**"FLOODSTAND Presentation in Brussels, 7.3.2012"**

Square de Meeûs 8 (Room SDME.7E), Brussels, Belgium

# EU project FLOODSTAND – Overview

## INTEGRATED FLOODING CONTROL AND STANDARD FOR STABILITY AND CRISES MANAGEMENT

*Apostolos Papanikolaou (NTUA) on behalf of*

**Coordinator:** Risto Jalonen

**Aalto University, School of Engineering**

**Department of Applied Mechanics**

**Marine Technology group / Marine Technology Research Unit**

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# FLOODSTAND Introduction (1)

## Background

## Why FLOODSTAND ?

- **missing data for validation** of time-domain numerical tools for **assessment of passenger ship* survivability** in case of flooding, a request for it given in IMO SLF/47/INF.6 2004, and
- **a standard** for a comprehensive measure of damaged ship stability addressing the flooding risk
  - reflecting the stochastic nature of **damaged ship stability in waves**
  - **based on first-principles** modeling
  - reflecting **foundering as a process** (loss of flotation/stability)
  - considering **risk-based decision making**

* Main focus is in passenger cruise ships and ropaxes



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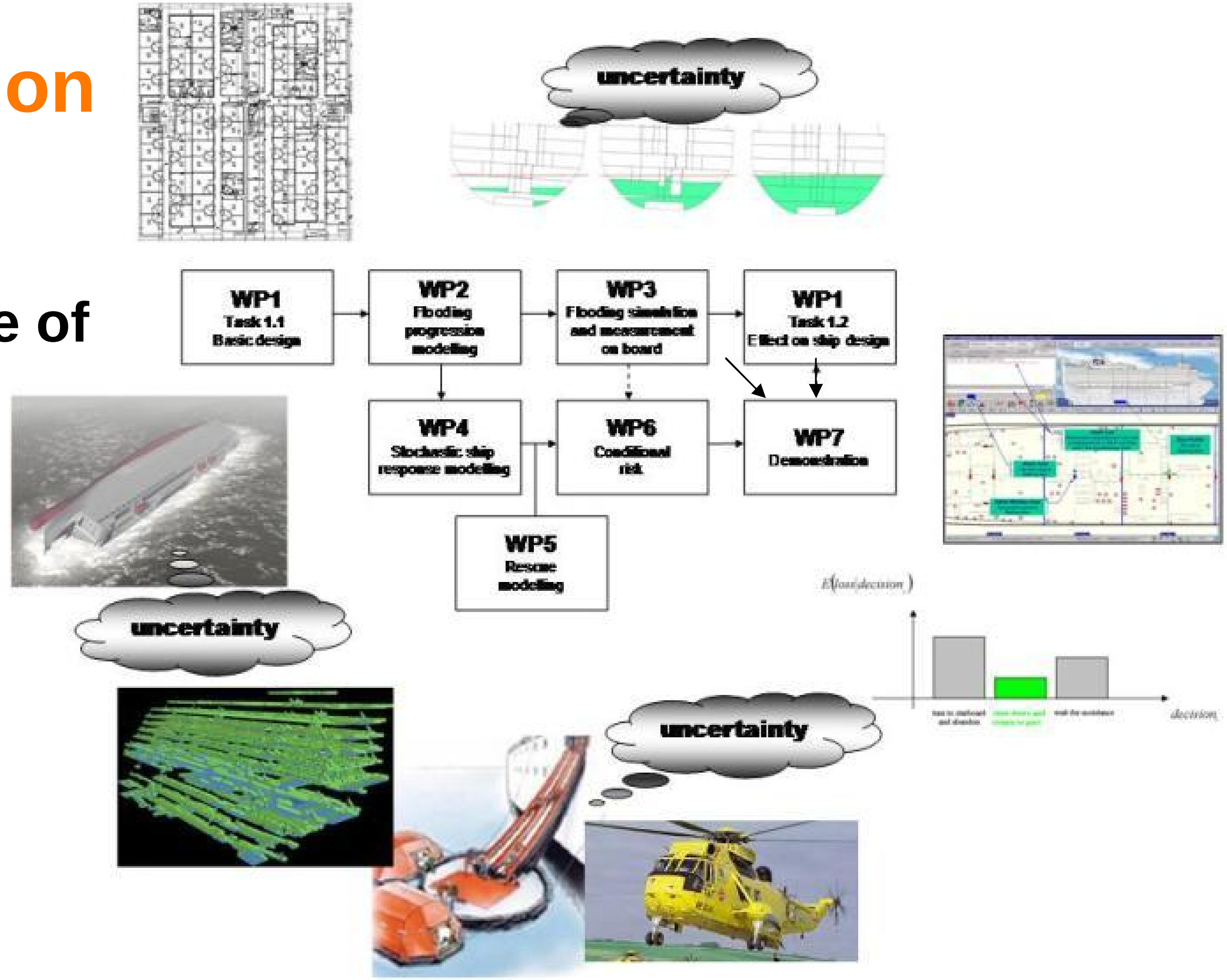
# Introduction (2)

## The structure of the project




**WP-leaders:**

WP1: STX Finland
WP2: AALTO
WP3: NAPA
WP4 & WP6: SSRC
WP5: BV
WP7: NTUA

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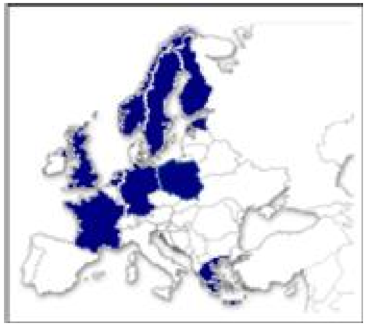
# FLOODSTAND: Who we are?

## The Consortium

**FLOODSTAND** Consortium consists of

17 beneficiaries located in 10 European countries:

classification societies, maritime administration, research organisations, shipyards, SMEs, universities etc.



**Aalto University** (coordinator),

STX Finland, CNRS, CTO, DNV, BMT Limited, MARIN, MEC, Meyer Werft GmbH, Napa Ltd, SSPA, SF-Control*, National Technical University of Athens, Bureau Veritas, S@S, MCA and University of Strathclyde (SSRC)

* merged to Rosemount Tank Radar AB since 2011/01

# FLOODSTAND: Who gave us advice?

- **FLOODSTAND** Advisory Committee consists of 8 members:

- **STA** (chairman),
  TraFi (member),
  USCG (member),
  IMO (member),
  GL (member),
  CAR (member),
  RCCL (member)
  NMRI (member)

=> maritime administrations, classification societie(s), ship operators, research institute

DNV was a member of AC in the first half of the project but acts now as a beneficiary

# Introduction (3): FLOODSTAND

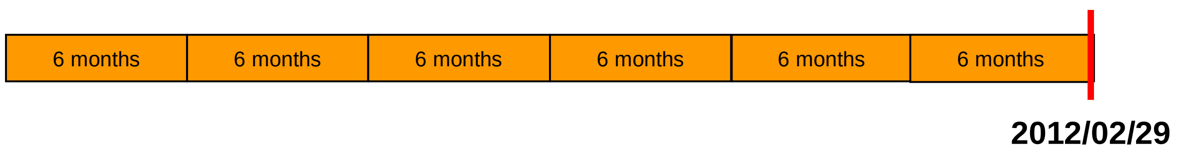
**FLOODSTAND**, a **3-year** collaborative research project

- focused on:

  **Safety** and security **by design** and

  **Crisis management and rescue operations**

- FLOODSTAND was started in **March 2009** and ended in the end of **February 2012**




- its planned project staff effort was in the range of 350-400 person months

- its total budget was of over 4 M€ with nearly 70% EC contribution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# Status and highlights of the Work Packages



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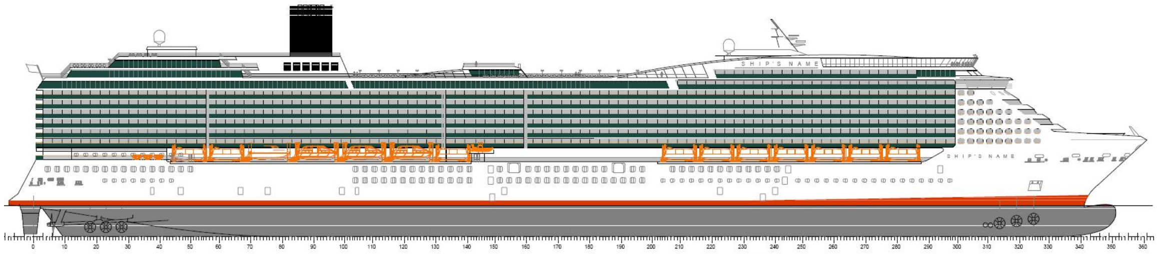
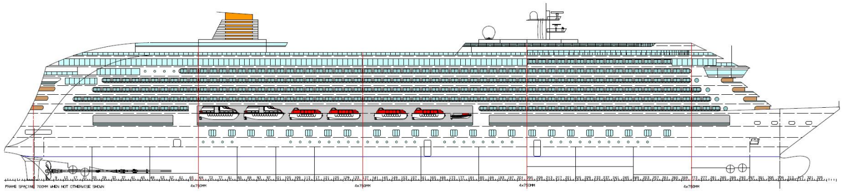
# WP1 Design and Application

## Development of basic design of passenger ships => Work completed

Responsible partners: **STX Finland Oy**, MW





Above: **Large**
Post-Panama sized cruise ship:
125000 GT, L = 327 m,
B = 37.4 m, T = 8.8 m, and

Below: **Handy-size**
i.e. medium sized cruise vessel:
63000 GT, L = 238 m,
B = 32.20 m, T = 7.4 m

## Analysis of the real flooding effects on design => Work completed

Responsible: **STX Finland Oy** and MW, DNV, AALTO



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# WP1 Design and Application

Highlights of the

**Analysis of the real flooding effects on design**

- No single major issue, but several important observations related to
  - -- flooding sequence through fire doors
  - -- instantaneous flooding on tank top through fire doors
  - -- restriction of flooding on bulkhead deck through fire doors
  - -- new formulation for cross flooding through ducts with restrictive effect of air pressure
  - -- restriction of flooding in cold room area



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# WP2 Flooding progression modelling

**Experiments with leaking and collapsing structures** => **Work completed**

Responsible: **CTO S.A.**; Other participants: STX Finland, MEC, MW, AALTO

- Semi-watertight doors, fire doors (sliding and hinged), cabin walls etc.

- Measured: **water pressure** and **flow rate** through the leakages during the structural deformation and collapse

Photograph of a door within the frame
sent from the shipyard
to the testing facility at
CTO in Gdansk, Poland, in 2010



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# WP2 Flooding progression modelling


Photographs of experiments in full scale in 2010 at CTO in Gdansk, Poland     Some video-clips may be shown, too



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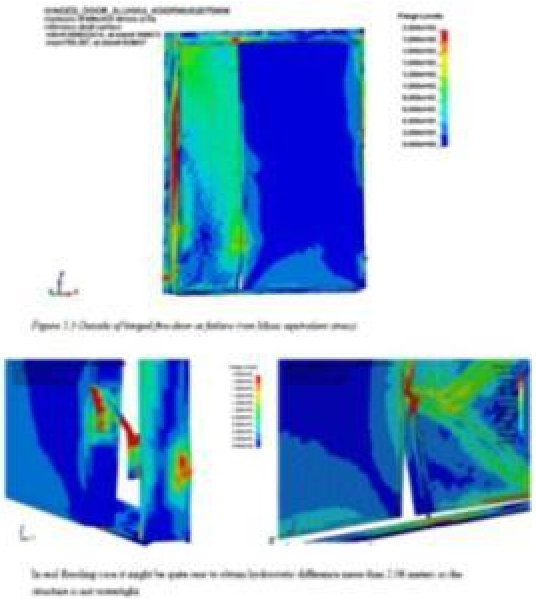
# Research topic: WP2 Flooding progression modelling

**Numerical modeling** and **criteria for leaking and collapsing structures** => **Work completed** (see D2.2a & D2.2b)

Responsible: **MEC**; Other Participants: CTO, NAPA, STX

- Focus on **failure mechanisms** for doors and structural components
- Numerical simulations; explicit FEM code
- Flow rate vs. water pressure
- Specific data obtained also on
  - -- **the leakage pressure**, i.e. when the structure looses watertight integrity and
  - -- **the collapse pressure** gets it to collapse.
- Computations validated with experiments

=> criteria for leakage and collapse of doors etc.



# WP2 Flooding progression modelling

**An example of FLOODSTAND results:**

**Based on this work rough guidelines for modelling leakage and collapse of various A- and B-class doors etc. for flooding simulations could be given**

**These guidelines will be further provided for IMO's use.**

Table 3: Rough guidelines for modelling doors and boundaries for flooding simulation, the values marked with an asterix (*) are estimations that are not based on experimental or FEM results

| Type | direction | $H_{leak}$ (m) | $A_{ratio}$ | $H_{coll}$ (m) | Notes |
|---|---|---|---|---|---|
| LWT | into | – | – | 8.0* | minimal leaking at lower pressures, full collapse likely for $H > 8$ m; note that only direction "out" was tested |
| | out | – | – | 8.0 | |
| A-class sliding | into | 0.0 | 0.025 | 1.0 | almost constant leakage area ratio |
| | out | 0.0 | 0.025 | 1.0 | |
| A-class hinged | into | 0.0 | $0.02 \cdot H_{ef}$ | 2.5 | $A_{ratio}$ depends on the gap size |
| | out | 0.0 | $0.03 \cdot H_{ef}$ | 2.5 | $A_{ratio}$ depends on the gap size |
| A-class double leaf | into | 0.0* | 0.025* | 2.0* | Not tested! Assumed to be independent on direction |
| | out | 0.0 | 0.025 | 2.0 | Collapsing could not be tested due to high leaking, value based on FEM |
| Cold room sliding door | into | 0.0 | $0.01 \cdot H_{ef}$ | 3.5 | Only one direction tested; collapsing pressure height assessed with numerical methods |
| | out | 0.0* | $0.01 \cdot H_{ef}$* | 3.5* | |
| B-class joiner door | into | 0.0 | $0.03 \cdot H_{ef}$ | 1.5 | panels around the door will fail first, $A_{ratio}$ expression is very approximate |
| | out | 0.0 | 0.03 | 1.5 | door is distorted, $A_{ratio}$ increases slowly |
| Windows | – | – | – | > 18 | can be excluded in simulations |



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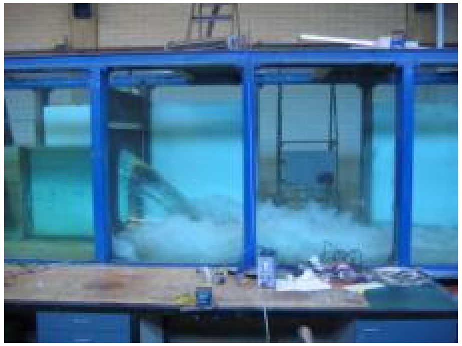
# WP2 Flooding progression modelling

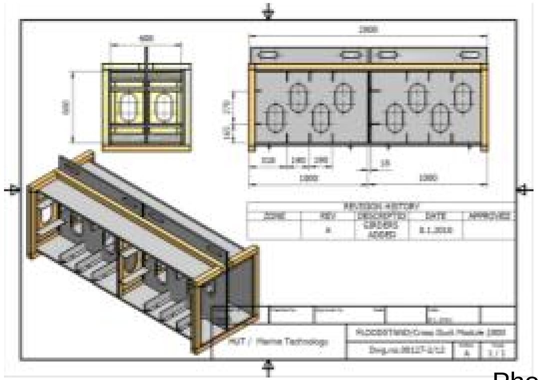
**Numerical studies on pressure losses T2.4 => Work completed**

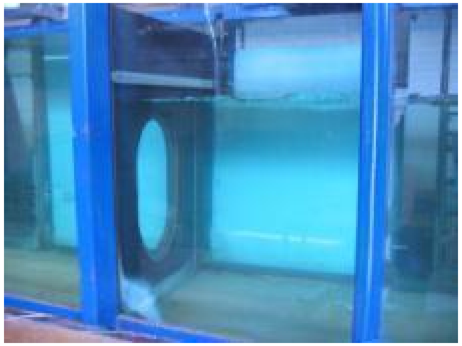
**Experimental studies on pressure losses T2.3** => **Work completed**

Responsible: **AALTO**; Others: STX Finland, Meyer Werft GmbH

- Hydraulic experiments on specific configurations encountered in floodings
- Manholes (1:1, 1:2 & 1:3) and cross-flooding arrangements: cross-ducts (1:3)
- Results: **Discharge coefficients** etc.







Photographs of model construction and tests carried out at AALTO



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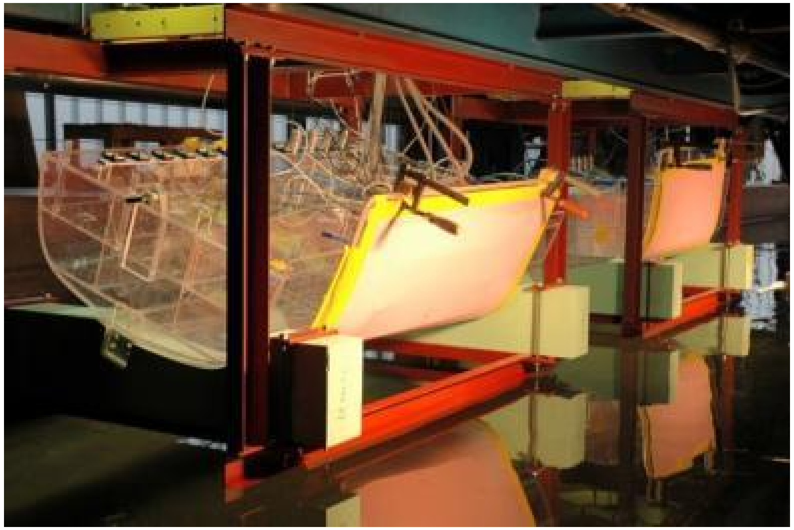
# WP2 Flooding progression modelling

Model tests for **complex compartments** in MARIN's vacuum tank

=> **Work completed**

Responsible: **MARIN**; Other: STX, MW, NAPA

- Objectives:
  - to collect validation material for simulation tools
  - to show the effect of air pressure on the flooding process
  - to show the effect of 'level of detail'



Flooding model test starting at MARIN

**Sensitivity** of simulation model

Responsible: **AALTO** & NAPA

=> **Work completed**

- Objectives:
  - to conduct simulations with a typical layout of ship to vary input parameters of the simulations systematically
  - to prepare guidelines for the preferred accuracy of the input data with simple error estimations



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# WP2 Flooding progression modelling

Highlights of the

**Work Package 2:**

- Experimental and numerical research => guidelines for modelling **leaking and collapsing structures** in time domain flooding analyses

  -- presented for IMO (IMO SLF54/INF.8/Rev.1 2011)

- Experimental and numerical research => guidelines for taking into account the pressure losses in **cross-flooding** duct

  -- developed and forwarded to IMO (IMO SLF54/INF.8/Rev.1 2011)

  -- a journal paper about the experiments with man holes and cross-flooding ducts has been published (Stening et al, 2010)

- Additionally, pressure losses in two typical **air pipe configurations** have been analysed with CFD and

  -- a journal paper, a summary paper about cross-flooding has been published (Ruponen et al, 2012)

- Flooding tests and **sensitivity analysis** to study the effects of some parameters on the progress of flooding in compartments has been carried out


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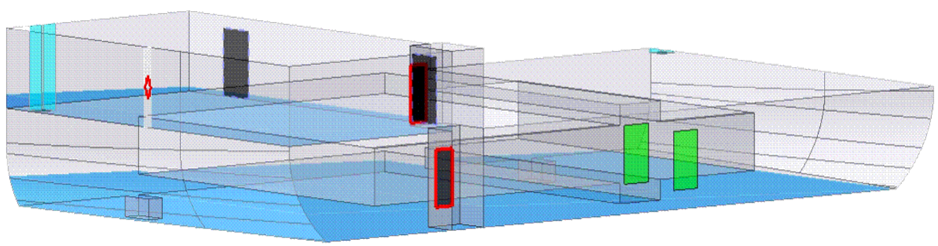
# WP3 Flooding Simulation and Measurement Onboard

- **Development of flood sensors data interpreter**

  Responsible: **NAPA**; Other participants: STX Finland, RTR   Status: Completed



An example of flooding status in compartments described by Napa Ltd

- **Impact of ship dynamics**

  Responsible: **AALTO**, Other participants: NAPA   Status: Completed

- **Design of flood sensor systems**

  Responsible: **NAPA**, Other participants: STX Finland, DNV, RTR  Status: Completed

# WP3 Flooding Simulation and Measurement Onboard

Highlights of the

**Work Package 3:**

- See Appendix 1 (description of WP3)



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# WP4 Stochastic ship capsize modelling

- Objectives:

Requirements and uncertainty bounds on methods for predicting the time it takes a ship to capsize or sink after damage

- Benchmark data on **time to capsize, ttc**

  Responsible: **SSPA**, Participants: SSRC — Completed

- Test/develop **analytical** time to capsize model

  Responsible: **SSRC**, Participants: SaS, NTUA — Completed

- Test/develop **numerical** time to capsize model

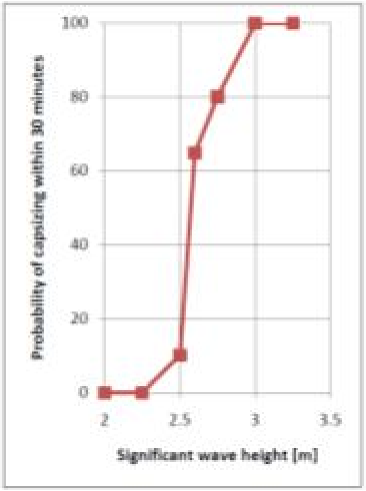
  Responsible: **NTUA**, Participants: SSRC, SSPA, SaS — Completed

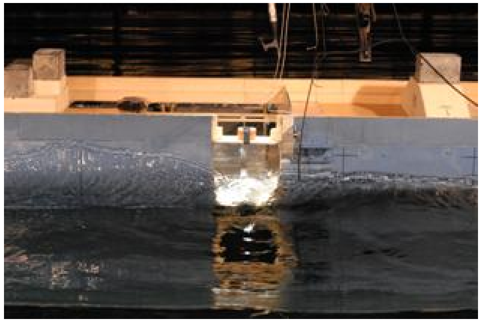
- Test/develop **hybrid** time to capsize model

  Responsible: **SSRC**, Participants: SaS, NTUA — Completed

- Establish **uncertainty bound** on ttc models

  Responsible: **SSRC**, Participants: BMT, SaS, NTUA, MCA — Completed



Capsize tests in model scale at SSPA

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# WP4 Stochastic ship capsize modelling

Highlights of the

**Work Package 4:**

- It has been shown by experimental (model tests with Estonia, *Rask (2011)*) and numerical studies that **the time to capsize may be shorter than previously expected** (*Spanos & Papanikolaou (2011)*)
- The **extent of flooding**, affecting parameters of $Gz_{max}$ and Range, seems to be the most critical information needed for confident assessment of criticality of flooding situation (*Jasionowski, 2012a*)
- Little or no enhancement on projections of the situation evolution can be attained during crises through observing (just*) ship **angle of heel**



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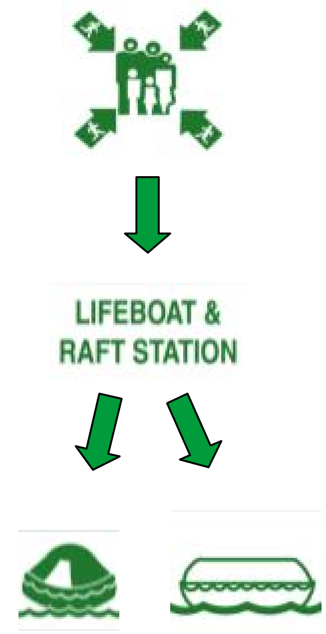
# WP5 Rescue process modelling

Objectives:

Test /develop **M-A-R**-models (Mustering-Abandonment-Rescue)

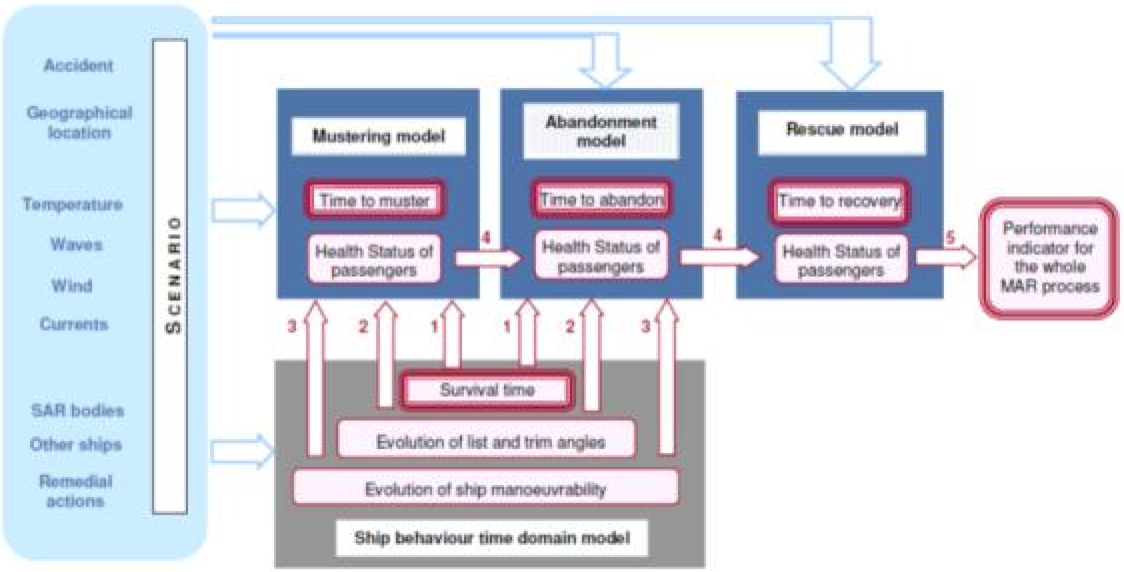
- requirements & uncertainty bounds
- required detail of representation etc.

- **Benchmark data** on mustering / abandonment / rescue
  Responsible: **BV**, Participants: SSRC, BMT Status: Completed
- Test/develop **mustering** model (M)
  Responsible: **BMT**, Participants: SSRC, SaS, BV Status: Completed
- Test/develop **abandonment** model (A)
  Responsible: **BV**, Participants: SSRC, BMT, SaS Status: Completed
- Test/develop **rescue** model (R)
  Responsible: **BV**, Participants: SSRC, BMT, SaS Status: Completed
- Establish **uncertainty bounds** on M-A-R models
  Responsible: **SSRC**, Participants: BMT, SaS, BV, MCA Status: Completed



# WP5 Rescue process modelling

Results of WP5/Task 1: **M-A-R**-model (Mustering-Abandonment-Rescue)







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# WP5 Rescue process modelling

Highlights of the

**Work Package 5:**

- Obstacle models were developed for each phase of the process on the basis of the degradation of the human health status
- Fatality rate was studied for several scenarios on two reference ships
- The Sea State was found to be the main parameter influencing the fatality rate
- In severe sea states, the manouevrability performance of LSAs to clear off the vessel is predominant



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# WP6 Standard for decision making in crises

## Objectives

Determine loss and likelihood function for integrated standard; should be reflecting the societal concerns pertinent to a “large” loss in a balanced way

Conditional probability (likelihood) should be reflecting the requirements on the methods to be used for generating basic information on stability, evacuation and rescue process as well as the associated **uncertainty**

- **Loss** function

  Responsible: **SSRC**, Participants: NTUA, MCA

  Status: ~ Completed

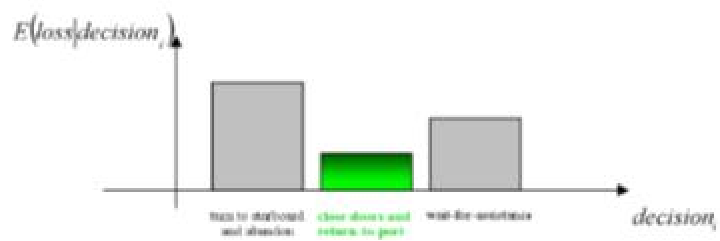
- **Likelihood** function

  Responsible: **SSRC**, Participants: NTUA, MCA

  Status: Completed

to be explored:

$$E(loss|decision_i) = \sum_j loss(j) \cdot p_{X|j}(j|decision_i)$$







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# WP6 Standard for decision making in crises

Highlights of the

**Work Package 6:**

- Are presented in Appendix 2 (WP4&WP6)



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# Demonstration (WP7)

Objectives:

- Test effectiveness of the standard in rating decisions for various casualty cases (hypothetical & real-life, historical scenarios) in working (operational) environment
- Test the approach in design process
- Feedback for modification, improvements/fine-tuning of the proposed standard

- **Benchmark data** on casualty mitigation cases
  Responsible: **NTUA**, Participants: SSRC, BMT, MCA Status: Completed
- Demonstration of a **casualty mitigation standard**
  Responsible: **BMT**, Participants: SSRC, SaS, BV, MCA, NAPA Status: Completed
- Demonstration for use as a **design standard**
  Responsible: **NTUA**, Participants: SSRC, SaS, BV, MCA Status: Completed

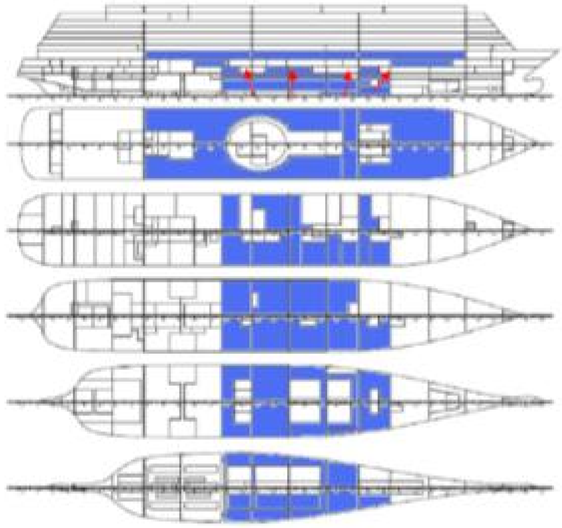

Fig.12 Long raking grounding scenario B2



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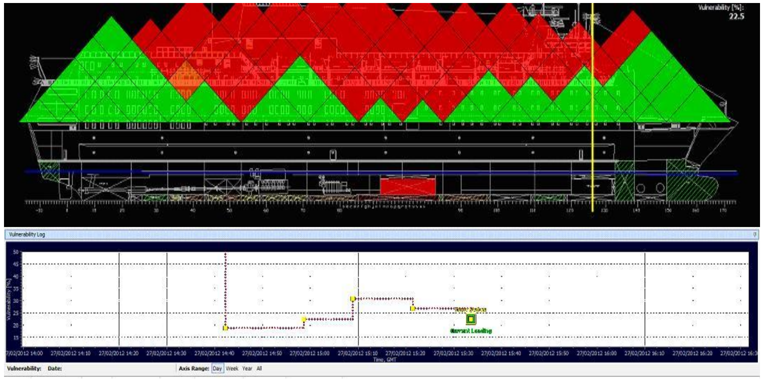
# WP7 Scope

- The effectiveness of the approaches (elaborated in FLOODSTAND) in rating decisions for casualty mitigation were tested within working environment for
  - Ship in **operation** (**onboard** applications)
    - Assessment of specific (assumed) damage conditions
    - Two approach: 1) *Crisis management, 2) Flooding control*
  - Ship in **design** (**office** applications)
    - All probable damage conditions
    - One approach: 1) *Crisis management*

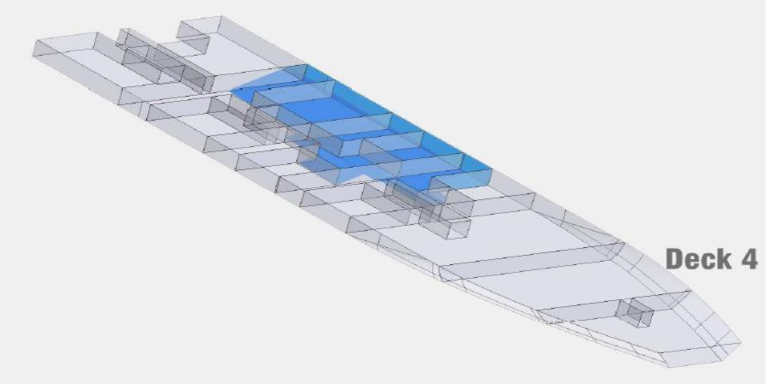
# Testing for Ship in Operation

- The '*Crisis Management*' (BMT, SSRC) approach was applied to the analysis of casualty scenarios for one RoPax and one Cruise ship, with emphasis to the proactive assessment of ship's vulnerability against the possible operational relaxation of the ship's watertight subdivision.
- The '*Flooding Control*' (NAPA) approach was applied to casualty scenarios of one cruise ship to estimate the flooding process through the very complex arrangement of compartments.
- Beyond the recorded progress for both approaches, *the difficulty for onboard estimation of the damage extent on hull shell which determines the ship flooding, remains an open challenge.*

*'Crisis Management'*



*'Flooding Control'*



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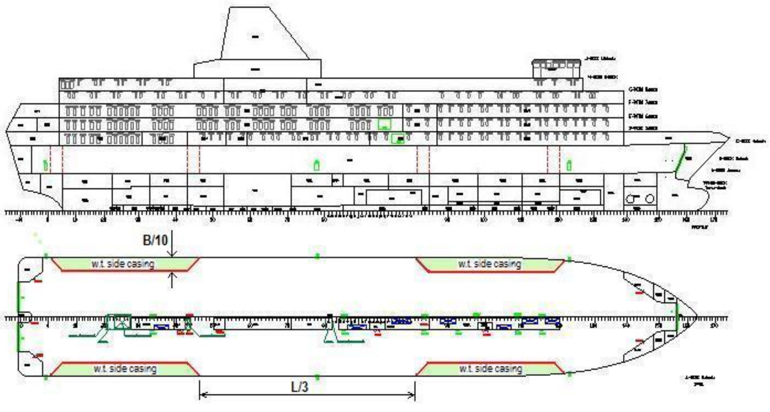
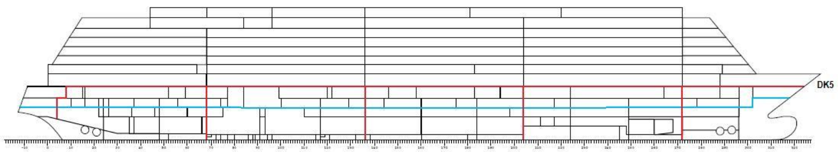
# Testing in Design Stage

- Two basic types of passenger ships, one RoPax and one Cruise, were analyzed by an analytical (WP4, SSRC) and numerical simulation approach (NTUA) with *MC* simulations (NTUA) for side collisions.
- The results show that the capsize, if it occurs, takes place in short time range, and in less time than the time required for orderly abandonment.
- In this respect the applicability of the '*Crisis Management*' approach (founded on TTC/TTE time estimations) for the design practice proved not meaningful.
- The mitigation of the casualty risk for people on board remains an open challenge, particularly for large passenger ships, and calls eventually for ***enhanced subdivision requirements.***

*RoPax*




*Cruise*



# Altogether (WP1-WP7)

**FLOODSTAND: Summary**

- The output of project FLOODSTAND is considered to fill many gaps of information and lack of data to enhance more reliable flooding simulations
- The results offer good prospects to improve timely support for designers and operators of passenger vessels
- The work carried out and the achievements can be assumed to be valuable for the development of safety regulations concerning passenger vessels



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# Altogether (WP1-WP7)

**Papers from FLOODSTAND:**

- **Altogether four journal papers have been published so far**
- Several conference papers have been published, too
- Three **IMO SLF documents** have been published so far

… and more of them are expected to come

**Deliverables:**

- **All RTD-deliverables are now in SESAM**
- The deliverables from WP1 (3), WP2 (11), WP3 (3), WP5 (5) and WP7 (3+1) have all been completed
- In WP4, D4.3 is approved, too, and in SESAM

Still to be done:

- Minor adjustments (cosmetic) are expected for D4.2 & D4.4, already in SESAM, but in category “in progress”
- Minor comments on D4.5 have been given, but may not to have been taken into account , yet
- In WP6, D6.2 is in SESAM, and will be soon finally submitted
- D6.1 is also in SESAM, but still in category “in progress”
- More text and the definition of one central concept expected to be added to D6.1



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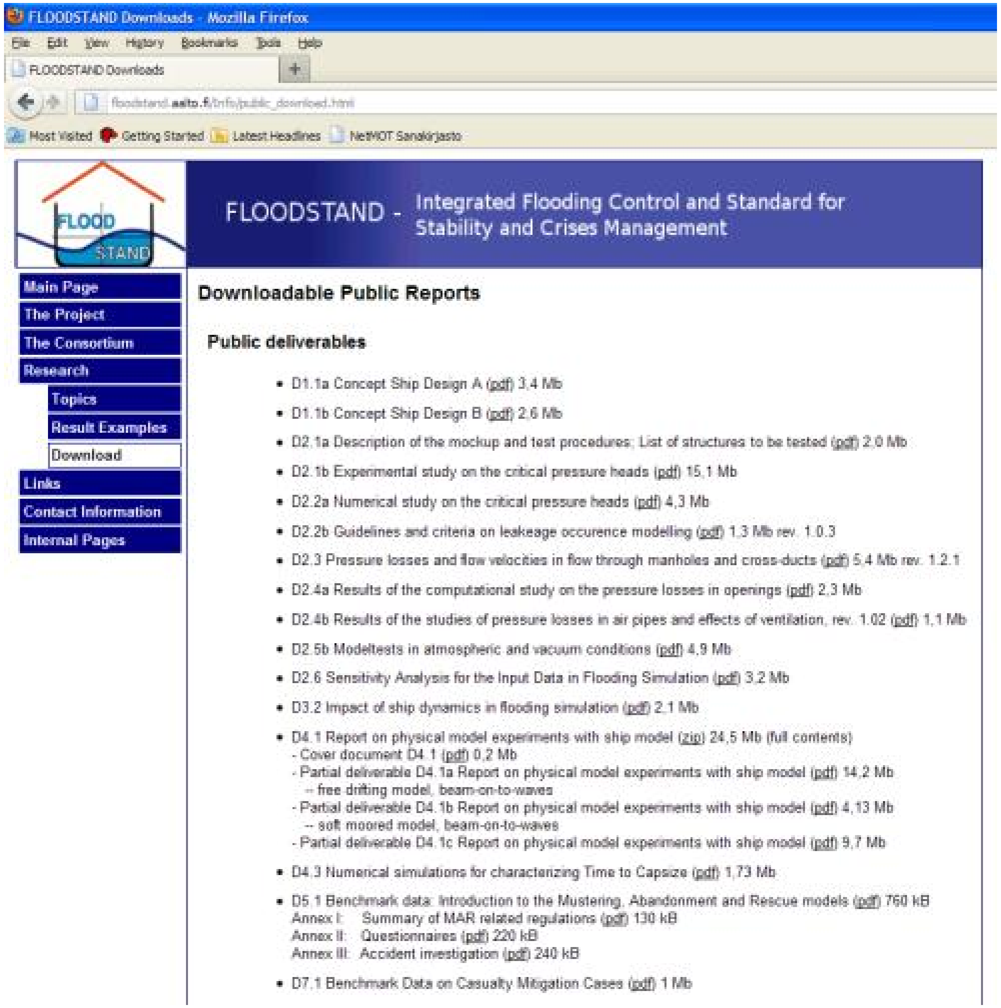
# Results are **publicly** reported. Now available at our project's web site http://floodstand.aalto.fi/ as follows:



FLOODSTAND Downloads - Mozilla Firefox

FLOODSTAND - Integrated Flooding Control and Standard for Stability and Crises Management

Main Page
The Project
The Consortium
Research
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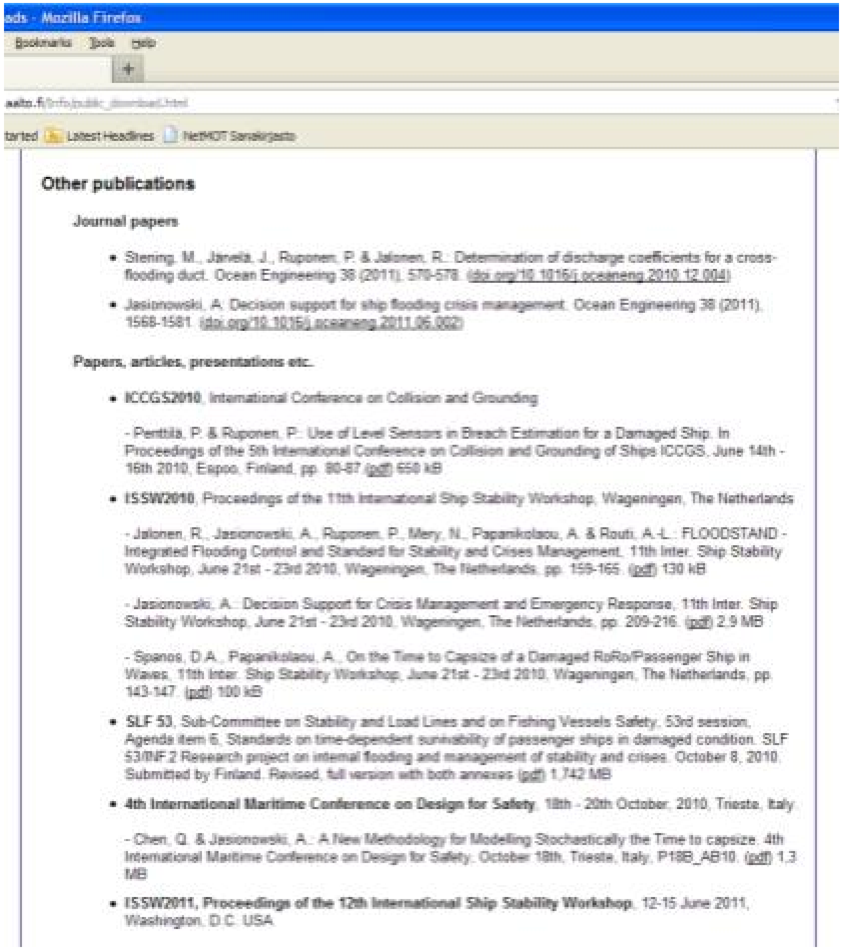
## Downloadable Public Reports

### Public deliverables

- D1.1a Concept Ship Design A (pdf) 3,4 Mb
- D1.1b Concept Ship Design B (pdf) 2,6 Mb
- D2.1a Description of the mockup and test procedures; List of structures to be tested (pdf) 2,0 Mb
- D2.1b Experimental study on the critical pressure heads (pdf) 15,1 Mb
- D2.2a Numerical study on the critical pressure heads (pdf) 4,3 Mb
- D2.2b Guidelines and criteria on leakeage occurence modelling (pdf) 1.3 Mb rev. 1.0.3
- D2.3 Pressure losses and flow velocities in flow through manholes and cross-ducts (pdf) 5,4 Mb rev. 1.2.1
- D2.4a Results of the computational study on the pressure losses in openings (pdf) 2,3 Mb
- D2.4b Results of the studies of pressure losses in air pipes and effects of ventilation, rev. 1.02 (pdf) 1,1 Mb
- D2.5b Modeltests in atmospheric and vacuum conditions (pdf) 4,9 Mb
- D2.6 Sensitivity Analysis for the Input Data in Flooding Simulation (pdf) 3,2 Mb
- D3.2 Impact of ship dynamics in flooding simulation (pdf) 2.1 Mb
- D4.1 Report on physical model experiments with ship model (zip) 24,5 Mb (full contents)
  - Cover document D4.1 (pdf) 0,2 Mb
  - Partial deliverable D4.1a Report on physical model experiments with ship model (pdf) 14,2 Mb -- free drifting model, beam-on-to-waves
  - Partial deliverable D4.1b Report on physical model experiments with ship model (pdf) 4,13 Mb -- soft moored model, beam-on-to-waves
  - Partial deliverable D4.1c Report on physical model experiments with ship model (pdf) 9,7 Mb
- D4.3 Numerical simulations for characterizing Time to Capsize (pdf) 1,73 Mb
- D5.1 Benchmark data: Introduction to the Mustering, Abandonment and Rescue models (pdf) 760 kB
  Annex I: Summary of MAR related regulations (pdf) 130 kB
  Annex II: Questionnaires (pdf) 220 kB
  Annex III: Accident investigation (pdf) 240 kB
- D7.1 Benchmark Data on Casualty Mitigation Cases (pdf) 1 Mb



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- **ISSW2010**, Proceedings of the 11th International Ship Stability Workshop, Wageningen, The Netherlands

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- **SLF 53**, Sub-Committee on Stability and Load Lines and on Fishing Vessels Safety, 53rd session, Agenda item 6, Standards on time-dependent survivability of passenger ships in damaged condition. SLF 53/INF.2 Research project on internal flooding and management of stability and crises. October 8, 2010. Submitted by Finland. Revised, full version with both annexes (pdf) 1,742 MB
- **4th International Maritime Conference on Design for Safety**, 18th - 20th October, 2010, Trieste, Italy

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- **ISSW2011, Proceedings of the 12th International Ship Stability Workshop**, 12-15 June 2011, Washington, D.C. USA




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**Note!**

Results of the project are publicly available at web-site:

**http://floodstand.aalto.fi/**

# Thank you!

**Appendix 1 (WP3)**
**Appendix 2 (WP4&6)**
**Appendix 7 (WP7)**