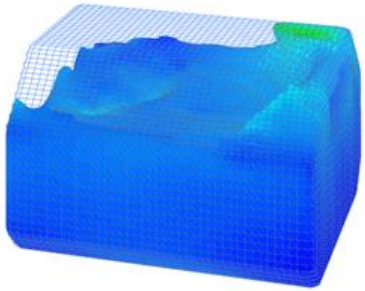
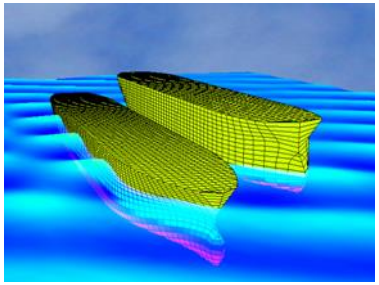
Classification of the Largest Ever Floating Storage Regasification Unit

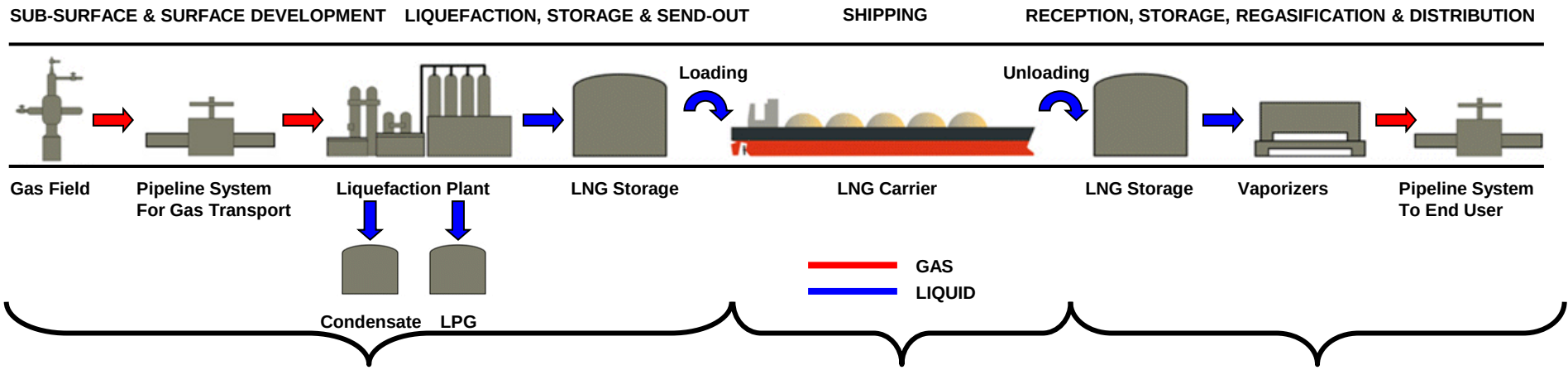

Philippe CAMBOS
Bureau Veritas

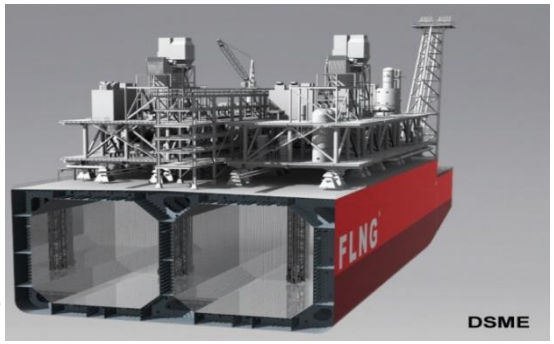
AGENDA

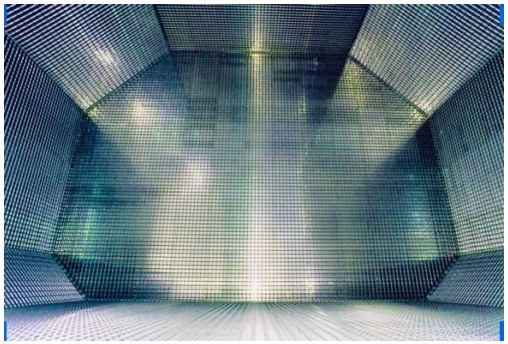
1. Introduction
2. The project
3. Liquid motion analysis
4. Structural analysis
5. Fatigue analysis
6. Conclusion

Production, Storage, Transport & Regasification of LNG

- LNG Production & Storage ⇨ FLNG – LNG-FSPO
- LNG Transportation ⇨ LNG Carriers (ships)
- Storage et Regasification of LNG ⇨ FSRU

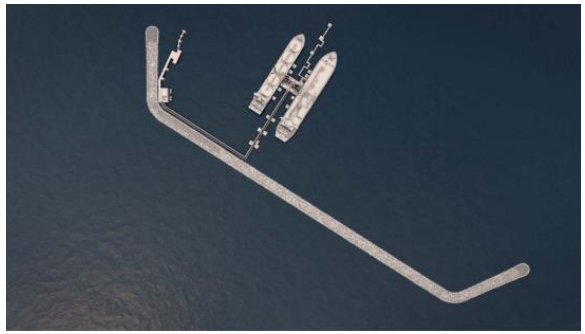






The project

- **Context**
  - New terminal for South America,
  - Moored along a jetty.

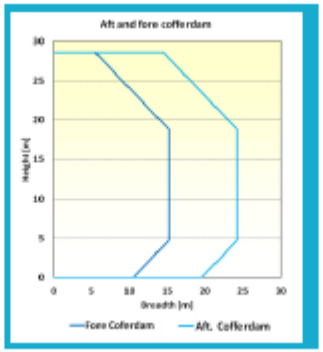


- **Unit**
  - LNG-FSRU of 263 000 m^3 Capacity,
  - Storage and regas LNG on board.

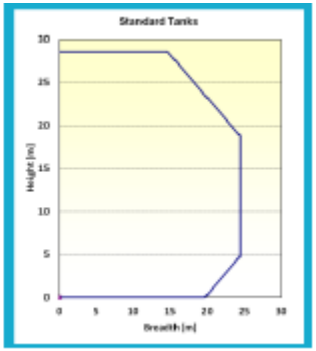
Dimensions	(m)
LOA	345.0
LBP	333.0
Breadth MLD	55.0
Depth	27.0
Draft Design	12.0
Draft Scant.	13.7

- **Tanks**
  - Unit with 5 cargo tanks (QMAX size)
  - Built with NO96 Cargo containment system.

N327 LNGC FSRU		Tank n° 1
Length	[m]	32.52
Breadth Fore \ Aft	[m]	30.42 \ 48.48
Height	[m]	28.57
Upper Chamfer	[m]	9.76
Lower Chamfer	[m]	4.75



Standard Tanks
45.12
48.82
28.57
9.76
4.75



Production, Storage, Transport & Regasification of LNG

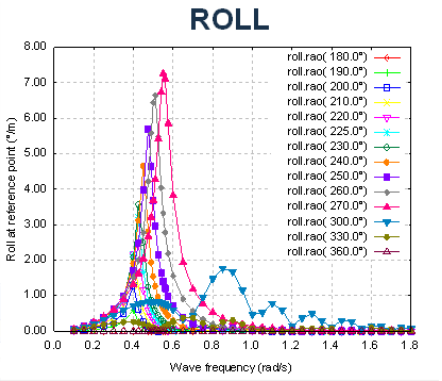
- **Largest FSRU in service:**
  - LNG-FSRU of 173 000 m3 Capacity,
  - 4 cargo tanks
  - BV Class.

- **Largest FSRU under building:**
  - LNG-FSRU of 263 000 m^3 Capacity,
  - 5 cargo tanks
  - BV Class notations: **I, ✠HULL, ✠MACH, Liquefied gas carrier – RV, Unrestricted navigation, ✠VeriSTAR-HULL CM FAT (40 years), INWATERSURVEY, ✠POSA-JETTY, ✠AUT-PORT, ✠ALM/ALP**

Hydrodynamic analysis - Méthodology

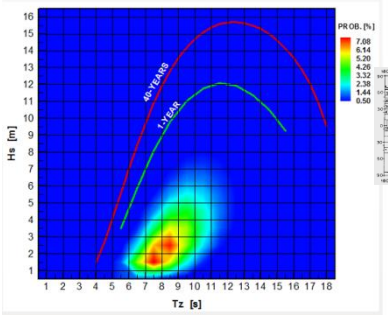
FSRU Project

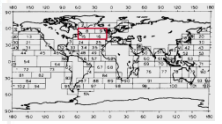
Hydrodynamics



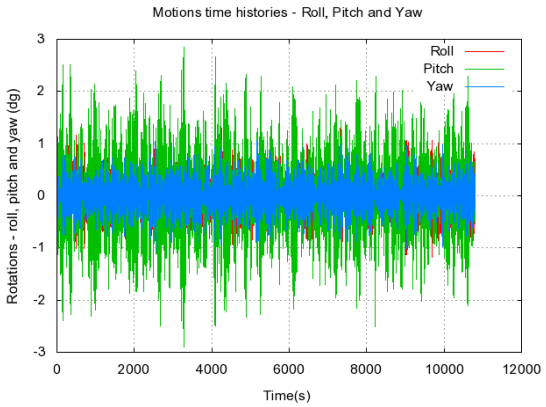
Metocean conditions TMA Spectrum

$$S(w) = \frac{1}{4\pi} H_s^2 \left(\frac{2\pi}{Tz}\right)^4 w^{-5} e^{-\frac{1}{\pi}\left(\frac{2\pi}{T_z}\right)^4 w^{-4}}$$

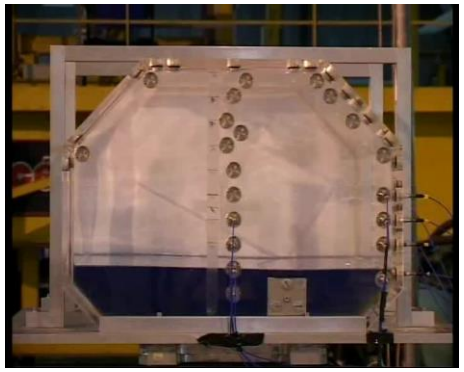


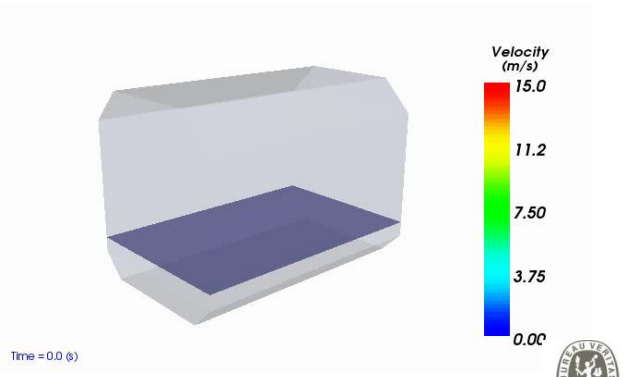


Spectral Calculations
⇨ Irregular Excitations



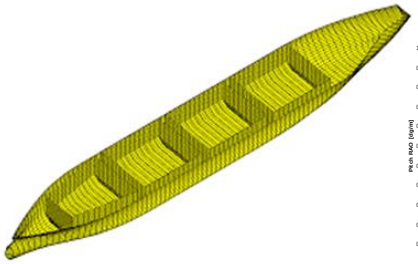
Sloshing Simulations & Sloshing Model Tests

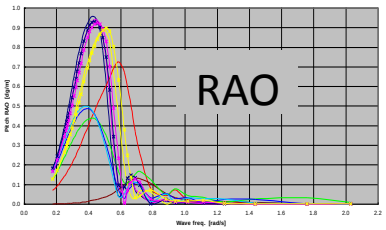




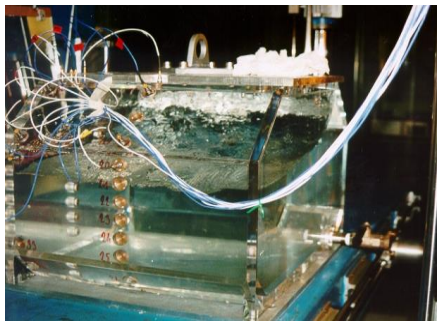
Liquid Motion analysis methodology

SEA KEEPING

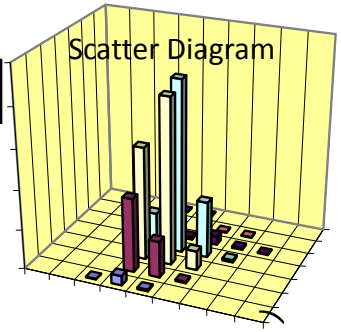




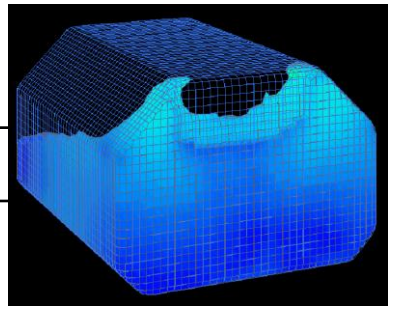
MOTIONS



MODEL TESTS



CFD SIMULATIONS



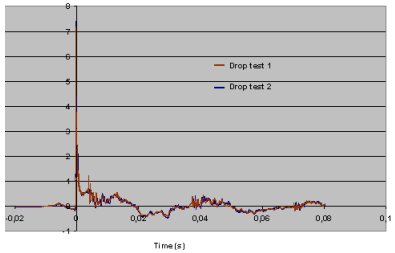
P_M

E_K, V_I, P_{QS}

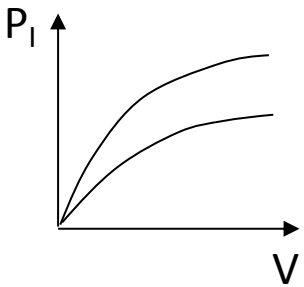
$P_I, \Delta t$

Calibration

$P_I, P_{QS}, \Delta t$



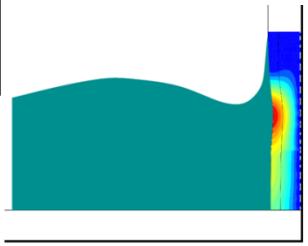
DROP TESTS

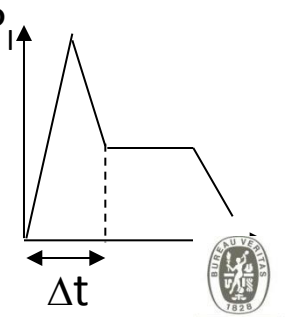


Membrane Qualification

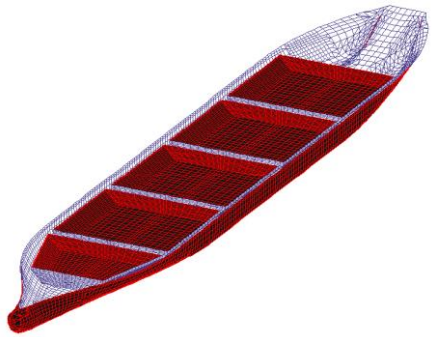
BV Rule Verification
Structural Analysis

Hull Scantlings

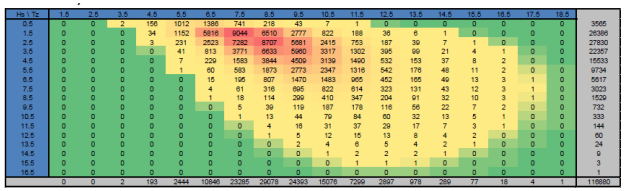




Assumption of Liquid motion analysis

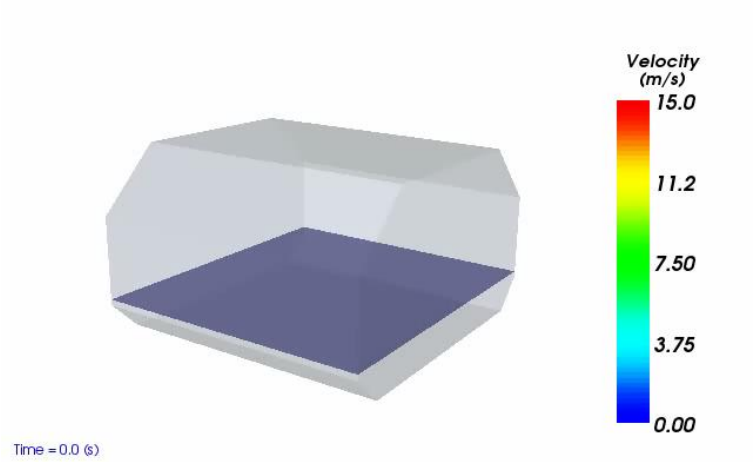


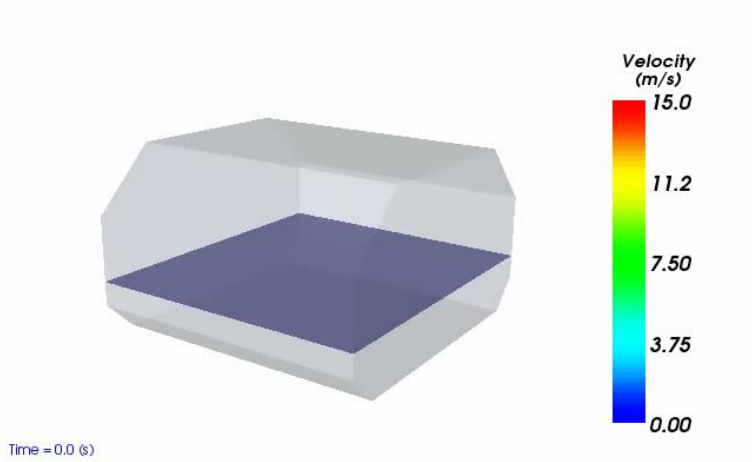
- **Hydrodynamic mesh**
  - Tanks are modeled for seakeeping/sloshing coupling.
- **Navigation mode**
  - North Atlantic 40-year scatter diagram (as recommended by IACS Rec.34)
  - Cases for each of the filling levels {10%H; 70%h & 95%H} for standard tank & tank n°1
  - 32 (cases) * 3 (filling) * 2 (std. tk/tk N1) = 192 cases (3 hours irregular motions)
- **FSRU mode**
  - Scatter diagram is provided (30 years of hindcast data),
  - Extreme cases (100 year RP) are investigated,
  - Filling levels investigated {15%H, 20%H, 25%H, 30%H, 40%H & 50%H}
  - Water Depth = 15m ⇨ Shallow water depth, V=0

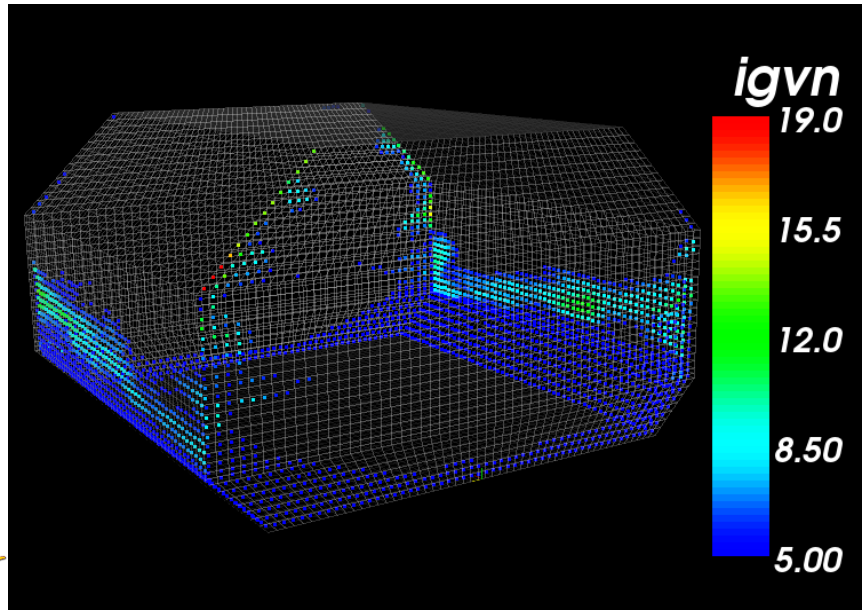


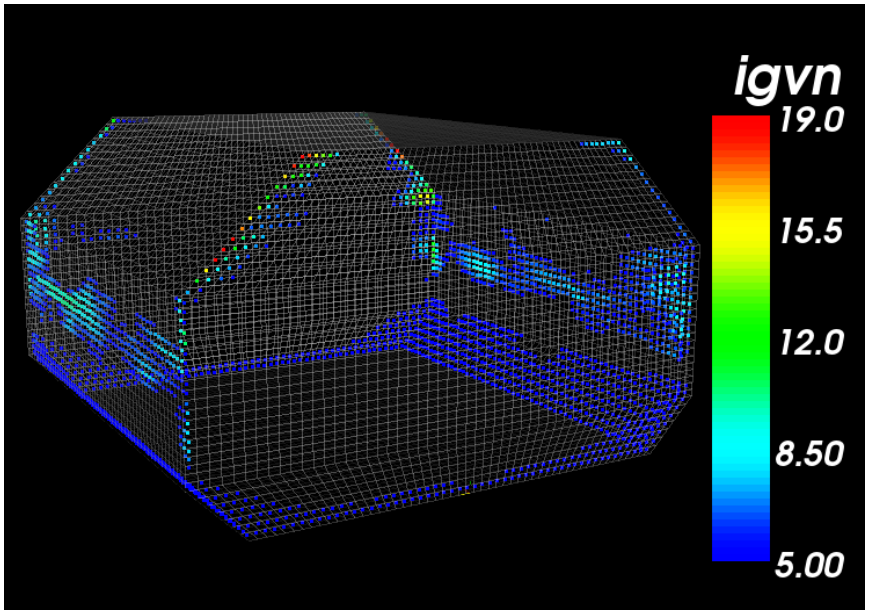
Hs \ Tz	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	
0.5	0	0	2	156	1012	1386	741	218	43	7	1	0	0	0	0	0	0	0	3565
1.5	0	0	0	34	1152	5816	9044	6610	2777	822	188	36	6	1	0	0	0	0	26386
2.5	0	0	0	3	231	2623	7282	8707	5681	2415	753	187	39	7	1	0	0	0	27830
3.5	0	0	0	0	41	813	3771	6633	5960	3317	1302	395	99	21	4	1	0	0	22367
4.5	0	0	0	0	7	229	1583	3844	4509	3139	1492	532	153	37	8	2	0	0	15533
5.5	0	0	0	0	1	60	583	1873	2773	2347	1316	542	176	48	11	2	0	0	9734
6.5	0	0	0	0	0	15	195	807	1470	1483	965	452	165	49	13	3	1	0	5617
7.5	0	0	0	0	0	4	61	316	695	822	614	323	131	43	12	3	1	0	3023
8.5	0	0	0	0	0	1	18	114	299	410	347	204	91	32	10	3	1	0	1529
9.5	0	0	0	0	0	0	5	39	119	187	178	116	56	22	7	2	0	0	732
10.5	0	0	0	0	0	0	1	13	44	79	84	60	32	13	5	1	0	0	333
11.5	0	0	0	0	0	0	0	4	16	31	37	29	17	7	3	1	0	0	144
12.5	0	0	0	0	0	0	0	1	5	12	15	13	8	4	2	0	0	0	60
13.5	0	0	0	0	0	0	0	0	2	4	6	5	4	2	1	0	0	0	24
14.5	0	0	0	0	0	0	0	0	0	1	2	2	2	1	0	0	0	0	9
15.5	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	3
16.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	0	0	2	193	2444	10946	23285	29078	24393	15076	7299	2897	978	289	77	18	4	1	116680

Liquid motion analysis - Results



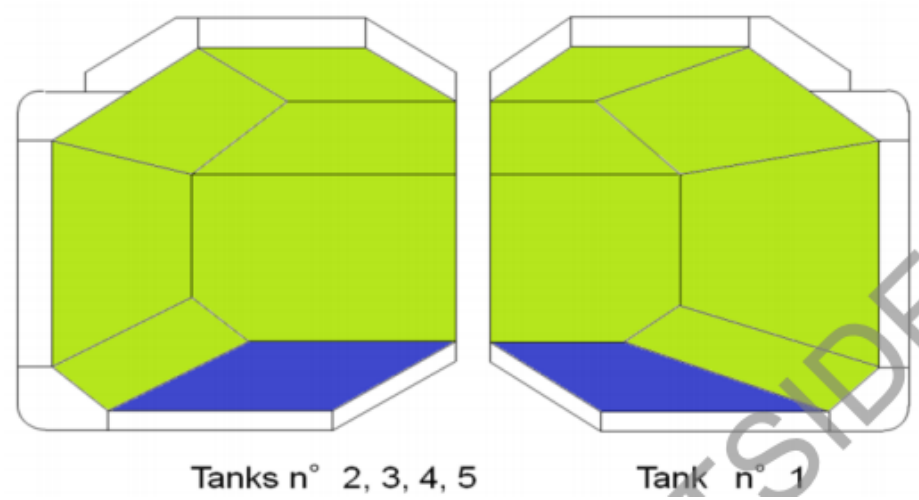


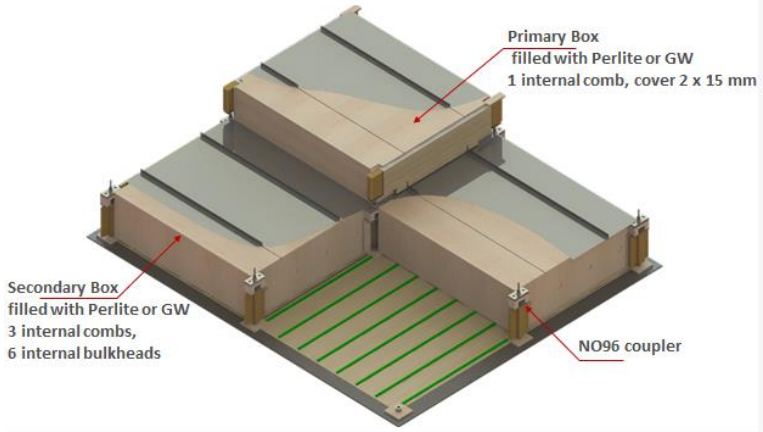




Conclusion of liquid motion analysis - BV approval of CCS

First, BV has no objection regarding the conclusion of the project. The conclusion is that the Cargo Containment System (NO96 Mega Reinforced) is suitable to sustain the sloshing loads in the different cargo tanks when the ship is operated for 40 years of navigation in North Atlantic conditions within the standard filling limits (below 10%H and above 70%H) and without any filling limitation in FSRU mode for regas conditions on the site.





Design NO96 mega-renforcé

NO 96 CCS configuration

Mega Reinforced

Standard

Résistance – Modèle 2D

Several transverse sections analysed along the ship length for :

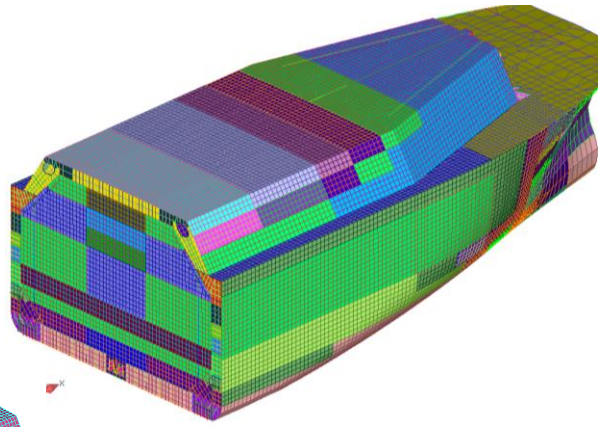
- Longitudinal strength assessment,
- Longitudinal ordinay stiffeners,
- Plating thickness between stiffeners.

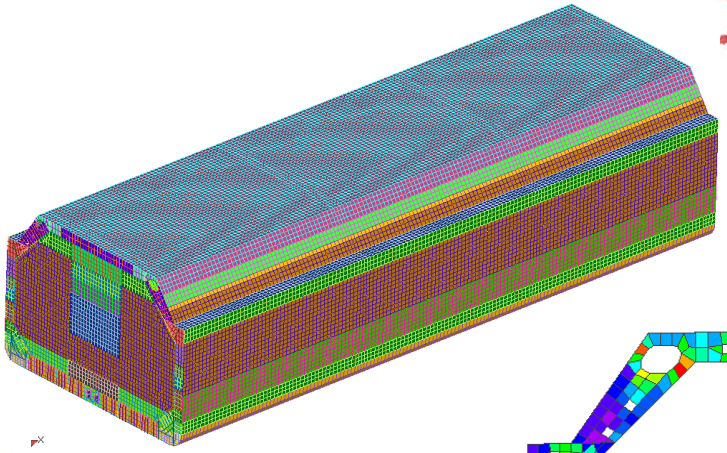
Strength analysis – Modèle 3D

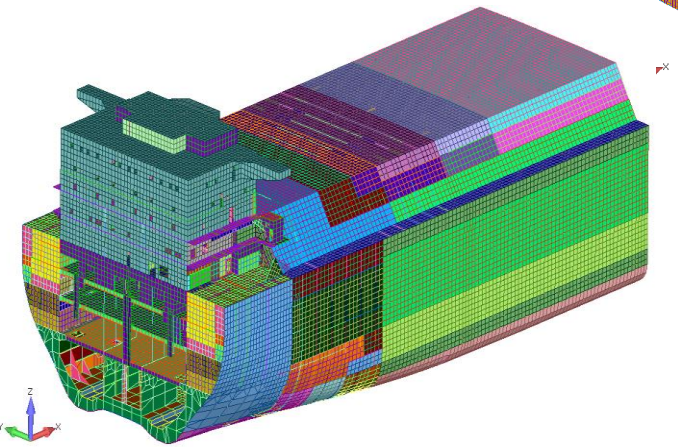
3 structural models extended over 3 cargo tanks:

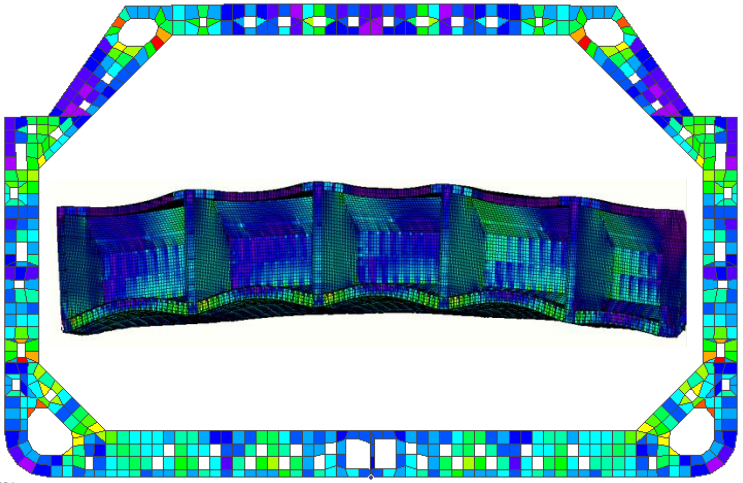
- Typical tanks at Midship,
- Fore tank and trunck deck end,
- Aft tank and connection with accomodation.

Assessment of the primary structural members.



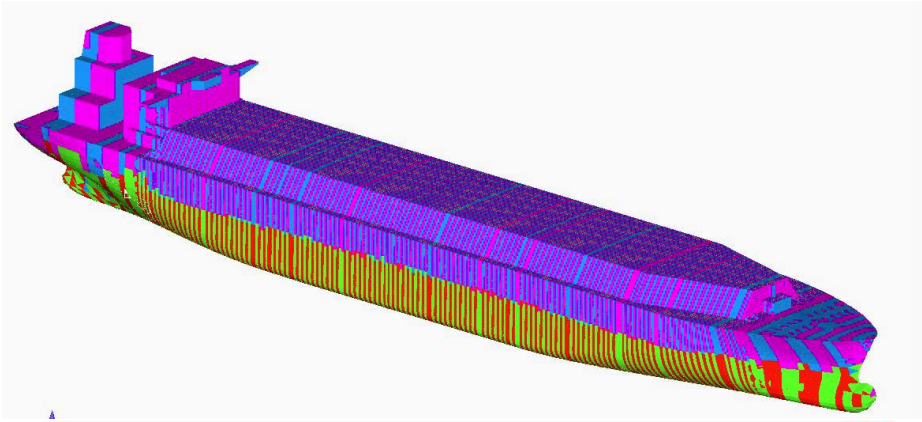


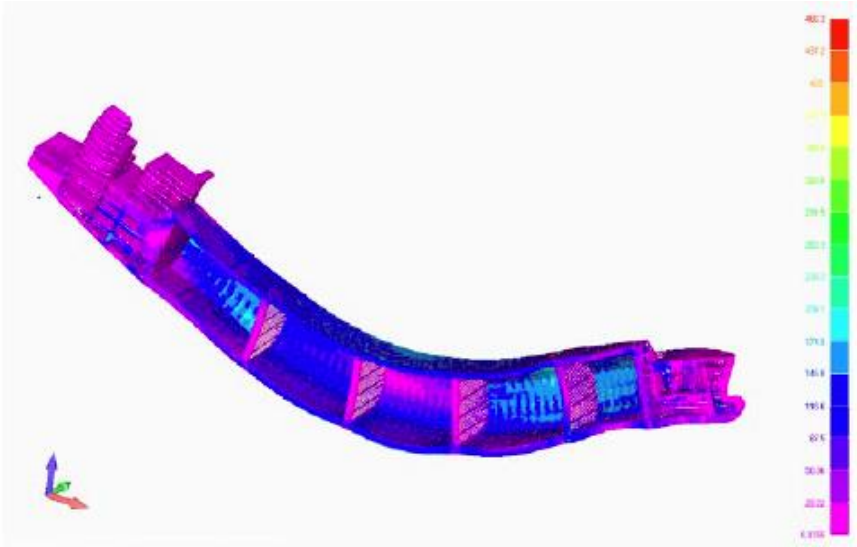


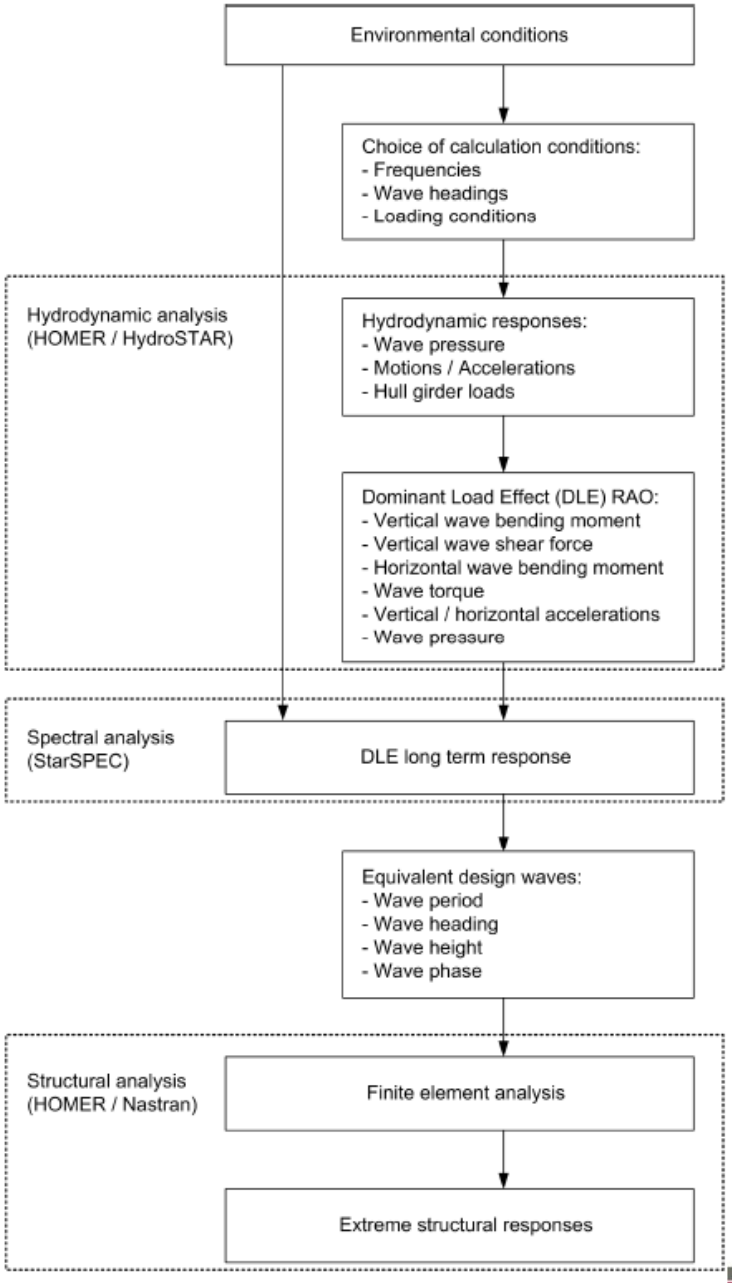


Strength – Full ship model

- VeriSTAR Hull FLM (FLM: Full Length Model)
- Méthodology of the equivalent design wave.



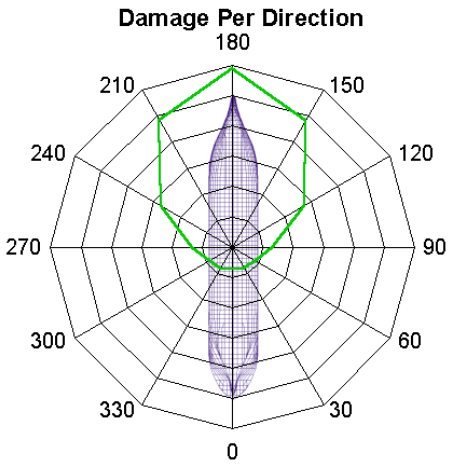


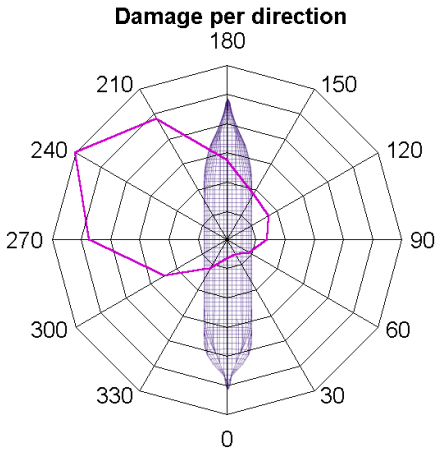


Spectral Fatigue analysis for Offshore units

Typical Spectral Fatigue Analysis

(more than 1000 load cases)





Structural Mesh

↓

Hydrodynamic Calculation

↓

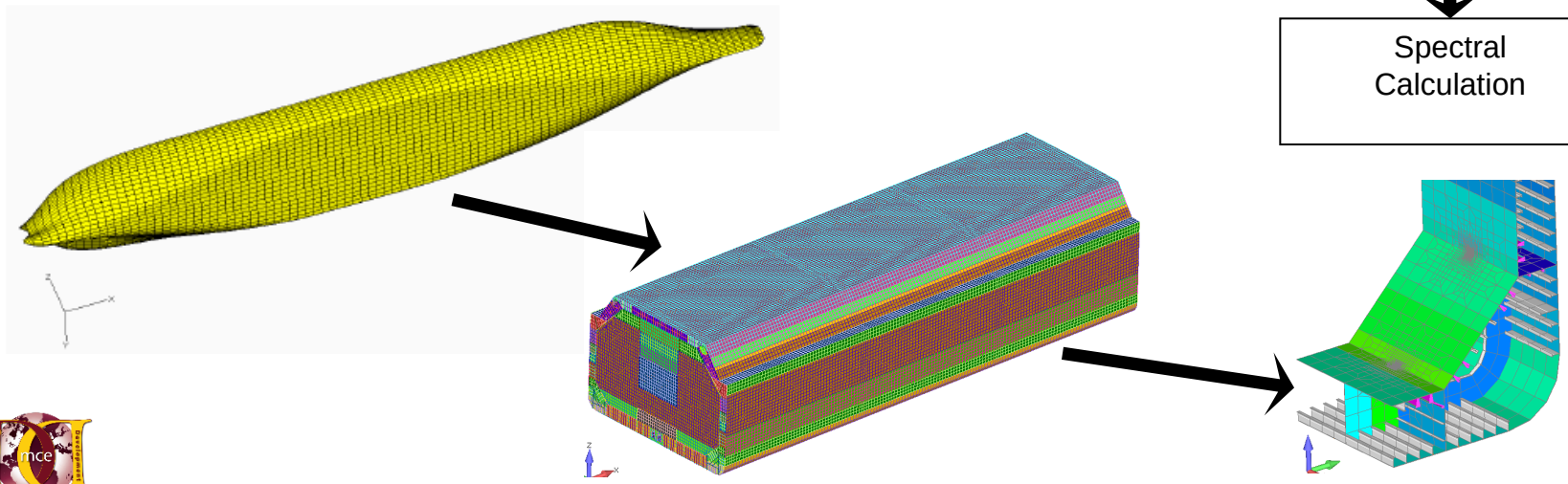
Coarse Mesh Calculation

↓

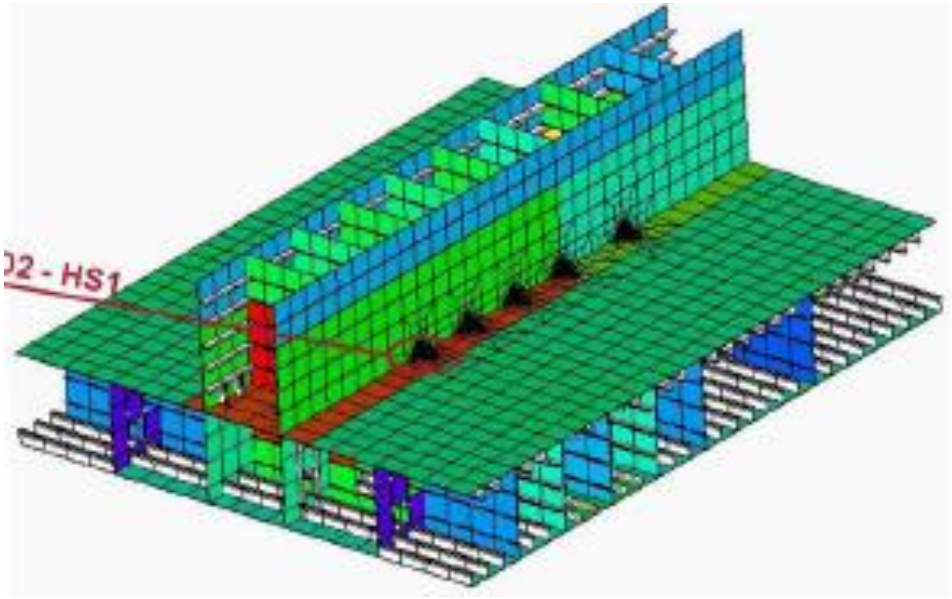
Fine Mesh Calculation

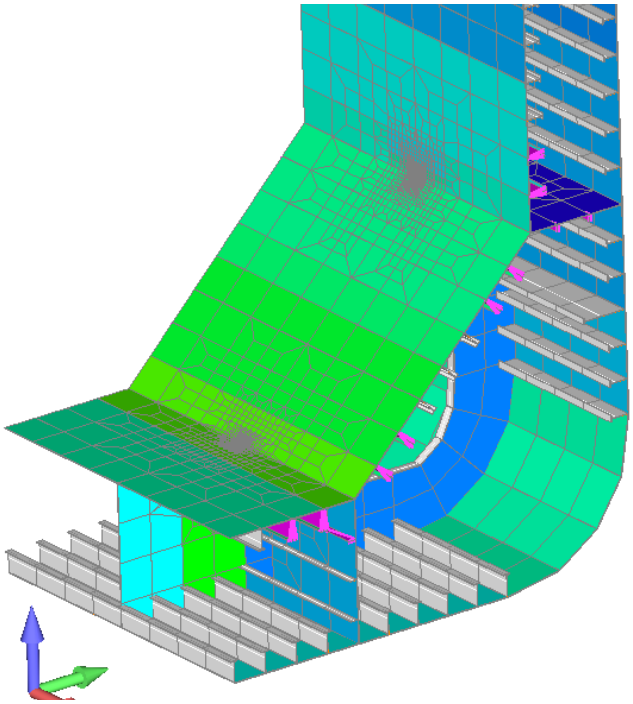
↓

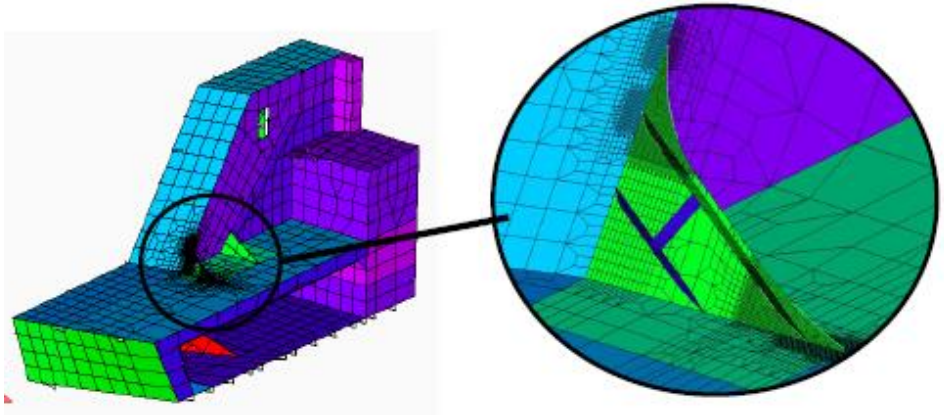
Spectral Calculation

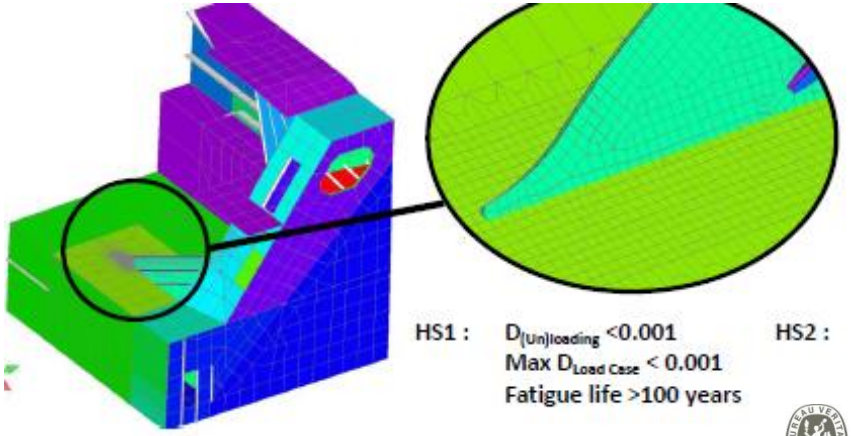


Fatigue strength assessment – Analysed Hot spots









HS1 : $D_{(Un)loading}$ <0.001
Max $D_{Load\ Case}$ < 0.001
Fatigue life >100 years

HS2 :

Conclusion

- Classification of the largest FSRU,
- Several independant analysis were carried out,
- Use of most advanced methodologies,
- Validation of reinforcements for partial fillings,
- Assessment of the Cargo containment system,
- Assessment of the structure strength under extreme loads,
- Fatigue assessment.

Thank you for your attention!

BUREAU VERITAS

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