COMPARISON OF PIANC, ANKUDINOV and CADET SHIP SQUAT PREDICTIONS

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Michael J. Briggs, Coastal and Hydraulics Laboratory, ERDC
Paul J. Kopp, NSWC, Carderock Division
Vladimir Ankudinov, TRANSAS USA Inc.
Wilbur Wiggins, U.S. Army Engineer District, Savannah

Outline

- **Introduction**
  - **Squat major component of underkeel clearance (UKC)**
  - **Consists of underway sinkage (vertical motion of hull) and dynamic trim (rotation about center of rotation)**
  - **Increased interest in ship squat in deep-draft navigation community**
  - **Compare CADET predictions with Ankudinov & PIANC squat formulas**
- **PIANC Squat Formulas**
  - **Barrass**
  - **Eryuzlu et al**
  - **Huuska/Guliev**
  - **Römisch**
  - **Yoshimura**
- **Ankudinov Squat Formula**
- **CADET/BNT Squat Program**
- **Ship and Channel Parameters**
  - **Port of Savannah, Georgia**
  - **Susan Maersk Containership**
- **Comparisons**
  - **Unrestricted Channel (U)**
  - **Light and Fully-loaded**
  - **3 Water Depths**
- **Summary and Conclusions**

Introduction

- PIANC ship squat formulas
  - Empirical
  - Limited lab and field measurements
  - Developed for past generation ships
  - User friendly, but limited ship and channel parameters
  - 3 idealized channel cross-sections
  - Widely used and accepted
  - No one formula best for all scenarios
- Ankudinov ship squat formula
  - Recent revisions
  - Thorough and complicated
  - Ship & channel parameters
  - Mid-point sinkage & trim
- CADET program
  - Risk-based tool for predicting underkeel clearance (UKC)
  - Based on Navy's tools for deep draft ships in shallow channels
- CADET squat module
  - Beck Newman Tuck (BNT)
  - Based on Beck Newman Tuck (BNT) slender body theory
  - Numerical modeling ship lines with potential flow theory
  - Validated with model tests

PIANC Squat Formulas I

- **Five of most user friendly and “popular”**
  - **Barrass**
  - **Eryuzlu et al**
  - **Huuska/Guliev**
  - **Römisch**
  - **Yoshimura**
- **All give bow squat**
- **Stern squat**
  - **Only Römisch predicts stern squat for all channels**
  - **Barrass stern only for unrestricted or open channels and other channels depending on C_B value**

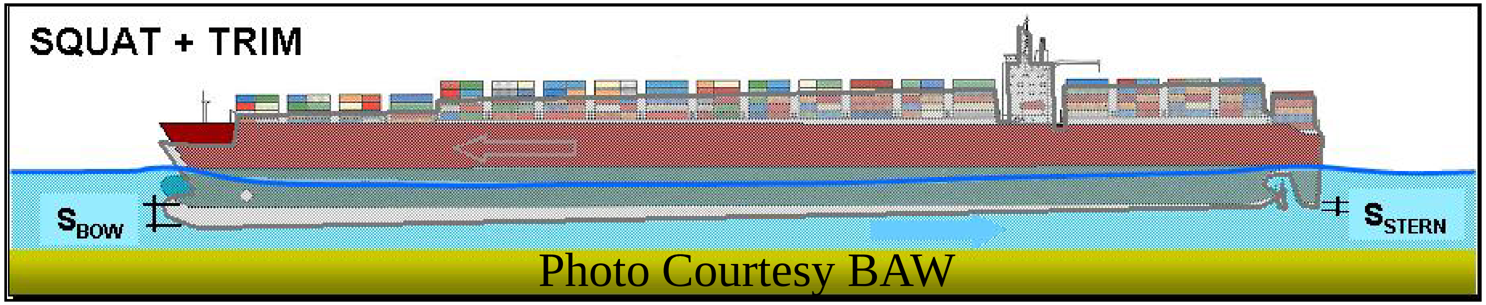


Photo Courtesy BAW

PIANC Squat Formulas II

- **Barrass**

$$\frac{K C_B V_k^2}{100} = \begin{cases} S_b & C_B > 0.7 \\ S_S & C_B \le 0.7 \end{cases}$$

- **Eryuzlu et al.**

$$S_b = 0.298 \frac{h^2}{T} \left(\frac{V_s}{\sqrt{gT}} \right)^{2.289} \left(\frac{h}{T} \right)^{-2.972} K_b$$

- **Huuska/Guliev**

$$S_b = C_S \frac{\nabla}{L_{pp}^2} \frac{F_{nh}^2}{\sqrt{1 - F_{nh}^2}} K_s$$

- **Römisch**

$$S_b, S_s = C_V C_F K_{\Delta T} T$$

- **Yoshimura**

$$S_b = \left[\left(0.7 + \frac{1.5T}{h} \right) \left(\frac{B C_B}{L_{pp}} \right) + \frac{15T}{h} \left(\frac{B C_B}{L_{pp}} \right)^3 \right] \frac{V_e^{\;2}}{g}$$

Ankudinov Squat I

- **Mid-ship sinkage S_m**
  - **Ship propeller**
  - **Ship hull**
  - **Ship speed**
  - **Water depth**
  - **Channel**
- **Trim T_r**
  - **Ship propeller**
  - **Ship hull**
  - **Ship speed**
  - **Initial trim**
  - **Bulbous bow**
  - **Stern transom**

Ankudinov Squat II

- **Maximum squat S_{Max}**

$$S_{Max} = L_{pp}\left(S_m \mp 0.5T_r\right)$$

- **Mid-point sinkage S_m**

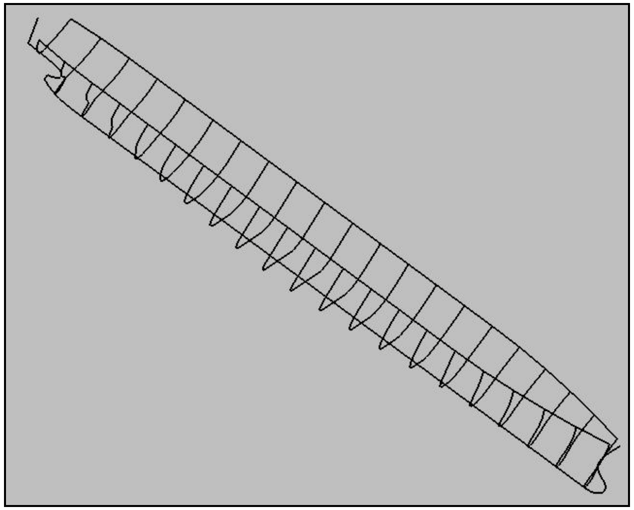
$$S_m = \left(1 + K_P^S\right) P_{Hu} P_{F_{nh}} P_{+h/T} P_{Ch1}$$

- **Trim T_r**

$$T_r = -1.7 P_{Hu} P_{F_{nh}} P_{h/T} K_{Tr} P_{Ch2}$$

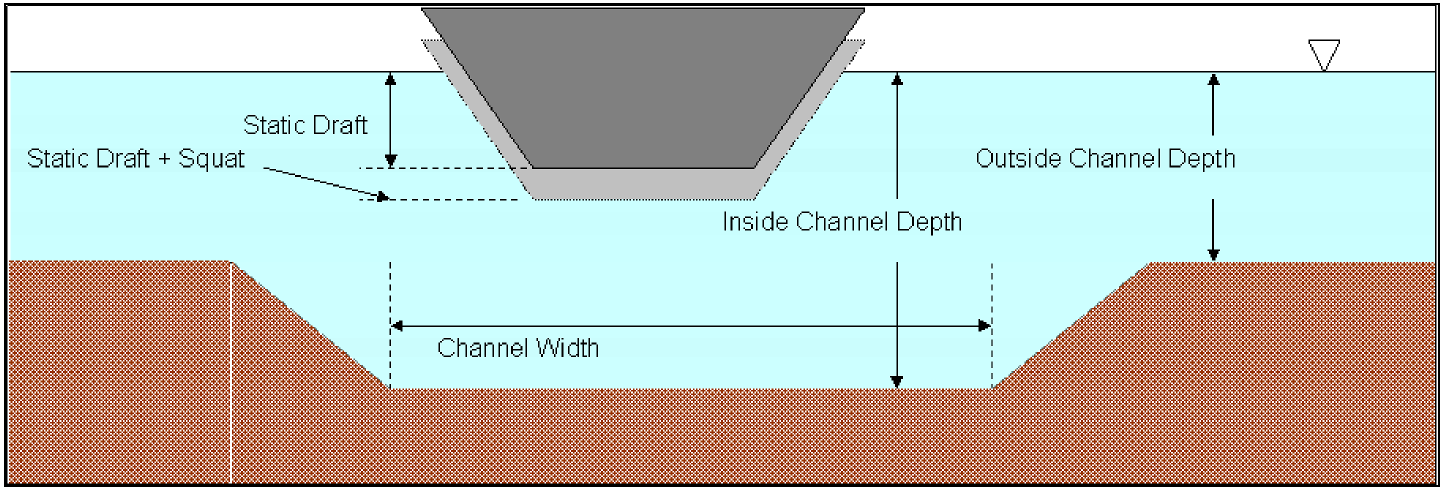
CADET Organization

- **Ship**
  - **Hull geometry and ship lines**
  - **Static draft and trim**
  - **Loading**
  - **Ship speeds**
  - **Control points**
  - **BNT ship squat**
  - **Heave, pitch and roll transfer functions**
- **Project**
  - **Channel reaches**
  - **Directional spectral waves and probabilities**
  - **Corresponding ships, BNT squat predictions, and loading conditions**
- **Analysis**
- **Results**



BNT Ship Squat Predictions

- **Based on early work of Tuck (1966 and 1967)**
- **Beck and Newman expanded to include typical dredged channel (1975)**
- **Sinkage and trim from dynamic pressure on hull**
- **Sorted by depth Froude Number and converted to squat**



Savannah Entrance Channel, Georgia

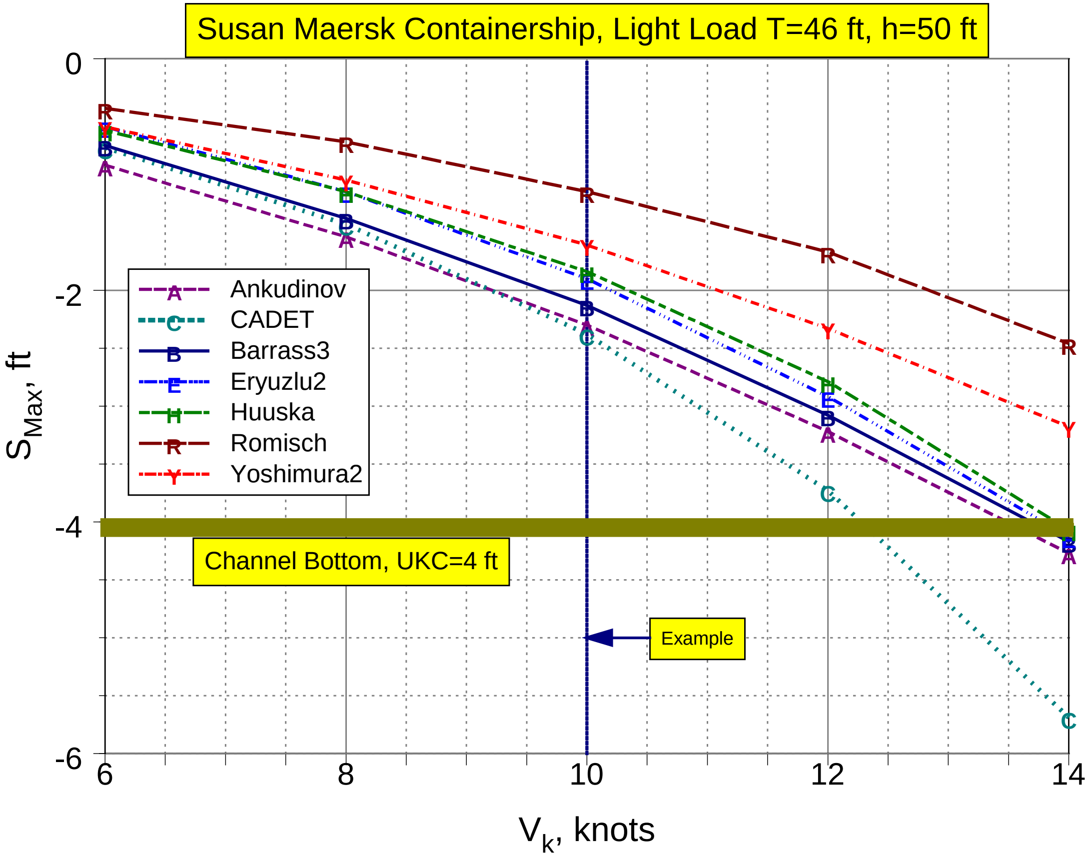
- **14 nm Outer Channel**
  - **Subject to waves**
  - **Existing depth of 44 ft MLLW**
  - **Plans to dredge to 50 ft**
  - **Tide range 8 ft**
  - **Offshore 5.8 nm segment like Unrestricted or open channel with Width = 600 ft**

Susan Maersk Containership

- L_{pp} = 1,088 ft
- B = 140.4 ft
- Draft
  - Light load T = 46 ft
  - Full load T = 47.5 ft
- C_B = 0.65
- V_K = 8 to 14 kts

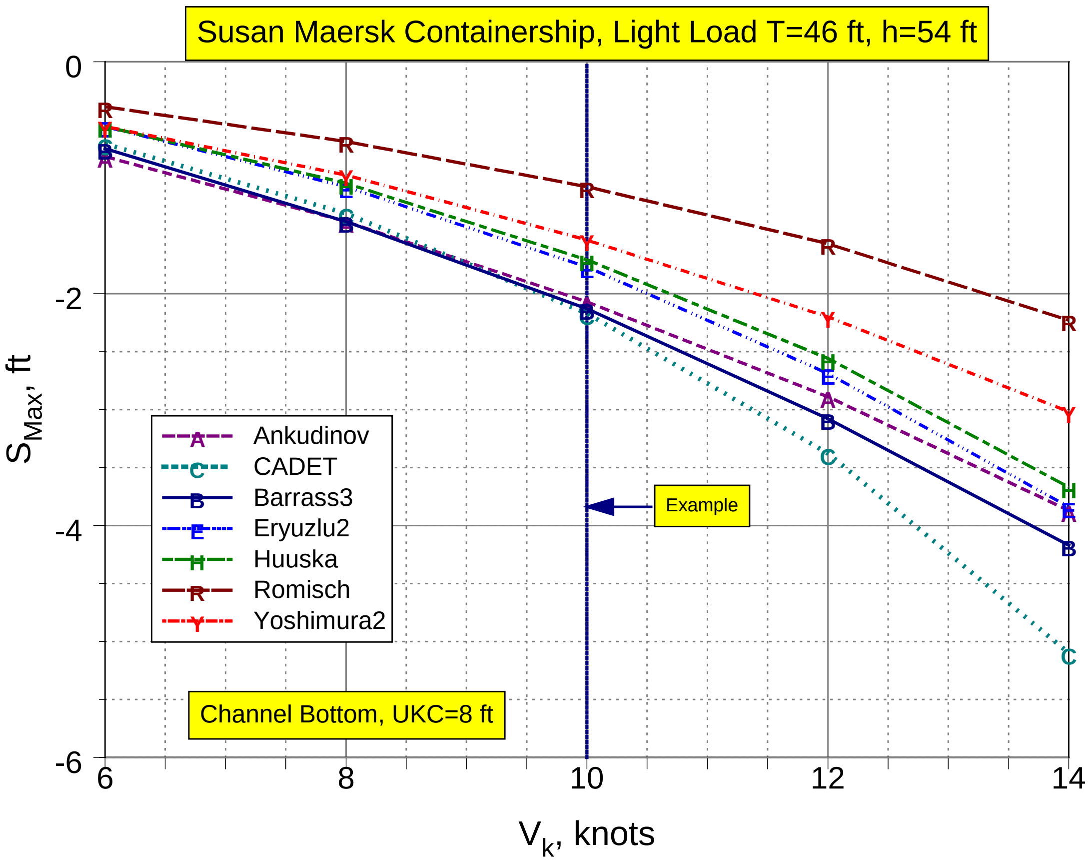
Light Load T=46 ft, h=50 ft (h/T=1.09)

- **No tide**
- **Available UKC=4 ft**
- **Ankudinov & CADET general agreement with PIANC predictions**
- **Both conservative**
- **Ankudinov tracks OK**
- **CADET tracks OK to V_k=10 kt**
- **Example @ V_k=10 kt**
  - **PIANC Ave=1.7 ft**
  - **Ankudinov=2.3 ft**
  - **CADET=2.4 ft**
- **Grounding due to squat at V_k=12+ kt**



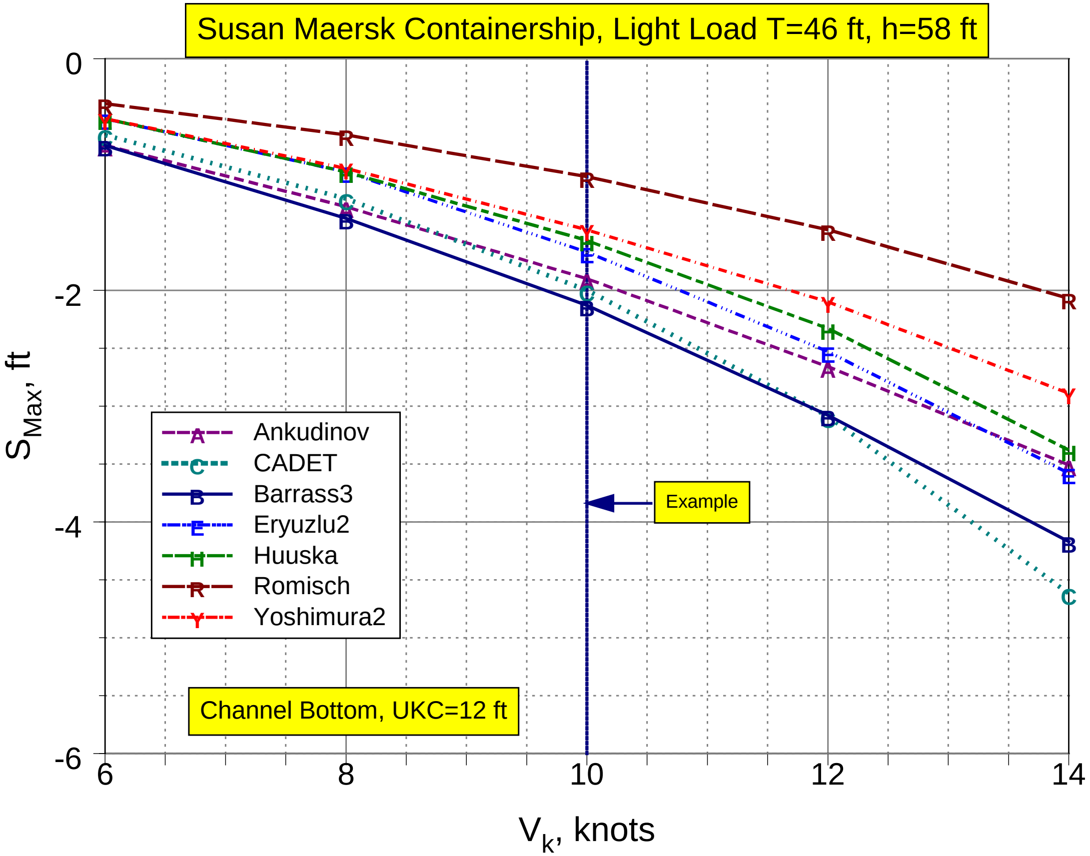
Light Load T=46 ft, h=54 ft (h/T=1.17)

- **Tide=4 ft, 4 hr/day, 365 days/yr**
- **Available UKC=8 ft**
- **Ankudinov & CADET general agreement with PIANC predictions**
- **Both conservative**
- **Ankudinov tracks OK**
- **CADET tracks OK to V_k=12 kt**
- **Example @ Vk=10 kt**
  - **PIANC Ave=1.6 ft**
  - **Ankudinov=2.1 ft**
  - **CADET=2.2 ft**
- **No grounding due to squat**



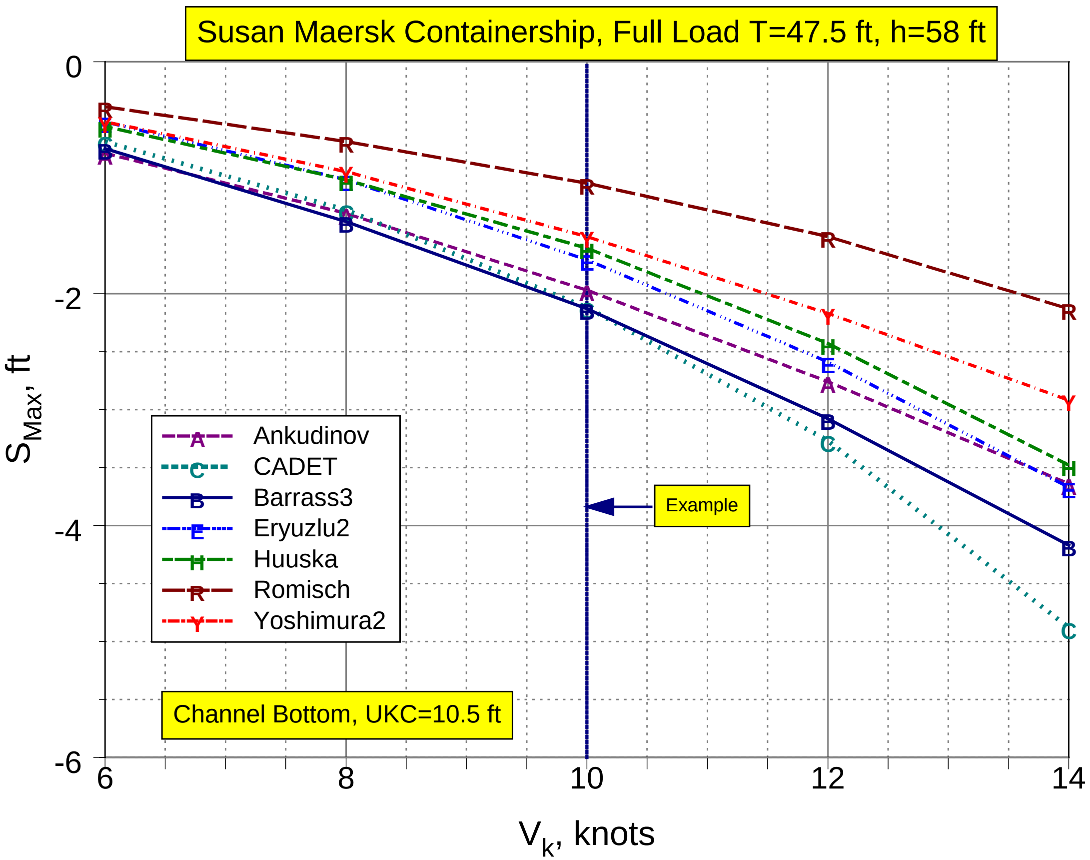
Light Load T=46 ft, h=58 ft (h/T=1.26)

- **Tide=8 ft, 1 hr/day, 7 days/yr**
- **Available UKC=12 ft**
- **Ankudinov & CADET general agreement with PIANC predictions**
- **Both conservative**
- **Ankudinov tracks OK**
- **CADET tracks OK to V_k=12+ kt**
- **Example @ V_k=10 kt**
  - **PIANC Ave=1.6 ft**
  - **Ankudinov=1.9 ft**
  - **CADET=2.0 ft**
- **No grounding due to squat**



Full Load T=47.5 ft, h=58 ft (h/T=1.22)

- **Tide=8 ft, 1 hr/day, 7 days/yr**
- **Available UKC=10.5 ft**
- **Ankudinov & CADET general agreement with PIANC predictions**
- **Both conservative**
- **Ankudinov tracks OK**
- **CADET tracks OK to V_k=12+ kt**
- **Example @ V_k=10 kt**
  - **PIANC Ave=1.6 ft**
  - **Ankudinov=2.0 ft**
  - **CADET=2.1 ft**
- **No grounding due to squat**



Summary and Conclusions

- **Comparisons of numerical CADET with PIANC and Ankudinov empirical squat prediction formulas**
- **Theory, advantages, and disadvantages of PIANC, Ankudinov, and CADET squat predictions presented and discussed**
- **Susan Maersk containership, 3 water depths, 5 ship speeds for unrestricted or open channel type**
- **CADET and Ankudinov reasonable agreement with PIANC predictions, conservative side**
- **Ankudinov and CADET squat predictions can be used with confidence in deep-draft channel design**

Questions?

Recent Interest in Ship Squat

- Capt Stephen Best, Port of Vancouver, Canada
- Capt Richard A. Hurt, Port of San Francisco, CA
- Albert Lavanne, Engineer, Port of Rouen Authority, France
- Karin Hellström, 2nd Officer, M/T Prospero, Donsotank, Sweden
- Papoulidis Panagiotis, Master Mariner, Greece
- Capt. Marco Rigo, Venice, Italy
- Capt. Michael Lloyd, Senior Advisor, Witherby Seamanship International Ltd, United Kingdom
- Anton Holtzhausen, Cape Town, South Africa
- Capt Jonathon Pearce, Marico, United Kingdom
- Nisrine Alderf, PhD. Student, UTC University of Technology of Compiegne, France

Challenge Questions

- **Near term and long term visions for MTS**
- **Drivers shaping MTS**
  - **Size of ships**
  - **Safety**
- **Near term and long term research required**
  - **Ship squat for larger ships**
  - **Vertical and horizontal ship motion prediction**
  - **Ship interaction with entrance channels, non-symmetrical channels, other ships during passing and overtaking**
- **Advantages of national CMTS R&D strategy**
  - **Consistent and proven design and guidance**
  - **Improved safety**
- **Challenges of national CMTS R&D strategy**
  - **Consensus among various parties**
  - **Research funding**