SIMULATION TECHNIQUES
by
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Introduction

In order to provide a basic insight into the various simulation methods, the different simulation techniques will be addressed as used for maritime training of pilots and tug masters, and for nautical studies of approach channels, fairways and port design and entrance policies for certain types and sizes of ships. This will include the use of physical models for training. With respect to nautical studies on simulators, pilots and tug masters frequently play a crucial role in these studies, which at the same time can provide useful training for pilots and tug masters, or are followed up by such a training.
Attention will particularly be paid to those simulators that are suitable for tug master training.

General description of simulator types and use

Various approaches can be followed in investigating the performance of a ship assisted by tugs in restricted waters, e.g. for port studies. Full-scale experiments are rarely recommended because of the risks and costs involved. Simulation techniques often provide a viable alternative. A simulator set-up for such a port study would then consist of a fully equipped bridge simulator for the ship to be simulated as well as for the assisting tugs. The individual simulators interact with each other through the mathematical models as well as through the out-of-window view, a so-called full-mission interactive bridge simulator set-up. Such a set-up is also used for training of pilots and tug masters.
However, a simulator set up consisting of various simulator ship and tug bridges is costly. Simpler, less costly simulation methods are therefore sometimes preferred in particular for training and for a preliminary investigation. The following basic alternatives exist to save costs or to limit the necessary simulation time:

- Fast-time simulation, where, to a certain level, the behaviour of the navigator (captain, pilot, tug master) of the ship and tugs is simulated by using mathematical models of this behaviour. In this approach, only the mathematical ship and tug models of the simulator are used, i.e. there is no involvement of a human operator. Less simulation time is needed and the costs of a projection system, which form the major part of the cost of a simulator, are avoided. This system is often used for a preliminary investigation.

- Simulation with simpler simulator techniques. Cost reductions can be obtained by using simpler projection systems, a smaller projected range of view, or by using a simulator without a projection system. For the latter system in particular, information with respect to the environment must be presented to the navigator from an (additional) display or from a radar screen.

- A ship bridge simulator, where tugs are simulated by force vectors only. The high costs of using more than one simulator can so be avoided.

In addition to these alternatives, free-sailing ship models can be used to determine their response to steering and engine control commands given by the navigator. Free-sailing models experience the effects of shallow water, interaction with other ships and banks, as do full mission simulators.

These basic alternatives have resulted in the development of many different simulator designs, varying from simple pc-simulators to very sophisticated full-mission simulators. Depending on the capabilities and limitations of these simulators, they serve a certain purpose and can all be used in one way or other for maritime training projects, for nautical research studies, or for both.

Basically, simulation methods can be divided into three groups:

a. Non-interactive simulation

In this case the complete navigation process is mathematically modelled. There is no human interaction with the process. This type of simulation is often called **fast-time simulation**, a process briefly explained above. As this method of simulation is not suitable for training projects, it will not be considered further in this paper.

b. Interactive simulation by physical models

Physical models are the so-called **manned models**. Interaction with the physical model takes place by the human operator(s). It is a kind of fast time simulation where the time factor depends on the scale of the model. The system is used mainly for training of pilots and ship captains. A much larger tug model than the ones used in the training basins is now being developed for training of tug masters.

c. Interactive simulation by simulators

In this case interaction with a simulator device takes place by a human operator. This mainly refers to **real-time simulation**, which takes place on e.g. full mission ship bridge simulators. Full mission ship bridge simulators, and comparable simulators, are often used for research and training of pilots, ship captains and tug masters as well.
As already mentioned before, within a simulator institute a number of ship bridge simulators can cooperate. For instance, one or more tug simulators can be handled by tug captains with a ship simulator handled by a pilot.

Simulation by physical models and by simulators will be addressed below.

INTERACTIVE SIMULATION

Physical models

a. Manned models

Manned models are used for training of ship captains and pilots in ship handling and tug use and can be found in different places in the world, such as in the UK (Warsash), Australia (Port Ash), and France (Port Revel-Grenoble. *See photo at the left*), USA (Massachusetts Maritime Academy . *See photo at the right*) and Poland (Ilawa).
As this training system is mainly used for ship

captains and pilots, no further attention will be paid to this system.

b. Larger manned models

One of the newest developments in training of tug masters is training on board a specifically designed small training tug. The BRatt training tug is such a tug, designed by Robert Allan Ltd and Burchett Marine Inc. Training on board this small training tug is a step closer to the practical and realistic on-the-job training and could be a more cost-friendly system than training on a ship bridge simulator. It is interesting to hear about the training experiences with this training tug.

The BRatt is a tug with a length of 7.80 m and a width of 3.60 m having a representative ASD hull form, with two azimuth drives and an engine power of 316 bhp. It has furthermore a fully operational bow winch and all around resilient fendering. Ultimately this training tug type can be fitted with a variety of alternative propulsion systems.

c. Remote-controlled models

Remote-controlled models can be used for specific training purposes or for research. For instance, scale models of tugs and a ship or barge are used to train tug crews in tug handling. Suitable models can also be used to investigate situations that would be hazardous if a full size ship and tug were used.

Ship manoeuvring simulation

a. Full-mission bridge simulators

Introduction

Full-mission bridge simulators are the most comprehensive manoeuvring devices available today. There are several simulator manufacturers, such as Kongsberg, MARIN, V-STEP, Transas, etc. The full mission bridge simulators consist of a full-scale mock-up of a ship's bridge, with all instruments required for navigation and manoeuvring, as well as a full-scale display of the ship and surrounding area as seen through the windows of the wheelhouse. Video projectors based on computer-generated imagery generate generally the out-of-window view.
In all ship manoeuvring simulations, the manoeuvring behaviour of the ship - or tug - and the environmental influences due to current, wind, bank effects, etc. are described mathematically. Human navigators, pilots, ship captains and tug masters perform the steering and engine control functions of the mathematical model. Steering and engine control is a facility that can artificially reproduce the workings of the real system.
It must be said that there is a continuous progress in simulators, caused by new developments and by the increased performance of computers, including desktop computers, and by the high costs of the large ship bridge simulators.

Vector tugs or interactive tugs simulate tug assistance; a combination of both systems is also possible. Vector tugs in their basic form simply represent a towing or pushing force in the required direction. The simulator operator handles them.

The concept ‘interactive tugs’ implies that the tugs are simulated on separate bridge simulators, also with all instruments, real control handles for manoeuvring, and deck equipment, as well as a full-scale display of the assisted ship and surrounding area as seen through the windows of the tug wheelhouse. The simulated tugs are handled by real tug masters, if needed interacting with the simulated ship as they would in real life.

Out-of-window view

For navigation and manoeuvring in confined waters, the out-of-window view is essential for realistic performance on a simulator. This is because masters, pilots and tug captains in particular, are strongly visually oriented; they base their decisions of rudder, engine and tug movements to a large degree on visual information – such as the ship's speed, drift, heading, rate of turn and distances off - obtained from the outside world. It must, however, be said that more and more `portable pilot units' are used to assist pilots in the navigation and manoeuvring of large vessels.

Nevertheless, on a simulator the visual information should be presented directly and accurately, without any time delay, to the person navigating or manoeuvring the ship or tug.

It should be carefully considered whether a 360^0 outside view is needed or whether a smaller field of view - for instance 225^0 – is sufficient. This depends to a large extent on the area to be simulated and the manoeuvres to be executed.

The vertical angle of view is mostly in the range 35^0 - 40^0. On modern simulators, larger vertical angles can be accommodated to fit training or research requirements. A suitable vertical angle is of particular importance for berthing/unberthing simulations.

Many ship bridge simulators have indeed a 360^0 out-of-window view. Out-of-window view for tug simulators is often 180^0 – 220^0. However, for a tug working in confined areas this is not sufficient. A tug captain also needs a 360^0 view. Sometimes an extra projection screen is added for a rear view. Some simulator institutes may provide a tug simulator with a 360^0 out-of- window view.

A monitor with a bird's eye view is sometimes installed showing the ship's and tug's outline and the surrounding area in order to compensate for the lack of sufficient outside view and to allow distances off to be estimated more accurately. The provision of such a monitor depends to a large extent on the degree of confinement of the area under consideration and the manoeuvres to be executed. The monitor should only be seen as a supplement, and not be used as a reference for carrying out manoeuvres.

On ship and tug simulators different eye points can be selected. A view can, for instance, be presented from the bridge wing or astern. One should, however, be aware that when on a tug simulator a stern view is projected on the ahead screen, orientation of all controls is 180 degrees off.

The projection of various environmental conditions, e.g. reduced visibility, day and night, waves, clouds and ice should be realistic. When simulating navigation in ice, it may be necessary to simulate changes in the ice field as the ship passes through it, e.g. the view of the broken channel behind the ship.

Tugs - interactive or vector tugs - should be visible in the out-of-window view when not obscured by the ship.

One problem of the present out-of-window views with respect to navigating and manoeuvring in confined waters is the difficulty in assessing distances off. Secondly there is a tendency to sail at higher speeds than required or than are really safe. For developments in improving the possibility to assess distances off more accurately, please see *Compact Simulators.*

Bridge lay-out

The simulator bridge lay-out should be such that navigation and manoeuvring tasks can be performed as they would in real life. In this context, several aspects should be taken into account, as they may have consequences for the bridge lay-out of a ship and tug. The equipment found on the real ship or tug should be available on the simulator bridge, and this may include:

1. Rudder control(s) and rudder indicator(s). For a tug simulator the rudder control should be as on board the real tug.
2. Engine/propeller control(s), including indicators for engine and/or propeller revolutions (fixed pitch propellers), or engine and/or propeller revolutions and propeller pitch settings (controllable pitch propellers). For a tug simulator the engine/propeller/pitch controls to be as on board the real tug.
3. For ships or tugs propelled by thrusters or podded propulsion units: thrusters/podded propulsion units to be controlled as on the real ship or tug, comprising separate and/or combined controls, thruster or podded propulsion unit direction indicators, propeller revolution indicators or propeller revolution/pitch indicators.
   Thruster controls on a tug simulator should be of the same type and design as used on board the real tug.
4. For ships and tugs operated with joystick control: the joystick control system, indicators and characteristics as on the real ship and tug. The controls should be of the same type and design as those used on board the real ship and tug.
5. Transverse thruster controls and transverse thruster indicators; the ship can be equipped with a bow thruster as well as a stern thruster, or with only a bow thrusters as on several tugs.
6. Compass, speed log, water depth indicator, wind speed/direction indicator, ARPA radar, ECDIS. For tugs: Radar equipment to be as on the real tug.
7. Communication equipment for VTS communication, communication between ship and tugs and simulator operator.
8. Line handling possibilities and anchor handling controls and monitors.
9. Doppler log, Rate of Turn indicator, (D)GPS, LORAN and Electronic Chart display. In any case those relevant instruments as on board the real ships

For simulation of a tug it is a further requirement that:

10. characteristics of towing line and towing winch as well as fender characteristics are correctly simulated. Simulation of a slack and tight towline is important, as well as a read-out for tow line tension and pushing forces.

Further remarks

Interaction effects

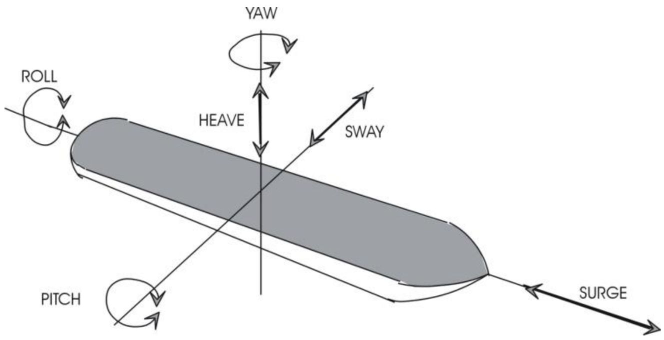
Interaction is an important aspect. A tug travelling close to a seagoing vessel and moving from astern to ahead of her will experience varying forces and turning moments. It is not just the suction forces and turning moments between a ship and tug as - for instance- those working in the middle of a ship, but also the effect on a tug of the interaction of the flow patterns around the moving ship and tug. All these forces and turning moments differ by ship shape, draft, trim, speed, under keel clearance and confinement of the fairway. A large loaded bulk carrier has, for instance, a pronounced bow wave with a large effect on a tug close ahead of the ship.
These effects, particularly around the bow, play an important role when preparing for passing a tow line or when releasing a tow line. It should therefore be well understood that these risky interaction effects and particularly the effects around the bow are very seldom simulated. This means that making fast at the bow or retrieving a tow line near the bow will generally be much easier on a simulator than in reality.

There are indeed developments that will permit these interaction forces to be simulated in one way or another, which is a great step forward, particularly for training of tug captains.

Other interaction effects are the effect of the ship's propeller slip stream on a tug, which can be simulated, and the interaction between a tug's propulsion and the ship's hull. Due to the counter-acting effect of the tug's propeller wash impinging on the ship's hull, the towing/pulling effectiveness of the tug decreases. This loss of effectiveness is sometimes accounted for in an approximate manner.

Ship motions

In the early days of marine simulation, projects featured mainly slow moving tankers and bulk-carriers. It was found sufficient to simulate the horizontal plane motions of surge, sway and yaw only. Roll was not considered important, not even in hard-over turning circles at full speed. As high-speed container ships entered service, the necessity to include roll motion as the fourth degree of freedom became evident. Rolling motion and angles of heel induced in normal manoeuvring – even in calm conditions – could no longer be ignored. Further extension of mathematical models to include the vertical plane motions of heave and pitch induced by squat or the action of waves became possible as computer power increased and simulation technology advanced.



Depending on the simulator's capabilities, ship motions can be reproduced in the basic mode of three degrees of freedom (3 DOF: surge, sway and yaw), four degrees of freedom (4 DOF: surge, sway, yaw and roll), five degrees of freedom (5 DOF: surge, sway, yaw, roll and pitch) or in full six degrees of freedom (6 DOF: surge, sway, yaw, roll, heave and pitch) by the methods of on-screen projection and/or the provision of a motion base for the simulator bridge (familiar from aircraft simulators). Compared to the present state-of-the-art of screen projection techniques, ship motion platforms have their limitations.

Whether 4, 5, or probably 6 DOF is needed depends on the environmental conditions in the simulated area and the research study or training requirements. In the absence of waves and swell, 4 DOF would normally be sufficient, whereas for simulation of squat effects, a full 6 DOF model is desirable. Navigation in ice requires simulation of ship motions in at least the 5 DOF mode. Finally, for research studies of e.g. a design for an approach channel in an open sea environment, simulation of ship and tug motions in the horizontal as well in the vertical plane due to waves is a requirement – leading to the implementation of a 6 DOF model for the ship and tug.

Courtesy: STC, Rotterdam

Tug master and instructor on the tug simulator

Although the degree of realism of ship motions due to waves, wind or manoeuvres should be verified, it should be kept in mind that the simulation of ship motions, in particular wave induced motions, has its limitations. For instance, when a ship's manoeuvrability is affected in situations of broaching or surf-riding in adverse sea conditions, the interaction between high waves and/or swell and the ship's manoeuvring ability cannot be simulated properly.

For tugs simulation of motions is a necessity. Heel due to towline and/or thrusters forces should be as in reality. The same applies to wave induced motions. Operating in wave conditions reduces a tug's performance. Simulation of tug's motions and of performance in waves should therefore be as realistic as possible, which should include the effect of the tow line on tug's motions. In summary, when operating in wave conditions, simulations in 6DOF becomes necessary and ship and tug motions should be perceived as realistic.

Wind indicator

Due to lack of information from the outside environment, a good wind indicator is essential and should clearly show the relative wind direction and speed. For a tug a separate monitor showing the wind as it is blowing on the assisted ship is often needed.

Noise and vibration

Wind noise on the bridge, fluctuating with wind gusts, will enhance the feeling of realism; the same applies to engine noise and vibration, if this can indeed be heard and/or felt on the real ship/tug bridge; or alarms for overload conditions, which are of particular importance for navigation in ice conditions, for example.

b. Anchor Handling Simulators

Introduction and training objectives

A present new and important development is the Anchor Handling Simulator (AHS). These simulators have become a necessity, in light of the tragic accident with the *Bourbon Dolphin.*

Anchor handling operations are high risk operations. The anchor handling simulators are designed for the education and procedures training of navigators and winch-operators of anchor handling tugs.

Some manufacturers of these simulators are MARIN, the Netherlands, and Kongsberg, Denmark *(see photo next page).* The MARIN Anchor Handling functionalities can be installed on any size of simulator, Full mission, Compact (see below), or (onboard) Desktop simulators (see below).

Simulation of proper wave response characteristics is an essential element for a realistic behaviour of the anchor handling support tug, for the effect on the performance of the tug and the forces working on the tug. There should furthermore be consistency between the waves in the visual system and the tug's wave responses.

A realistic simulation of the catenaries is needed, with all the forces acting on specific elements such as anchor, chaser ring, tug and platform, with its corresponding motions.

On the AHS it is possible to plan and carry out anchor handling operations on various systems, different types and sizes of winches and other anchor handling equipments. All these systems are used in situations where the anchor handling equipment is affected by extreme forces. It is furthermore possible to simulate and train people in safety procedures.

Photo Courtesey of Kongsberg

Anchor Handling Simulator of Kongsberg

Bridge equipment

The instrumentation resemble real equipment and includes all relevant controls to initiate and control anchor handling operations. Instrumentation includes winch controls and monitoring, towing pin controls and emergency release, azimuth thruster controls, thruster panels, joystick control panel, alarm and emergency indicators and controls and communication equipment.

Modular design makes various bridge and equipment configurations possible.

Kongsberg full mission AHS of Maersk Offshore And Innovation Centre, MOSAIC, Denmark, has a full mission bridge and three satellite simulators.

Visual system

A visual system allows full view of deck operations to aid decision making. The Kongsberg full mission AHS of MOSAIC has a 360^0 outside view.

Instructor station

The instructor station has dedicated operation functions to control men on deck, connect and disconnect wires and chains, position wires and chains, etc. Various environmental conditions can be simulated, such as wind, waves ,current, fog, snow and ice. Different failures can be introduced, for instance broken wire or chain, broken guide pins, propulsion failures, fire, etc. (references: leaflets from Kongsberg and MARIN)

c. Compact manoeuvring simulator

This type of simulator (*see photo next page)* comes closest to a full mission bridge simulator, and has similar training capabilities. There are various designs, some very sophisticated. A large advantage is that the compact simulator can be transported. This type of simulator is already in use by a number of towing companies for training of tug masters.

Considering one type of compact simulator, the MARIN Compact Manoeuvring Simulator, this type is a tailor-made and compact version of the full mission simulator with identical software. It has three LCD screens providing a 180^0 view and in addition a rear-view display. With respect to tug simulation, different types of tugs can be simulated, such as ASD and Voith tugs with their own specific real controls. The simulator also has ECDIS, ARPA, winch controls, RPM indicators, thruster angle indicators and rudder indicators. Optionally a separate pilot/captain or tug master station can be added, providing the opportunity to work with two tug masters. This separate station is a small simulator similar to the desktop simulator discussed below, with a mini-console for the controls and up to three LCD screens. With these compact simulators 6 DOF movements can be presented in the out-of-window screens. Due to the compactness of the simulator it may have some disadvantages compared to a full mission simulator, with regard to the size of the out-of-window view and the number of simulator bridges that can operate together. The remarks made earlier, such as regarding assessing distances off and simulation of interaction effects, apply to this simulator as well.

There are, however, developments towards the possibility of assessing distances off more accurately, such as by stereo vision systems which provide a more realistic depth perception for tug captains, and/or by a head mounted stereo display (see *Virtually reality based simulators* below). Simulation of the important interaction effects is gradually becoming possible, as has been mentioned in the relevant paragraph.

Courtesy: MARIN, the Netherlands

Compact manoeuvring simulator

d. *Desktop simulators*

Desktop simulators may consist of an Instructor Operator Station and a Pilot/Captain Station. The Pilot/Captain Station may be equipped with a monitor or a LCD or Plasma screen showing a 60^0 out-of-window view, with a synthetic radar screen and a monitor showing the ship and/or tug and its surroundings. The bridge equipment is often limited to an interactive keyboard for steering and engine control, although it might be possible to have it replaced by a hardware control panel to handle, for instance, conventional and/or ASD-tugs. A display showing the most important instrument read-outs may be available.

Desktop simulators can be quite flexible in simulating various ship and tug types, port areas, environmental conditions and tug assistance methods.

These simulators can be used as part task simulators for training or research purposes. They have the disadvantage that the operator, a pilot or captain, has to manoeuvre on information from a monitor or a screen with a limited view. The whole concept differs essentially from reality and it is therefore not the most suitable tool to train tug masters.

e. *Radar simulators*

Radar simulators can be used as a manoeuvring device for training purposes. The operator, a pilot or captain, navigates or manoeuvres on radar information as if he were in dense fog. Some radar simulators are equipped with a quite realistic bridge mock-up, in which all navigational steering instruments are available. It is not the best tools for training of tug masters, except when training in fog navigation is required.

Please, see next page for some more simulation techniques.

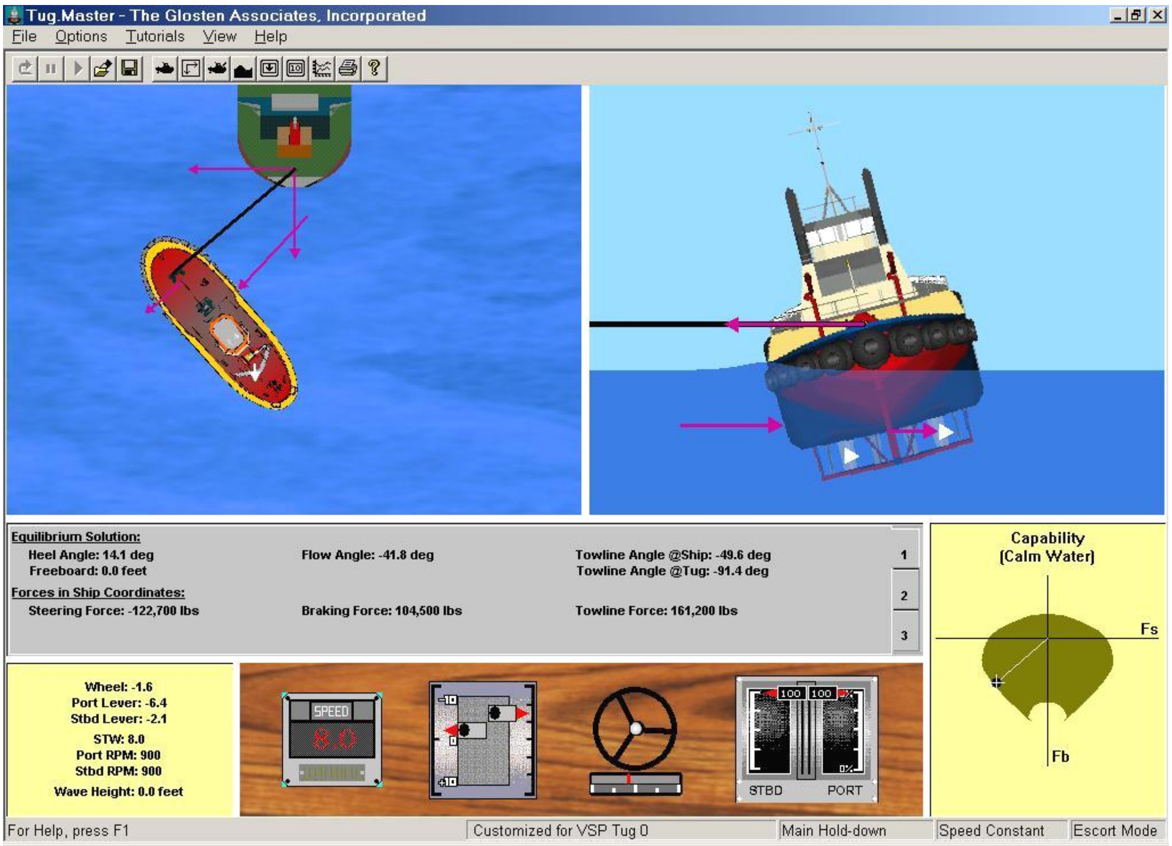
Some more simulation techniques

Virtual reality based simulators

State-of-the-art virtual-reality technology (VR) as used for marine simulation comprises visual image generation, head mounted displays, head motion tracking systems, speech recognition and response systems, surround sound and tactile feedback. Tactile feedback applies to handling of controls, push buttons, etc. Simulation based on this technology is already in use for training junior Canadian Navy officers in formation manoeuvring in deep, open water. Virtual reality based simulators for US Navy submarine officers training for harbour navigation were operational in the year 2000.
The potential advantages of a VR-type simulator include a possible significant reduction in costs associated with the simulator infrastructure and visual screen projection. Potential limitations include simulator sickness caused by head mounted displays, interaction with physical equipment and difficulties in collaboration between members of the bridge team.

Tug Master

A nice simulation program for a normal PC is Tug Master, developed by The Glosten Associates, Seattle, USA, some years ago. See screen below. The program, which calculates equilibrium solutions for a stern tug towing on a line, e.g. an escort tug, can be customized for a particular tug and be used as a performance prediction program and as a training tool.
A number of ASD and VS tugs can be simulated. The tugs can be controlled by keyboard and mouse. Speed, wave height and towing point can be varied. Detailed information on forces, moments, freeboard, heel and tow line angle is displayed.



PC program `Tug Master', developed by The Glosten Associates, Seattle, USA.

Finally

It is most important that the simulator reflects reality in an accurate way. This applies in particular to the tug model. For instance, a small mistake in location of the towing point may have large effects on the performance of the tug.

The tug model, including skegs and propulsion units, should be accurately simulated, as should be stability, loading condition, freeboard, towing winch, tow line and fender characteristics. Manoeuvring and performance (towing, pushing, etc.) characteristics should be simulated accurately, as is the case with the turning speed of thrusters.

Before a training starts the simulated tug should be tested rigorously by tug masters having an extensive experience with the tug being simulated, or in the case of new tugs with similar tugs. This should also include the testing of side stepping and running astern. Every departure from reality should be corrected.

As already mentioned before, it should be known by the instructor whether and in what way interaction forces and moments are simulated, such as the interaction forces and moments between a ship and tug, and the loss of effective pulling power due to tug's propeller wash hitting the ship's hull.

Much information has been obtained from the books **"Ship Bridge Simulators. A Project Handbook"** and **"Tug Use in Port. A Practical Guide",** published by The Nautical Institute in London. Therefore, for further information the reader is kindly referred to these books.

A final remark:
Tugs are a large investment. Training is only as good as the instructor. The instructor should have the training and ability to instruct and be an experienced tug master with proper practical experience in handling the specific tug for which he is instructor.
If this is not the case, the risks involved in handling such a tug might not be sufficiently recognized and the capabilities of the tug might not be sufficiently passed on to the trainee(s).

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GLOSSARY OF TERMS

Competence	:	The ability to perform the activities within an occupation or function to the standards expected in employment.
Course stability	:	Also called stability of route or dynamic stability of route. It is that property of a ship that causes it, when disturbed, to damp out extraneous motions set up by the disturbance and to reduce them progressively to zero. Course stability should not be confused with directional stability, which is, strictly speaking, the ability of a ship to follow a certain direction, e.g. by means of an automatic steering system. A ship closely following a selected heading has directional stability but may be course unstable (see below), which results in frequent and large rudder actions to hold the ship on its course.
Course stable ship	:	With a constant position of the steering systems (rudders, thrusters, etc.), a ship is defined to be course stable if, after experiencing a brief disturbance, it will resume the original manoeuvre without any use of the means of steering. Course stability on a straight course, with the rudder in the equilibrium position, is mostly only considered. A turn initiated by a brief disturbance of a course stable ship will thus not continue. However, after the disturbance has vanished, the actual course of the ship will generally be altered. A course stable ship needs relatively large rudder angles for course changing. A course stable ship has good yaw checking ability.
Course unstable ship	:	A ship is called course unstable, if, after it is disturbed, it will immediately start to turn. Course changing, with relatively high rates of turn, can be achieved with relatively small rudder angles. A course unstable ship therefore generally has poor yaw checking ability.
DOF	:	Degrees of Freedom refers to the ability of simulators to reproduce ship motions, whether by the projection screen and/or by a hydraulic platform. Ship motions are expressed in sway, surge and yaw, being the motions in the horizontal plane, and heave, pitch and roll. There are in total six degrees of freedom of movement for a vessel that is unrestricted in its motions.
Familiarisation	:	For persons performing on a simulator, the process of becoming used to the working of a simulator, such as with respect to bridge equipment, out-of-window view, communication and procedures. Familiarisation runs, prior to the real training or research runs, are used for this process.

Fidelity	:	The degree of similarity between the simulated situation and real operation. It is a multi-faceted concept and can refer to different forms of realism, including both physical and psychological similarities.
Mathematical model	:	A set of formulae representing the manoeuvring characteristics of a ship under certain loading conditions as well as under certain environmental conditions.
Simulation, non-interactive	:	Simulation without any human interference with the navigation and manoeuvring process. The navigation and manoeuvring process is mathematically modelled.
Simulation, interactive	:	Simulation with interference with a simulator device by a human operator.
Simulation, fast-time	:	A technique whereby a ship's passage, and/or manoeuvres, is simulated in a fraction of the time as in reality. It is mostly a non-interactive simulation technique.
Simulation, real time	:	A technique whereby a ship's passage and/or manoeuvres is simulated according to a time scale as in reality. In general an interactive simulation technique.
Simulator	:	A device, designed to satisfy objectives, which mimics part of real situation in order to allow an operator to practice and/or demonstrate competence in an operation in a controlled environment.
Tugs. Vector tug simulation	:	Simulation of applied tug forces by a force vector.
Tugs. Interactive tug simulation	:	Simulation of tugs by interactive tugs using a ship bridge simulator.
Validation	:	A project phase. The validation session takes place prior to the actual training or research, to test in co-operation with the client the performance of simulator, ship and tug models and procedures and to review data collection, analyses method and reporting.