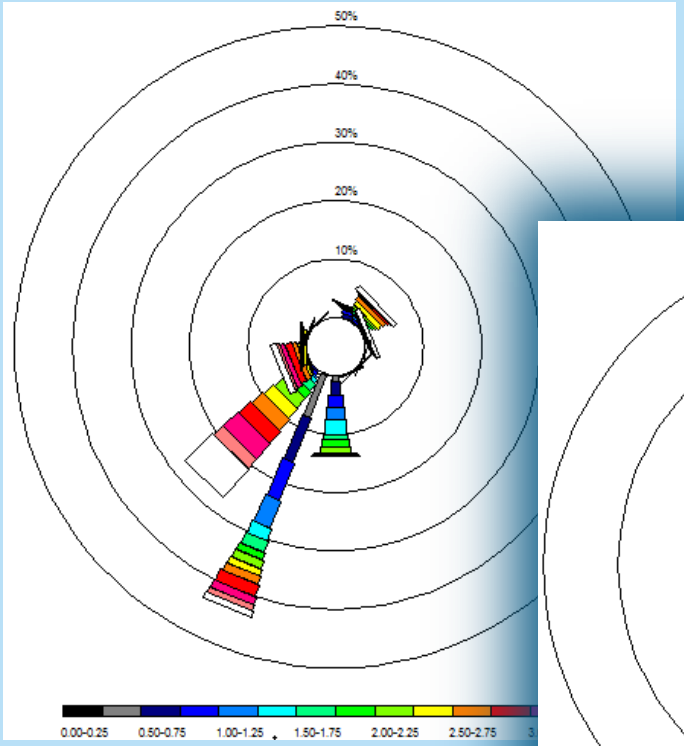
- **Single point moored**
- **Environment loads F, M function of angle of incidence**
- **One mean stable equilibrium orientation**



SPM *(with tandem mooring)*

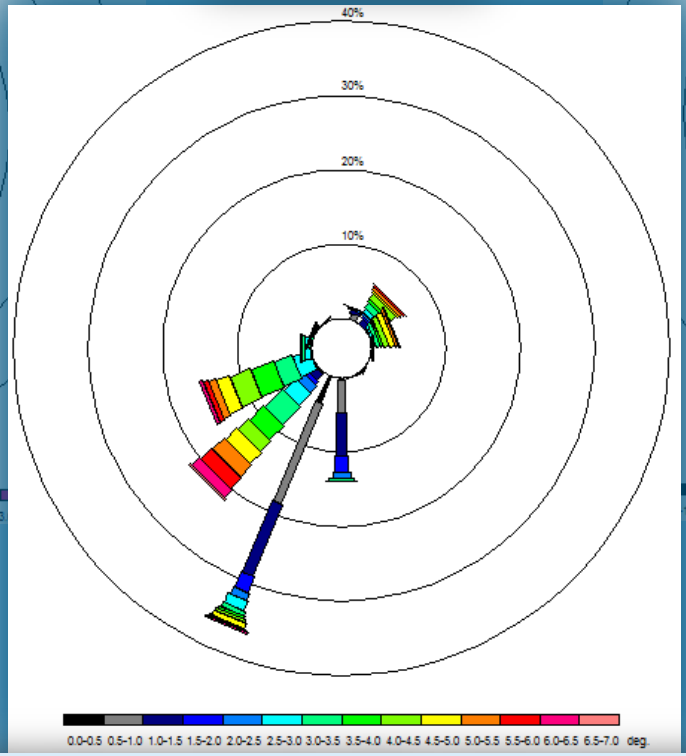
Heading analysis (SPM)

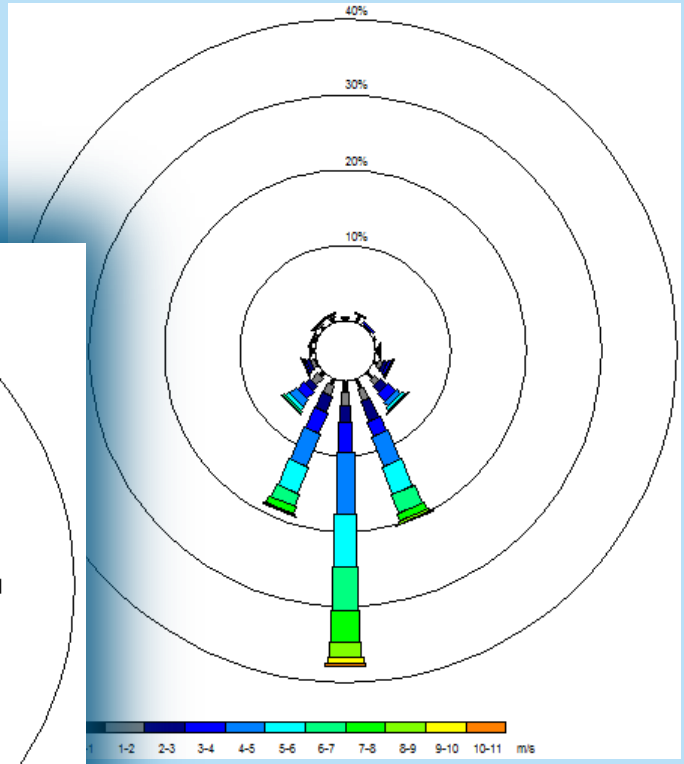
Compute wind & wave loads to obtain heading of the ship



Wave Rose

Heading

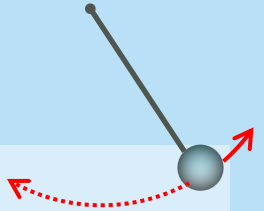




Wind Rose

Sig. roll amplitude / Sig. wave amplitude

Wave response of floating body



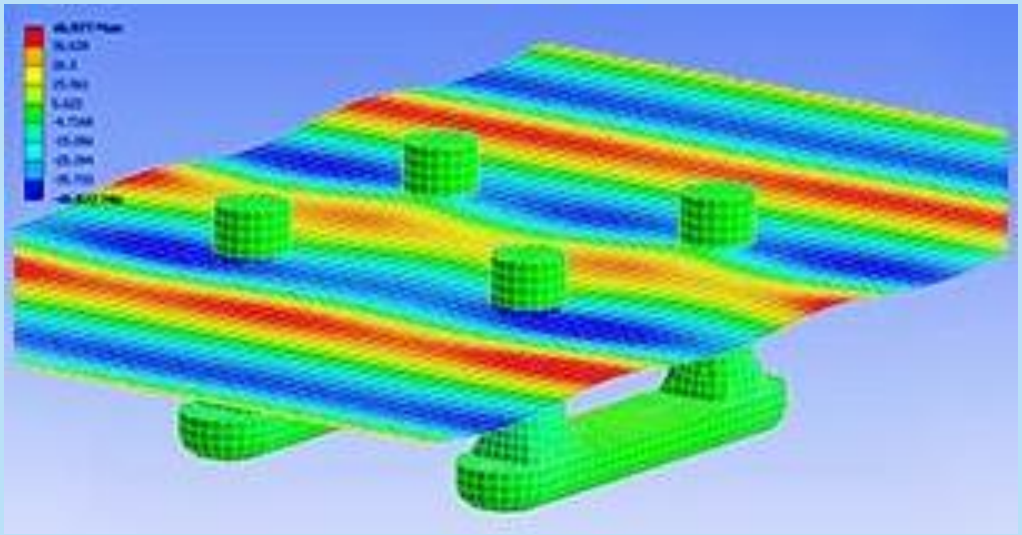
Mass – damper – spring system **(Forced pendulum:)**

Eq. of motion: $\left(M + A(\omega_{e,i})\right)\ddot{x} + \left(B(\omega_{e,i}) + B_{VISC}\right)\dot{x} + Cx = \sum_{j=1}^{N} Fw(\omega_i, \beta_j)$

Solve x, **with** $x(t) = R\exp\{-i\omega_e t\}$

AQWA (frequency domain):

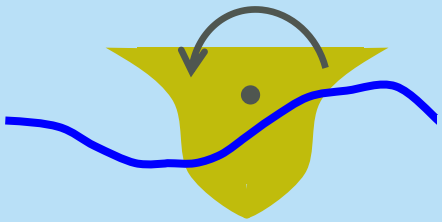
- **Response Amplitude Operators**
- **Wave forces Fw :**
  - Incoming,
  - Diffracted
  - Radiated A and B
- **Function of wave height & direction**



Motion response at a site

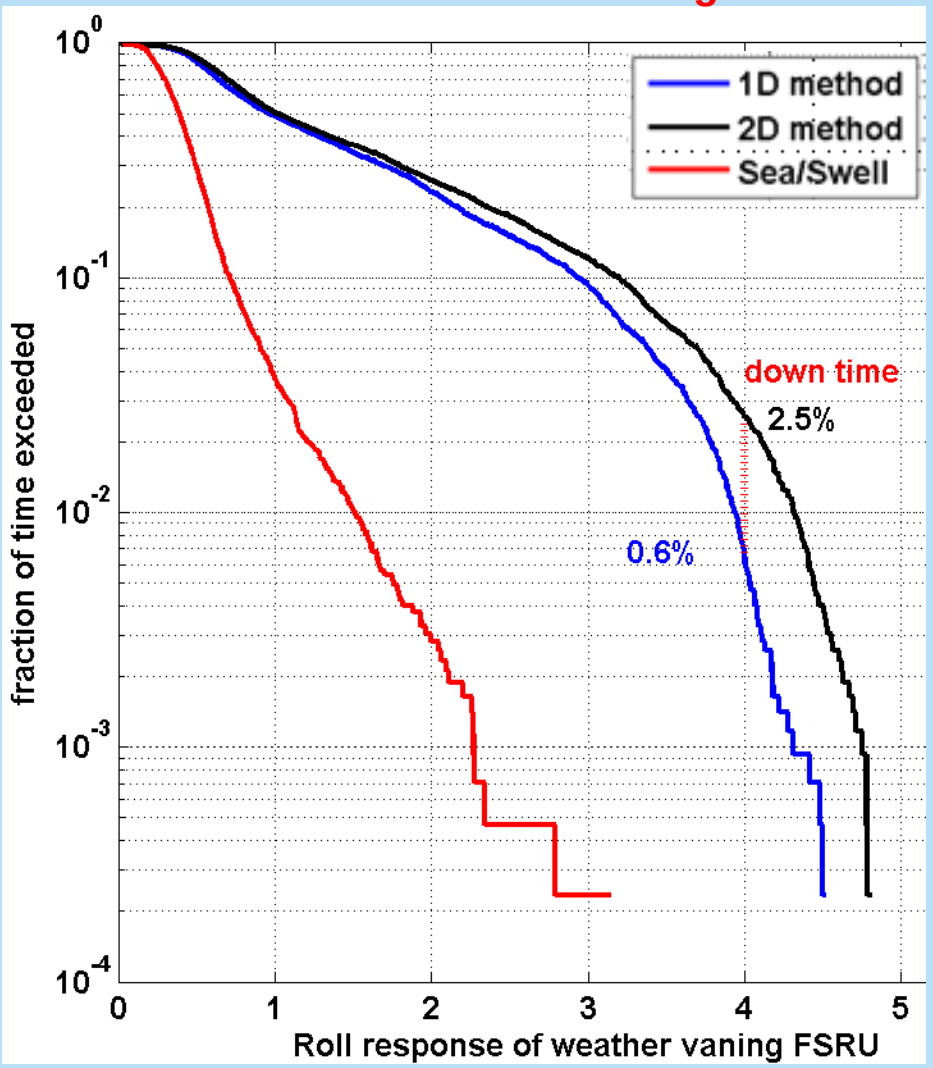
Feasibility question:

What roll motions can we expect at the site



Time series of hindcast wave data

- Integrated parameters Hs, Tp, Θ_0, σ
- Splitted Sea & Swell
- Quasi 1D wave spectra
- Full 2D wave spectra

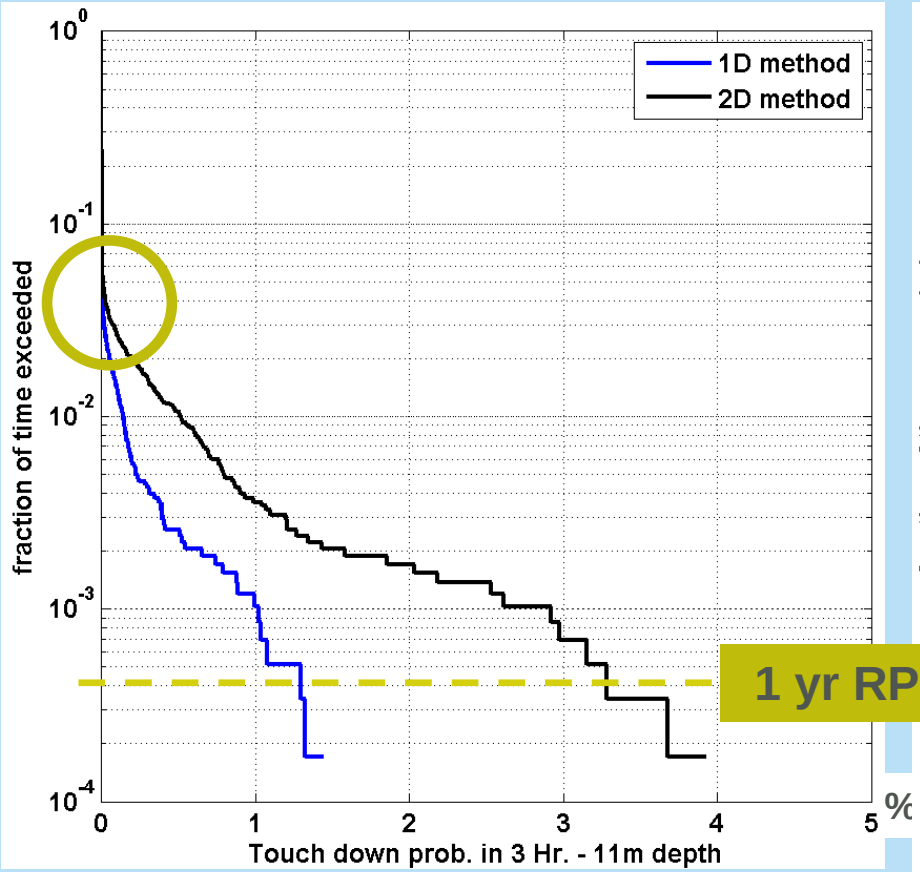


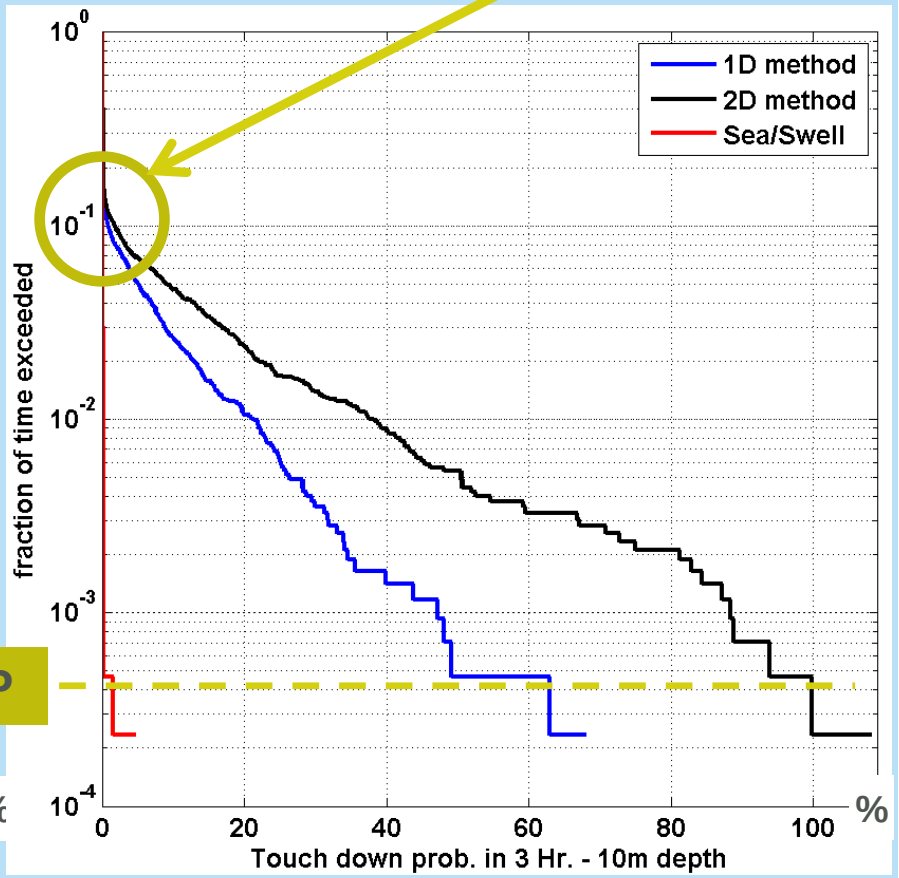
UKC / bottom contact assessment

Feasibility question:

How much do we need to dredge?

many events have negligible risk of seabed contact



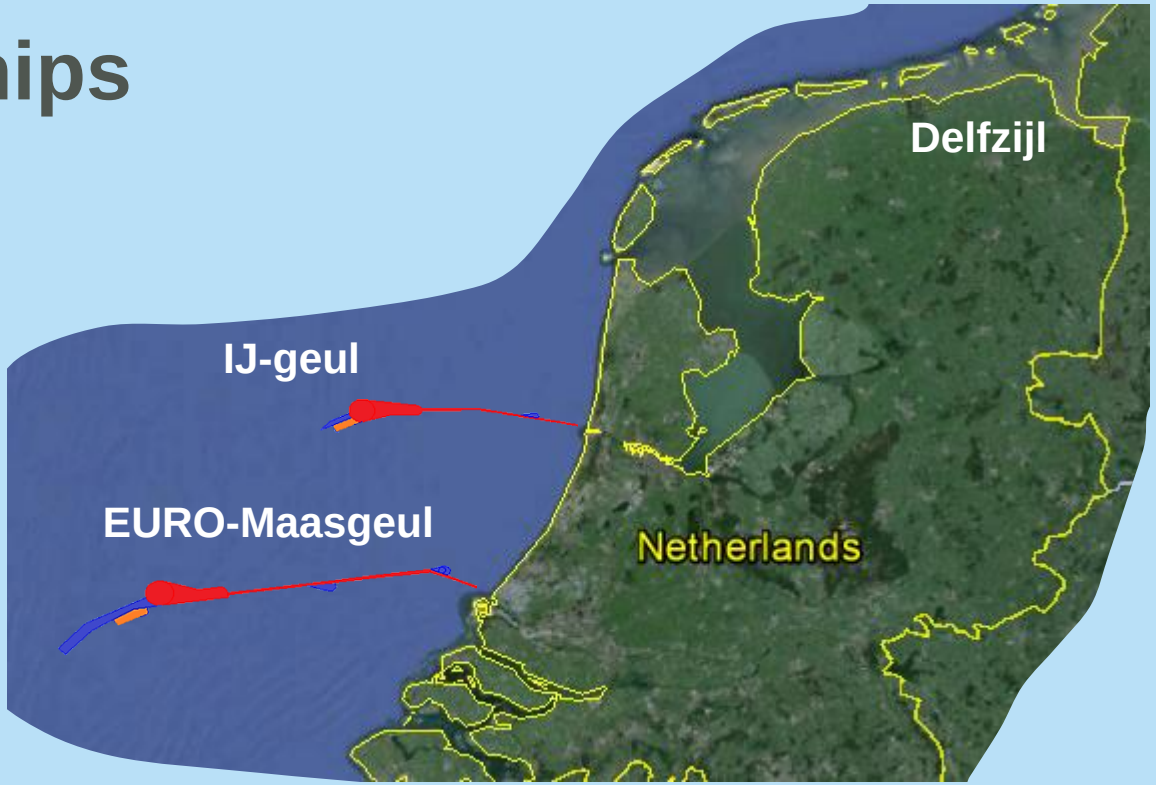


Deep drafted ships

Capacity question:

Can we allow for deep drafted ships in the access channels?

Use the tide!



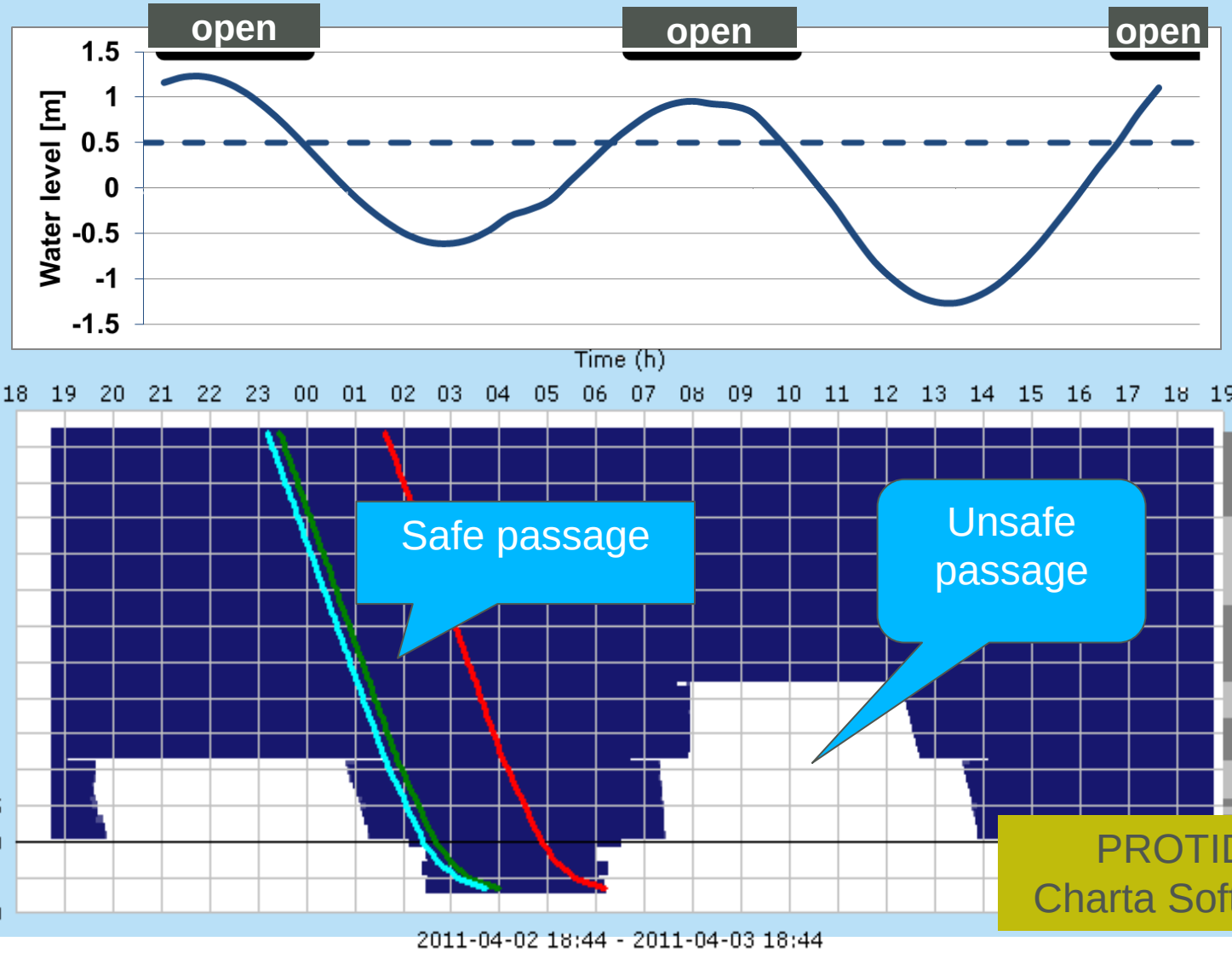
Forecast:
- Water level
- Waves
- Currents

→ Tidal Window

Tidal window based on:

- Type of ship
- Sailing velocity
- Risk of seabed contact

Tidal window example



PROTIDE by Charta Software BV

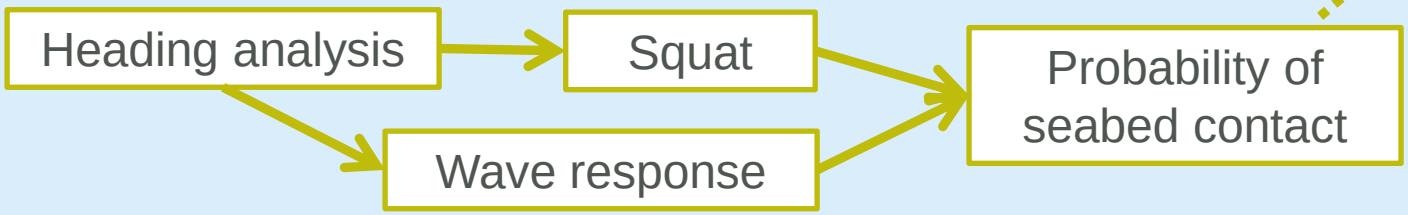
Nautical depth of channels

Can we optimise the channel usage & reduce dredging costs?

METRIS

- **Hindcast of ships arriving & sailing in the approach channels**
- **Long year statistics**
- **Conditional design conditions:**
  ships restricted under admittance policy

Per tidal window:



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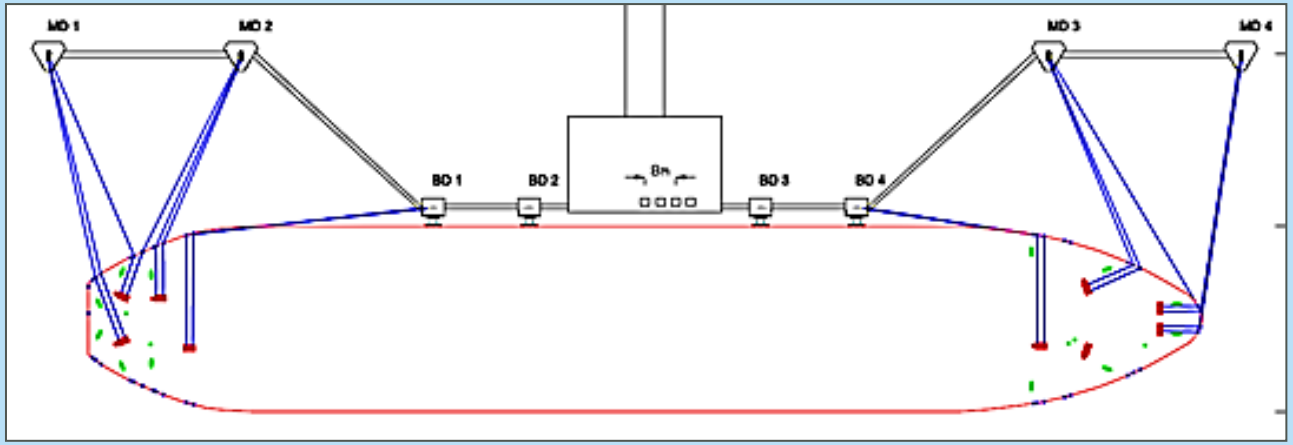
Afterthought

Why has it worked out so far?

→ **Designers take conservative combinations:**
E.g. design based on 1000 year RP storm AND
perpendicular 100 year RP swell

2D spectra do not always give higher response than 1D
E.g. single storm systems or single swell systems as
1D spectra can have a broad directional spreading per frequency bin

Implications on moored ships (exposed jetties)
Operability & survival conditions at a terminal:
non-linear Dynamic Mooring Analysis → DMA computations on our cluster



“Where will our knowledge take you?”

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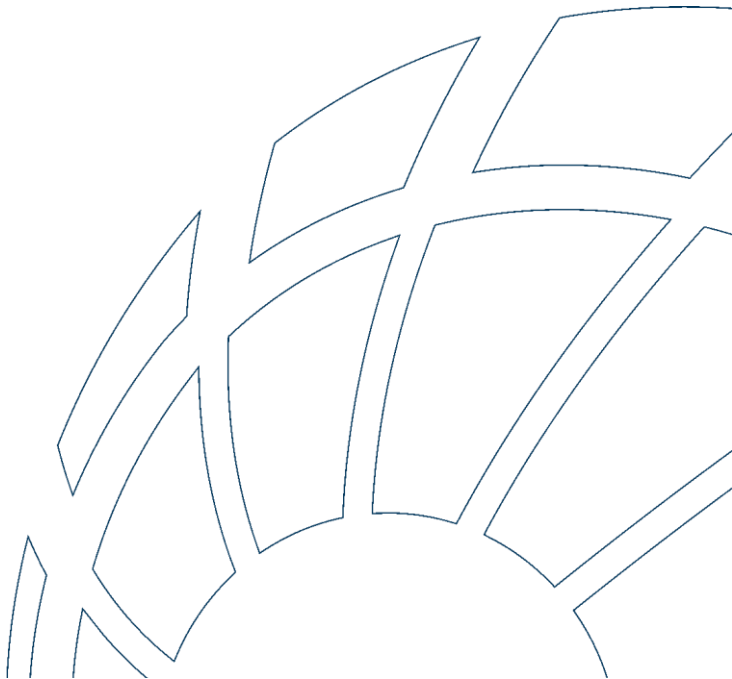

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