

THE EFFECTIVE USE OF ENGINE ROOM SIMULATORS

Robert F. van Kuilenburg¹,
Douwe Stapersma¹
Peter A. Wieringa²

¹*Marine Diesel Engines, Section Marine Engineering and*
²*Man-Machine Systems, Faculty Design, Production & Engineering,*
Delft University of Technology, The Netherlands
r.f.vankuilenburg@wbmt.tudelft.nl

ABSTRACT

Ships are highly automated systems that can be operated with a limited number of operators. In order to reduce the likelihood of an accident it is generally accepted that training of seafarers is essential.

Engine room simulators are extensively used for training and assessment of seafarers in the Netherlands. Past research on bridge simulators shows that simulator training is highly effective. However, the effectiveness of engine room simulators has not been determined. Since the bridge tasks and engine room tasks have different characteristics we cannot use the results of the bridge simulator research directly.

The other role of simulators is providing a test environment for research purposes. When automation systems fail the role of the operator will change considerably. The mental task load and system performance will change. Simulators can be used to assess different design options and mental work load.

In this research we plan to use an engine room simulator to :

- 1. Determine if there is a relationship between the type of pre-training and operator performance*
- 2. To determine the relationship between the mental load of the operator and the degree of automation of the controlled system*

INTRODUCTION

Ships are highly automated systems that can be operated with a limited number of operators. Due to the increased awareness of environmental and safety factors the consequences of accidents are now no longer accepted by the general public.

Research shows that the human factor is an important element of accidents^[2]. In order to reduce the likelihood of an accident it is generally accepted that training of seafarers is essential.

The use of simulators for the training of seafarers is standard practice in the Netherlands; driven by international conventions and the lack of a training ship. Despite the increased interest for simulator training, surprisingly little is known about the training effectiveness of current and new types of engine room simulators.

The other role of simulators is providing a test environment for research and system design purposes. When automation systems fail the role of the operator will change considerably. The mental task load and system performance will change. Simulators can be used to assess different design options and mental work load.

In this paper we will give an overview of the role that automation systems have on board a ship. Differences between the navigational and engineering department are highlighted. Implications of these differences for simulator and training design are given and Dutch conventions regarding training of seafarers are discussed. Special attention is given to the STCW⁹⁵ convention (International Convention on Standards of Training, Certification and Watch keeping for Seafarers) which plays a vital role in the education of seafarers. We will then focus on the tasks that are trained on the engine-room simulator. For several tasks the degree of automation is calculated. Finally the construction of the test environment at a Dutch nautical institute is discussed and a scenario is given.

MODERN SHIPS & MANNING LEVELS

One result of automation on board a ship is that a ship can now theoretically be controlled by a crew of only three crewmembers. Three officers each which are on a 8 hour duty. For ships on certain routes the option "no crew members" is becoming realistic now. The former relation between ship size and amount of crew has been broken by automation systems. As a result of the increased degree of automation manning levels are decreasing^[1]. From an average of 16 crew members in 1977 to an average of 10 crew members in 1996. The average ship size remained fairly constant in this time period (figure 1).

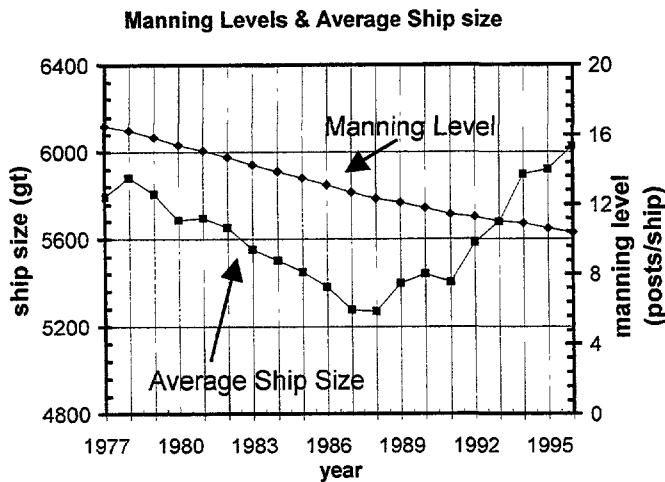


Figure 2, Manning level & Average ship size during time^[1]

A schematic of a propulsion control system^[3] is given in figure 2. It gives an overview of the tasks and layout of such an automation system. We can identify two layers. The overall Propulsion Control System (PCS) and a layer with system specific automation systems (engine control). The main task of the propulsion control system is to control the different components in order to give the ship the speed and course that is demanded from the bridge.

Officers can concentrate on sailing the ship while the PCS takes care of all the operational details (such as (dis)engaging clutches).

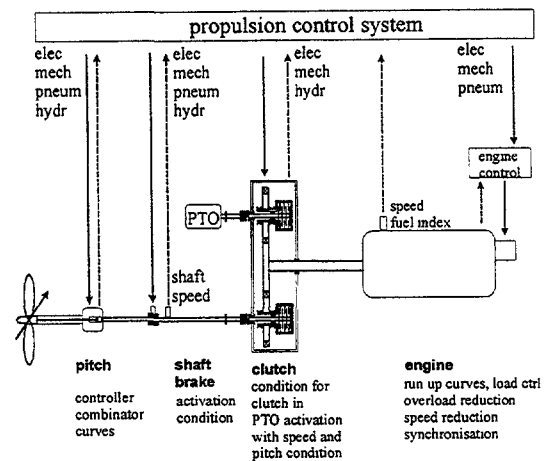


Figure 1, Schematic of a propulsion control system^[3],
(PTO = Power Take Off)

On the bridge automation is not so ever present as it is in the engine room most attention is given to sensor fusion. The most automated piece of equipment is the autopilot. Autopilots are often coupled to GPS and weather information databases to find the most economic route. From the situation where there are separate information sources like a paper chart, radar screens and compass readings the trend is now to incorporate everything into one electronic system.

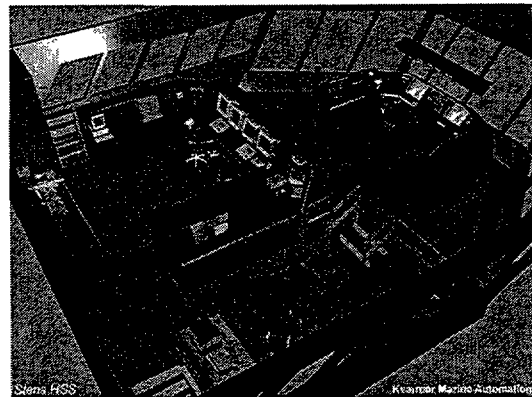


Figure 3, Bridge Stena Line HSS

There are electronic charts on which radar images can be superimposed. Bearing and ship speed can be displayed numerically or graphically. The same screen can be used to display all the relevant engine data or even be used to control the engines. This places high demands on the design of these systems. There is the danger that operators think that the artificial picture presented on the screens is an accurate picture while in reality it is not. Radars have a limited accuracy, compasses can have deviations, electronic charts can be outdated and GPS can

fail to name but a few of the reasons why the electronic picture could not be accurate.

A recent example of failing automation systems is the Stena Line HSS ferry. A highly automated fast ferry which can reach speeds up to 60 km/h. Unfortunately the central computer system crashed twice since the vessel was in operation requiring tugboats to get the ship back in port. There was nothing wrong with the engines only the crew didn't know or could not bypass the automation systems to start the engines manually^[5]. That automation systems fail regularly shows one survey among 41 ships in the period of 1982-1987^[6]. The survey showed a Mean Time Between Failures for the automation systems of 362 hr/case. Automation failures comprised 24% of all system failures. Notwithstanding these recorded failures ships are still very reliable^[7], see figure 4

The low manning level places high demands on the education and professionalism of nautical officers. In the former days crew members could specialize but nowadays officers have to be generalists. Only when troubles arise they suddenly have to be specialists again. This is an example of the classic "catch 22" problem encountered when using automation systems. Automation systems take care of almost all the controlling tasks of the system leaving only a supervising task to the operator. When the system or automation fails the operator does not have enough experience or routine to quickly recognize and solve the problem. One solution is to leave to the operator some controlling tasks but then why do we need an automation system for? Continuous training on simulators can break this loop. This can be done in simulator centers or on board

Reliability of containerships

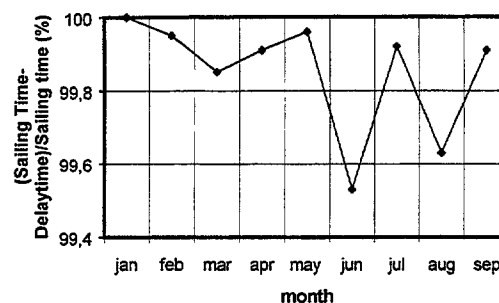


Figure 4, Reliability of containerships as percentage of sailing time^[7]

TASKS ON BOARD A SHIP

In accordance with the STCW⁹⁵ code^[8] we divide the on board tasks into two main groups : bridge tasks and engine room tasks. Bridge tasks are tasks that have mainly to do with navigating the ship (including the seaworthiness of the ship). Engine room tasks are tasks that have mainly to do with the machinery that is required to operate the ship. One typical example of machinery is the main engine. On modern highly automated ships the both task groups Orequire only one control room; the bridge.

Bridge Tasks

The common factor of bridge tasks is that they all involve interaction with the environment. The environment is the geographical area and other ships. The bridge tasks have not been changed significantly since the beginning of shipping. This means that when the electronic aids fail almost all the tasks can be done manually. To

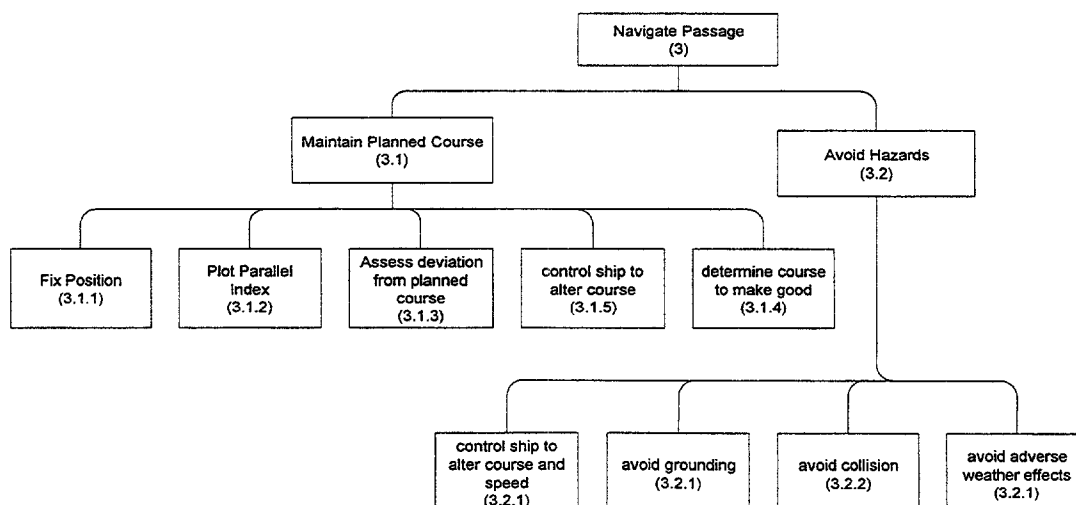


Figure 5, Part of a HTA analysis of the tasks on the bridge [9]

give an example. The task "Avoid hazards" requires the acquisition of potential hazards (which are mostly other ships). Nautical officers use pre dominantly ARPA and RADAR systems to plot the course of other ships and assess if they are posing a threat to their own ship. When the RADAR and ARPA fail the seafarers can still plot the courses of other ships and assess if there is the need for a corrective action such as altering course. There is no fundamental difference in what the nautical officer sees outside and on his computer screens. The electronics only enhance the picture (greater range, better accuracy, etc). Furthermore the interaction is in 99% of the cases based on (human) rules and regulations. Therefore almost all the actions can be classified as procedural actions.

Common bridge tasks are ^[9] :

1. Maintain planned course
2. Avoid Hazards
3. Fix position
4. Control Ship to alter course and speed

Engine room tasks

The common factor of engine room tasks is that they all involve interaction with machinery. In contrast to bridge tasks engine room tasks have changed considerably during time. From sailing boats to steam ships and finally nuclear powered ships is a long way. This has had its impact on the education of engine room officers which are now highly educated professionals.

A consequence of the interaction with machinery is that to be able to perform the tasks, the engineer is dependent on sensor systems. Without sensors it is almost impossible to estimate the condition of the system. When these sensors fail this will have consequences for the number of tasks that can be done. In contrast to bridge tasks not all the tasks can be performed from one place. Maintenance requires in most cases that an engineer has to go to the physical system to change or clean components. This means that there are at least two different (mental) pictures of a system an engineer must posses. A mental picture that is presented by the control room away from the actual machinery and a mental picture of the physical machinery itself. Furthermore the engineer has the task to diagnose and repair failed equipment. This is a task that is not present in bridge tasks. Failure diagnosis is very difficult to learn and demands a thorough knowledge of the systems.

Common engine room tasks are ^[10] :

1. Controlling the main engine
2. Starting and Stopping of generators
3. Maintenance (corrective, preventive)
4. Trouble shooting

Discussion

The main difference between a bridge task and an engine room task is the type of interaction. A bridge task involves interaction with the environment while engine room tasks involves interaction with machinery. The interaction with the environment is governed by human rules while the interaction with machinery is governed by physical laws. An engineer or controlling system is dependent on sensor systems. An engineer has to work in at least two different working environments: the control room environment and the engine room itself compared to one working environment of the bridge tasks. A significant number of the engine room tasks are knowledge based actions.

TASKS AND SIMULATORS

The differences between the bridge tasks and engine room tasks have their impact on simulator design and usefulness. A bridge simulator can provide all the sensory inputs to the nautical officer which he will receive during operational duty; an outside view and stimulated operational equipment. Normally the nautical officer is not required to leave the bridge. Therefore the simulator can provide a complete and high fidelity image of the reality for almost all of the bridge tasks. An engine room simulator can provide an accurate simulation of a ship's engine control room. However, what almost none of the simulators provide is the second environment; the physical equipment itself. This means that an important working area is missing in contrast to the bridge simulators who provide a complete working environment. Simulator manufacturers acknowledge this and try to provide at least the local control units of the systems. The local control units are often located in a different room. It is clear that this is a very crude approximation of reality. Trouble shooting can be done with engine room simulators but only using the equipment typical of a control room. No manual or visual inspections can be done. A leaking pump is very easy to detect when looking at the pump but less easy from computer screens.

STCW⁹⁵

Every training for a future maritime function mentioned in the STCW⁹⁵ [8] code has to satisfy the demands presented in the STCW⁹⁵ code. STCW⁹⁵ stands for : "International Convention on Standards of Training, Certification and Watch keeping for Seafarers". The STCW exists from 1978 (STCW⁷⁸) but was revised in 1995. The STCW⁹⁵ code is a publication of the IMO (International Maritime Organization) and is international binding. This means that the STCW⁹⁵ code has far reaching consequences for the set-up, content and development of maritime courses which are taught at the maritime colleges. Any ship that has officers on board with certificates not satisfying the STCW⁹⁵ code can be detained by port control until "competent" officers are on board.

The great interest in simulator training apart from other advantages of simulator training can be traced back to this code. With the acceptance of the 1995 edition simulator training is now mandatory for a number of tasks (ARPA/RADAR) and permitted for a large number of other tasks.

Structure

The STCW⁹⁵ code recognizes six different task groups on board a ship :

1. Navigation
2. Engine department
3. Radio
4. Special training
5. Rescue/Fire/Medical
6. Duty/Watch keeping

The two main tasks are 1) navigation and 2) engine department. The engine department task is divided into three levels :

1. Operational Level
2. Management Level
3. Support Level

Each level is divided further into specific competences. For each competence the code describes the :

- a. Knowledge
- b. Methods for demonstrating competence
- c. Methods for evaluating performance

Roughly half of the competences can be demonstrated and evaluated using a simulator.

The main point is that the code defines first the competence: "*what must an engineer be able to do*". After definition of the competence the required knowledge, training aids and testing aids are defined.

STCW⁹⁵ & Simulators

The STCW⁹⁵ document also gives general rules to which simulators have to comply. However, these rules are very general. We give three qualitative rules from the code :

A simulator must

1. be **suitable** for the selected objectives and training tasks
2. be capable of simulating the operational capabilities of shipboard equipment concerned to a level of physical realism **appropriate** to training objectives and include the capabilities, limitations and possible errors of such equipment
3. have **sufficient** behavioral realism to allow a trainee to acquire the skills appropriate to the training objectives.

The STCW⁹⁵ makes a difference between physical realism and behavioral realism of a simulator. Furthermore the STCW⁹⁵ code only demands that there exist training objectives. This leaves a lot of room for interpretation. Which training objective are appropriate and the definition of "*sufficient*" remains an open question. This is an interesting area of research. The Dutch authorities issue certificates for simulators based on these general demands.

SIMULATOR TRAINING EQUIVALENCE RESEARCH

It is permitted to replace actual sailing time with training time done on a simulator although exact conversion times are not defined internationally. In the Netherlands 10 days of simulator stands for 30 days sailing time but there are some plans to increase this to 60 days of sailing time with 15 days on the simulator. An interesting fact from the initial research was that training on the job was highly ineffective compared to simulator training ^[11].

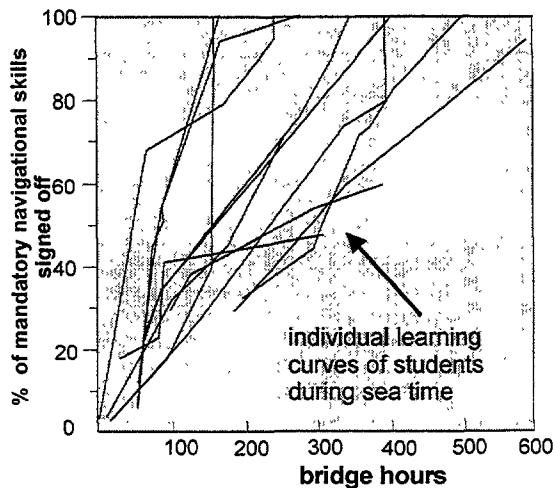


Figure 6, Individual learning curves of students during sea time ^[11]

Care must be taken with these figures because the research project to determine the equivalent times only looked into bridge tasks. The final report recognizes this limitation. The 30 days decrease in sailing days must primarily come from a decrease in bridge tasks that a student must do. The engine room and other tasks must stay at the same level. During the operational sailing time the mentor of the students keeps track of the skills that a student masters. Each student has a workbook with all the mandatory navigational skills that the student is required to master. When the mentor has the opinion that the students has a satisfactory skill level he signs off the skill in the workbook. The percentage of the skills that are signed off as function of time spent on the bridge is given in figure 6. Looking at figure 6 and 7 it is visible that students who had signed off all the mandatory tasks during their sea time apparently do not master all the skills. The performance of the sea going group is less compared to the results of the simulator trained group after three weeks of training. Even one week of training on the simulator results in an almost equal performance compared with the sea going group. It is also visible that the learning curve of the simulator group has a power-curve learning trend while the average learning curve of the sea follows a more linear curve.

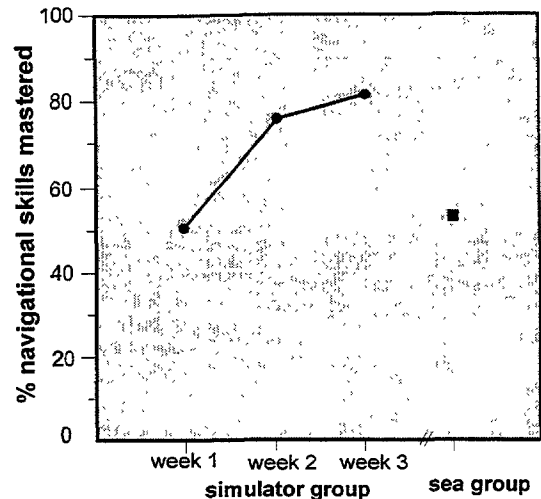


Figure 7, Performance of simulator group and sea going group who had completed their mandatory sailing time measured with post-simulator-test ^[11]

Other research programs

Other research programs compared the levels of experienced nautical officers and trainees which just had done their basic training on the simulator ^[12]. The mean test result of the students is 43% with a standard variance of 7.1%. The mean result of the experienced officers is 59% with a standard deviation of 10.6% ^[12]. One interesting fact from this research program was that 33% of experienced officers performed worse than 36% of the students which had only simulator experience (figure 8). An annual retest of the nautical officers could well be very beneficial from a safety point of view.

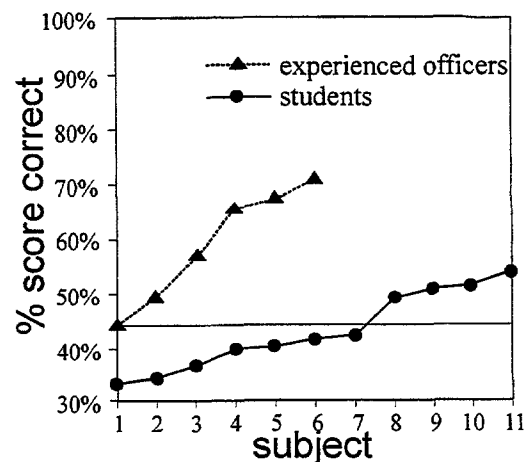


Figure 8, Comparison between experienced officers and students ^[12]

This research aimed at providing evidence that a condensed training course could deliver students with satisfactory level.

We can conclude that simulator bridge training is more effective than the current training on the job. Whether or not simulator engine room training is more effective than operational training is still an open question. Simulator bridge training is particularly effective when dangerous or unknown situations are trained. Probably this is also the area where simulator engine room training will be most effective. However, training in dangerous or unknown situations is also the area where most simulators are not suited for. Troubleshooting is difficult and care must be taken that operational system characteristics and simulated system characteristics are reasonably well matched.

Estimates of marine simulator types at 1/6/96

#	description	1	2
1	Simulators with a visual ship handling capability	106	55
2	Radar en Radar Navigation	380	125
3	Engine Room	110	110
4	Navigation Instruments	60	47
5	Cargo and Ballast Control	45	33
6	Fisheries	30	13
7	Global Maritime Distress and Safety System (GMDSS)	60	16
8	Oil Spill management trainer	4	0
9	VTS (Vessel Traffic management Systems)	10	12
10	High Speed Craft	2	2
11	Riverboat	3	0
12	Dynamic Positioning (DP)	0	2

Table 1, Number of simulators in use,
column 1 from ^[13] and column 2 from ^[14]

OVERVIEW OF MARITIME SIMULATORS

There are many different types of simulators in use today. From full bridge simulators with 360° virtual views to stand alone radar simulators. In table 1 a list of different simulators is given. Most manufacturers deliver several types of

simulators. One of the largest manufacturers of maritime simulators is Norcontrol.

Classification of simulators

In the STCW⁹⁵ document gives only general rules to which a simulator must comply. The maritime colleges and simulator manufacturers have the need for more detailed specifications. Currently there is only one classification of maritime simulators in existence: the DNV classification (Det Norske Veritas). The DNV classification recognizes 4 different classes of simulators, class A,B,C and X. The difference between the classes lies in the type and number of simulated components. Detailed demands on simulators are divided in :

1. Physical Realism
2. Behavioral Realism
3. Operating environment

As such the DNV classification follows closely the STCW⁹⁵ code. The DNV code gives no rules regarding exactly what level of realism is necessary. To quote the DNV classification document : *“When simulating real equipment the behavior of such simulated equipment should behave as identical as possible as the original. Critical parameters of the behavior are to be documented”*. What "exactly as possible" means remains an open question and what are critical parameters? Also it is a common fact that high fidelity does not guarantee good training results or even makes training more difficult for procedural training^{[15],[16]}. The DNV classification does make a difference between machinery systems and connected controlling systems. As such the DNV code strongly resembles ISO-9001 codes only ensuring that information is documented.

Reasons to use a simulator

Apart from the legal demands set forth by the STCW⁹⁵ code there are other advantages in using a simulator for training purposes. The advantages which are mentioned in the literature can be summarized into 4 main categories :

1. Improved training environment
2. Training cost reduction compared to training on operational equipment
3. Improved safety
4. Additional advantages

Simulator training has also disadvantages :

1. High cost compared to traditional educational methods
2. Low fidelity
3. Student performance different in the simulator and real situation
4. No fatigue / boredom
5. Negative effect on morale
6. Specialized personnel (expensive)

Many of the disadvantages can be avoided by carefully designing training sessions and simulators. Especially the improved safety outweighs many of the disadvantages. Running a 300.000 tons tanker on the rocks is a very expensive mistake compared to making the same mistake in a simulator session.

AUTOMATION SYSTEMS

The performance of modern systems is more and more determined by the automation systems. A method for defining and estimating automation levels can be very valuable during training and design of the systems.

In this paragraph we propose a four layer method for defining and classifying automation systems. The method starts with the definition of tasks that have to be done. Such a task list can be created using HTA methods. This kind of task list is not unique for a system but it has to be consistent. A unique division is a division on which automation systems can only be placed in one way on the different layers. For large interconnected systems this is not possible or only on certain conditions. The consistence demand is a weaker demand and in most cases can be fulfilled. To ensure consistency computer tools can be very helpful. For every task in the task list we define three properties :

1. Input demands
2. Output
3. Internal functions (if present)

Input demands are information and energy needed to perform the task. Output is the task that has to be done. An example of a task is "provide cooling". Internal functions connect the input signals and the output. We will describe this later in more detail.

We define three failure classes :

1. Input can fail
2. Output can fail
3. Internal functions can fail

Automation systems can be connected to form larger interconnected systems. The method has four layers :

1. Automation functions which control whole systems. These automation functions consist of abstract system wide goals and complex procedures.
2. Automation functions which can perform simple procedures. These automation functions can control several systems
3. Simple automation functions which are located on the components themselves. These automation functions cannot perform procedures
4. Components

Why use this kind of classification method which has similarities with GFM and EID methods? Wei^[17] used in his PhD thesis a HTA analysis to define the level of automation. Automation systems were recognized and research was done on mental load levels when these failed. However, we can make some comments on this method. When we use the three failure modes defined earlier we can conclude that Wei only looked at failure of internal functions. The operator had full knowledge of all the input signals and the output signals of the automation system that had failed.

The experiments of Wei were only laboratory experiments but it is an interesting question what the results will be when simulating the other two failure modes. One interesting side result of the use of the method of Wei is that it provides a

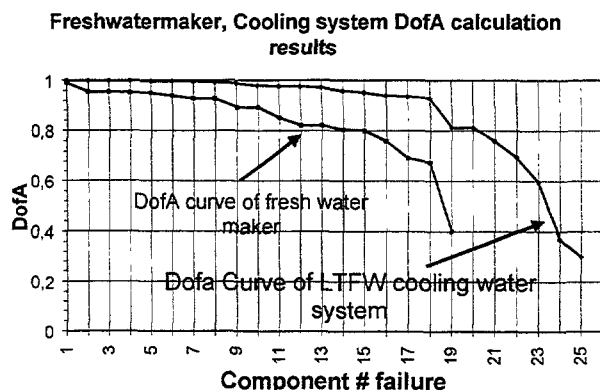


Figure 9, The degree of automation as function of the failing of different components for a fresh water maker and a cooling water system

quick insight in the relative importance of systems. From an economic point of view the more functions we can combine into one system the better. From a safety point of view this combination of systems is not always optimal. Packing a lot of functions into one system has the disadvantage that when a system fails more functions will fail at the same time. The relative importance of the systems (in terms of lowering the degree of automation) is illustrated in figure 9. As can be seen there are a lot of systems with only minimal influence and several systems which have a large influence on the degree of automation. That a system has a minimal influence on the degree of automation does only mean that controlling that system manually is relatively easy. It does not mean that the whole system can run without that particular system.

TEST ENVIRONMENT

All the tests are to be done at the Maritime Training Centre (MSTC). The MSTC is one of the three maritime training centers in the Netherlands. The MSTC has two bridge simulators, one engine room simulator and several specialized simulators (cargo handling). As a special feature the engine room simulator and one of the bridge simulators can be coupled into one functional unit. Annually around 800 students are trained at the MSTC.

RESEARCH GOALS

The research consists of two experiments:

Experiment A :

To determine if there is a relationship between the type of pre-training and operator performance

Experiment B :

To determine the relationship between the mental load of the operator and the degree of automation of the controlled system.

The relation between the experiments is that both look at system performance; Experiment A deals with system performance from the perspective of training of operators. Experiment B looks at system performance from the perspective of system design.

General experiment A

From the literature we know that there is a possible relationship between the type of pre-training and operator performance. In experiment

A we investigate the effect of two forms of pre-training on operator performance:

1. Training with the focus on first principles (TOF)
2. Training with the focus on procedures (PT)

The main feature of TOF training is that it is not system dependent. TOF focuses on functions like "heat transfer" and other fundamental functions. On the other hand PT training is in most cases system dependent. Procedural training (PT) focuses on applying the correct procedure for each situation. Typical procedures are "starting an engine" or "connecting generators to the electrical power grid". We expect that operators who are trained on first principles (TOF) have the same performance level when performing standard procedures compared to procedural trained operators but will perform better than procedural trained operators when unknown situations are encountered.

Gerdes^[18] used six different hypotheses (see table 2).

H _i hypotheses	RB behaviour required	KB behaviour required
T : amount of RB behaviour	RBT > KBT	RBT > KBT
P : production performance	RBT > KBT	KBT > RBT
S : safety performance	RBT > KBT	KBT > RBT

Table 2 Overview of H_i hypotheses. For example, RBT > KBT signifies the presumption that the amount of RB behavior, or the production or safety performance, of Rule-Based training subjects exceeds that of Knowledge-Based trained subjects, in the particular plant operating conditions ^[18] (RBT = Rule Based Training, KBT = Knowledge based training.)

In this research we focus only on the production performance hypotheses. The reason for focusing on the production performance is the relative ease with which we can define performance indicators. The definition of *T: amount of RB behaviour* and *S: safety performance* is much more difficult especially because we do not have access to the simulator. Gerdes recognised two distinct operating conditions, *RB behaviour required* and *KB behaviour required*. Our test scenario will be build up out of these two operating conditions (RB, KB) so that in a later

analysis stage the other two hypothesis can be tested for each operating condition.

Measuring performance A

Measuring the performance of an operator is difficult since performance is not clearly defined. For simple systems measuring performance can be relatively simple. If there is one output parameter the value of this parameter can be used to estimate performance. However for larger systems performance is not so easy to determine. There can be several output parameters, procedural actions and alarms that can serve as performance indicators. It may well be that some indicators are contra dictionary. On a simulator performance can even be measured with variables which are not available in real systems. This adds an extra dimension to the concept of performance. Since we want to investigate the relationship between training and performance we have to determine first what we want to accomplish with the training sessions. If we know the "training" goals it is easier to determine correct performance indicators.

We estimate that we can measure seven variable classes at this moment.

#	Variable
1	Mental load
2	Trust in own actions
3	Trust in system
4	Use of controls and information sources
5	Time to perform (sub) tasks
6	Time to solve problems
7	Values of "key" parameters
8	Video recording

An option can be to measure them all. As long as the measurements do not interfere with the operator and can be done automatically there is no reason not to do the measurements. Measurements which interfere with the normal operation of the operator have to be treated differently. Interference with the operator is unwanted because this can change the "normal" performance to the operator. This applies for three variables (mental load, thrust in own actions, thrust in system). For these variables we have to make a choice a) if we have to measure them and b) how many times during the scenario. Since the scenario is a combination of several sub-scenarios a choice could be to measure these three variables after each sub-scenario.

Scenario

The scenario serves as a starting point for the definition of learning goals and necessary procedures. The scenario will be defined in close cooperation with the instructors at the MSTC. Care must be taken that the training-goals are tested in the scenario. To measure the performance of an operator we have to choose a realistic scenario. We probably will use the "cold ship in harbor" condition as a starting point and "sea going" condition as end point of the scenario. Cold ship means that the ship does not provide its own energy. In between the two points the ship can be thought to be sailing through the harbor or some waterway.

This type of scenario has several advantages :

1. During starting up of the engine several sub-systems have to be brought on-line. This can be used to perform some variability tests and knowledge tests of the operators
2. The engine is not in steady state condition which affects the operator load.
3. During the normal passage, standard procedures can be evaluated
4. At the end of the session failures can be introduced
5. Failures can be introduced at fixed places in time and space.
6. It is a realistic scenario (especially if we take an existing harbor as starting point).
7. The scenario can also be used in a full mission mode when the bridge simulator and the engine room simulator are coupled.

General Experiment B

It has been shown by Wei^[17] that there is a relation between the level of automation of a system and the mental load of the operator. In this experiment we try to validate the results of Wei in a more realistic environment. We also want to get more information on the operator reactions when the automation level is changing.

Measuring performance

The same experimental set-up is used to measure performance as is the case in experiment A. The focus lies more on the mental load measurements.

Scenario

The operator has to control manually a fresh water maker. This is a special type of boiler which is fed with sea water and the hot cooling water of the main engine and produces fresh water. It is a system with several feed back loops and has some large time constants. It is a realistic scenario because real fresh water systems are prone to failure. Manual control does occur quite often. The operator has the task to produce the required quantities of fresh water. During this task several automation systems can fail.

CONCLUSION

Nowadays ships are highly automated and highly reliable systems. The ships can be operated with a very limited number of crew members. As a consequence these crew members have to be highly educated. Simulators are extensively used to train and assess operators but surprisingly very little research has been done on the effectiveness of engine room simulators. Research has been done on bridge simulator effectiveness and this indicates that the use of engine room simulators could be very beneficial. One result of the lack of research is that there are no detailed rules for simulator design. Our research does not focus on simulator design but on teaching methods and system design. In our research we want to find two relationships :

1. To determine if there is a relationship between the type of pre-training and operator performance
2. To determine the relationship between the mental load of the operator and the degree of automation of the controlled system.

REFERENCES

- [1] Li K.X. , J. Wonham (1999), A method for estimating world maritime employment, Transportation Research Part E, Pergamon, p183-189, Elsevier Science.
- [2] Eide H.J., Assessing and certifying manning and training establishments in the maritime-labor-producing countries, Marine Log's Maritime Operations, The human Element Conference, Washington Marriot Hotel, DNV Training and Qualification Support.
- [3] Roskam R. 2001, Modular Control System for Ship propulsions, CIMAC congress, p982-987
- [5] Kuilenburg R.F. 2000, Conversations with the crew of the HSS Stena Line Ferry, 2000.
- [6] Kido H. 1990 , Outline of diesel engine plant and automation system reliability, ISME, Kobe, Japan
- [7] Heel H.J.J. 2001, A ship operator's view on propulsion systems, CIMAC congress, p 1055-1059
- [8] STCW⁹⁵1995, IMO publication 938-E
- [9] Crawshaw C.M., A. Healey, G.R.J. Hockey, J.A.I. Lambert 1993, Task Analysis and Critical Incidents, The Impact of New technology on the marine industries, MARSIM, Rotterdam
- [10] Leerdoelen van de Machinekamer simulator 1999, MSTC, Terschelling.
- [11] Simulator time and its sea time equivalence 1994, DGSM project 634(70/3/017).
- [12] Zieverink 1996, Het toetsen van vakbekwaamheid op een simulator, Werkgroep veiligheid/R96-60 Leiden
- [13] Muirhead 1996 : "The revised STCW convention and the new simulator performance standards : some implications for simulator designers, operators and instructors."; Balkema, Marine Simulation and Ship Manoeuvrability, p 257-265
- [14] IMO 1998, MSC 721,852,633
- [15] Baum D.R 1982, Specification of training simulator fidelity: A research plan, Technical Report 558, Honeywell Inc, Minneapolis
- [16] A. Mirabella A, Wheaton GR 1974, Effect of task index variations on transfer of training criteria, final report, American Institutes for Research in the behavioral sciences ; Silver Spring, 1974.
- [17] Wei ZG 1998, Mental load and performance at different automation levels, PhD study, Technische Universiteit Delft
- [18] Gerdes V 1997, Identification and analysis of cognitive errors, PhD study, Technische Universiteit Delft.