

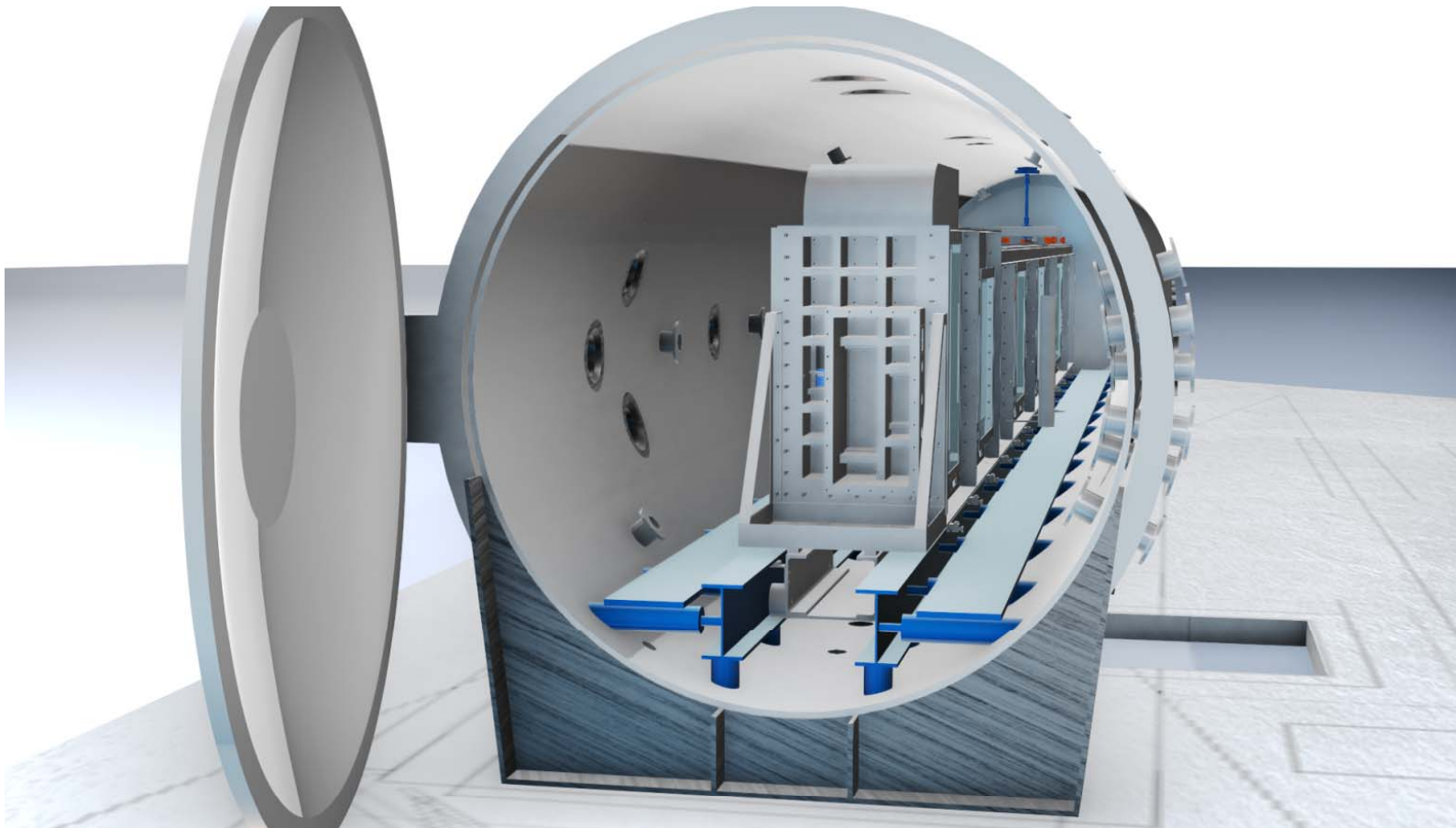
Multiphase Wave Lab

Introduction



18th October 2017 – Multiphase Workshop 2017 – Paris

New facility under construction



Safe and cost-effective storage and transport of LNG

LNG PITCH-4
Product development



Phase Transition
Applied research



SLING
Fundamental research



Applied and Engineering Sciences



UNIVERSITY OF TWENTE.



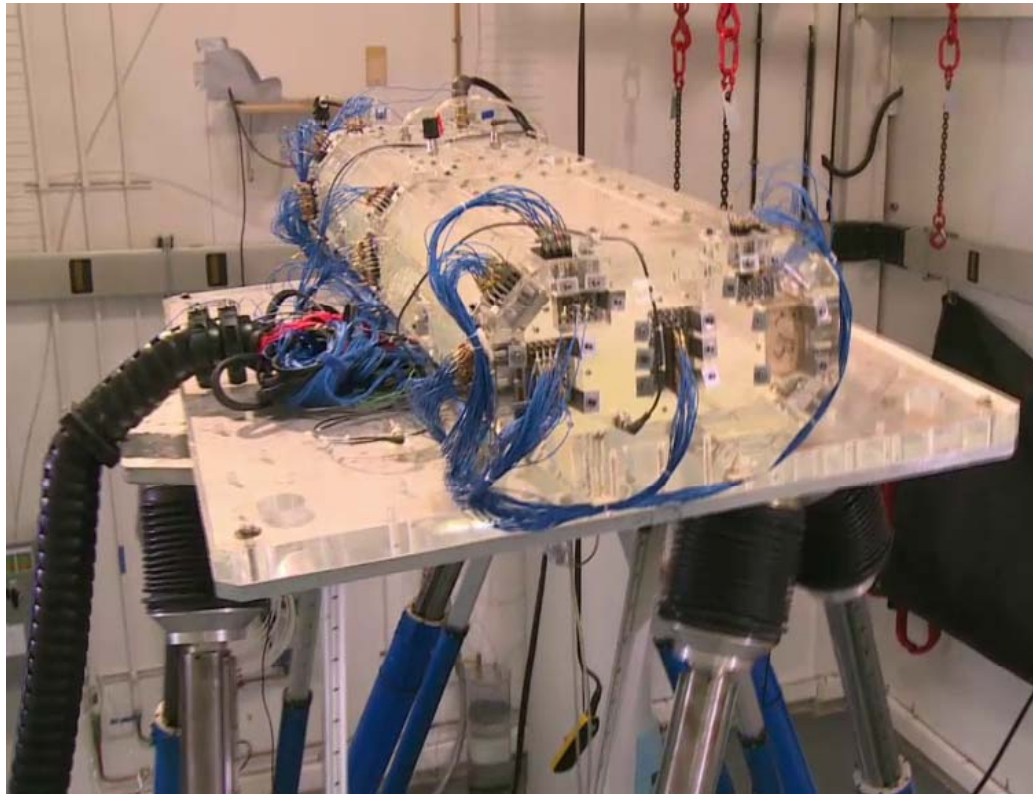
university of groningen



femto | E engineering



Sloshing model tests

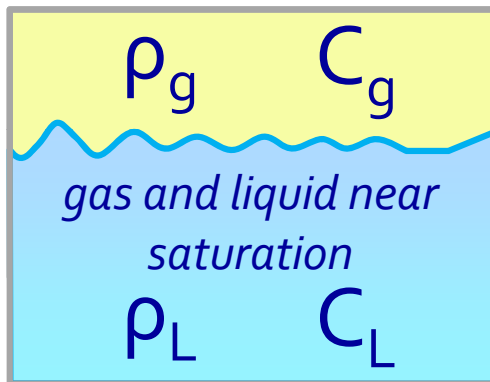


Correctly scaled
 Not present
 Biased

- Transfer of liquid momentum to gas momentum (DR)
- Development of free surface instabilities
- Compression of escaping gas (GC)
- Compression of entrapped gas (GC)
- Phase transition (PT)
- Change of liquid momentum
- Compression of liquid (LC)
- Fluid structure interaction (FSI)
- Propagation of time-space distributed loads through composite structure



Sloshing model tests – control options

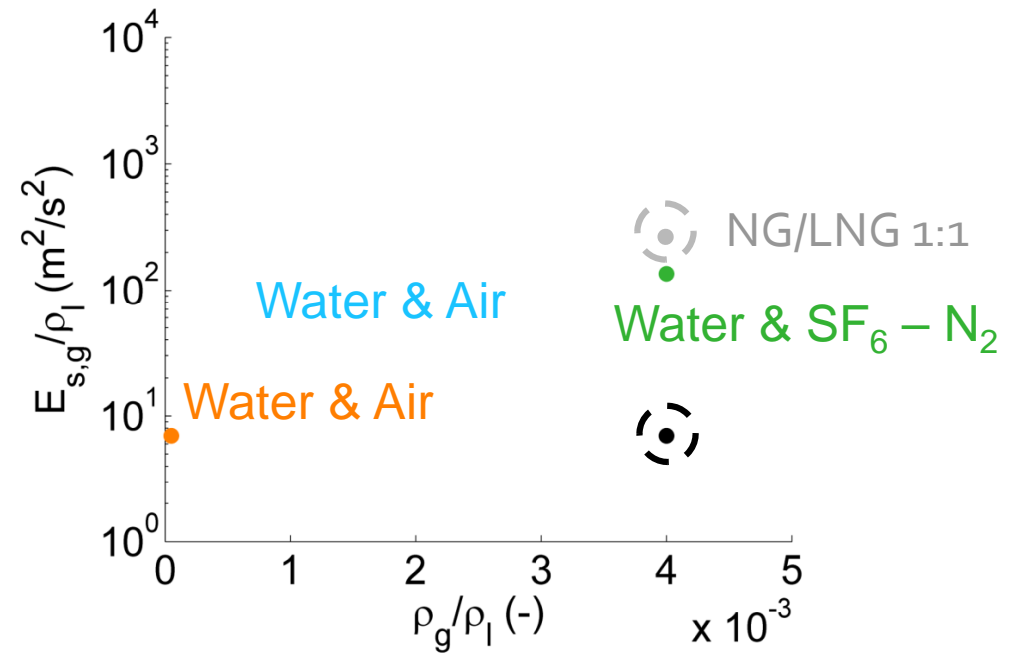
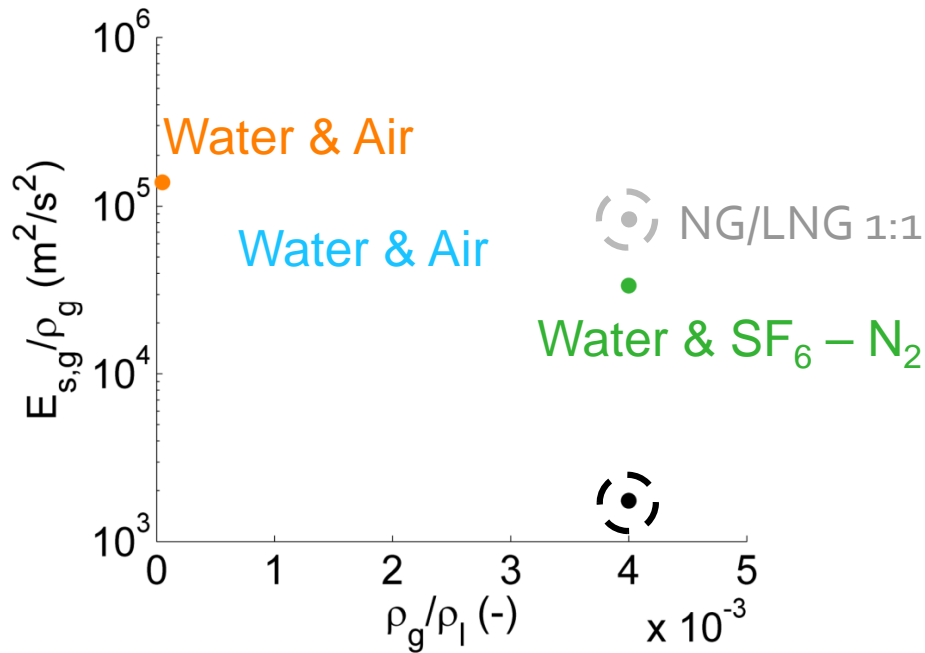


- ρ (density): ↗
 - M (molar mass) ↗, p (pressure) ↗, T (temperature) ↘
- C (speed of sound): ↗

$$c = \sqrt{\left(\frac{\partial p}{\partial \rho}\right)_s}$$
 s : isentropic process
 - M (molar mass) ↘, T (temperature) ↗
- E (bulk modulus or modulus of compressibility)

$$E = \rho \frac{dp}{d\rho}$$
 - Property: depends on process (isothermal to isentropic)

Density ratio & Gas compressibility & Phase Transition



P = 1 bar, T=20°C - 97.7% Air and 2.3% H₂O - Liquid H₂O

Similarity for level approximation: Global flow + DR + GC + PT

P = 1 bar, T=20°C - 59% SF₆, 38.7% N₂ and 2.3% H₂O - Liquid H₂O

P = 0.05 bar, T=20°C - 55% Air and 45% H₂O - Liquid H₂O



PhaseTransition JIP (2013)

Objective: identify effect of multiphase dynamics on sloshing loads

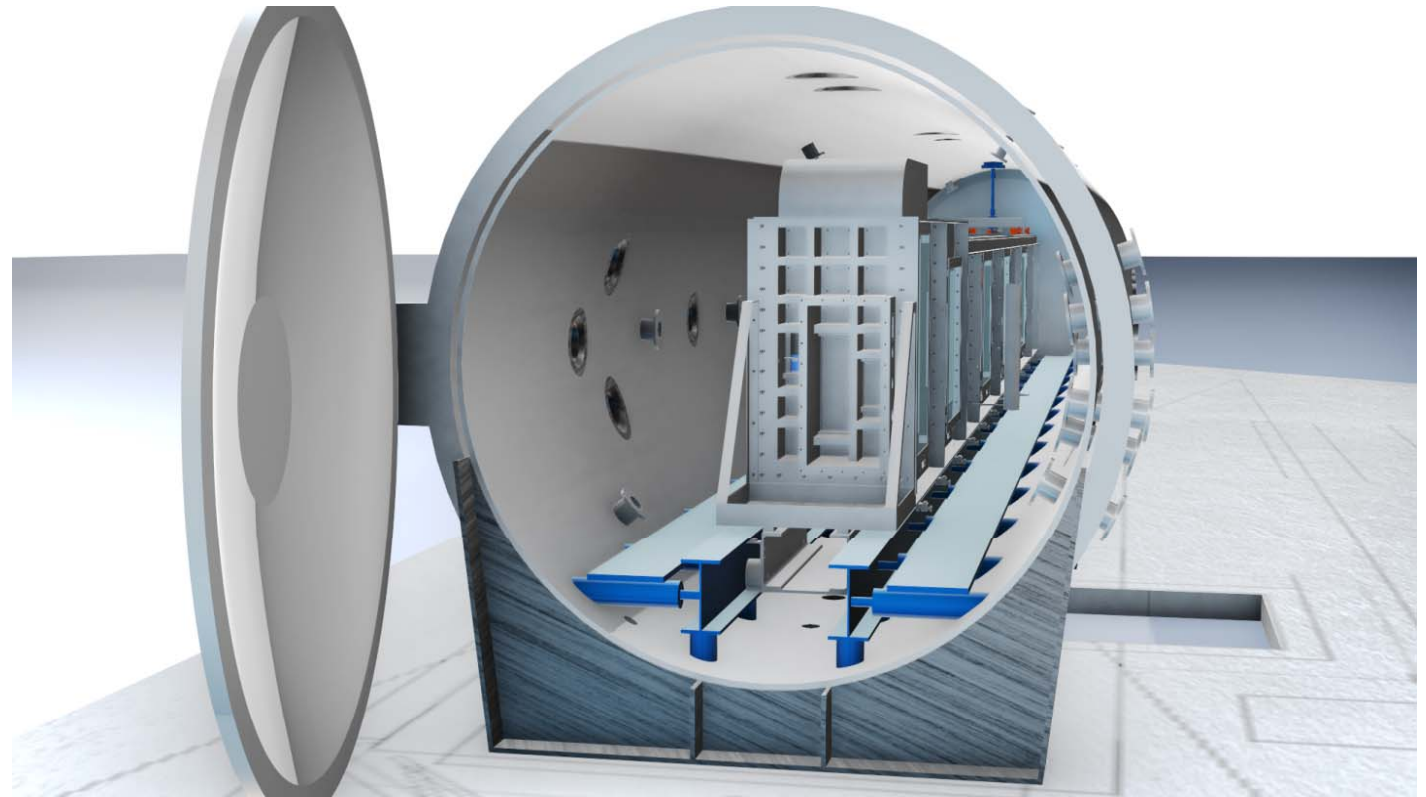
ClassNK



MARIN



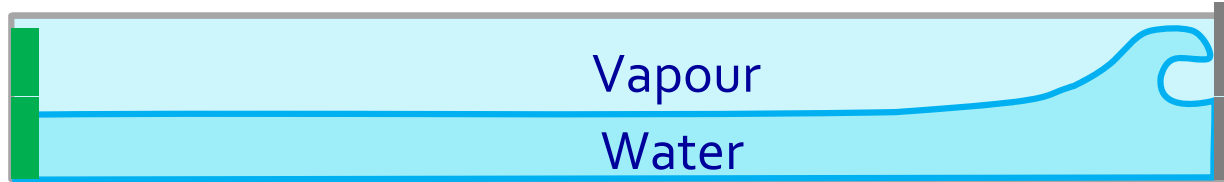
TOTAL



Wave impact tests

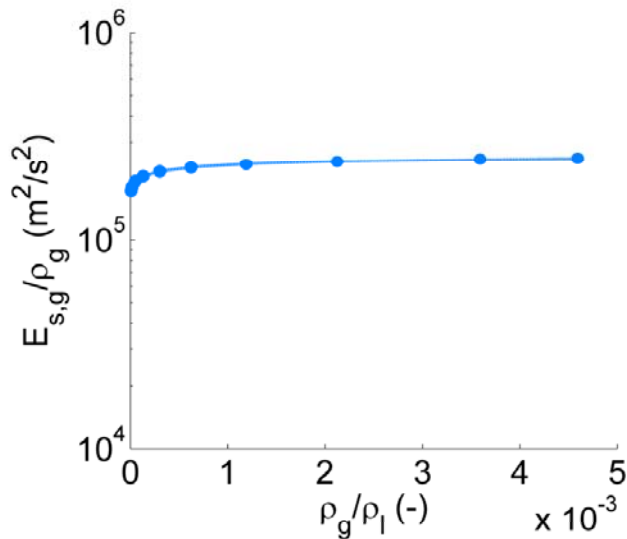
wave generator

impact wall

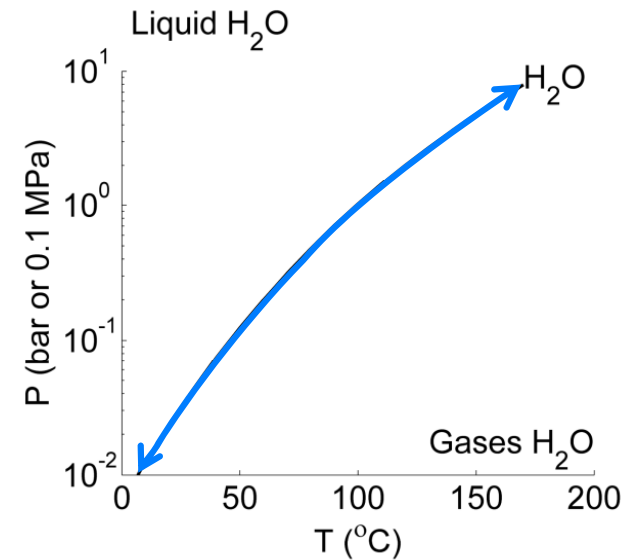


1. Test conditions: condensable gas

Gas Compressibility



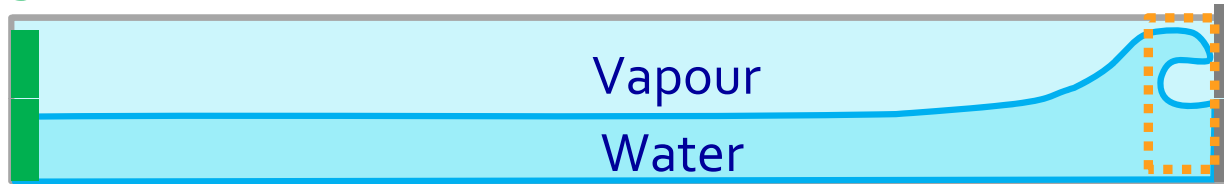
Density ratio



Wave impact tests

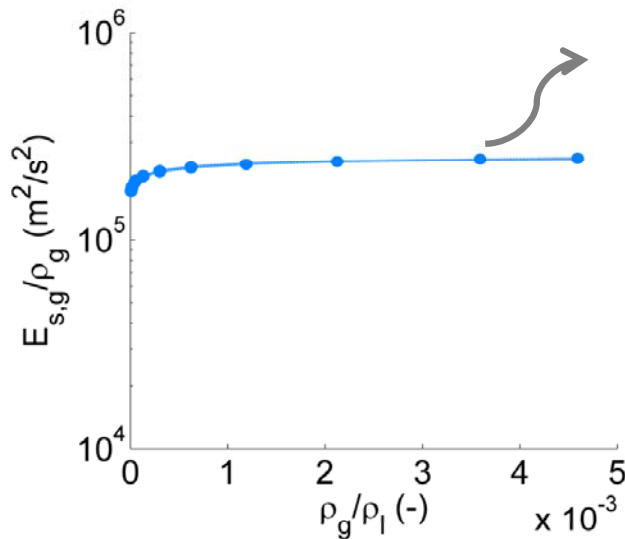
wave generator

impact wall



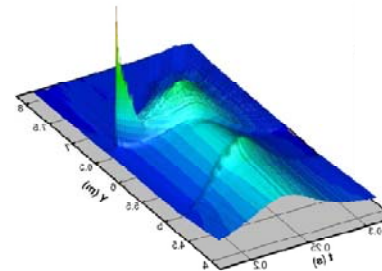
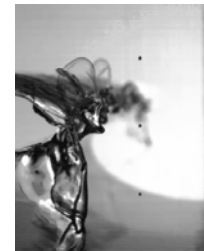
1. Test conditions: condensable gas

Gas Compressibility

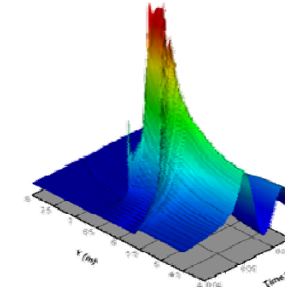


Density ratio

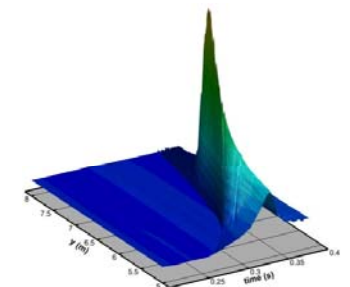
Large gas pocket



Small gas pocket



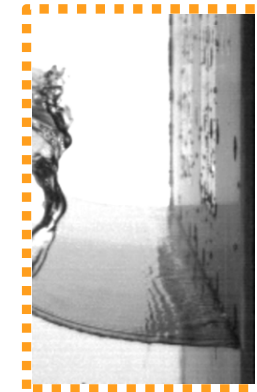
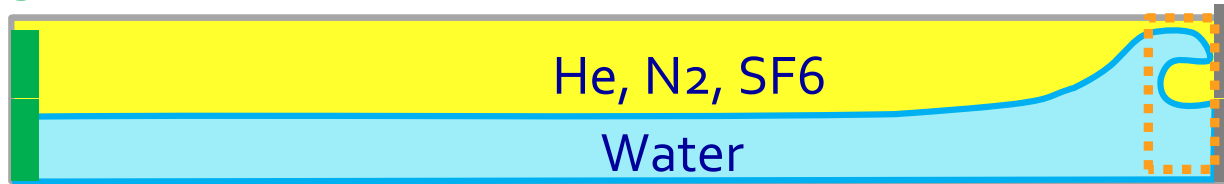
Sharp slosh



Wave impact tests

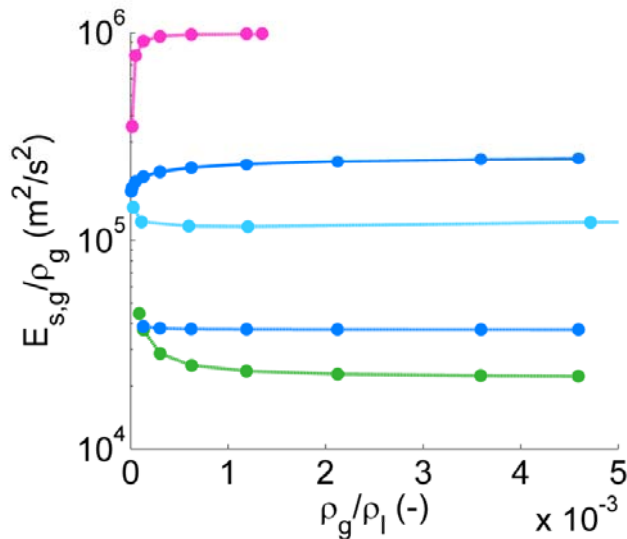
wave generator

impact wall



2. Test conditions: non-condensable gas

Gas
Compressibility

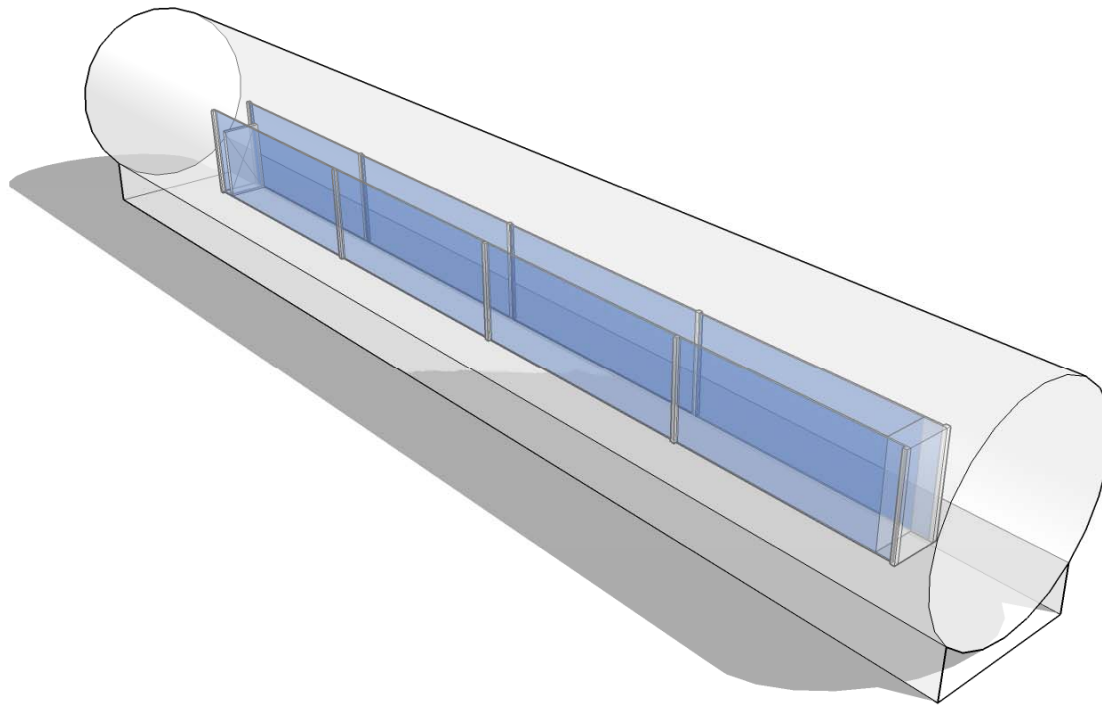


Density ratio

- Pressure: 5 mbar to 10 bar
- Temperature: 5°C to 200°C
- Gases: SF6, He, N2, Steam

Phase Transition JIP - Feasibility study 2013

- Open test tank in cylindrical pressure vessel



PhaseTransition JIP - Feasibility study 2013

- Open test tank in cylindrical pressure vessel

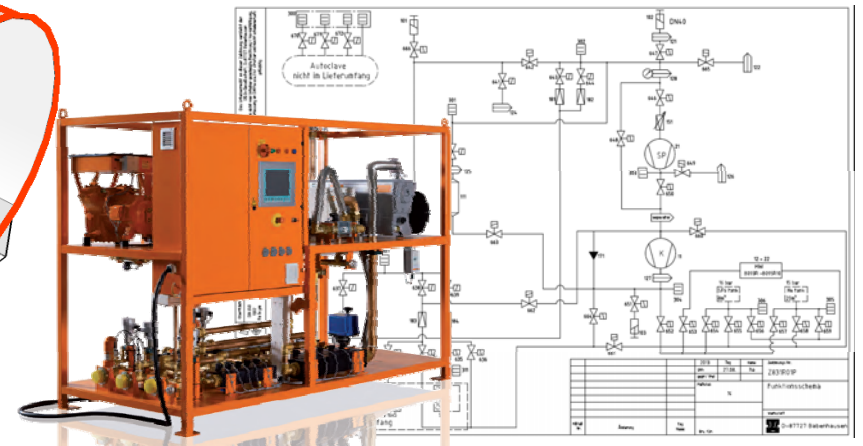
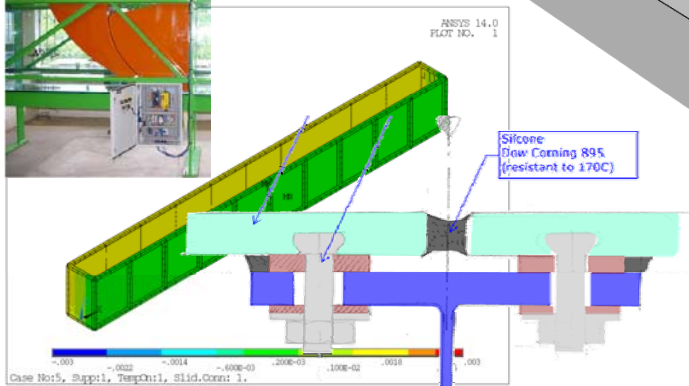
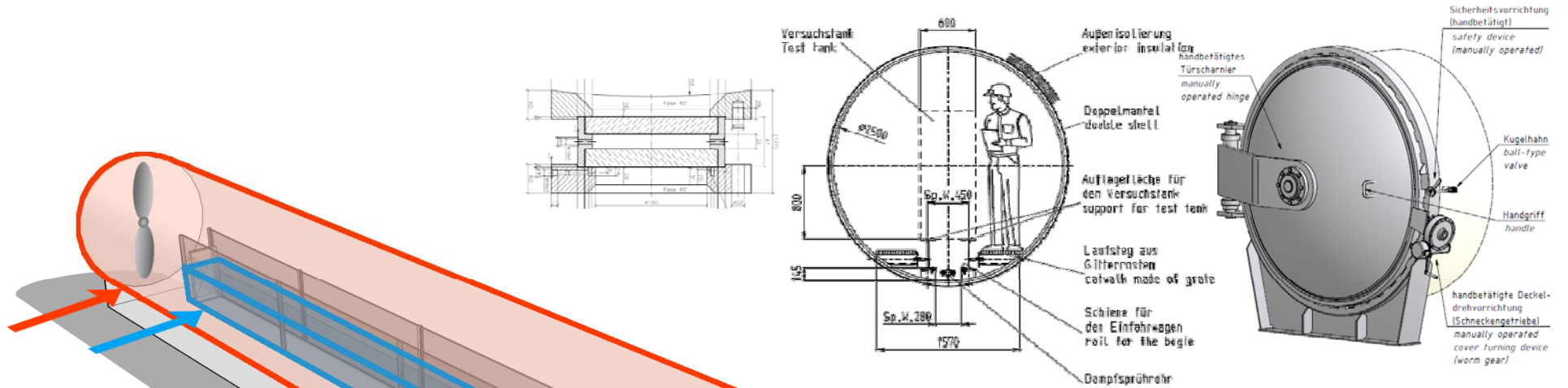


FOKKER
AEROSTRUCTURES

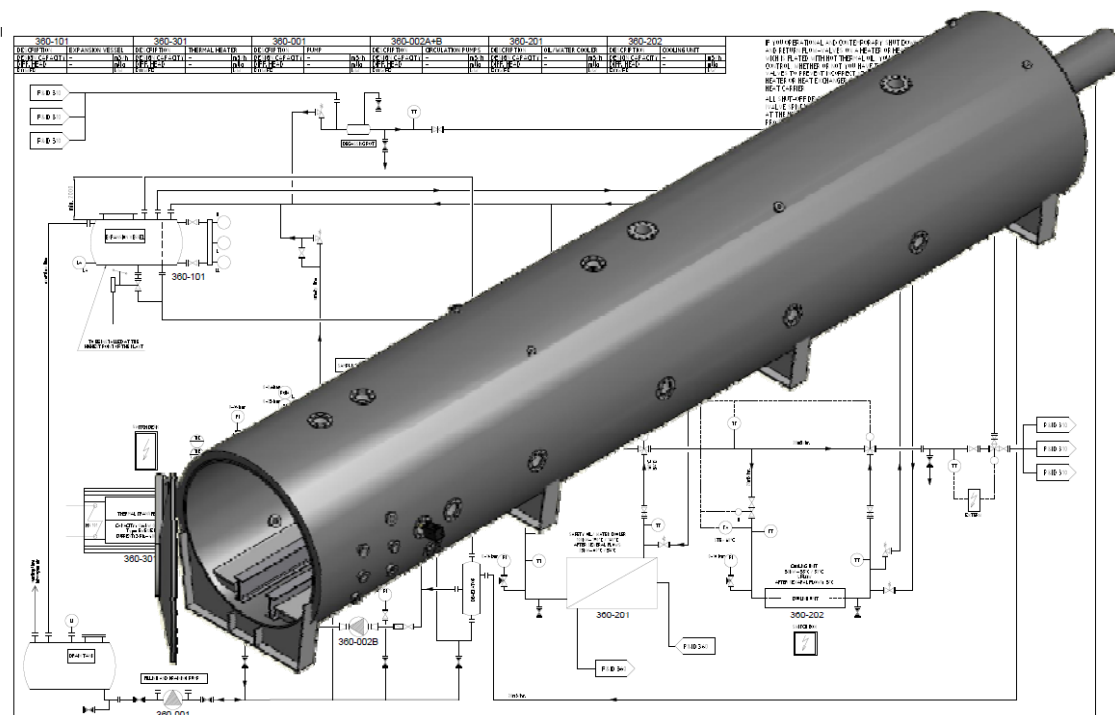
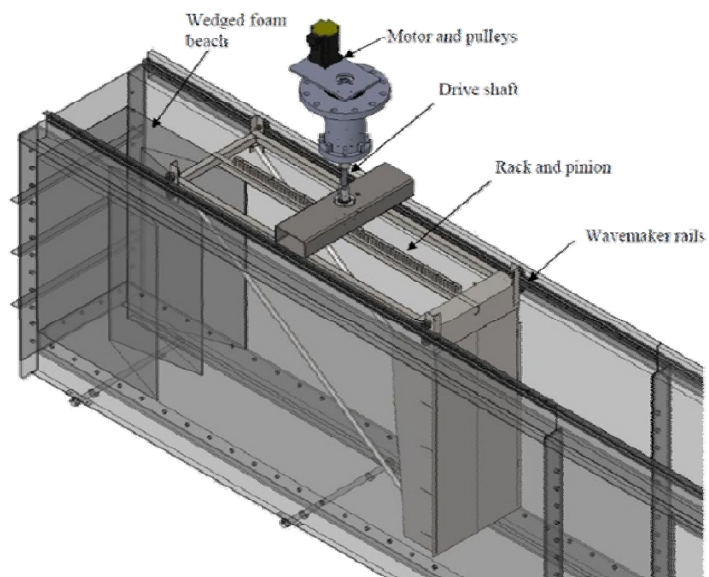


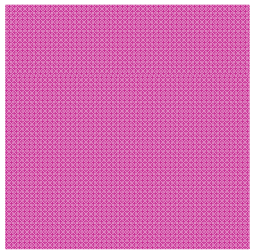
HZDR
HELMHOLTZ
ZENTRUM DRESDEN
ROSSENDORF

Phase Transition JIP - Feasibility study September 2013



Phase Transition JIP - Basic engineering August 2014





Launch of SLING Programme



SLING Programme

- 4 universities, 5 faculties



UNIVERSITY OF TWENTE.

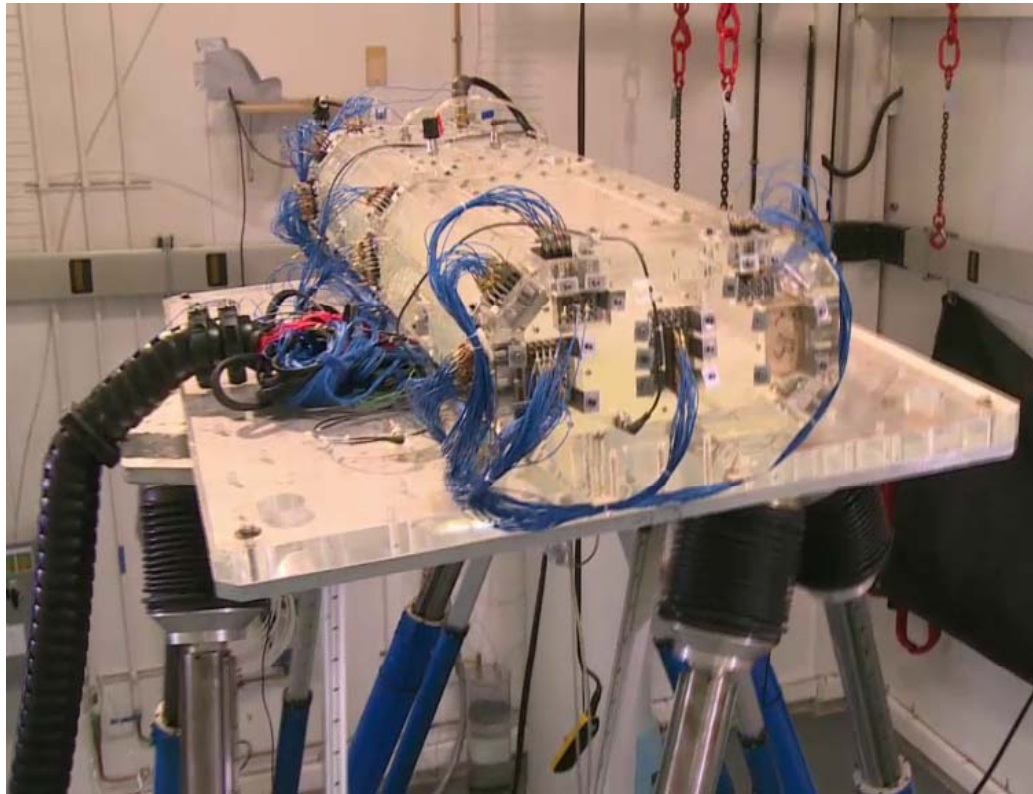
- Ship & Offshore structures: Prof. dr. ir. M.L.Kaminski
- Process & Energy: Prof. dr. ir. J. Westerweel
- Inst. of Math. & Computing Science: Prof. dr. ir. R.W.C.P. Verstappen
- Depart. of Math. & Computer Science: Prof. dr. ir. B. Koren
- Physics of Fluids: Prof. dr. D. Lohse

- User committee



- 5.35 M Euro Innovation programme, of which 3.45 M Euro from STW
- Programme duration of 5 years (started in April 2016)

3 thematic projects



- Transfer of liquid momentum to gas momentum (DR)
- Development of free surface instabilities
- Compression of escaping gas (GC)
- Compression of entrapped gas (GC)
- Phase transition (PT)
- Change of liquid momentum
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3 thematic projects

Project 1

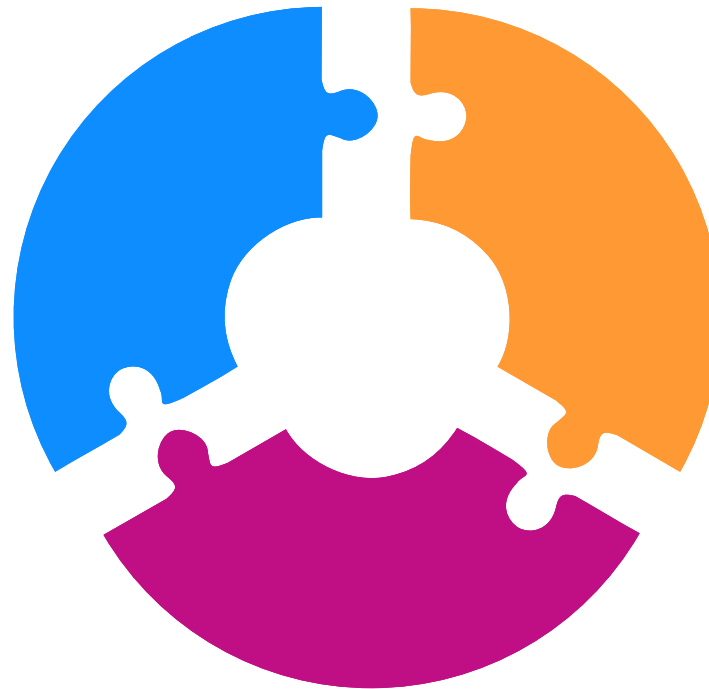
Multiphase dynamics

Objective:
identify separate and
combined effect of DR, GC, LC
and PT on liquid impact loads

Project 2

Variability of impact loads

Objectives:
determine the development of
free surface instabilities and
their effect on variability of
impact pressures

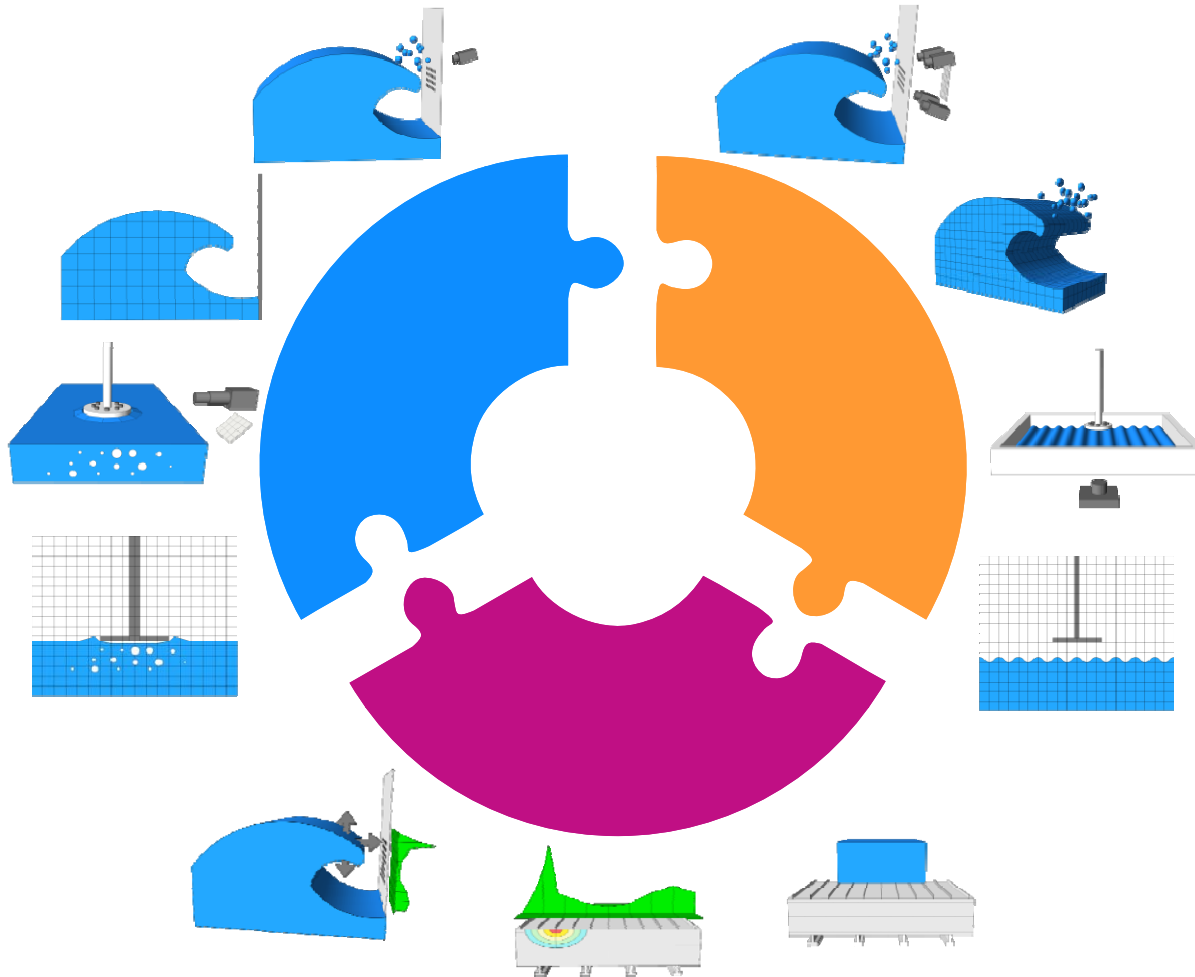


Project 3 Structural response

Objectives:
determine the effective part of the load and
quantify the effect of the structural response on impact loads



3 thematic projects

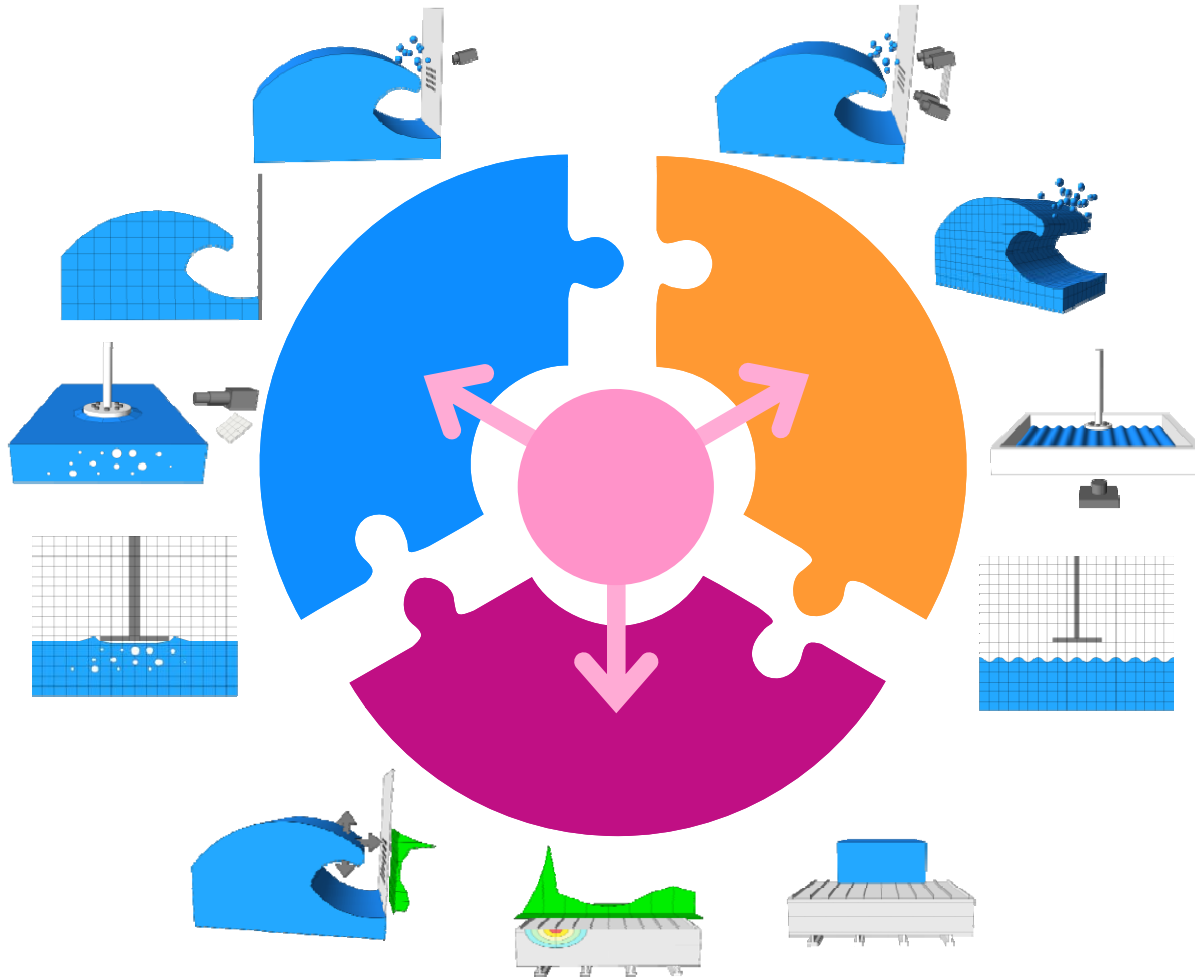


Project 1 - Multiphase dynamics

Project 2 - Variability of impact loads

Project 3 - Structural response

Supporting project



Project 1 - Multiphase dynamics

Project 2 - Variability of impact loads

Project 3 - Structural response

Project 5 - Multiphase set-up design

Overarching project: integration



Project 1 - Multiphase dynamics

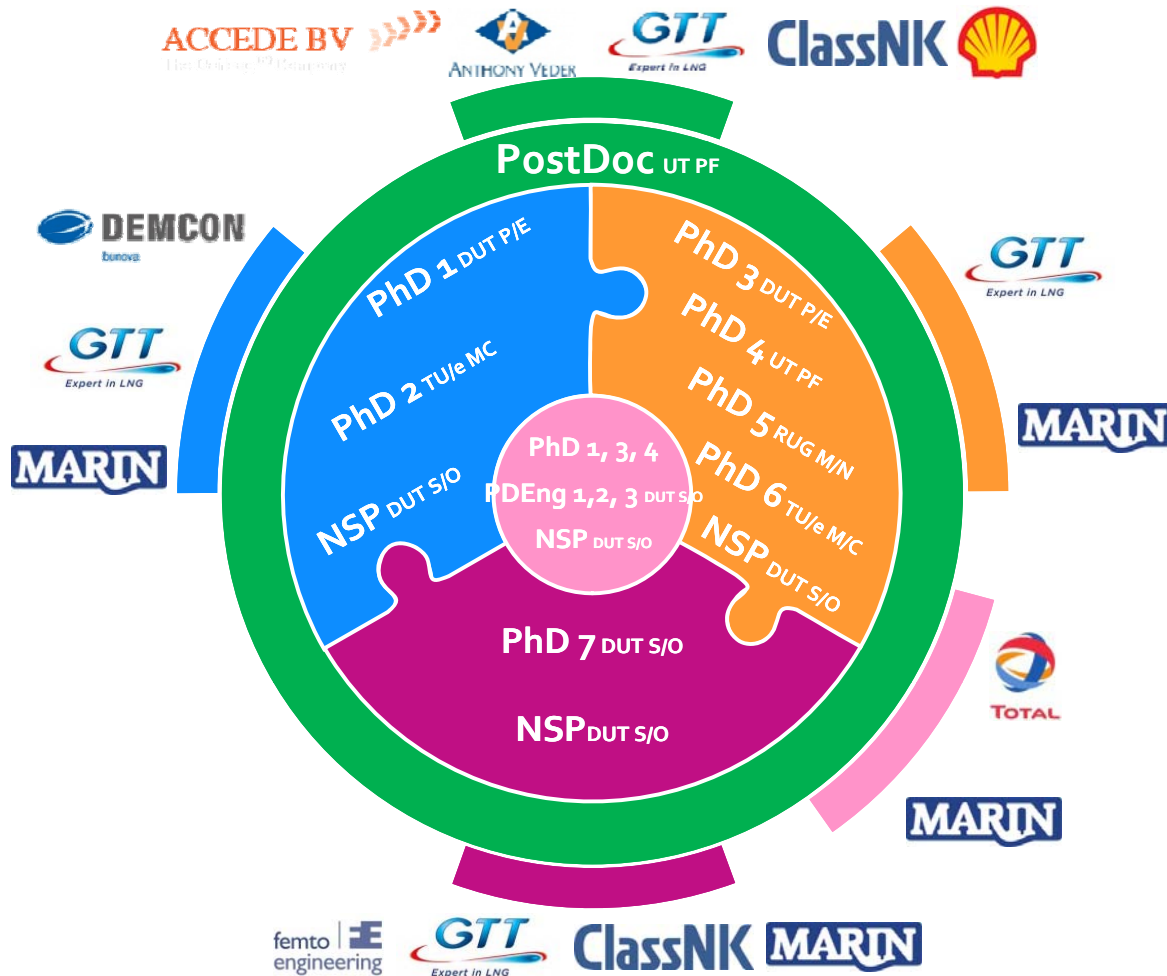
Project 2 - Variability of impact loads

Project 3 - Structural response

Project 4 - Sloshing assessment

Project 5 - Multiphase set-up design

SLING's task force



- Research team:

- 7 PhDs
- 1 Postdoc
- 3 Professional Doctorates in Engineering (PDEng)
- 1 Non-Scientific personnel (NSP)

TU Delft TU/e Technische Universiteit Eindhoven University of Technology

university of groningen UNIVERSITY OF TWENTE.

- Users (in-kind contributions)

Researcher team

- **Project 1**



PhD 1:
Wout
Cornel



PhD 2:
Rien
de Böck

- **Project 2**



PhD 3:
Mike van
Meerkerk



PhD 4:
Utkarsh
Jain



PhD 5:
Ronald
Remmerswaal



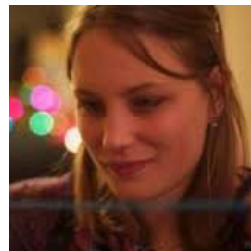
PhD 6:
Yous
van Halder

- **Project 3**



PhD 7:
Reinier
Bos

- **Project 4**

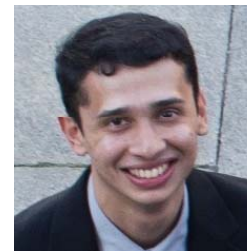


PostDoc:
Anais
Gauthier

- **Project 5**



PDEng 1:
Panagiotis
Efsthathiou



PDEng 2 :
Ashwin
Fernandes



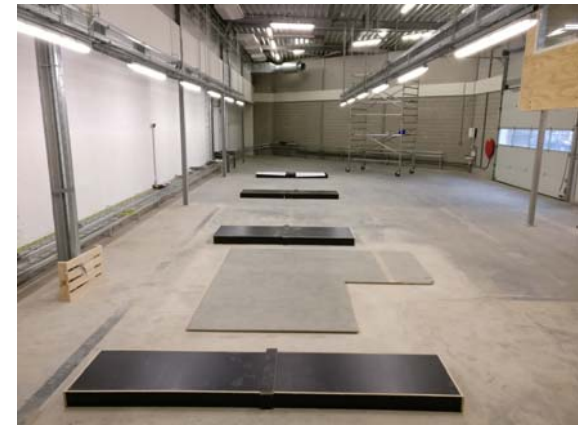
PDEng 3 :
Vladimir
Novakovic



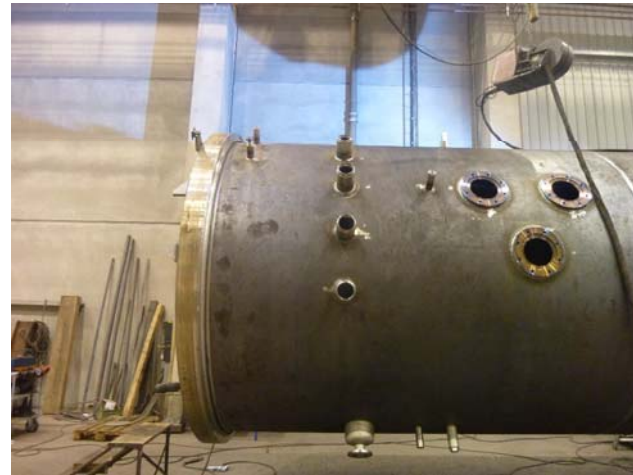
NSP:
Vladimir
Novakovic

Multiphase Wave Lab (MWL) - Status Infrastructure

- Construction works started in May 2016



MWL- Autoclave



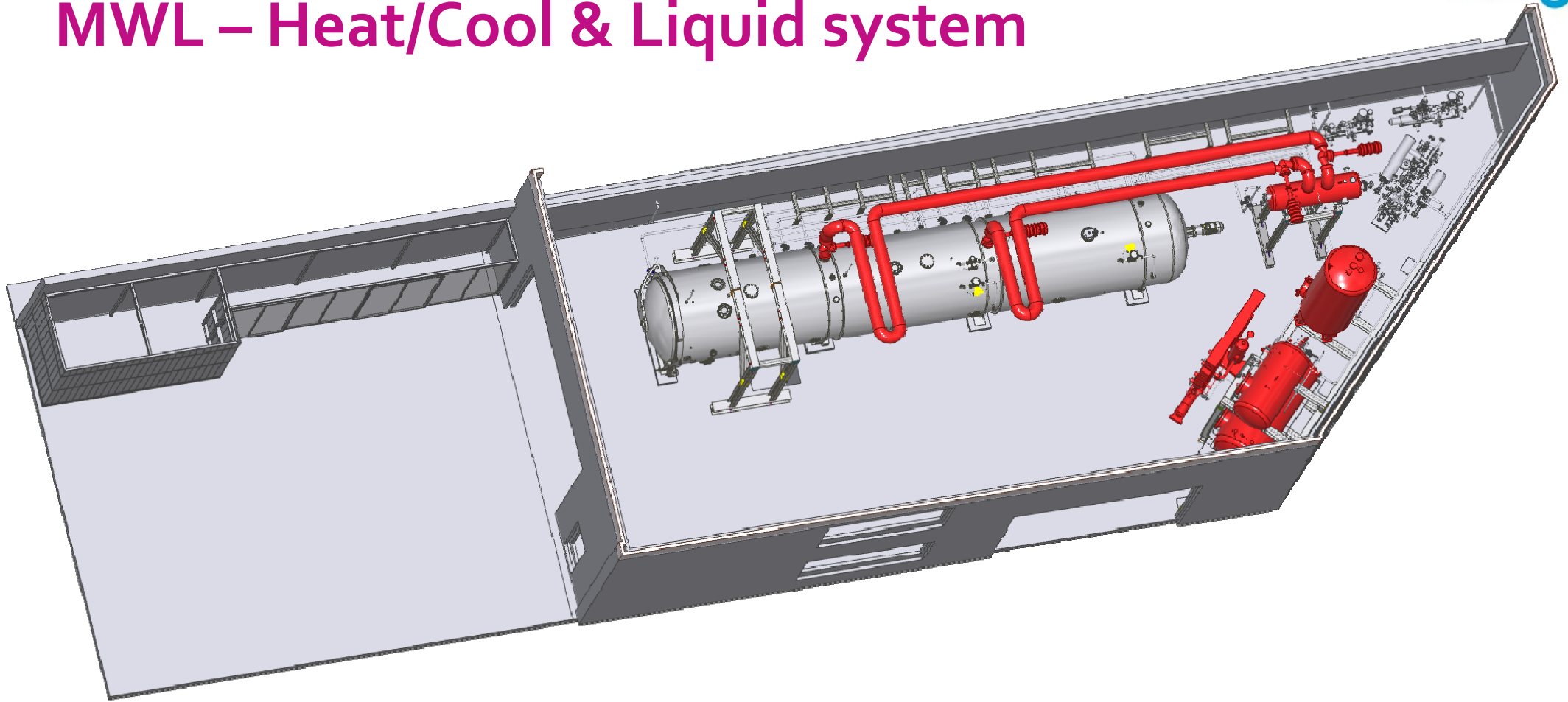
MWL- Autoclave



MWL – Heat/Cool & Liquid system



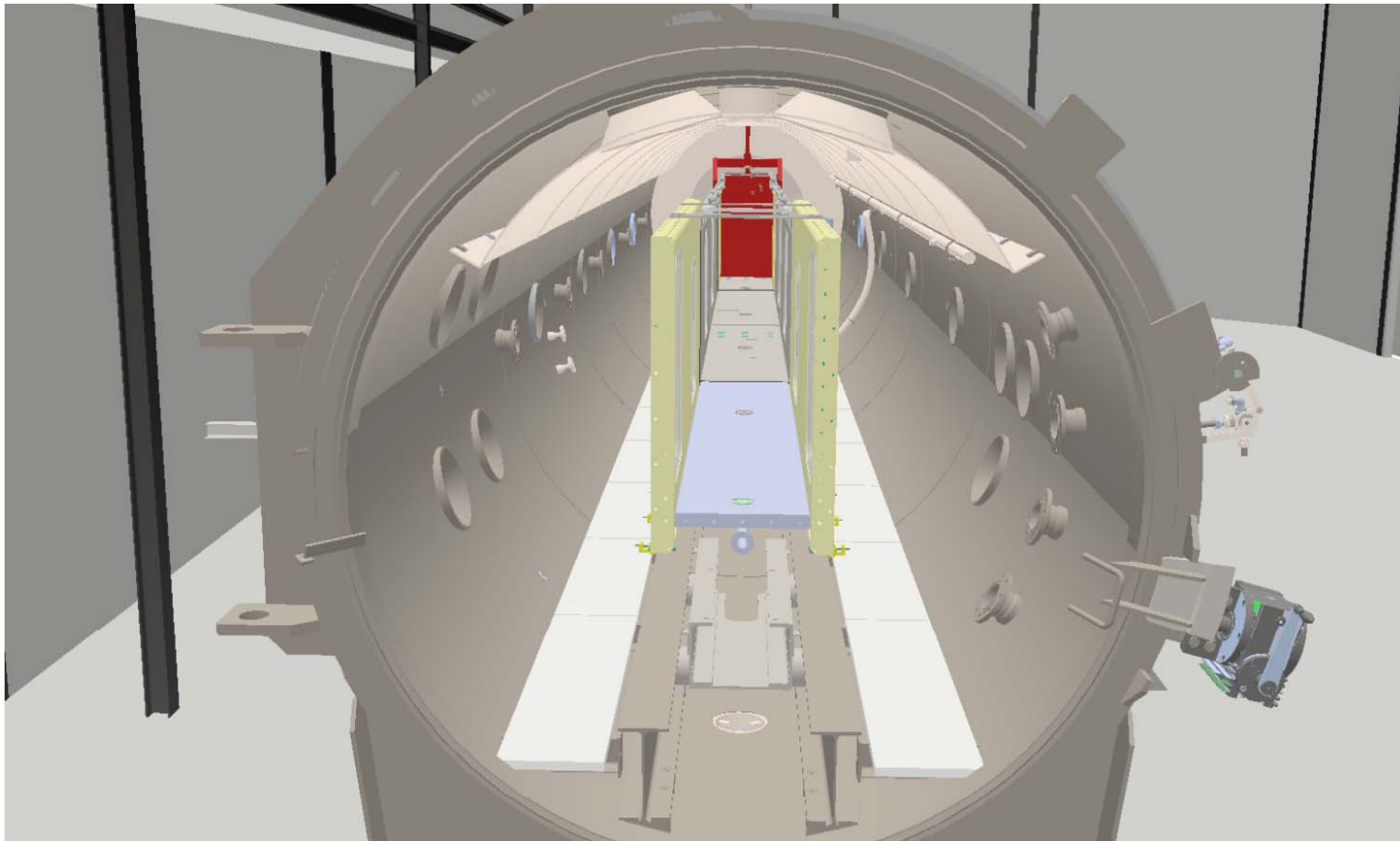
MWL – Heat/Cool & Liquid system



MWL– Gas system



MWL– Test set-ups



Multiphase Wave Lab: in operation in 2018

NWO Applied and Engineering Sciences

OPoost
operationeel programma oost

Europees Fonds voor Regionale Ontwikkeling

