# Intuitive operation and pilot training when using marine azimuthing control devices

AZIPILOT

**Report Title:** Deliverable 2.6: Summary of Simulation

**Work package:** MARINE SIMULATION

**Task Number:** 2.6

**Task Title:** Summary of Simulation

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**Partner Code:** TL

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## Contents

## EXECUTIVE SUMMARY

The aim of this task was to sum-up existing Marine Simulator capabilities with respect to their capabilities regarding azimuthing devices and their application and including their validation and limitations. The task was focusing on condensing the knowledge obtained in Phase 1 of this WP into a form that is readily accessible by other WPs; including:

- Condense knowledge on existing simulator capabilities for azimuthing control devices.
- Condense knowledge on existing simulator capabilities in harbours.
- Sum-up ability to simulate tug/tow interactions.
- Encapsulate ability to simulate azimuthing control device interactions.
- Encapsulate ability to model bridge systems and human interface.

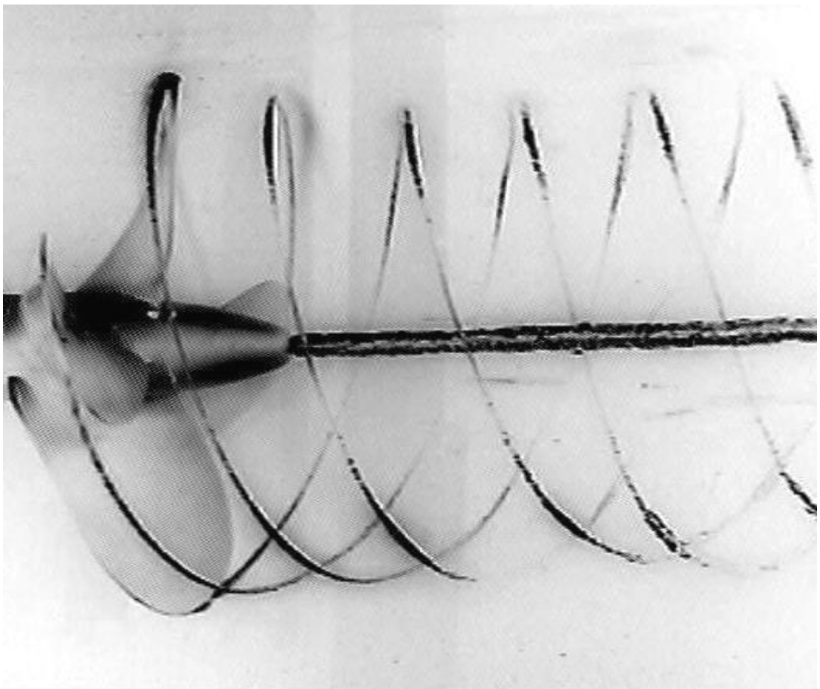
The task culminates in a present task report that delineates the above aims and objectives and constitutes one deliverable.

**1: CONDENSE KNOWLEDGE ON EXISTING SIMULATOR CAPABILITIES FOR AZIMUTHING CONTROL DEVICES**

Major elements of simulation

- Visual data base of simulation scenario with relevant current, wind, wave and channel effects
- Visual data base of the ship itself (see two Figures below)
- Hydrodynamic and simulation modeling

Simulation realism requires adequate simulation capability of azipod devices verified with full scale data and pilot handling validation.

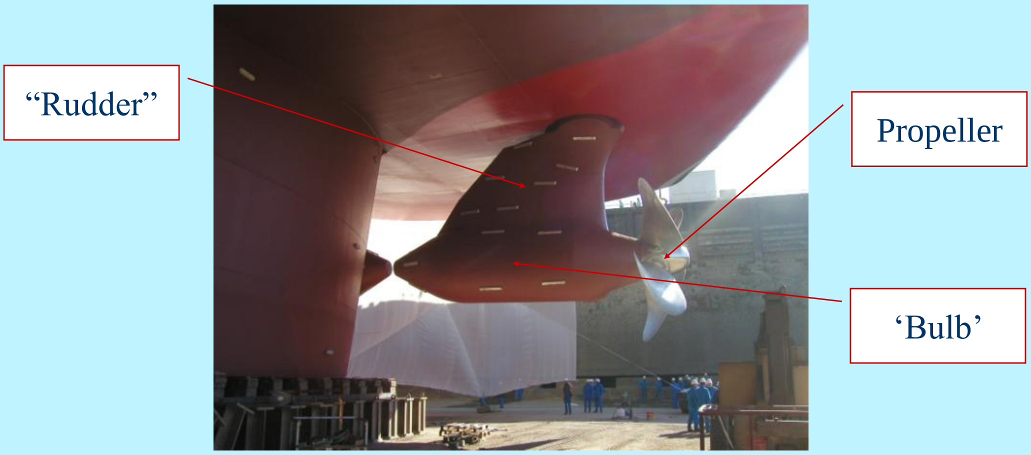


HYDRODYNAMIC FORCES ACTING ON A POD

Pod's Elements and Forces acting on it

## What is a Pod ?

- Simplistically – a rudder combined with a propeller

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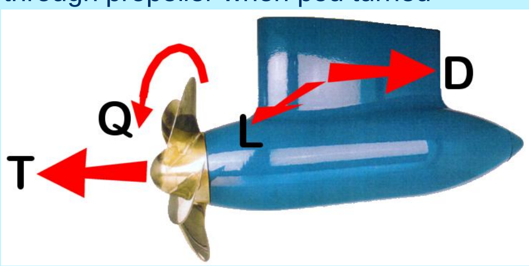
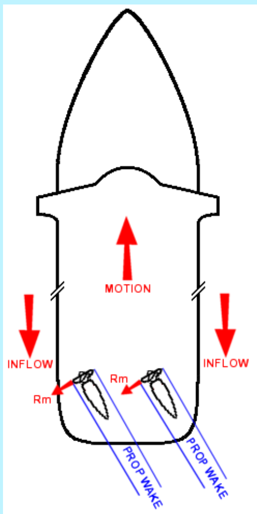
Hydrodinamic Forces

## Forces Acting on a 'Pod'

- Propeller Thrust (T)
- Propeller Torque (Q)
- Lift (L) and Drag (D) of 'pod sail'
  - Similar to rudder but less efficient due to shape
- Momentum Drag (Rm) of propellers
  - Due to altering flow direction as water passes through propeller when pod turned

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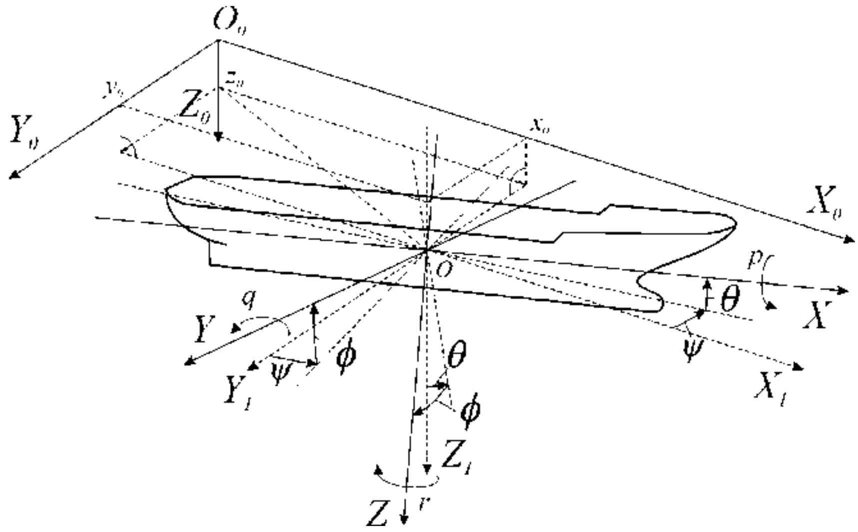
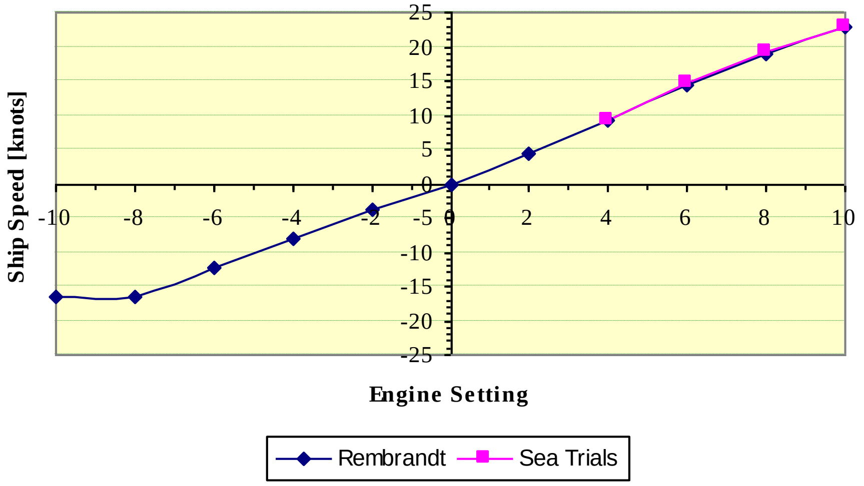
## 6 DOF HYDRO MODEL

- To evaluate the total hydrodynamic forces and ship responses in surge-sway-yaw- roll -hew-heave and pitch, the hydrodynamic forces acting on the hull, propellers, and other appendages simulators are using a large amount of computational and empirical data



- Below are few examples of the simulation capabilities of the azimuth control devices (AZD tug and 3 pods cruise ship) including those used in harbors.
- For more comprehensive analysis see our report in the Task 2.4

## SHIP SPEED VS. TELEGRAPH SETTING FOR CRUISE SHIP AZIPOD 3



Simulator capabilities for azimuthing control devices.

| Parameter | Model Test | Predicted (Rembrandt) | Deviation |
|---|---|---|---|
| Initial Speed (kts) | 24.1 | 24.1 | - |
| Advance (m) | 580 | 523 | -9.8% |
| Transfer (m) | 183 | 224 | +22.4% |
| Tactical diameter (m) | 514 | 577 | +12.3% |
| Steady speed (kts) | 9.2 | 8.6 | -0.6 kts |
| Steady heel angle (deg) | 5 | 4.2 | -0.8 ° |
| Steady rate of turn (°/min) | 70.8 | 68.6 | -2.2 °/min |

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Simulator capabilities for azimuthing control devices.

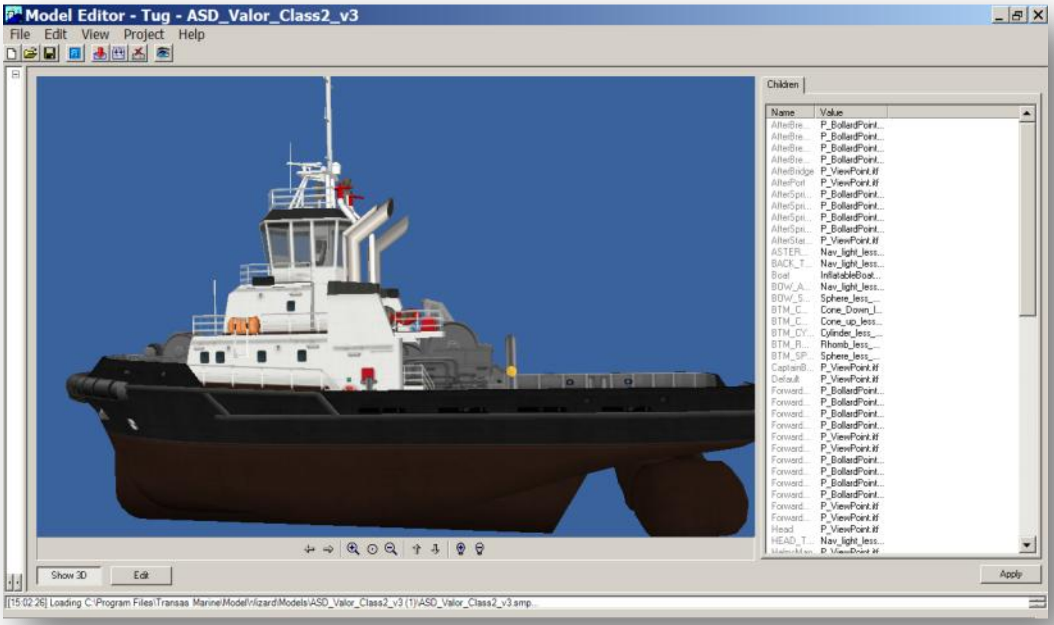
| BMT | Initial Speed (kts) | Advance (m) | Transfer (m) | Time at $90^0$(sec) | Time at $180^0$(sec) | Time at $270^0$(sec) | Tactical Diameter (m) | Steady Speed (kts) |
|---|---|---|---|---|---|---|---|---|
| Sea Trials | 23.7 | 1411 | 890 | 165 | 295 | 422 | 1820 | 15.6 |
| Rembrandt | 23.7 | 1270 | 770 | 147 | 278 | 414 | 1620 | 15.8 |
| Deviation | - | -10% | -13% | -11% | -6% | -2% | -11% | 0.2 kts |

| Transas | Initial Speed (kts) | Advance (m) | Transfer (m) | Time at $90^0$ (sec) | Time at $180^0$ (sec) | Time at $270^0$ (sec) | Tactical Diameter (m) | Steady Speed (kts) |
|---|---|---|---|---|---|---|---|---|
| Sea Trials | 23.7 | 1411 | 890 | 165 | 295 | 422 | 1820 | 15.6 |
| Transas | 23.55 | 1348 | 758 | 161 | 325 | - | 1826 | 15.4 |
| Deviation | 0.1kn | -4.5% | -15% | -2% | 10% | - | 0.3% | -0.2 kts |

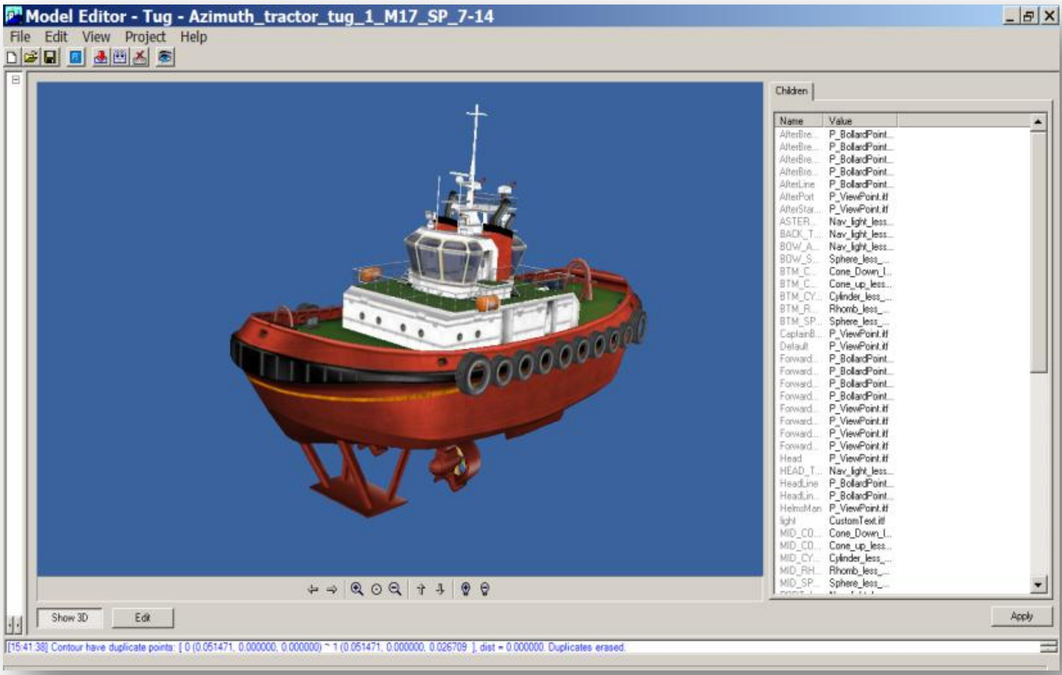
- Mathematical Models used by modern Simulators adequately describe Maneuvering Operations of most Ships equipped with Pods in the practical range of ship speeds and pods angles.
- Azipod Modeling  and Simulations apparently need to be more accurate for large pods angles and slow speed maneuver
- Hydrodynamic Interaction of the multiple pods requires the
- Additional research efforts and validation test data

## 2: CONDENSE KNOWLEDGE ON EXISTING SIMULATOR CAPABILITIES IN HARBOURS AND SUMMING- UP ABILITY TO SIMULATE TUG/TOW INTERACTIONS.

TRANSAS POD DRIVEN TUG

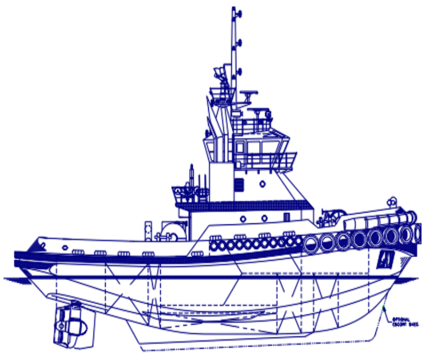


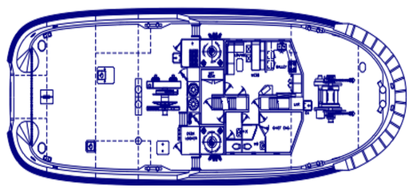

AZIMUTH TRACTOR TUG



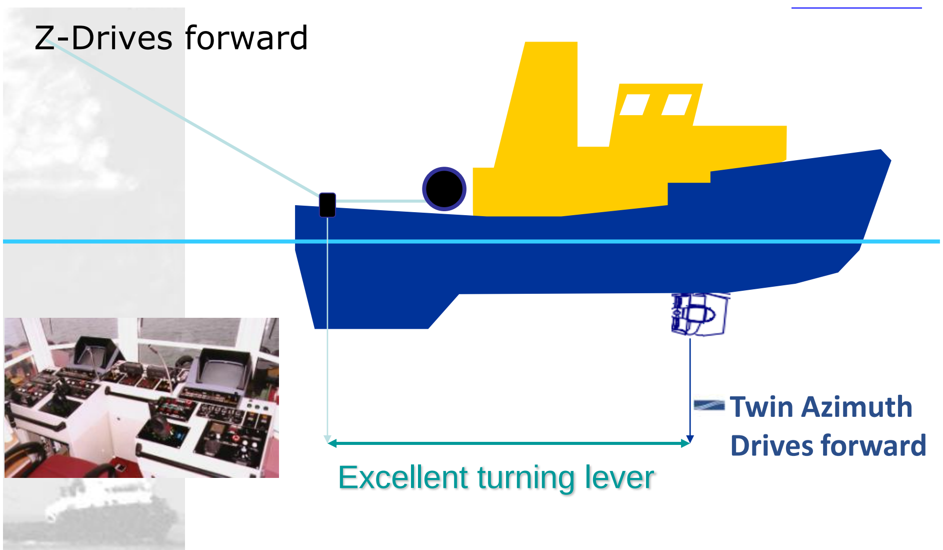
**BASIC MANEUVERS OF THE ASD TUGS ON SIMULATOR:**

- Stopping and Turning – reverse arrest
- Managing the Speed
- Turning
- Putting Steering and Speed Together
- Rotating without Advancing
- The “Flip”
- Walking (flanking)
- Transitions
- Undocking
- Berthing and Anchoring
- Cycling and Tandem
- Maneuvering in Current





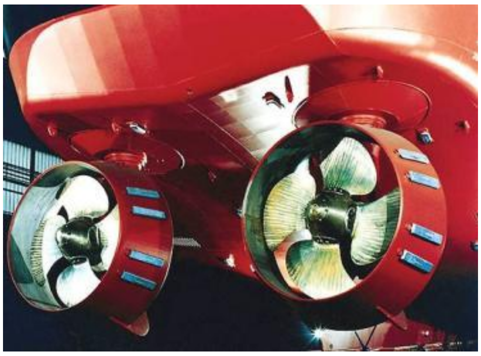
TRACTOR TUGS



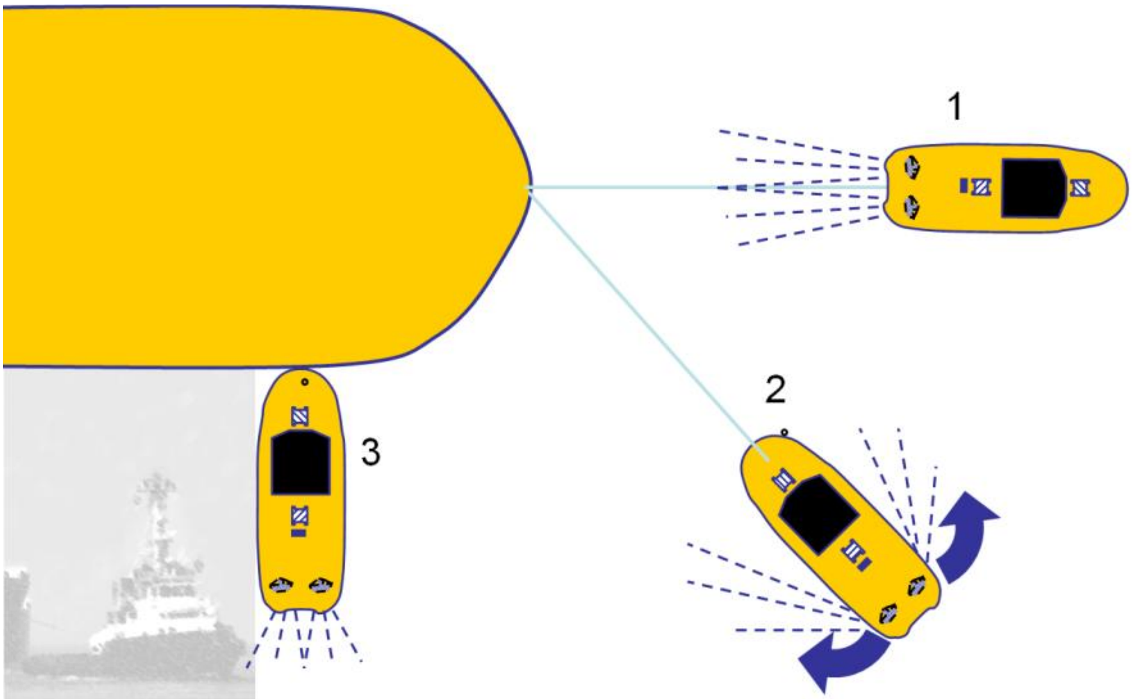
AZIMUTH STERN DRIVE (ASD)

Multi Directional Propellers

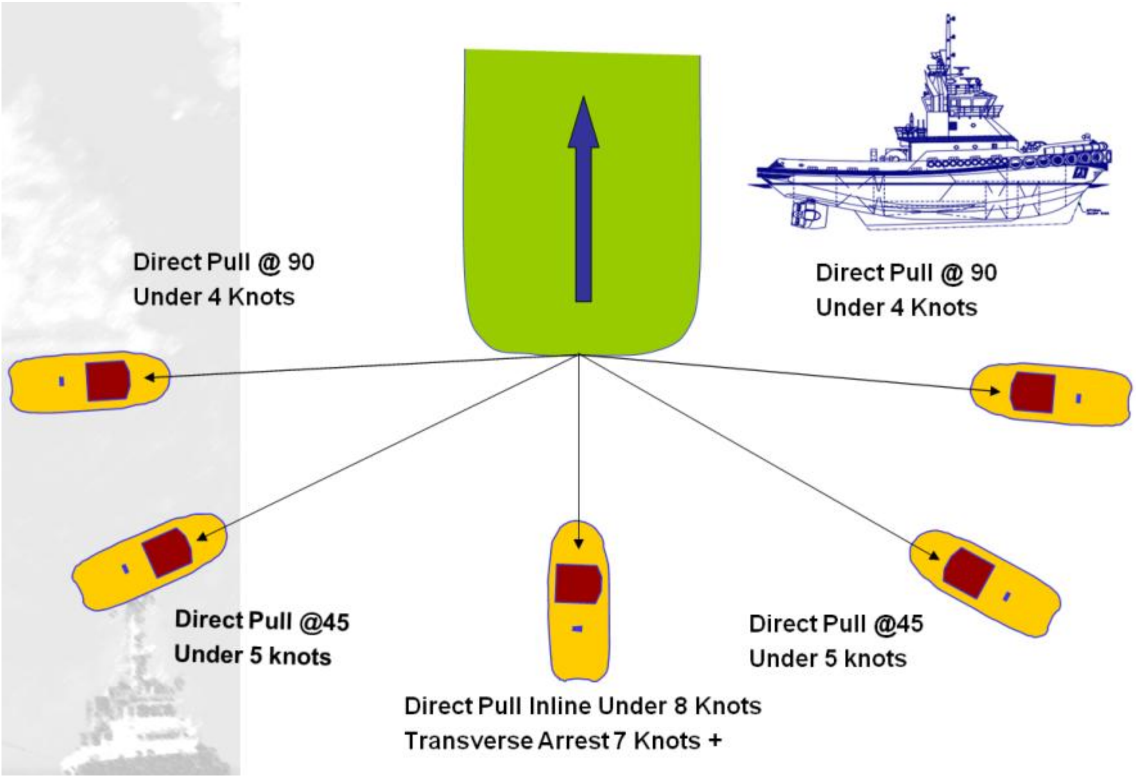
- Rotate through 360 in the vertical axis
- No rudders
- Two towing points
  - » One forward
  - » One near amidships



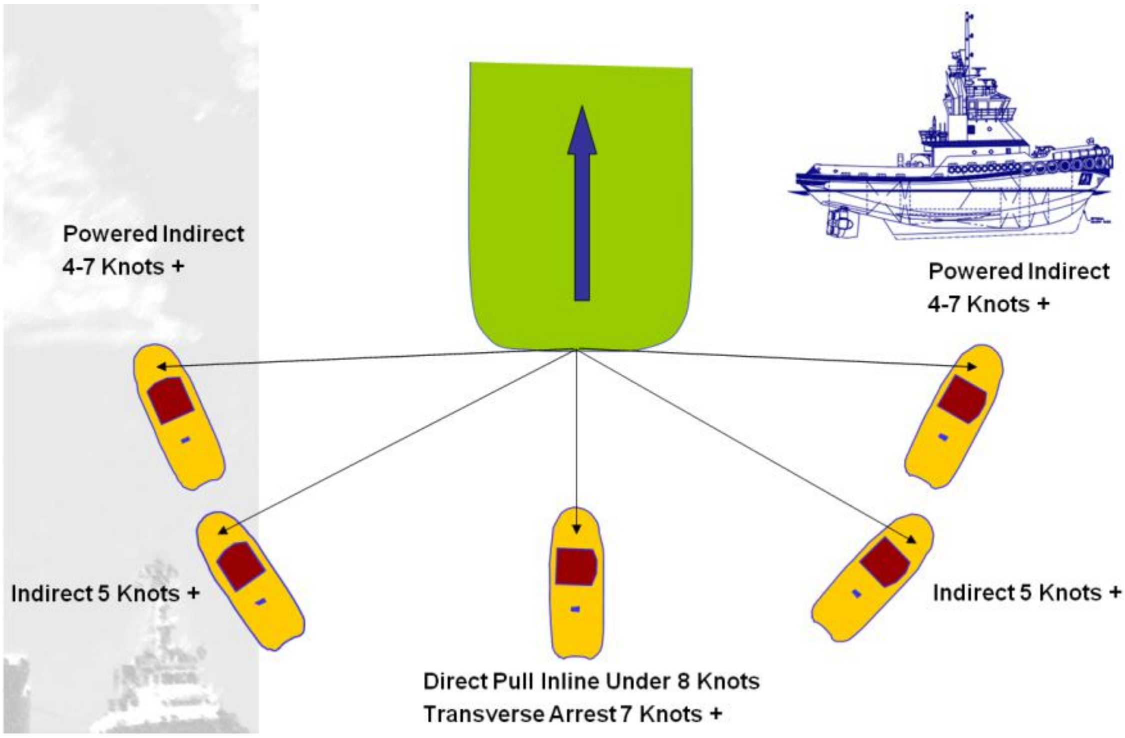
WORKING AN ASD TUG FORWARD



AZIMUTH STERN DRIVE (ASD) DIRECT MODE




AZIMUTH STERN DRIVE (ASD) INDIRECT MODE



**MANEUVERING SIMULATION OF THE TUG WITH AZIMUTH DEVICES**

AZIMUTH DRIVE TUG 1: AZIPODS AT STERN

COMPARISON OF VESSEL AND MODEL PERFORMANCE

| | Vessel Performance | Model Performance |
|---|---|---|
| Rated bollard pull ahead (tons) | 77 tons | 78 tons |
| Rated bollard pull astern (tons) | 75 tons | 74 tons |
| Engine time from Neutral to Idle Ahead, s | STBD 5 sec, Port 4 sec | 4 sec |
| Engine time from Idle to Full Ahead, s: | 25 sec | 23 sec |
| Ahead clutch in | 70RPM = 4.2 kts | 70RPM = 4.1 kts |
| Ahead half | 160RPM = 9.6 kt | 160RPM = 9.5 kts |
| Ahead Full | 245RPM = 13.5 kts | 245RPM = 13.5 kts |
| Astern clutch in | 70RPM = 4.2 kts | 70RPM = 4.1 kts |
| Astern half | 160RPM = 9.4 kts | 160RPM = 9.3 |
| Acceleration: Stop – Full Ahead | 77 seconds to 13.6 kts | 80 seconds to 13.5 kts |
| Acceleration: Stop – Full Astern | 63 seconds to 11.0 kts | 72 seconds to 11.1 kts |

Simulation capabilities of azimuth driven tugs

- Azimuth devices for TUGS are still developing technology and subject to restrictions until the limitations are addressed
- Azimuth Devices for TUGS offer great advantages in ship handling and significant advantages in technical and hydrodynamic terms
- The modern simulators realistically simulate most of the TUG typical operations including coastal passage, assisting in berthing and anchoring operations and require accurate visual image
- Simulation Improvements should include more accurate modeling of ship-TUG interaction effects and low speed maneuvers with large pods angles
- In application of the TUG podded propulsion in DP systems and in joystick systems, the simulation software has to perform within the latest guidelines and restrictions

## 3: ENCAPSULATE ABILITY TO SIMULATE AZIMUTHING CONTROL DEVICE INTERACTIONS

- In the range of small and moderate pods angles modern simulators capture pods interactions with great realism.
- Azipod Modeling and Simulations for large pods angles will require the comprehensive CFD computations combined with the specialized model and full-scale trial testing.
- Hydrodynamic Interaction of the multiple pods also requires the additional research efforts (including CFD) and validation test data.
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Simulator capabilities for azimuthing control devices.

Comparison of the Predictions and Trial Data in Stopping Maneuver

| Description | 2 Pods in use | 2 Pods in use | 1 Pod in use, 1 wind-milling | 2 Pods in use, maneuvering mode, pods at 180$^o$ |
|---|---|---|---|---|
| Approach Speed (kts) | 24.6 | 15.0 | 15.0 | 15.0 |
| Head Reach | | | | |
| Sea Trials (m) | 1893 | 957 | 1863 | 649 |
| Rembrandt (m) | 2024 | 1034 | 1622 | 705 |
| **Deviation** | **+6.9%** | **+8.0%** | **-12.9%** | **+8.6%** |
| Time to Dead In Water | | | | |
| Sea Trials (sec) | 331 | 254 | 422 | 182 |
| Rembrandt (sec) | 320 | 254 | 411 | 190 |
| **Deviation** | **-3.3%** | **0%** | **-2.6%** | **+4.3%** |

| *Description* | *2 Pods in use* | *2 Pods in use* | *1 Pod in use, 1 wind-milling* | *2 Pods in use, maneuvering mode, pods at 180$^o$* |
|---|---|---|---|---|
| Approach Speed (kts) | 24.6 | - | - | - |
| Head Reach | | - | - | - |
| Sea Trials (m) | 1893 | - | - | - |
| Transas (m) | 2135 | - | - | - |
| **Deviation** | **+11.3%** | | | |
| Time to Dead In Water | | - | - | - |
| Sea Trials (sec) | 331 | - | - | - |
| Transas (sec) | 324 | - | - | - |
| **Deviation** | **-2.1%** | | | |

## 4: ENCAPSULATE ABILITY TO MODEL BRIDGE SYSTEMS AND HUMAN INTERFACE

- Simulations of the Emergency Maneuvers on the bridge are relatively limited due to the lack of the specific guidelines and quantitative measures define their success.
- In US and other countries there are significant efforts to define in more accurate manner the complexity of the human interaction to minimize or avoid emergency situations on ship board, see also the extensive references in Annex 2, taken from the Paper by Dr. E. Suhir of U of California.
- His numerical technique is already under testing by the US Air Forces and NASA.
- The novelty of his approach is that finally provide a numerical bridge between human factors uncertainties and external factors. By employing quantifiable and measurable ways to assess the role of these uncertainties and by treating a “human-in-the-loop” as a part (often as the most crucial part) of the complex man-instrumentation-equipment-vehicle-environment system one could improve dramatically the human performance, to predict and, if needed, specify and even avoid the probability of the occurrence of a mishap
- Plenty of additional analyses and human-psychology related effort will be needed, of course, to make the guidelines based on the suggested concept practical for particular applications. These applications might not be even necessarily in the vehicular technology domain, but in many other systems where a human interacts with equipment and instrumentation, and operates in conditions of uncertainty
- In recent discussion with Dr. Suhir he told me that he is also working on defining the more accurate “the upper boundary level” of required human training for the standard and Emergency Cases.

References: none

# Annex 1

To the EU AZIPILOT Project Report Task 2.6

Title:"Azimuth Tug Escorting Manoeuvres simulated on TRANSAS simulators for LNG pilot training"

# Annex 2

To the EU AZIPILOT Project Report, Task 2.6

## Likelihood of Vehicular Mission Success and Safety, and the Human Factor Role

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AIAA Member

"If a man will begin with certainties, he will end with doubts;

But if he will be content to begin with doubts, he shall end in certainties."

Sir Francis Bacon, English Philosopher and Statesman

"If you bet on a horse, that's gambling. If you bet you can make three spades, that's entertainment.

If you bet the mission will be safe and successful, that's probabilistic risk management. See the difference?"

Unknown Probabilistic Risk Analyst