# THE RE-DESIGN OF A MARINE ENGINE ROOM SIMULATOR IN CONSIDERATION TO ERGONOMICS DESIGN PRINCIPLES

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**SUMMARY**

Simulators can be used as sophisticated, flexible and realistic training tools which are capable of meeting many of the designated functions and tasks. An engine room simulator consists of simulation of various machinery systems in the engine room of a ship. This type of simulator is very significant and compulsory for marine engineering education. Istanbul Technical University Maritime Faculty (ITUMF) obtained a set of full-mission simulator and workstation simulators in 2001. However, it was realized that the ergonomic principles were not applied properly. Therefore it was not possible to generate the real engine room conditions with this simulator due to lack of some operations and displays on the mimic panel. Some of the mimics and displays were not similar to ones on board ship. This situation was negatively affecting the performance of engine room simulator training. And the mimic panel was re-designed and installed in 2006. In this study, the ergonomics principles for designing a mimic panel are determined and the application of ergonomic principles to a mimic panel is explained. The ergonomic gains of applied ergonomics principles are mentioned. Even more the effects on the marine engineering education are stated.

## 1. INTRODUCTION

Displays and controls have great importance on human-machine interaction for exchange of information. Operational information of the systems is provided to human operators through displays, and human takes necessary actions through control devices and change system states. Therefore, the efficient and error-free functioning of systems depends on properly designed displays and controls. Displays and controls in the man-machine systems provide a communication medium for humans interacting with the machines. The problem of designing compatible displays and controls has been studied for a long time to improve human performance (Chan at al., 2003).

Today, cognitive training tools consist of high density of displays and controls. Simulators can be used as sophisticated, flexible and realistic training tools which are capable of meeting many of the designated functions and tasks. Simulators provide mimics for trainees to undertake supervision and control of complex systems. During the simulator education trainee is not in the actual environment (ship engine room) and he/she must monitor the system through symbolic displays, rather than direct observation. Simulator design decisions prescribe how the world is represented to operating staff. Therefore, it substantially influences what has to be trained.

Since training decisions are always affected by design decisions, design decision should be cognizant of training implications. If thought is given to tasks and how personnel trained, then some aspects of simulator design can be modified to make training more effective and system integration far more successful.

With a simulator which is designed according to ergonomics principles, the training is much more effective by better system monitoring, functional by increased operations on mimic panel. Even more same applications can be managed in shorter times because the operations are not interrupted between mimic panel and work station. A complex system can be presented simply and the confusion of trainees is prevented.

Li summarized some general ergonomics principles for design of human machine interface of simulation training systems. They indicate the proper exchange of the information between the human and the training system. They focused on the functionality, friendliness and aesthetics as main parameters (Li, 2015).

Zheng et al. designed a human machine interface system for truck-driving-simulator. The aim of the study is to evaluate the driver behavior under different driving conditions. They conducted the experiments by using three different human machine interface (HMI) systems which are numeric, graphic, and numeric and graphic (Zheng et al., 2013).

Weir studied an HMI for a driving simulator. They considered HMI requirements such as usability, driver comfort, and an acceptable level of attentional demand in dual task conditions (Weir, 2010).

Another HMI development for driving simulator is carried out by authors in which study they analyzed the influence of haptic cues. The developed steering device's performance has been investigated by frequency-and time domain techniques and has been found to be reliable and accurate (Katzourakis et al., 2011).

The latest simulator studies are started to concentrate on virtual reality environment for training and education. In this study the authors use the virtual environment for developing an HMI. They result that virtual environments and simulators can be used for HMI design

and testing of mobile working machines (Heikkinen and Handroos, 2013).

In this study, the important ergonomics principles for the engine room simulator (ERS) design are figured out. The present mimic panel is inspected according to these principles and all design steps of new mimic panel is explained. The educational gains are also explained.

## 2. ERGONOMICS PRINCIPLES FOR AN ERS DESIGN

The mimic panel is the most important part of the simulator. Mimic panel is developed specifically pertinent to controls provided in association with mimic displays. In this regard the following considerations are included: providing the information necessary to accompany the control capability, the procedure for selection of the component and the desired operation, the procedure for starting the action and precautions for unintended control activation. One of the most important principles in determining the usability of a system is the simplicity with which relevant information and controls can be accessed (Beare at al., 1992).

The ergonomics principles which are taken into consideration for simulator design are display of dynamic data, realism, direct manipulation, placement of information, grouping of information, color usage, contrast, geometric shapes, line sizes, manual/auto stations, and controls on mimics, visibility & readability.

A marine power plant is a very complex and dynamic system. Display of these dynamic data is important for reliable and easy management of the data from the complex systems.

Realism aims to offer users a completely natural experience, through their engagement in realistic simulated systems. In this context, the trainee should feel the system as real as the marine environment. Therefore, the controls, displays etc. should be as similar as the ones in the ship.

ERS should carry the potential to help people construct an effective environment for learning. A fundamental challenge to learning is coping with the dilemma caused by the limited material that one can learn and the unlimited nature of the real world. Direct manipulation demonstrates how a complex assembly process can be shown to trainees in a simulator and how trainees deal with a complex systems operation task.

Placement of information provides determination of all requirements of real system which is simulated and inclusion to the simulator. Therefore the comprehension of system is achieved.

Color has been demonstrated to aid performance in both identification and search tasks when the code is unique and known in advance.

Luminance contrast is the difference in luminance between two adjacent objects. Color contrast is the difference in the chromaticity of adjacent objects. It is important for improving the visual performance on colors.

Visibility & readability means the illustrated system to be easy to see and perceive and to be able to get the information.

Geometric shapes and line sizes are important for the visual perception. The shapes and illustrations are selected as similar as the real system and easy to perceive.

The color and geometric shapes have more complications and design items on simulator mimic panel design. Therefore some more information about the ergonomics design principles of color and geometric shapes is presented as color coding, color contrast, transilluminated displays, coding by shape, the design of displays, and design of symbols.

### 2.1 CODING BY LOCATION

The people get used to find things according to a standard localization. Therefore, the devices and systems are designed such that the human may find what he/she seeks easily. In case of the ERS, a very complex system is represented by a mimic panel. Therefore, the localization of the systems should be in accordance with the real ship. The trainee should be able to find a system easily by considering the location coding.

### 2.2 CODING BY COLOR

In color coding, a different color is assigned to an item for different function and task. Color coding typically requires a double reaction time than location coding. This is because the human should reflect on the meaning of the color before the task can be performed (Helander, 2006).

### 2.3 COLOR CONTRAST

Human sensitivity to violet and red is less than to green and yellow. It is because violet and red are at the opposite ends of the color spectrum while green and yellow are at the center. A photometer produces lower values for violet and red than for green and yellow (Helander, 2006). Figure 1 shows the electromagnetic spectrum of colors.

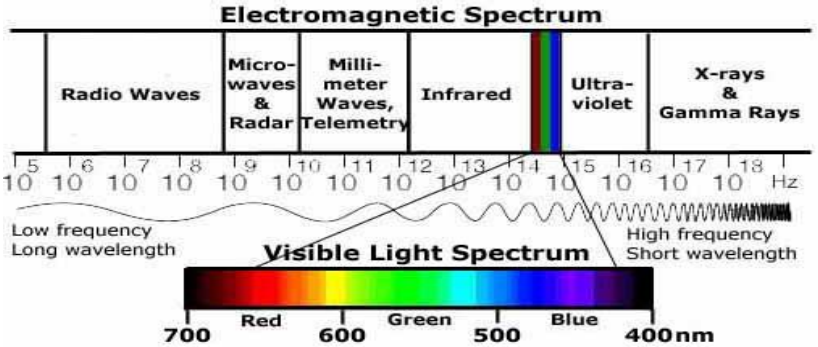



Figure 1. Electromagnetic spectrum of colors

## 2.4 TRANSILLUMINATED INDICATORS

Transilluminated indicators provide qualitative information to the operator such as system status or a warning requires an immediate action by the operator (Matisoff, 1990). Such indicators may also be used occasionally for maintenance and adjustment function.

## 2.5 CODING BY SHAPE

Shape of a control is also an important parameter. The best control design is obtained by resembling the control shape to the control function.

## 2.6 THE DESIGN OF DISPLAYS

The main tasks of a supervisor in a complex system are monitoring, pattern recognition and diagnosis. The display design is one of the topics that interesting developments take place.

Data and information are not the same things. Data are simply letters or numbers, but information is a meaningful combination of data that indicates system state (Noyes and Bransby, 2001).

The dimensions of a dial displays should be determined according to the formula $L = 7 \times 10^{-1.3} \times D$ (in mm). D is viewing distance and *L* is circumference of the circle. For example, the optimum dial diameter for a distance of 600 mm is about 60-75 mm. A comfortable viewing distance is necessary for the size of object and environmental conditions. (Corlett and Clark, 1995)

### 2.6 (a) Fixed or moving scale

A pointer moving over a fixed scale gives more readable information to see how a process is going on and direction of some change. A moving pointer is preferable in the processes where a particular set value (e.g. temperature or pressure) is needed. Therefore, a second pointer or a marker can be pre-set and the process can be accurately controlled as the two pointers come together. In the processes where wide scale range is covered the moving-scale instrument will serve better than a moving-pointer display. Table 1 illustrates the three types of dials and the processes for which they are appropriate (Kroemer and Grandjean, 1997).

## 2.7 DESIGN OF SYMBOLS

In visual displays, symbols and labels can be designed user friendly so that they are easy to understand. These displays carry visual information which must be given a semantic interpretation, so that the reader understands what to do. Symbols are used in industry for identifying controls, machine functions, and states of processes. A symbol can be more concise than a label with many words. The other advantage can be its international nature. A symbol is not needed to be translated and can be understood independent of operator's language (Helander, 2006).

Table 1. Different display types (Kroemer and Grandjean, 1997).

| Type of display |  Moving pointer |  Fixed marker moving scale |  Counter |
|---|---|---|---|
| Ease of reading | Acceptable | Acceptable | Very good |
| Detection of change | Very good | Acceptable | Poor |
| Setting to a reading: Controlling a process | Very good | Acceptable | Acceptable |

## 3. THE ENGINE ROOM SIMULATOR AT ITUMF

Maritime training institutions all over the world started to recognize the value of simulation systems as a training tool. Engine Room Simulator (ERS) is designed to simulate various types of machinery and equipment as used in the engine room of an actual ship. The main objective of ERS training is that the training is carried out efficiently, reliable with cost-effective configuration by simulating realistic environment.

Istanbul Technical University Maritime Faculty (ITUMF) ERS consists of two types of simulators. One is computer based training (CBT) type ERS; the other one is full mission type ERS. There are six units of CBT type ERS and one full mission type ERS. CBT type ERS is called Work Station (WS). The trainee is able to practice the operation of the engine plant in individual or a small number of trainees on the WS.

The full missions type ERS consists of the large-sized mimic panel which imitates an engine room, a control console which imitates a control room, an instructor console which imitates a bridge of an actual ship and a main switchboard which has same function as monitoring system and remote control system. By full mission type ERS; the trainee is able to practice more realistic operation than WS in suitable size of group.

## 4. THE INSPECTION OF MIMIC PANEL THROUGH ERGONOMICS PRINCIPLES AND DETERMINATION OF ERGONOMICS DEFICIENCIES

The mimic panel represents an actual engine room and it is the most significant component among the system components to carry out an effective ERS training. Regarding the former mimic panel shown in Figure 2, there were lack of functions and all the necessary procedures from starting up the propulsion plant to the state of navigation cannot be done on the panel. Under processing the operation of the former mimic panel, it is needed to press the key board to continue the procedures. The keyboard is in the control room and not on the mimic panel. Therefore the operation is interrupted for a simple action which is not good for concentration and understanding of trainees.

The former mimic panel causes the trainees to get confused and interrupts their comprehension. Besides, it is realized that there is not adequate analog meter on the mimic panel which causes trainees unable to monitor the system condition. In other words, the operator has lack of information about the machinery system which may result in human errors. Therefore, renewing the mimic panel was necessary to implement an effective ERS training.

To comply with the situation when the trainees work as a team, the philosophy states that common information important for all team members has to be visible from all locations, and should be provided on centrally located displays or panels. The displays should present partly pre-defined information (e.g. plant overviews) and partly specific information as selected from any of the workstations, the latter concerns large screens. Furthermore, the philosophy states that all available information should be accessible on all workstations and all process control should be possible from all operator workstations.

Before design period of the new mimic panel, the following points are considered for modifying the mimic panel in accordance with determined ergonomics principles:

Figure 2. The Former Mimic Panel

1. All necessary procedures related to starting up the propulsion plant can't be done on the panel.
2. Analogue meters for monitoring the system mounted on the panel were not adequate. Operators must be able at all times to identify the state of the system. Therefore displays should watch both the engineering requirements of the system and the cognitive properties of operators, and should encourage the optimal distribution of attention over the interface.
3. GSP (Group Starter Panel) is not adopted and placed on panel.
4. Main engine ignition indicator lamps to realize the difference between engine running and inertial rotation do not exist.
5. A propeller model which rotates by the revolution signal to make a realistic environment is missing for better monitoring of the system.
6. The boiler flame indication lamp was missing.
7. Color arrangement was not good enough for visual perception and identifying the system easily.
8. Control-Display integration was not considered. Where controls and displays (such as a motor controller and gauge board) are associated with a specific piece of equipment (for example, a pump, filter, heater, and so forth) and the controls or displays are located for local operation of the equipment, they shall be located above, or immediately adjacent to, the equipment so that it is visually obvious that all of the components are functionally related. (ASTM Int., 2006).

In this respect the above deficiencies were related to following ergonomics principles; 1 and 3 is related to direct manipulation, 2 is related to display of dynamic data, 4,5,6 is related to placement of information, 7 is related to color, 6 is related to geometric shapes, 8 is related to direct manipulation and realism.

## 5. APPLICATION OF DETERMINED ERGONOMICS PRINCIPLES TO MIMIC PANEL

Considering the above mentioned ergonomics deficiencies of the former mimic panel a new design drawing is created by ITUMF staff which can be seen at Figure 3. This design was unique which is designed for ITUMF. After design drawing is created the simulator company is asked for manufacturing the mimic panel according to created design principles and drawing. This unique mimic panel is manufactured and installed to ITUMF which can be seen in Figure 4.

The differences and ergonomic outcomes between the new mimic panel and the former mimic panel are listed in the Table 2. (Kocak et al., 2007) When the numbers of instruments of the new and the former mimic panel are compared the increase in numbers is as follows: number of switches increased from 493 to 724, the number of indication lamps are increased from 56 to 285, the number of analogue meters are increased from 7 to 174, a rotating model propeller is newly added. The increase in the number of switches means that the operator can perform more actions on the mimic panel comparing to former mimic panel. The increase in the number of lamps and analogue meters means a better monitoring availability of the system by the operator. The operator can see the situation of devices such as running (green lamp) or stand-by (yellow lamp). Besides, he/she can obtain more values (temperature, pressure, flow etc.) about the system through the analogue meters and can make a better evaluation about the overall system. Even more, the newly added propeller is rotating when the engine is running and propeller is connected. Therefore, the operator can see the rotation of the propeller inside the engine room and can take necessary actions especially in maneuvering conditions. These changes show the improvement of ergonomic conditions of new mimic panel.

## 6. SOME EXAMPLES OF ERGONOMICS APPLICATIONS FROM NEW MIMIC PANEL

An application of transilluminated displays on the new mimic panel is pump start-stop system. In the new design, the dual pumps (one pump running and the other stand-by) stand-by condition is displayed by a pilot lamp. Therefore, it is possible to understand which pump is running and which one is on stand-by condition. Figure 5 shows the new design of dual pump system and compares the pump start-stopping of the new and former mimic panel.

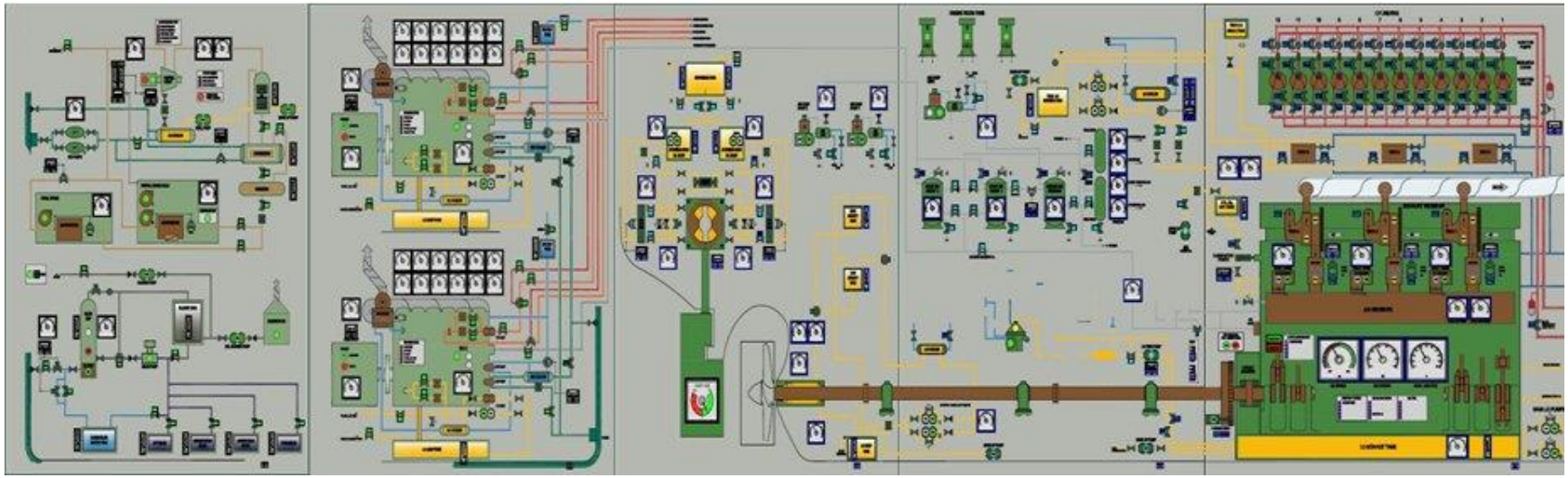
The displays of the new design can be seen in Figure 6 which is the type of moving pointer over a fixed scale. This type of scale is classified as the best type in the ergonomics principles part. Even more the color code for the display scales and the pointer is same and the black numbers used on the white background which is explained as the best display design.

The symbols are designed similar to the ship systems and standards. Therefore the trainee is not confused and the cognition is much better. In Figure 7 some symbols of valves, control valves, pumps and filters can be seen. The shape coding is overlapping with the real ship shape coding.

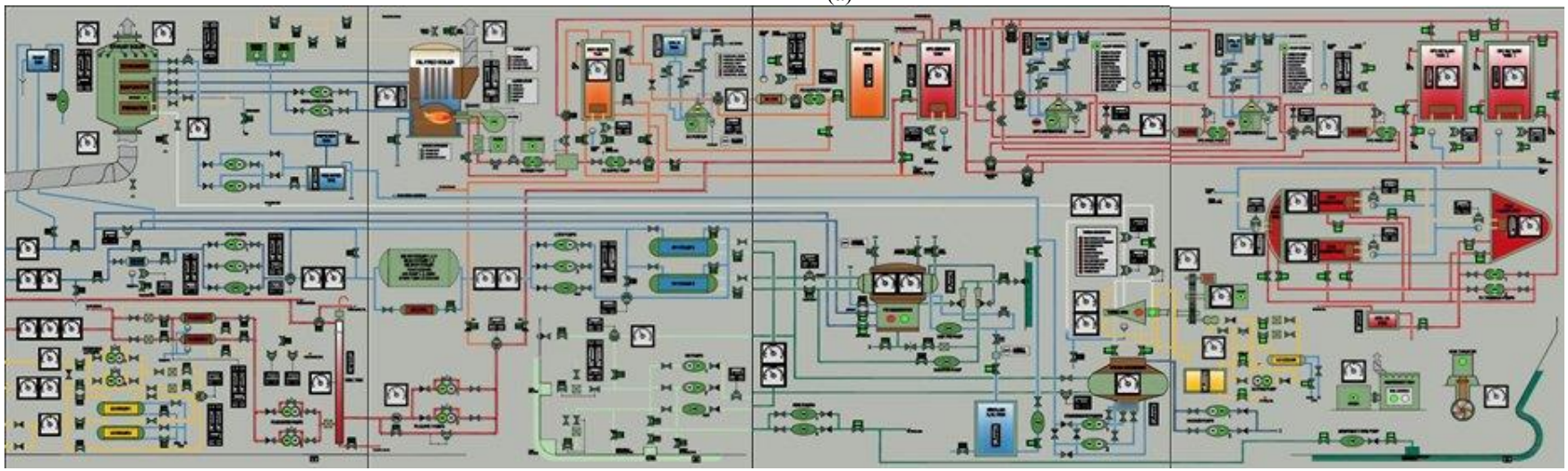
The displays of mimic panel are designed according to the ergonomic rules. The viewing distance is about 500-750 mm. and the diameter of the analogue meters are 55 mm. That is a sufficient size for good monitoring of displays.

At mimic panel design green, yellow, red, brown and blue colors are dominantly used. This is ergonomically more suitable for eyes and produces higher values for human sensitivity which is mentioned at design principles about color contrast.



(a)



(b)

Figure3. Connection of (a) and (b) is the design drawing of the new mimic panel

Table 2. The ergonomics outcomes and differences between the new mimic panel and the former mimic panel

| **New mimic panel** | **Former mimic panel** | **Ergonomics outcome** |
|---|---|---|
| Main engine was placed on the center and whole layout was completely rearranged. | Bunker system and bilge system were placed on the center. | Grouping of information, Placement of information, Geometric shapes, Line sizes |
| All cylinders were illustrated. | 5 cylinders were illustrated | Visibility and readability, Grouping of information, Realism, Direct manipulation, Color usage |
| All cylinder heads and all attached valves were illustrated. | Only 5 cylinder heads with no attached valve were illustrated. | Visibility and readability, Grouping of information, Realism, Direct manipulation, Color usage |
| ME ignition indicator lamps were added. | Non | Visibility and readability, Realism |
| Steering system was additionally illustrated and instruments concerned were added. | Non | Realism, Direct manipulation, Visibility and readability, Grouping of information, Placement of information, Controls on mimics, Manual/Auto Stations, Color usage |
| Refrigerant system was additionally illustrated and instruments concerned were added. | Non | Realism, Direct manipulation, Visibility and readability, Grouping of information, Placement of information, Controls on mimics, Manual/Auto Stations, Color usage |
| Emergency generator system was additionally illustrated and instruments concerned were added. | Non | Realism, Direct manipulation, Visibility and readability, Grouping of information, Placement of information, Controls on mimics, Manual/Auto Stations, Color usage |
| Engine room fans were additionally illustrated and instruments concerned added. | Non | Realism, Direct manipulation, Visibility and readability, Grouping of information, Placement of information, Controls on mimics, Manual/Auto Stations, Color usage |
| GSP was additionally placed and instruments concerned were added. | Non | Realism, Direct manipulation, Visibility, Control on mimics |
| Bow thruster was added. | Non | Realism, Direct manipulation, Visibility and readability, Grouping of information, Placement of information, Controls on mimics, Manual/Auto Stations |
| Boiler flame is illuminated. | Non | Realism, Visibility and readability, Color usage |

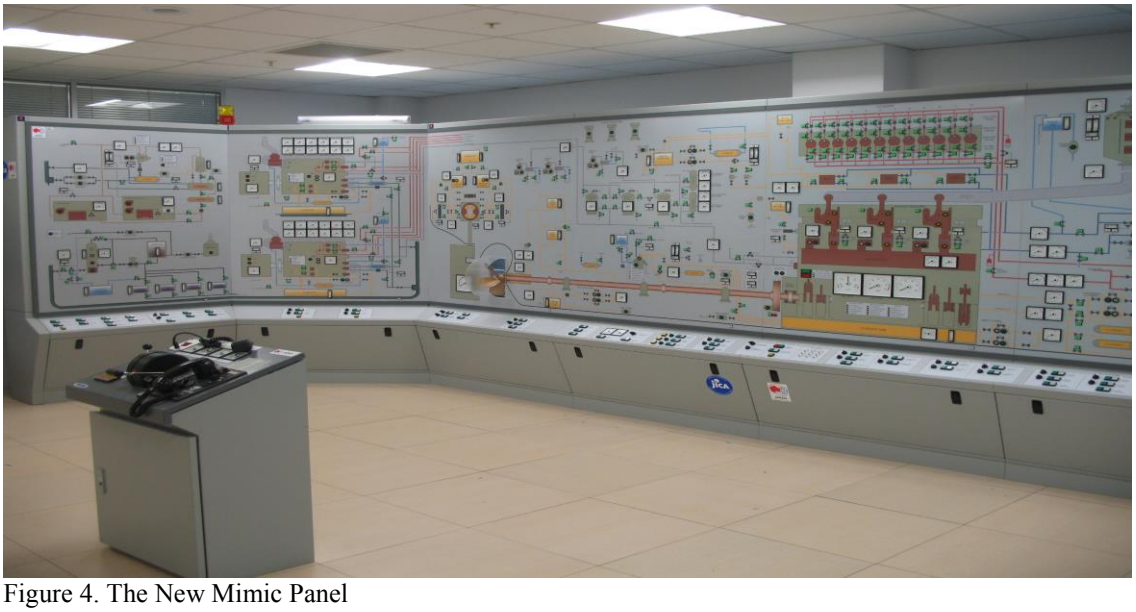


Figure 4. The New Mimic Panel

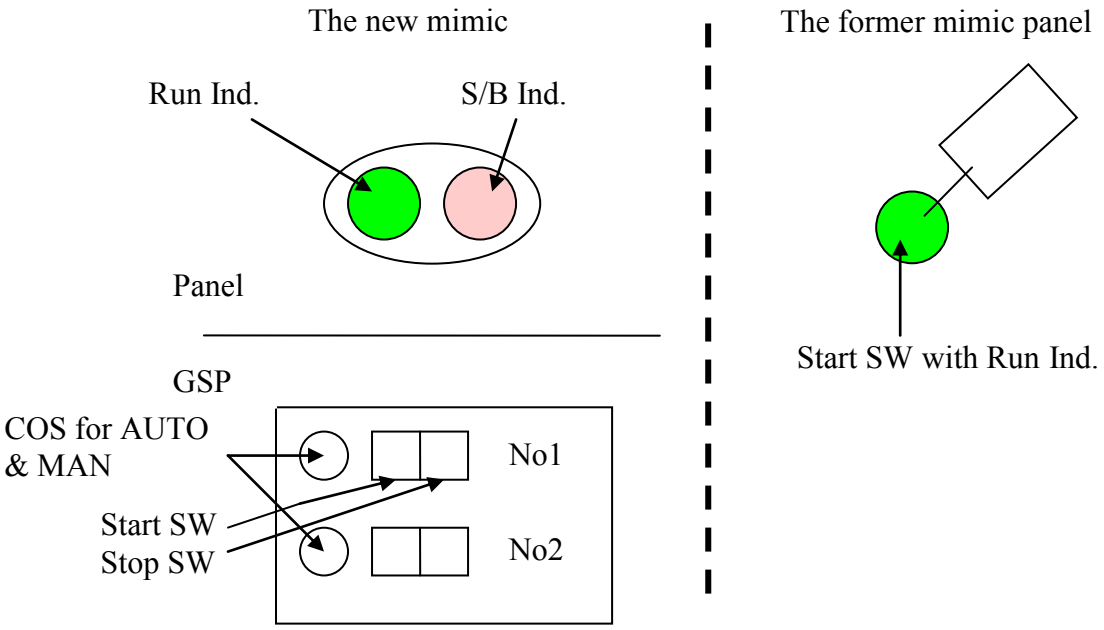



Figure 5. The mechanism of starting and stopping pumps

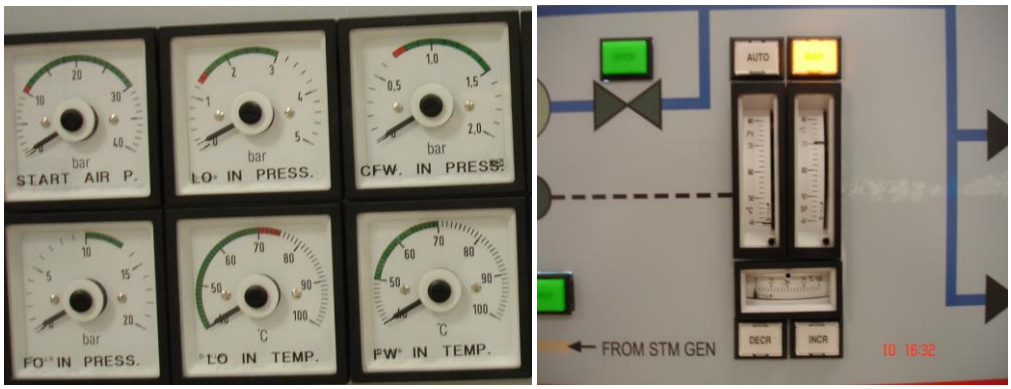



Figure 6. Some analogue meter samples

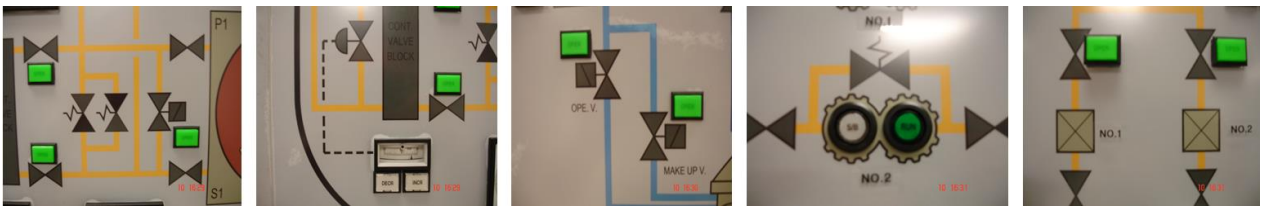


Figure 7. Some samples of ITUMF simulator symbols

As a complex system the ERS consists of many systems. The lines of different systems are coded in different colors. For example; the lubricating oil line is yellow, the cooling water line is blue, the fuel line is red etc. which can be seen in Figure 8. This color coding is as same as in the real ship. In other words it is realistic, as well.

## 7. THE ERGONOMICS GAINS OF THE NEW MIMIC PANEL

The deficiencies that are realized have been recovered and the function by using the mimic panel has been improved in terms of the following respects;

- It became easy to understand the system configuration of the propulsion plant due to the rearrangement of the layout,
- The color of the illustration is more noticeable and realistic and the color codes of the pipelines are as same as in the ship engine room,
- It is possible to perform all the procedures to start up the plant on the panel (The key board of PC to carry out some operations became unnecessary),
- Monitoring by the trainee standing in front of the panel became possible due to the analog meters which increased sharply in number,
- The mechanism of starting and stopping pumps has been completely changed. In dual pump systems, the operator can see whether the stand-by pump is actually in stand-by condition by additional stand-by indication lamps,
- Rearranged layout of the plant, more realistic illustrations, the model propeller, main engine ignition indicator lamps and special designed boiler flame lamp were very effective to create more realistic environment for the training and successful to improve trainee's motivation. The trainee's consciousness about the system is increased. The illustrations of mentioned systems and some additional systems from Table 1 are shown in Figure 9.

The concept of vigilance incorporates a number of key themes such as sustained attention, signals, detection, staying alert, being able to identify targets and maintaining performance over time. Therefore, vigilance can be identified as the ability to identify, recognize and interpret the information that is being monitored (Noyes and Bransby, 2001).

With the application of ergonomics principles to the mimic panel the operator can be more vigilant against the system. That is very important for managing such a complex systems especially in emergency conditions.

In the complex and dynamic environments such as power plants, human-computer interactions design has a great influence on situation awareness. (Hopkin, 1995) In such systems there is a large volume of information from a variety of sources including sensors and the operators of such systems must often pay attention to this information to increase situation awareness (Noyes and Bransby, 2001). The new mimic panel design yields situation awareness of this complex and dynamic system which subsequently increases reliability.

At Figure 8 a sample illustration is shown. It is seen that the system is very clear for visual comprehension, the colors used are suitable and the colors of pipeline is the same color code with the real system. Many analog meters are placed for display of dynamic data etc.

As an example the new and former pump starting and stopping mechanisms are introduced and illustrated in Figure 5. In the illustration we can see that in the new mimic panel, control of system is more comprehensive and easy to follow the information which gives us the present condition of the system such as the pump is running or on stand-by condition (Kocak et al., 2006).

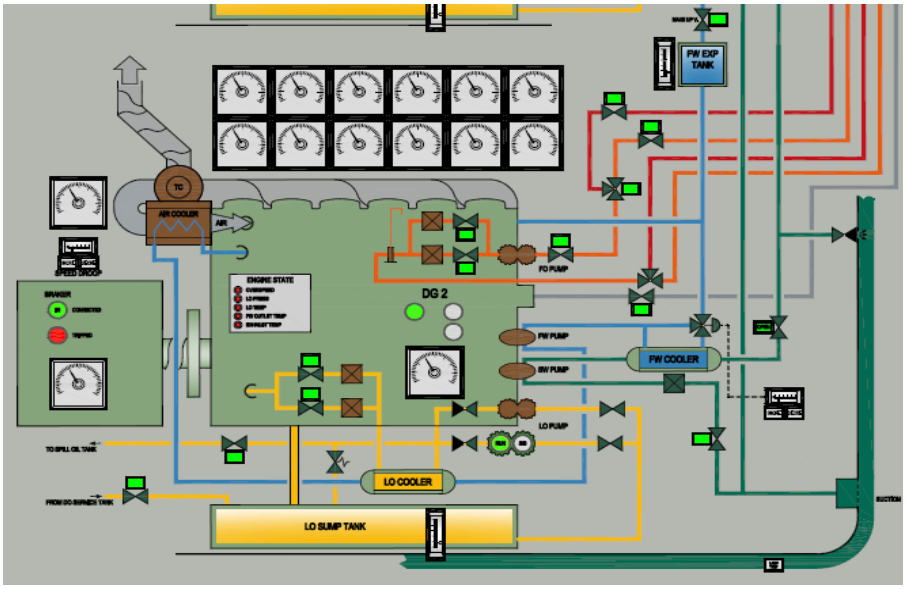
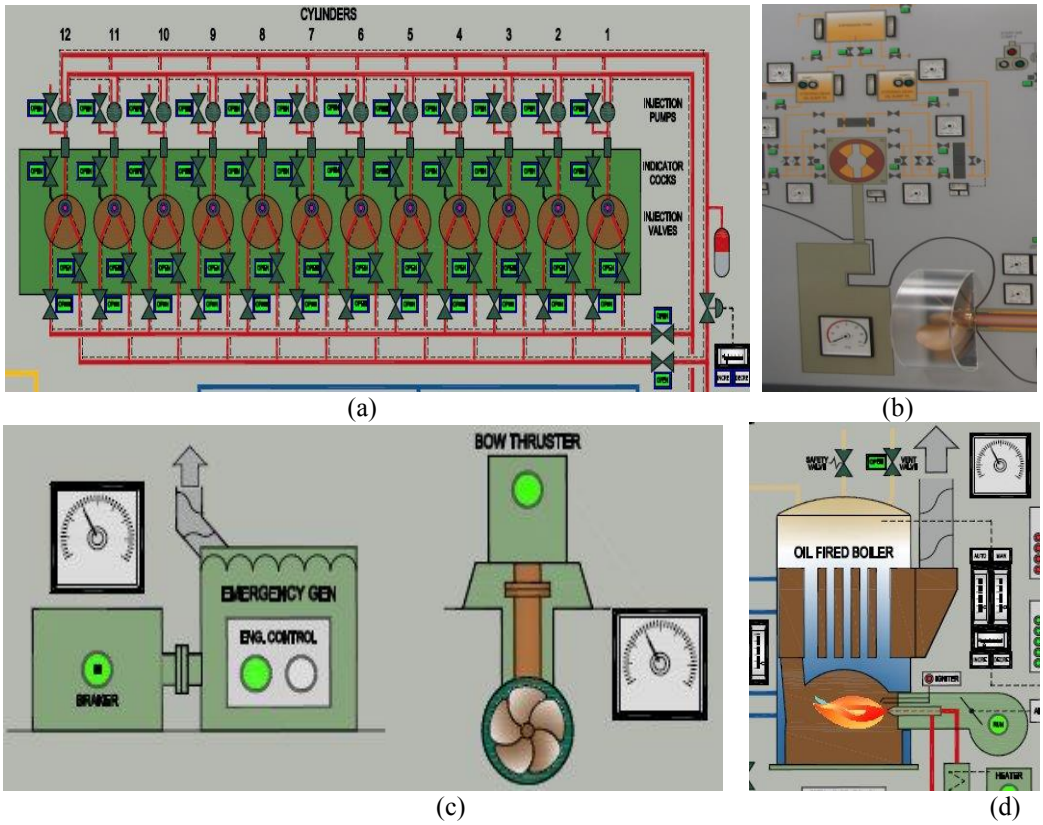



Figure 8. An example part of an illustration of new mimic panel




(a) Main engine cylinders indication lamps, (b) Model propeller and steering gear system, (c) Emergency generator and bow thruster, (d) Oil fired boiler (flame indication lamp)

Figure 9. Some illustrations of additional systems

## 8. CONCLUSIONS

For the effective training with simulators the simulator environment should be designed considering ergonomics principles. Therefore it can be more realistic and effective training tool. For the ergonomics of a training tool the cognitive ergonomics is as important as the physical ergonomics. It is important for determining the ergonomics design criteria of simulator.

The new HMI of the simulator ensures better monitoring and increased functionality on mimic panel which are important for effective training. The overall layout of the system is designed for easy understanding of operators so that they can find a sub-system easily. In the sub-systems, the figures are more user-friendly and informative. For instance, model propeller, main engine ignition indicator lamps and special designed boiler flame lamp were very effective to create more realistic environment for the training and successful to improve trainee's motivation. The number of analog meters and indicator lamps are increased. Therefore the operator can monitor more data about the system condition which increases situational awareness. The integrity of the system is realized which result in shorter operations due to not interruption of operation between mimic panel and work station. The complex ship system is developed on more simple and realistic approach to prevent the confusion of trainees.

Another educational gain is suitability of the new system for the team management and risk management courses. The former mimic panel was not sufficient for team organizations to study more efficiently due to absence of some systems and lack of instruments. The lack of instruments results in delaying perception of undesirable process. On the other hand, risk management is aiming to implement the true procedure at true time in the fastest way. Because all systems and necessary measurement instruments can be monitored on the new mimic panel, risk management training can be executed properly.

By application of determined ergonomics principles the ergonomics gains such as situation awareness and vigilance are achieved which has obvious importance for complex and dynamic systems.

## 9. REFERENCES


1. ASTM International F 1166-95a. (2006) *Standart Practice Design for Human Engineering Design for Marine Systems, Equipment, and Facilities*, ASTM International, US.
2. BEARE, A. N., GADDY, C. D., GILMORE W. E., TAYLOR, J. C., FRAY R. R., DIVAKARUNI, S. M. (1992) *Human Factors Guidelines for Fossil Power Plant Digital Control System Displays,* Fifth Conference on Human Factors and Power Plants, June 1992, Monterey, USA.
3. CHAN A.H.S., SHUM V.W.Y., LAW H:W:, HUI I.K. (2003) *Precise effects of control position, indicator type, and scale side on human performance*, International Journal of Advanced Manufacturing Technologies, 22, pp:380-386.
4. CORLETT E.N., CLARK T.S. (1995) *The Ergonomics of Wokplaces and Machines: A Design Manual*, second ed., Taylor & Francis, London.
5. HEIKKINEN, J. AND HANDROOS, H. (2013) *Design of a Human Machine Interface for a Mobile Machine using Simulation in Virtual Reality Environment*, International Review on Modelling and Simulations. Vol 6.
6. HELANDER M. (2006) *A Guide to Human Factors and Ergonomics*, CRC Taylor & Francis, Boca Raton, FL, USA.
7. HOPKIN V.D. (1995) *Human factors in air traffic control*, Taylor and Francis, London.
8. KATZOURAKIS, D. I., ABBINK, D. A., HAPPEE, R., and HOLWEG E. (2011) *Steering Force Feedback for Human–Machine-Interface Automotive Experiments*, IEEE Transactions on Instrumentation and Measurement, Vol. 60, no. 1, pp. 32-43. doi: 10.1109/TIM.2010.2065550
9. KOCAK G., DURMUSOGLU D., DENIZ C., KUSOGLU A., HASHIMOTO S. (2006) *The New Mimic Panel and its Effects on Simulator Education of Marine Engineers at ITU Maritime Faculty*, IAMU AGA7 Conference, China.
10. KOCAK G., DENIZ C., DURMUSOGLU Y. (2007) *The Effects of Ergonomics Design Principles to Engine Room Simulator and Marine Engineering Education*, 3rd International ERGONOMICS Conference, Zagreb, Croatia.
11. KROEMER K.H.E., GRANDJEAN E. (1997) *Fitting the Task to the Human: A Textbook of Occupational Ergonomics*, Taylor and Francis, London.
12. LI M. (2015) *Design and Evaluation of Human–Machine Interface of Simulation Training System*. In: Long S., Dhillon B. (eds) Proceedings of the 15th International Conference on Man–Machine–Environment System Engineering. Lecture Notes in Electrical Engineering, vol 356. Springer, Berlin, Heidelberg.
13. MATISOFF, BERNARD S. (1990) *Handbook of Electronics Packaging Design and Engineering*, Springer Netherlands. DOI: 10.1007/978-94-011-7047-5.
14. NOYES J., BRANSBY M. (2001) *People in Control: Human Factors in Control Room Design*, Institution of Electrical Engineers, London.
15. WEIR D. H. (2010) *Application of a driving simulator to the development of in-vehicle human–machine-interfaces*, IATSS Research, Vol: 34, Issue: 1, pp: 16-21.
16. R. ZHENG et al. (2013) *Human-machine interface system for simulation-based automatic platooning of trucks*, 16th International IEEE Conference on Intelligent Transportation Systems (ITSC 2013), The Hague, 2013, pp. 535-539. doi: 10.1109/ITSC.2013.6728286