Report of the Manoeuvring Committee

Members of the committee

- Frans Quadvlieg (MARIN)
- Guillaume Delefortrie (FHR)
- Jonathan Duffy (AMC)
- Yoshitaka Kurukawa (Kyushu University)
- Pierre Emmanuel Guillerm (ECNantes)
- Sun Young Kim (KRISO)
- Claus Simonsen (Force)
- Eduardo Tannuri (USP)
- Mao Xiao Fei (WHUT)
- Michael Woodward (Newcastle)

Meetings

- KRISO (South Korea) March 2012
- ECN (France) November 2012
- Flanders HR (Belgium) June 2013
- Wuhan (PR China) March 2014

All members were present at all meetings! (even during Carnival)

Tasks for the committee

Task 1
State of the art for predictions
Need for R&D ….

Task 2
Review manoeuvring procedures

Task 3
UA for captive model tests

Task 4:
Create guideline for V&V for RANS for manoeuvring

Task 5:
Guideline for restricted water

Task 6:
Free running manoeuvring tests:
Initial conditions and UA

Task 7:
Scale effects

Task 8:
Manoeuvring in waves

Task 9:
Support organising a 2nd SIMMAN workshop

Task 10:
Manoeuvring criteria

Tasks for the committee

Task 1

Update state of the art for prediction manoeuvring behaviour

- Potential impact of technological developments on ITTC
- Developments for ***manoeuvring & course keeping in waves***
- Experimental techniques & extrapolation methods
- New ***benchmark data***
- ***Practical*** application of computational methods
- Need for R&D for improvements
- Effect of FS, roll, sinkage & trim in numerical predictions

- Achieved by performing an extensive literature review
- Special section on manoeuvring in waves. More later…
- Special section on benchmark data, more later…

Tasks for the committee

Task 2

Review ITTC Recommended ***Procedures*** relevant to manoeuvring and

a. Identify any requirements for changes in the light of current practice and, if approved by the Advisory Council, update them.
b. Identify the need for new procedures and outline the purpose and content of these

- Reviewed and updated: More later…

Tasks for the committee

Task 3
Complete the work on the Procedure 7.5-02-06-04, ***Uncertainty Analysis; Forces and Moment***, Example for Planar Motion Mechanism Test, based on ISO approach. The present procedure 7.5-02-06-04 and the subsection on uncertainty analysis in the Procedure 7.5-02-06-02, Captive Model Test Procedure, prepared by the 23rd ITTC are based on the ASME approach. In view of the work already carried out for the Procedure 7.5-02-06-04, consider to keep the elaborated ASME example as one of the Appendices to the to-be-renewed 7.5-02-06-04.

- UA for captive manoeuvring tests brought in line with ISO GUM and significantly extended. More later

Tasks for the committee

Task 4

Based on results of the SIMMAN workshop held in 2008 and its next edition, continue the already initiated work to ***generate a guideline on verification and validation of RANS tools in the prediction of manoeuvring capabilities***. Liaise with the QSG with respect to definitions of Verification and Validation

- This guideline has been created

Tasks for the committee

Task 5

Restricted waters:

a. Produce a guideline for experimental methods.
b. Complete the initiated one for numerical methods which may serve as a basis for recommended procedures for manoeuvring in restricted waters.

- The guideline for experimental methods was integrated with the procedures for free running model tests and captive model tests
- We did ***not*** want to produce ***more paper*** than necessary. A merging was more efficient.

Tasks for the committee

Task 6

Free running model tests:

a. Update the Procedure 7.5-02-06-01, Free Running Model Test (FRMT) Procedure, in particular to include objective statements on the initial conditions of free manoeuvring model tests.

b. Elaborate the already initiated procedure on uncertainty analysis for free running manoeuvring model tests, including an example.

- An improper initial condition causes significant biases in outcome. The way to address these is included in the **uncertainty analysis for FRMT**. This became a practical UA methodology.

Tasks for the committee

Task 7

Scale effects in manoeuvring:

Report on knowledge and collect, analyse and summarize data on scale effects for manoeuvring predictions.

.

- Thorough discussion of scale effects
- Comparison of recent benchmark data.
- Suggestion for “the way to follow”

Tasks for the committee

Task 8
Review developments in methods and draft a validation procedure of ***combined manoeuvring and seakeeping*** with respect to simulation. Liaise with the Seakeeping Committee and the Stability in Waves Committee.

- Developments for combined seakeeping & manoeuvring are extensively reviewed. It is “way too early” for a validation procedure. Liaising with other committees requires also a task on “their” side.
- There are multiple simulations methods, overviewed and reviewed. A workshop with Seakeeping, Stability in waves should address joint progress.

Tasks for the committee

Task 9
Support the organisation of a second ***SIMMAN workshop***.

- SIMMAN Workshop on validation of manoeuvring predictions.

- First edition in 2008
- Next edition: ***December 2014***
- 2 MC members in the SIMMAN organising committee. All MC members active

Tasks for the committee

Task 10

Manoeuvring criteria and relations to IMO:

a. Report on manoeuvring criteria for ships not directly covered by IMO like POD and waterjet driven vessels, naval ships, inland ships, HSMV, etc.
b. Study possible criteria for manoeuvring at low speed and in shallow waters and if warranted communicate findings to IMO.

- Inventarisation of additional manoeuvring criteria.
- Extensively discussed later.

State of the art

Aspects worth mentioning wrt task 1

- Predictions in **deep** and unrestricted water:
  - Much used in practical (daily & commercial) work
  - However: uncertainty analysis, scale effects not so much investigated
  - **Towed stability** has increased attention, both experimentally and numerically
  - Researches on **heel to yaw** coupling
  - Much CFD research reported; the benchmark ships are useful

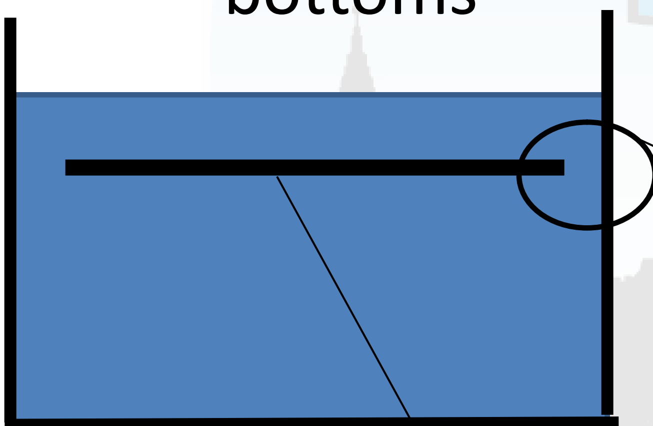
STATE OF THE ART

Definition of deep / shallow / restricted

- Deep water
  - Wd/T > 4
  - Speed 50% of critical speed
- Shallow water
  - WD/T < 4
  - High velocities compared to the critical velocity
- Restricted water
  - Implies ***lateral*** restrictions (banks, harbours, ship-ship)

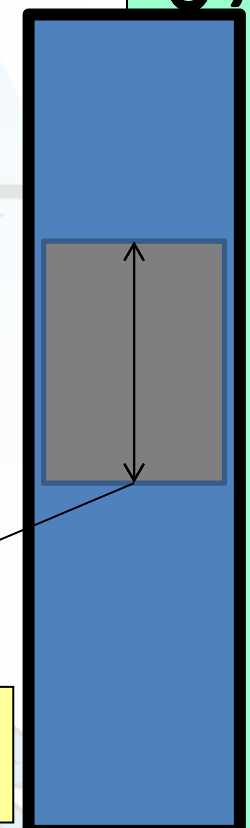
Aspects worth mentioning wrt task 1

- Predictions for shallow water:
  - Received again more attention
  - Experimentally: increased use of ‘false bottoms’



Are these openings allowed? How large?

Stiffness of the false bottom?



What is the required length of the false bottom?

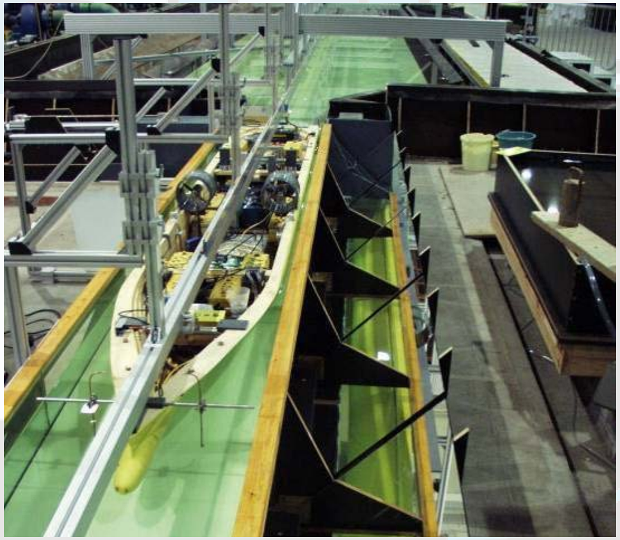
Recommendation 1: guidelines for false bottoms

Aspects worth mentioning wrt task 1

- Predictions for restricted water receive increased attention:
  - There has been a special workshop on “behaviour in locks” [Gent, June 2013]
  - Numerical and experimental investigation on ships in locks
  - Includes a “benchmark” case for entering a lock

Experimental techniques

- Set-ups for restricted water
  - Example: ship in lock



  - Captive tests in locks (measuring forces)
  - Free running tests in locks (restricted in sway & yaw, self propelled in surge)

Numerical developments

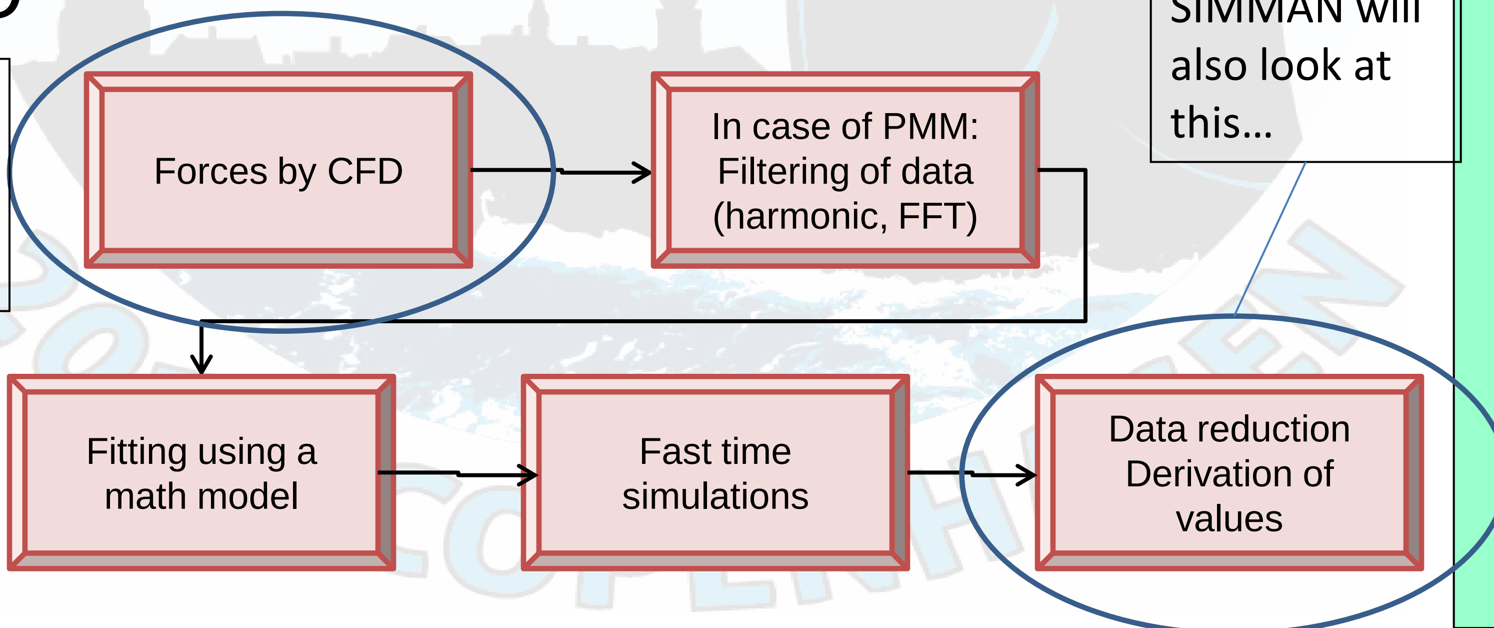
- Much more institutes are producing papers based on CFD simulations. In deep water *and* in shallow water, *and* in restricted water
  - Most papers use CFD as a “virtual captive tests”
  - In research: free running manoeuvres in CFD
  - Much RANS (URANS or DES) applied to KVLCC2, SUBOFF
  - In restricted water: much potential flow calculations
  - Fast ships: potential flow calculations

STATE OF THE ART

Current practice Numerical

- RANS CFD used as supplement/substitute for captive model tests.
- Much presentation on the comparison of force level, not yet on simulations based on CFD

Many publications focus on this...



SIMMAN will also look at this...

STATE OF THE ART

Numerical developments

- Issues for RANS predictions: propeller modelling for propeller rudder interaction and suction over the aft ship

Actuator disk

Actuator disk with rotation

RANS-BEM coupling

Frozen rotor

CFD with turning propeller

Increasing complexity & effort

Recommendation 2: R&D propeller modelling for RANS

STATE OF THE ART

Benchmark

Status on the benchmark

- SIMMAN related benchmark
  - EXTENDED WITH SHALLOW WATER
  - New benchmark cases elaborated and replaced
  - Workshop planned in December 2014

= new data

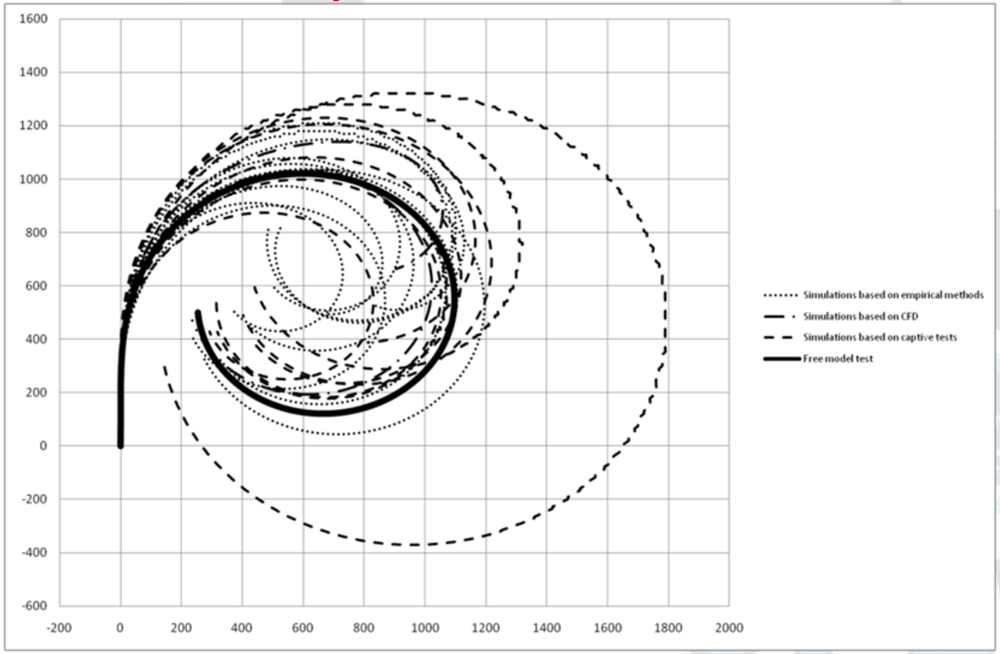
Status on the benchmark

	Hull	KVLCC2			KCS			5415M		
Captive	PMM app. deep	INSEAN (2014) missing	HMRI (2012)		FORCE (2009)			MARIN (2007)		
	PMM app. shallow	BSHC (2013)	FHR (2012)		FHR (2012)	MOERI (2013)				
	PMM bare deep	INSEAN (2014) missing			FORCE (2009)			FORCE (2004)	IIHR (2005)	INSEAN (2005)
	PMM bare shallow	BSHC (2013)	FHR (2012)							
	CMT app. deep	NMRI (2006)			NMRI (2005) 3DOF	CSSRC (2013) 4DOF	IHI (2012)	MARIN (2007)		
	CMT bare deep									
Free	Free app. deep	HSVA (2006)	MARIN (2007)	CTO (2007)	MARIN (2009)			MARIN (2000)		
	Free app. shallow	FHR (2012)	MARIN (2013)		BSHC (2008/ 2011)	FHR (2012)				

BENCHMARK

SIMMAN 2014

- December 8-10, 2014, Copenhagen (www.simman2014.dk)
- Objective learn about predictions
  - by comparing **trajectories (new blind cases)**
  - Compare **CFD dedicated cases**



BENCHMARK

SIMMAN 2014

Different methodologies to arrive at tactical diameter

Obtaining hydrodynamic force & moment:

- PMM tests
- Rotating arm & drift tests
- CFD for virtual PMM
- System identification
- Empirical

Fitted in a math model with (or without) hydrodynamic coefficients:

- Taylor series whole ship
- Taylor series bare hull with separate rudder, propeller models (*MMG*)
- Cross flow drag
- Tabular models
- Neural network
- CFD
- ...
- 3dof or 4 dof

Prediction of trajectories

FRMT

Measurement of trajectories

FR CFD

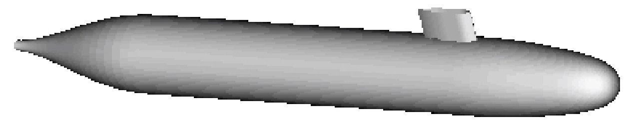
Prediction of trajectories

Data reduction of trajectories into manoeuvring parameters such as overshoot angles

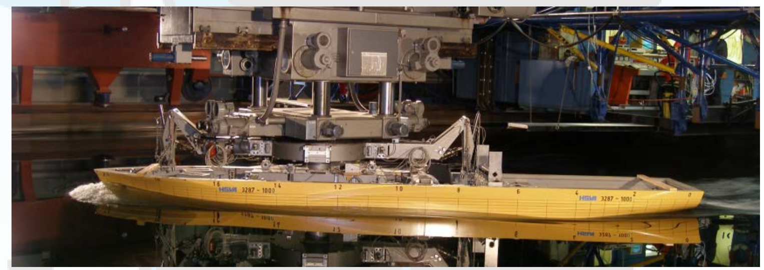
BENCHMARK

Other benchmark vessels

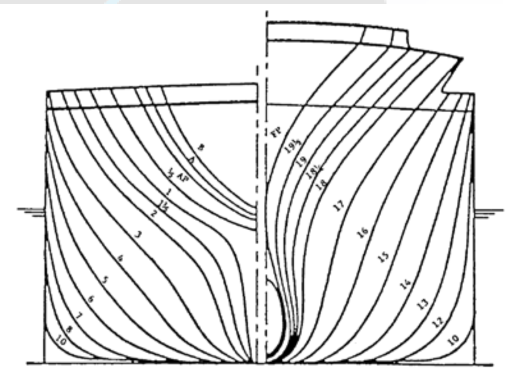
- DARPA SUBOFF (For CFD)
  - Rotating arm & PIV



- HTC (flow separation)
  - PIV while rotating
  - FRMT



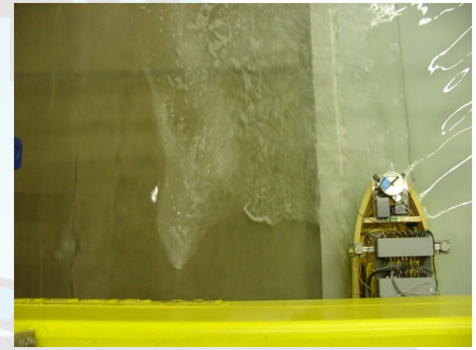
- S175 container ship
  - FRMT turning circles in waves



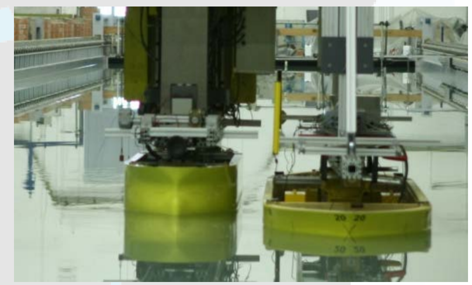
BENCHMARK

Benchmark for restricted water

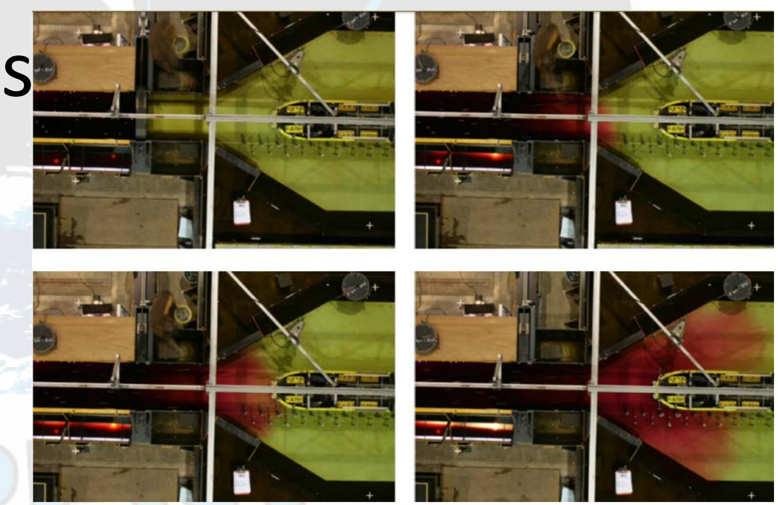
- FHR : Bank effects
  - (bank effect conference 2009)



- FHR : Ship to ship
  - (ship tot ship conference 2011)



- FHR : Lock manoeuvres
  - (lock conference 2013)



BENCHMARK

Manoeuvring in waves

Interpretation

Possible interpretations:

- Effect of waves on turning circle & zigzag (trial corrections)
- Finding the limit where the ship cannot return to head waves (manoeuvring in adverse weather)
- Course keeping in bow quartering waves
- Course keeping in stern quartering waves
- Broaching
- …

Used methodologies

Possible methodologies for quantifying behaviour:

- Free running experiments
- Time domain RANS
- Superposition of motions
- Two-time-scale methods
- ‘Unified’ methods
- …

Which method could be applied to what?

Proposed way ahead

- Clarify the insights together with Seakeeping Committee and the stability in wave committee
- Develop a workshop to gather different insights

Note: Several ongoing projects will help:
- SHOPERA European project (only for ‘manoeuvring in adverse weather”)

Procedures

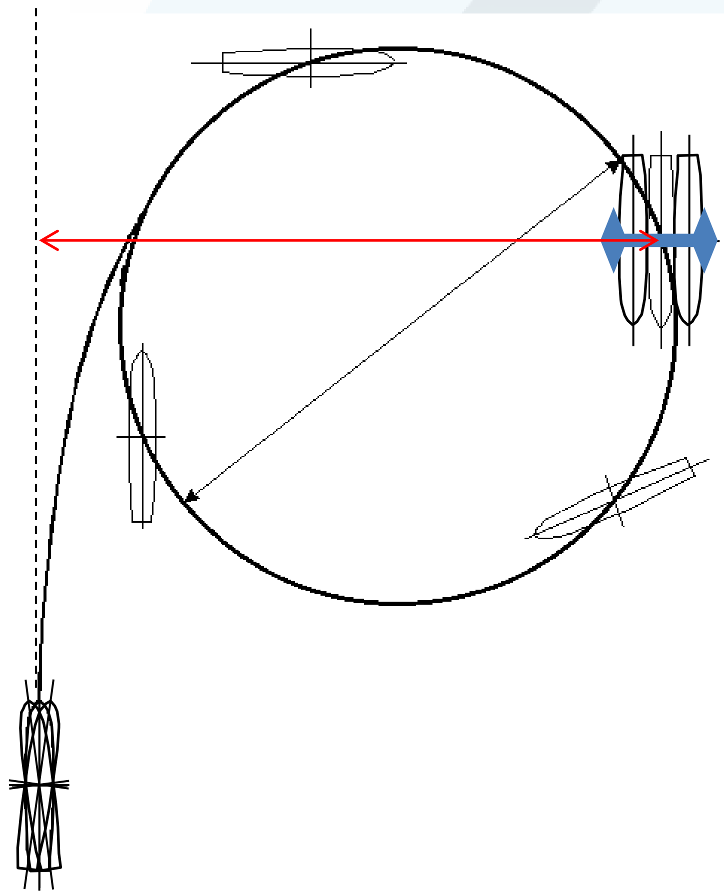
Updates of procedures

- FRMT: Inclusion of shallow water in the procedure for FRMT and CMT
- CMT: Inclusion of shallow water in the in the procedure for FRMT and CMT

New procedure **UA FRMT**

- Target: practical procedure
- Well applicable in a commercial activities without many repeat tests

Example

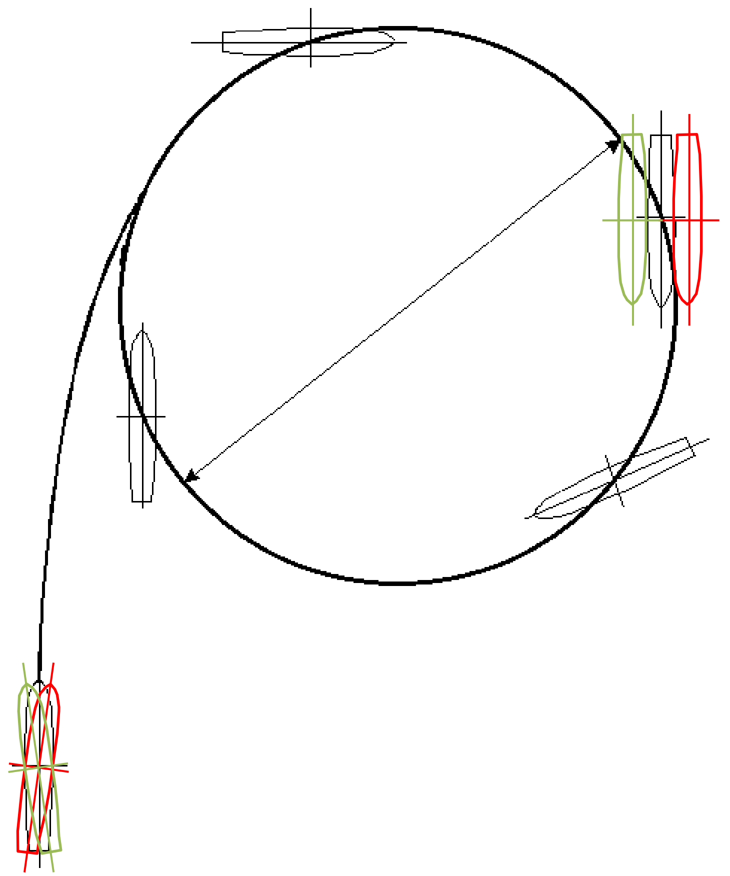


Uncertainty of tactical diameter

- Uncertainty of position measurement
- Uncertainty of length of ship (…)
- Uncertainty of the stochasticism in the experiment
  - Partly defined through repeatability
  - Partly not
  - Initial conditions which PROPAGATE are important

How to deal with this ***propagated uncertainty***?

- Define the sensitivity of the tactical diameter based on (for example) initial drift



This is how you derive:

$$\frac{\partial TD}{\partial \beta_{initial}}$$

This is done for multiple influencing factors (list given in procedure).

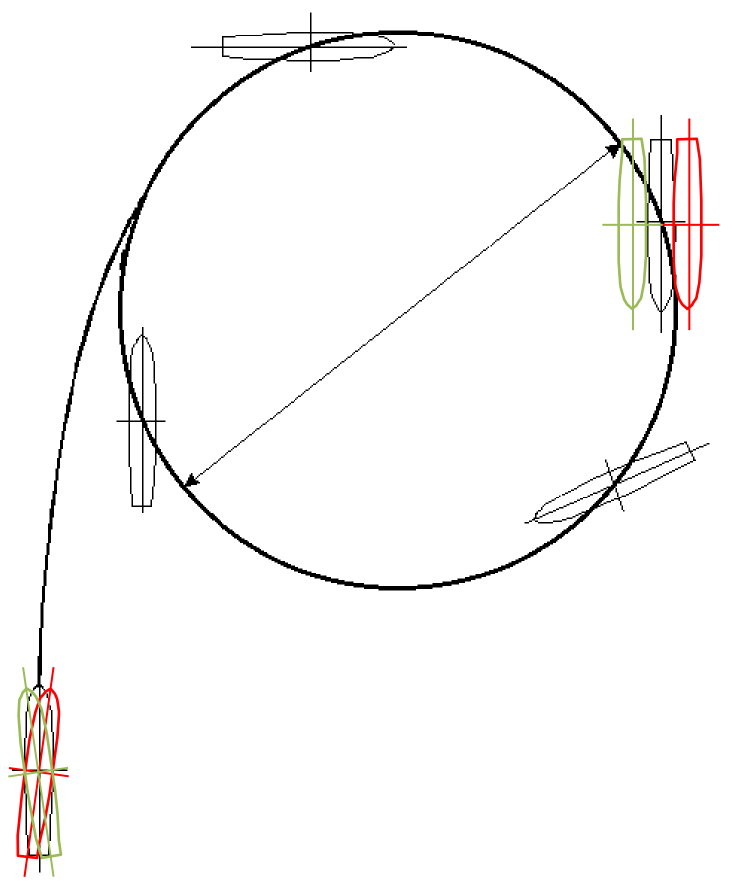
BY SIMULATIONS

PROCEDURES

Propagated uncertainty

- The uncertainty of the tactical diameter due to initial drift becomes:

$$u_{TD} = \frac{\partial TD}{\partial \beta_{initial}} \cdot u_{\beta_{initial}}$$



PROCEDURES

- Total uncertainty of the “tactical diameter” is r.s.s. sum of
  - the propagated uncertainties and
  - the measurement uncertainties and
  - an uncertainty obtained from repeat tests

- Described in a procedure (guideline)

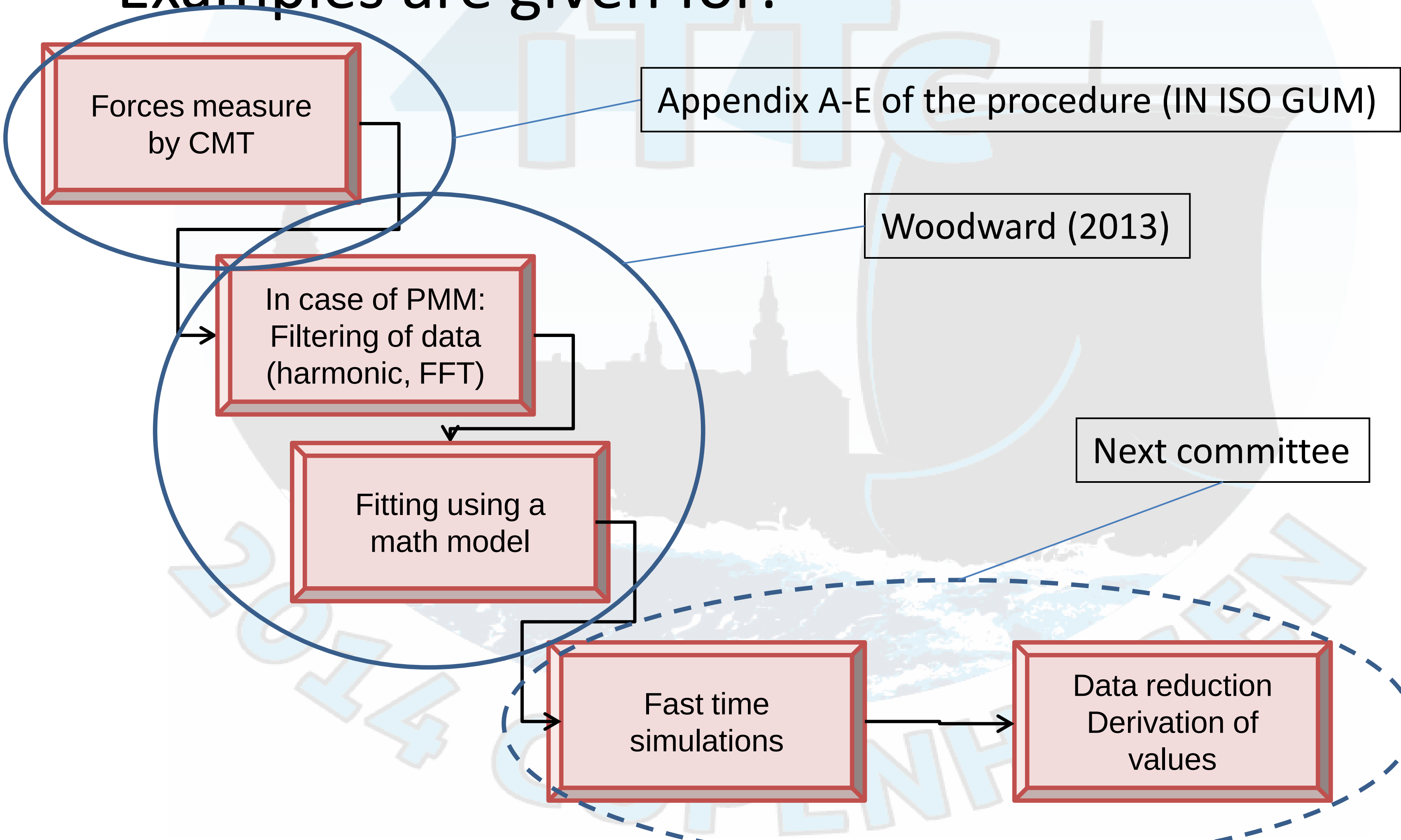
Quadvlieg & Brouwer (2011)

Significant updates of **UA Captive**

- Used to be : example of forces and moments during a captive drift and a pure yaw PMM test.
- Now:
  - Everything changed to ISO-GUM
  - Description of the uncertainty of the prediction

Procedure for UA of *predictions based on* captive test

- Now the whole process is described.
- Examples are given for:



PROCEDURES

New procedure V&V RANS

- V&V for
  - RANS used as virtual captive tests
  - RANS used as virtual free running tests

- Verification:
  - Iterative convergence
  - Grid & time step convergence
  - Time integration model

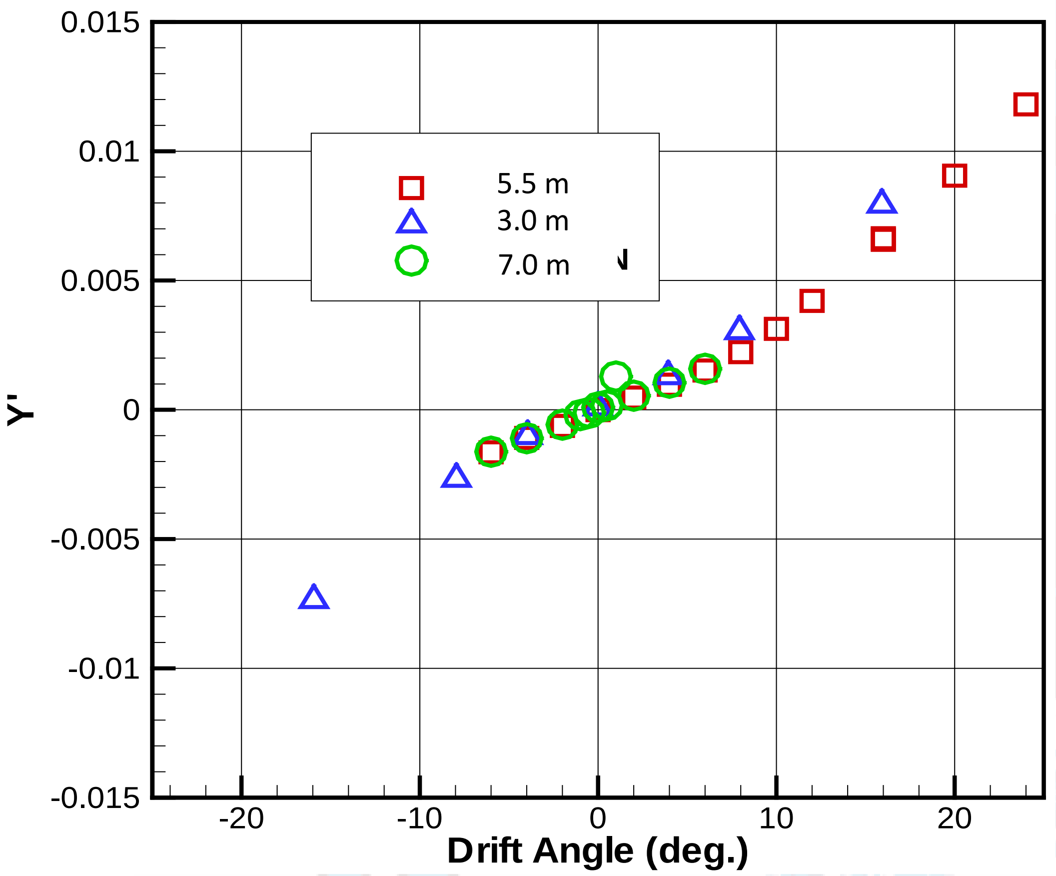
New procedure V&V RANS

- Validation:
  - For virtual captive tests
    - Based on comparison of forces & moments
  - For virtual harmonic tests
    - Based on comparison of time traces of forces & moments: by looking at the *harmonics*.
  - For virtual free running tests
    - Based on comparison of time traces of motions and th derived parameters (TD, ψ_{OS}, …)

Scale effects

Work on scale effects

- Based on SIMMAN 2008 results

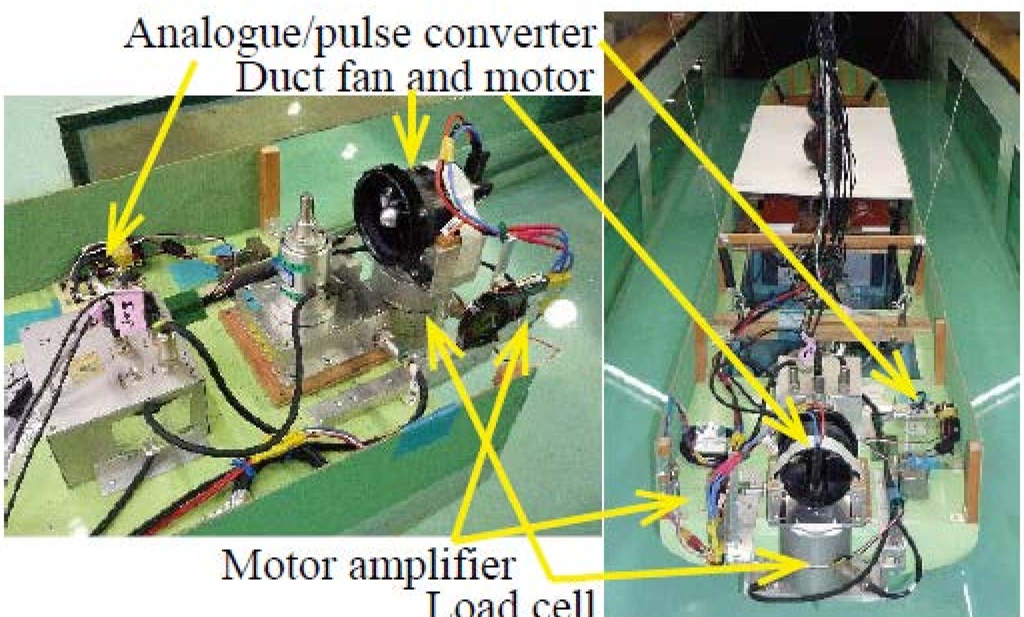


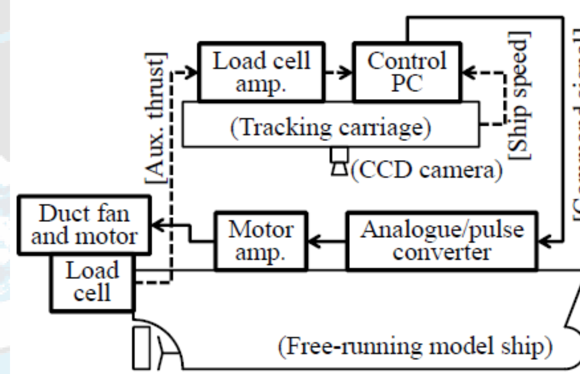
- For linear coefficients:
  - Quite good agreement
- For non-linear coefficients:
  - discrepancies

SCALE EFFECTS

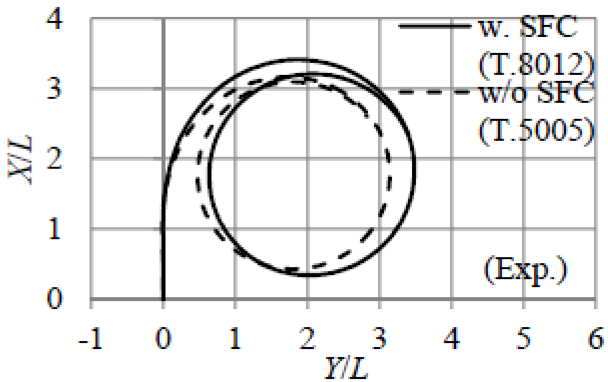
Scale effects FRMST

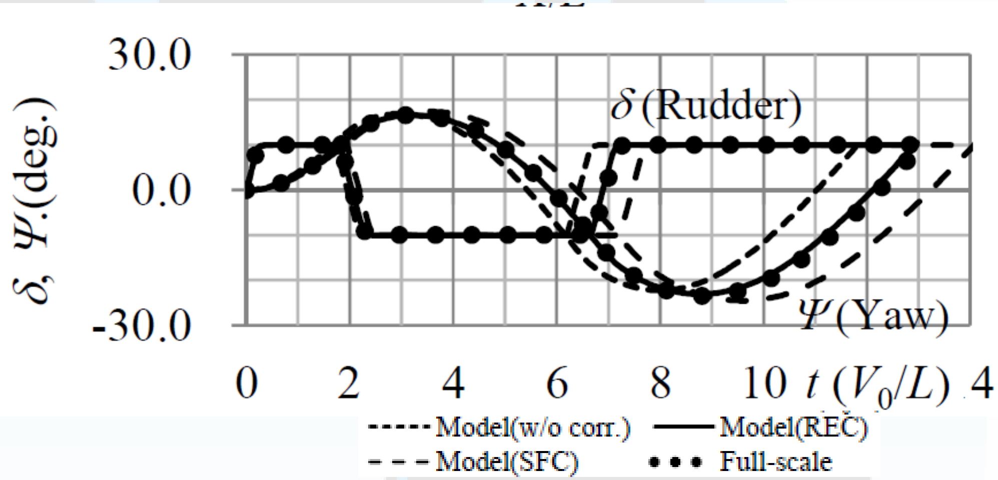
- Tsukada, Ueno et al, 2013.
- Application of fan on 3 meter model of KCS
  - RPM dependent on speed
  - NOT at self propulsion point of ship, but at equivalent RPM related to rudder force





BUT: skin friction correction is *not* correct: an intermediate "rudder force equivalent" should be used





For a 3m KCS experiments:

- Effect on TD is present
- Using skin friction correction!

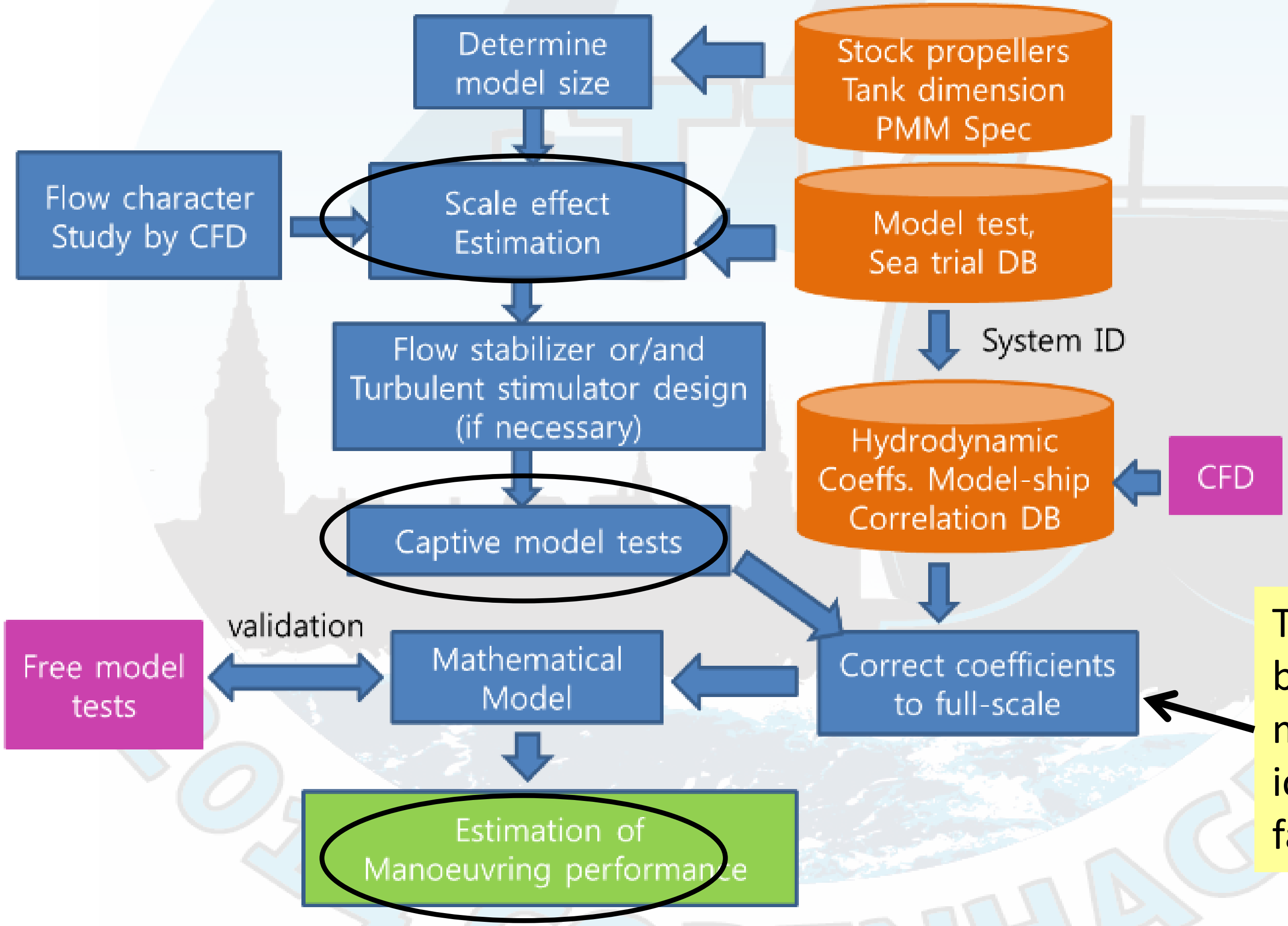
For another ship

- Effect on TD is present
- Effect on overshoot angles hardly present
- Including full scale

- Tsukada (2012)
- Ueno (2013)

SCALE EFFECTS

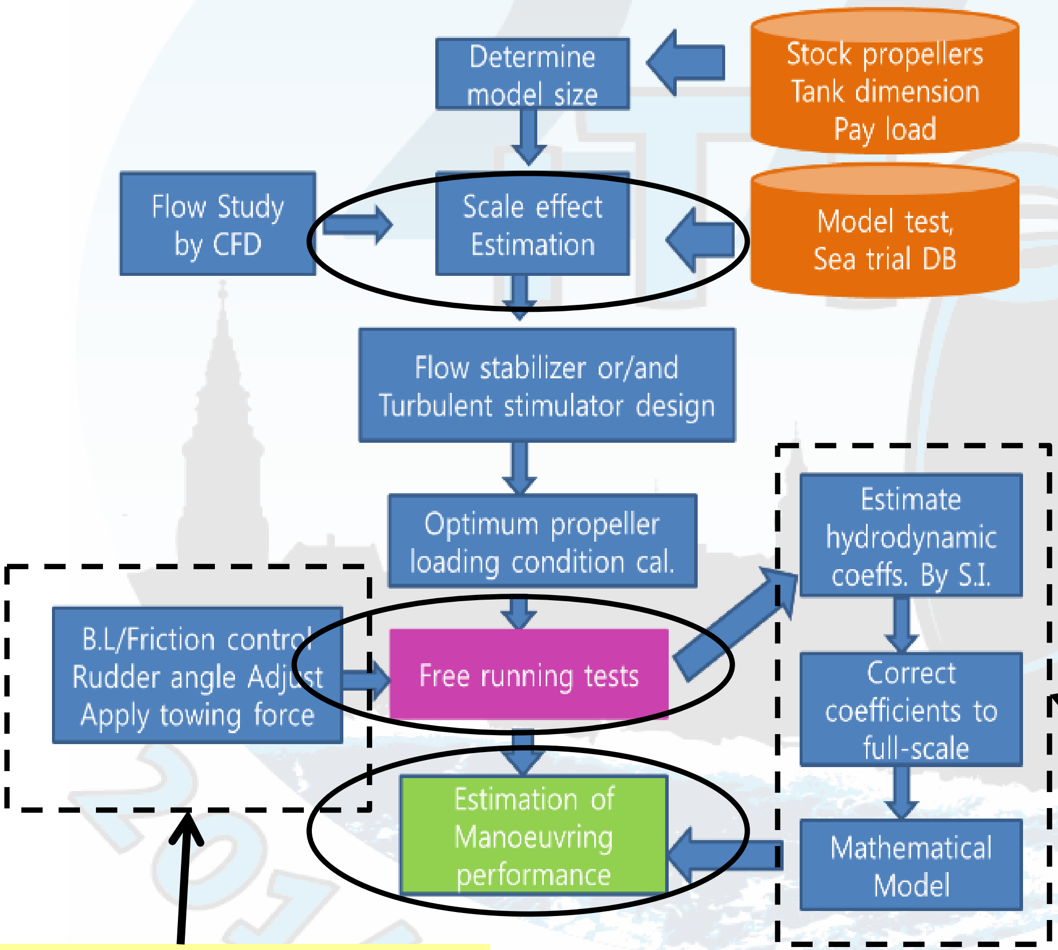
Outline of handling scale effects



This *could* be by multiplication with a factor 1

SCALE EFFECTS

Outline of handling scale effects



This *does*` *NOT exist.*

Several papers occurred on THIS issue

SCALE EFFECTS

Manoeuvring criteria

Task 10: Manoeuvring criteria

- IMO criteria MSC167
- Applicability to Podded vessels?
  - Woodward: Criteria are valid for podded vessels
  - Criteria are achievable for podded vessels (mini interview)
  - Practical: pod loads and heel angles and tend to be large.
    - Turning circle may be done at 20° rudder angle.
    - But 10°/10° and 20°/20° are VALID!!!

Ongoing project

Project containing model scale and full scale measurements MAROFF KPN “Sea Trials and Model Tests for Validation of Ship-handling Simulation Models” (led by MARINTEK).

- Develops standards for slow speed manoeuvres
- New benchmark data (incl. full scale)
- Method for validation of simulator models

Criteria for naval vessels

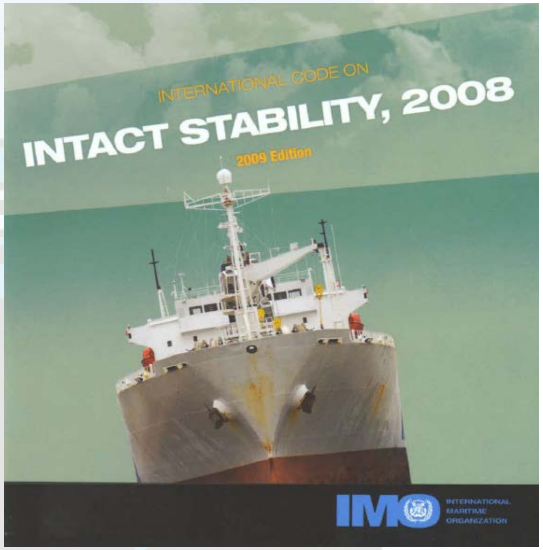
- Naval vessel manoeuvring criteria:
  - See Quadvlieg et al (2010)
  - For service speed and low speeds
  - Levels are mission dependent
  - Includes course keeping in waves
  - Also South Korea has adopted similar criteria

Criteria for inland vessels

- Overview of minimum requirements for inland navigation
  - For Rhine (Europe)
    - Minimum speed requirement, ahead & astern
    - Stopping distance requirement (in current)
    - Turning ability
    - ***Evasive manoeuvre***
  - For Yangtse river (PR China)
    - Maximum course variation while sailing ahead
    - Turning
    - Stopping
    - Maximum course variation while sailing astern
  - Levels are depending on waterway class, ship type and ship size, water depth, …

ITSC 2008

- “The angle of heel on account of turning shall not exceed 10° when calculated using the following formula:



$$M_H = 0.2 \cdot V_0^2 / L_{WL} \cdot \Delta \cdot (KG - d/2)$$

where:

M_H = heeling moment (kN·m)

V_0 = service speed (m/s)

L_{WL} = length of ship at waterline (m)

Δ = displacement (t)

d = mean draught (m)

KG = height of centre of gravity above baseline (m).”

- {Criterion for passenger ships -> adopted by Resolution MSC.267(85) on 4/12/2008}

This formula is traced back to come from equilibrium, so the “steady” heel angle

MANOEUVRING CRITERIA

- Heeling accident on M/V Crown Princess Atlantic Ocean Off Port Canaveral, Florida July 18, 2006
- Heel angle 24°
- http://www.ntsb.gov/doclib/reports/2008/MAR0801.pdf

Steering induced heel angle

- Suggest that the maximum heel angle is more important to look at.
- The present formula does not correlate with the maximum heel angle.

- *It is not our mandate to develop criteria. However, we do have an opinion. Here, we are raising a "warning flag"*

MANOEUVRING CRITERIA

Manoeuvrability in adverse weather

Definition of adverse weather has decreased over the years

Environment and indices	MEPC 62/5/19	MEPC 64/4/13	MEPC 65/22
Sig. wave height (m)	<9.8	<8	<5.5
Mean wind speed (m/s)	<21.4	<25	<19
Course deviation (°)	5-10	10	10
Min advance speed (kn)	2-4	4	4
Ability to turn to head waves	Yes	Yes	No

Where to look at

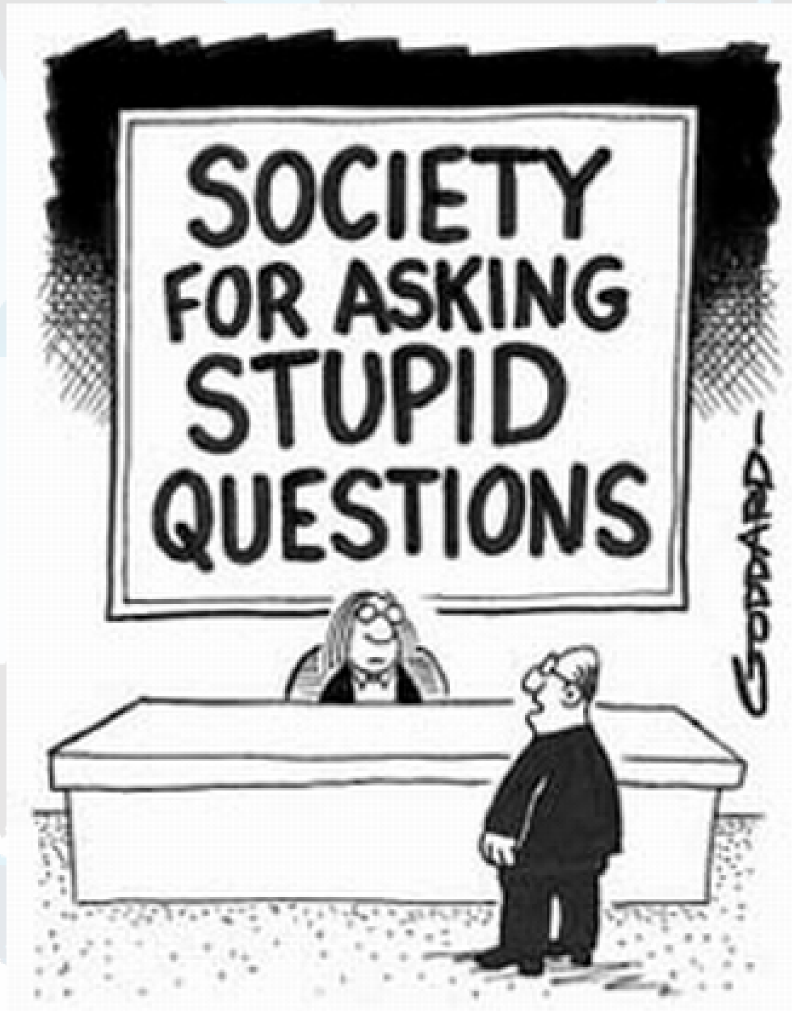
Ways to do it	MEPC 62/5/19	MEPC 64/4/13	MEPC 65/22
1st level	Curves	Curves	Curves
2nd level	Simplified	Simplified	Simplified
3rd level	Comprehensive	Comprehensive	-

Conclusions & recommendations

Summary of conclusions

- Continue promoting the benchmarks (SIMMAN and CMSCW)
- Keep on promoting the validation of manoeuvring predictions
- PMM procedure should be updated
- Consequences of movable floors
- Work in broader perspective on “manoeuvring in waves” (SC, SiWC, IACS) (through workshop), joint member

Any questions?



"Excuse me, is this the Society for Asking Stupid Questions?"

- ‘Sufficient manoeuvrability’ criteria behind the “2013 interim guidelines for determining minimum propulsion power to maintain the manoeuvrability of ships in adverse conditions (Resolution MEPC.232 (65))” is based on ‘ship’s ability to maintain course in any heading and wind conditions in the ‘defined adverse sea conditions’ in order to avoid grounding or collisions with shore or the other craft during coastal navigation and achieve a minimum navigation speed of 4 knots to leave the ports within reasonable period of time’.

- Further, the basic assumption for deriving Level 1 min power lines based on statistics is that most of the existing vessels within EEDI framework have sufficient manoeuvrability in the defined adverse sea conditions.

- The adverse sea conditions are then arrived through harmonisation of level 1 and level 2 assessments, resulting in significant   of 5.5m and Vwind=19.0 m/s for ships of more than 250m, and still milder condition for smaller ships.

- What is the expert opinion of the manoeuvrability committee on the above points ?