THE TEACHING PRACTICE WHEN USING A DIAGNOSTIC SIMULATOR TURBO DIESEL 3

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ABSTRACT

The teaching practice when using a diesel engine fault simulator is the subject of this paper. The mathematical model simulates an engine operation under various conditions and introduces various defects. This model has been implemented in a software, which is used for teaching of the relation between the diesel engine technical state and its operating parameters. The software can be also used for the maintenance strategy teaching.

1 INTRODUCTION

The first version of the PC-based diesel engine simulator, called Turbo Diesel for Windows was developed in 1994 [2], the latest one called Turbo Diesel 3 (Figure 1) was completed by the author in 2003. The 'heart' of the program is a diesel engine mathematical model, based on the physical structure of the modelled object. The model has been developed using the actual factory test bed results and the classic thermodynamic equations. The package allows an engine operation under selected initial conditions (for example, torque, RPM, ambient air pressure) and variable technical state (for example a dirty air blower, broken piston rings, a worn fuel pump and so on). The simulated engine reacts naturally under almost any combination of factors, although some combinations make operation impossible as they would in real life.

The diagnostic simulator is designed to teach the principles of the generic diesel engine operation. It is not designed to teach an operation of any specific engine or type of engine.

The general approach to the diesel simulator application in the diagnostic teaching was based on the author's long time academic experience in giving courses on diesel engines diagnostics and on some available publications [1,5,6] as well. The main teaching tasks implemented in the simulator have been described below.

1.1 Diagnostic principles.

The first task was for the software to teach about the relation between the diesel engine technical state and its operating parameters. This is performed by the program when working in Evaluation Mode. In this mode a student can freely change engine load and operating conditions, can select different engine faults, mix them and see the effects of these changes by inspecting the engine parameters. The student learns to understand the relationship between an engine state and the engine parameters. This is important particularly for students early on in their training. It also

makes clear the importance of the proper diagnostic method application, since only the correct diagnostic methodology can enable the identification of the engine faults.

1.2 Maintenance strategy and assessment

The second task was for a more pressurised mode where the student would be obliged to put his knowledge into practice - i.e. run the simulated engine and take responsibility for its condition and maintenance. In the program Live Run mode, the student becomes in effect a qualified user. he needs to monitor closely the engine operating parameters and carry out repairs when necessary. Apart from reacting to the student's actions, the software also generates random wear and tear factors, which means that no Live Run is ever exactly the same as another. The student's performance is logged and scored for assessment and de-briefing.

1.3 Design and implementation of course material

The third task was for a lesson-mode, both for instructors to be able to create their own specific course material, and for students who could be given set material to work through. The program has a separate lesson-writing program, where instructors can create course material. These courses can then be loaded into the main program for students to complete as required.

Because of the limited paper volume, only first two educational tasks will be discussed below in this publication.

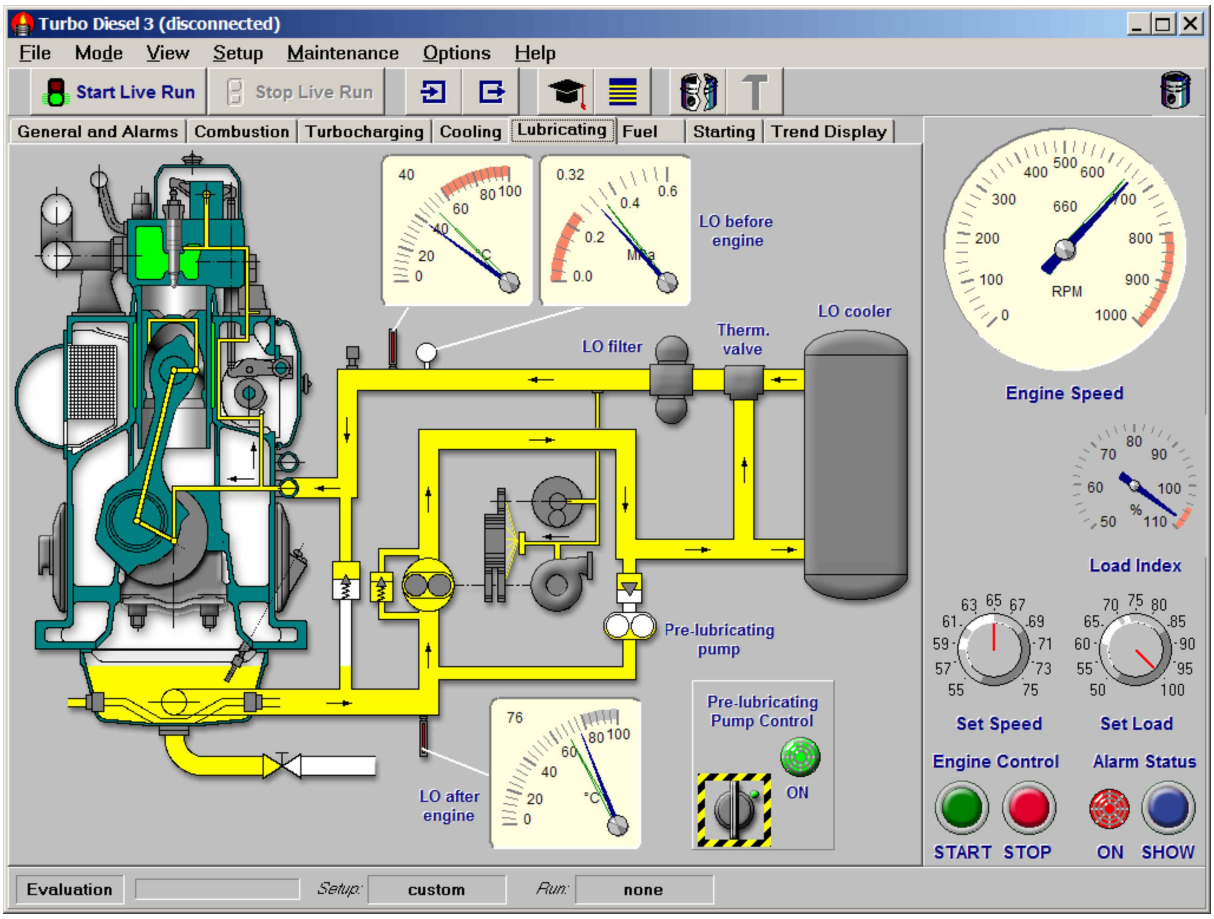

Figure 1: Simulator main window

2 EVALUATION MODE

In Evaluation Mode the student can work in the instructor's absence while trying to learn the relationship between the technical state of the engine or the operating conditions on the one hand and the operation parameters on the other.

The following list gives the recommended training plan for students:

a. The student has to start the engine and observe the operation parameters.
b. Later, he can increase and decrease the engine load and observe the parameters.
c. The trainee should find his way around the engine by changing some of the parameters and observing the effect on the gauges. The program tutorial shows how to do this and how to start making diagnoses by observing the gauges.
d. The current simulation setup and the engine parameters can be saved in the setup file.
e. The trainee can also load the previously saved simulation setup from a file, which is much faster than making a new calculation).

It is very important to know, that multiple simulations can be mixed freely, and each of them can be selected from the given range (Figure 2).

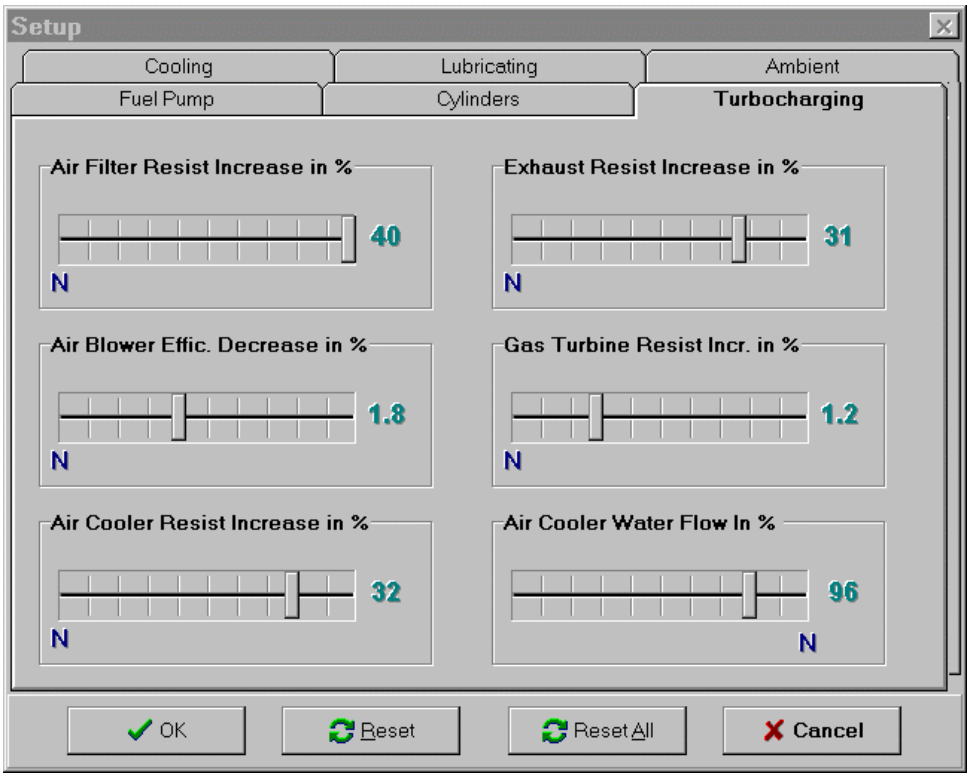

Figure 2: Fault mixer with multiple tabs.

Here is the complete list of the possible simulations:

- air filter - an increase of the air path resistance
- air blower - a decrease of the air flow efficiency
- gas turbine - an increase of the gas path resistance
- air cooler - a decrease of the air resistance
- gas leak through the piston rings or valves (or both)
- fuel effective quantity decrease

- injection advance angle change
- decrease of cooling efficiency
- friction coefficient increase
- engine speed
- engine load
- ambient air (pressure and temperature)
- air cooling water flow
- cylinder cooling water temperature
- lubricating oil temperature
- lubricating oil pressure drop at the oil filter air filter - increase in air path resistance

Every change in the technical state or in the operation conditions starts the calculation process. The calculation loop has to be repeated many types until the balance conditions listed below are fulfilled:

- the power required by the air compressor has to be balanced with the power produced by the gas turbine within the given range.
- the air mass flow delivered by the air compressor has to be balanced with the gas flow consumed by the gas turbine within the given range.
- the pressure drop on all passive flow resistors has to be balanced with compression ration produced by the air compressor.

It takes up to a few seconds until the engine parameters are stable depending on the actual fault setup. There are many different diesel engine and ambient parameters, which can be continuously monitored while running the Turbo Diesel 3 model engine. Gauges show more than one value (Figure 3). For single gauges the two readings are: the current and the reference value. On multiple gauges you see the actual value for each cylinder and the reference value which is common to all three. The bigger the difference between the actual and reference values the worse the technical state is. The principle that the deviations should be used rather instead of the actual parameter values is very important especially for the student without an experience of the simulated engine type. He can very hardly estimate if the observed parameter value is correct, so the parameter deviation is of a great help for the analysis.

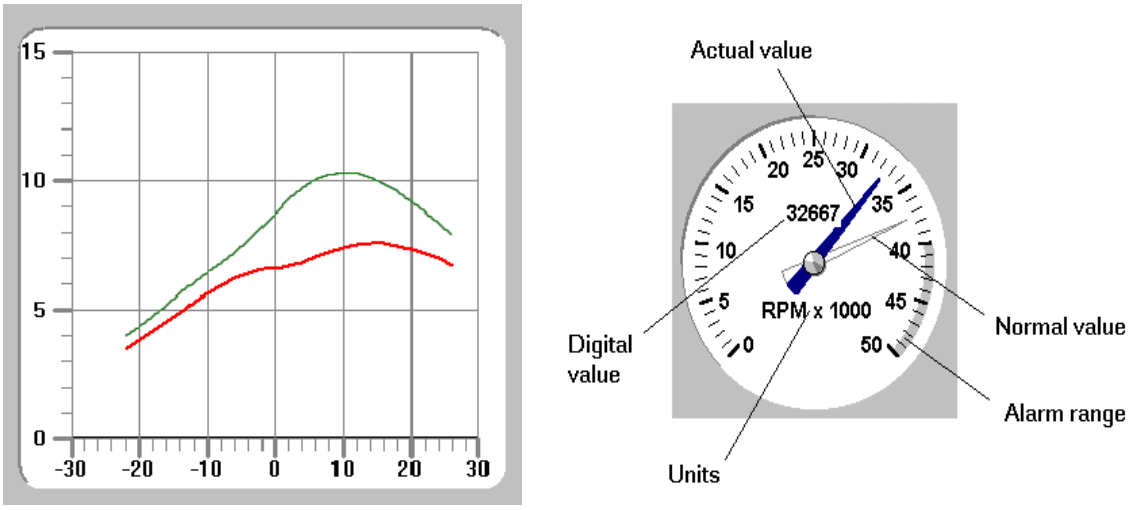

Figure 3: Simulation example. Left: The combustion curve caused by the late fuel injection (green colour – reference curve, red colour – actual curve). Right: Analogue gauge with multiple parameters display.

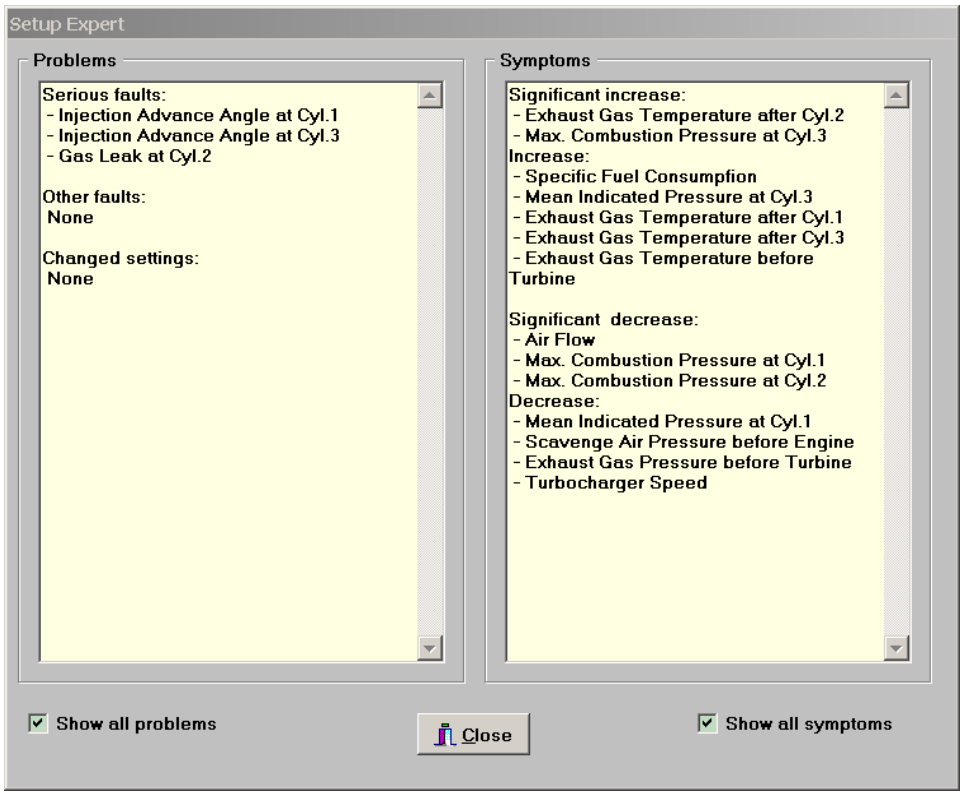

Figure 4: Setup expert window.

The Setup Expert (Figure 4) which has been also integrated in the simulator can always explain the relation between the change in the engine setup and the change in operation parameters, as this is very important when learning about engine diagnostics. This is very convenient from the instructor point of view: he does not have to repeat many times the same explanations and has more time for the student progress analysis.

It is interesting to observe, that there is only a little difference in performance between the cadets and experienced engineering officers (participating in the courses for the first class certificate) when working in the evaluation mode. The cadets mostly do not understand the practical meaning of the simulated faults but are rather well skilled in the abstract thinking and combining the diagnostic symptoms with the technical causes. The experienced engineers on the other hand, know very well most popular engine faults and they tend to ignore those which are less frequent.

3 LIVE RUN MODE

The Live Run mode is rather like other computer simulations (a flight simulator for example); the operator has to act as a qualified user, working against the computer, which simulates dangerous situations, faults and so on. Although the scenario is written by an author, random factors are also introduced by the computer.

Each Live Run starts with the engine in a particular technical state (set by the instructor or loaded from a previously created and saved setup). As time proceeds, any faults which are present at the outset become aggravated and affect the parameters. The student monitors the engine state and can carry out repairs or maintenance at any time (Figure 5); correct actions lead to more efficient and economical running while negligence, wrong or unnecessary actions lead to a loss of economical efficiency.

Here is the complete list of maintenance available in Live Run mode:

- ·cooling pump repair,
- ·water temp. controller adjustment,
- ·cooling system washing,
- ·lubricating pump repair,
- ·oil filter cleaning,
- ·oil temp. controller adjustment,
- ·engine bearing repair,
- ·turbocharger general repair,
- ·air side washing ,
- ·gas side washing,
- ·air filter cleaning,
- ·air cooler cleaning,
- ·exhaust system cleaning,
- ·cylinder general repair (piston rings and cylinder head)
- ·fuel pump general repair,
- ·fuel pump adjustment.

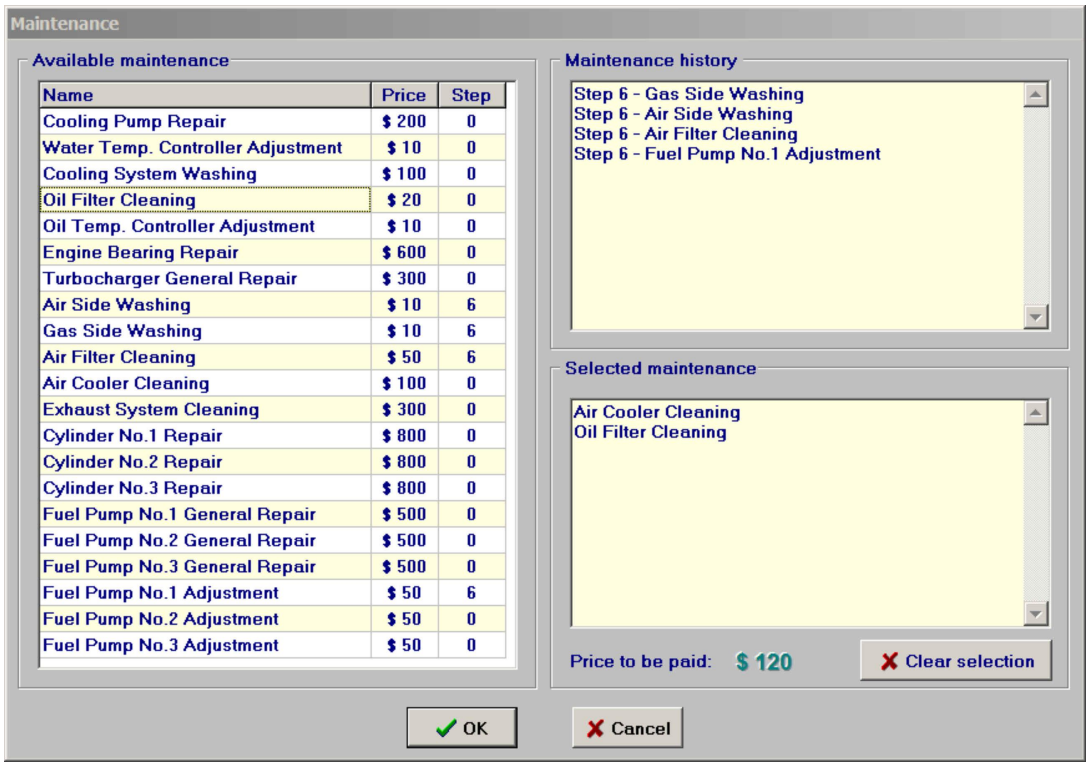

Figure 5: Maintenance window.

The global cost of the selected repairs is added to any previous repair and maintenance costs (Figure 6). This is a very important measure of his competency and can be used for his assessment. The engine user who has spent less money for the simulated engine operation costs (maintenance, repairs and fuel) will be usually more wanted by the company as the other one who produces higher operation costs.

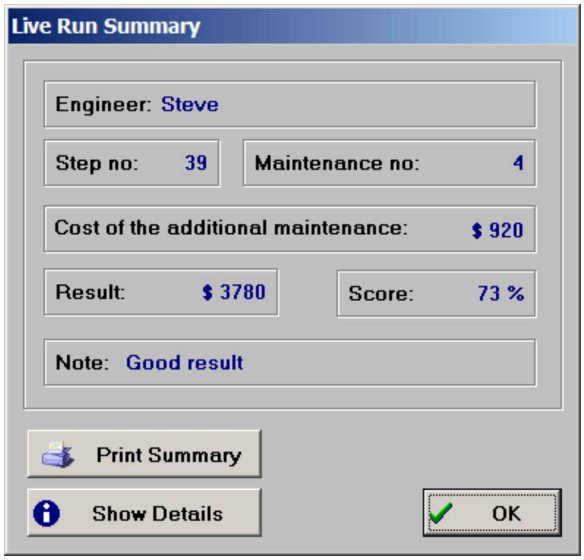

Figure 6: Example Live Run results.

The author's experience has shown that the trainees with a significant practice as an engineer officer at sea, require less money on the simulated engine running, than the young inexperienced cadets. It means, that in many cases they do not use the diagnostic knowledge learned when working in the Evaluation Mode, but instead, they rely on their experience and apply the maintenance as they would be doing in the real life. On one hand, it confirms the realistic behaviour of the simulator model, but on the other hand, it proves that the evaluation mode application should be improved.

4 EXAMPLE SYLLABUS

The presented below example syllabus of the training course (based on Turbo Diesel application), has been developed by the author and tested with both: young cadets and experienced engineering officers.

4.1. Introduction

* Turbo Diesel 3 basics
* operation instructions
* engine parameters inspection
* first steps

Aim: To learn how to operate Turbo Diesel 3.
Time: 90 min.

4.2. Start, stop and load change

* engine parameters when stopped
* engine parameters when running
* engine parameters under different speed and load
* actual and reference parameter values

Aim: To learn how the engine parameters change under different load and engine speed.
Time: 90 min.

4.3. Different operation conditions simulation (minimum and maximum value of the range)

* ambient air (pressure and temperature)
* cooling water (pressure and temperature)
* lubricating oil (pressure and temperature)

Aim: To learn how the engine parameters change under different operating conditions.
Time: 90 min.

4.4. **Single simulations (middle and maximum value of the range)**

* air filter - an increase of the air path resistance
* air blower - a decrease of the air flow efficiency
* gas turbine - an increase of the gas path resistance
* air cooler - a decrease of the air resistance
* gas leak through the piston rings or valves (or both)
* fuel effective quantity decrease
* injection advance angle change
* decrease of cooling efficiency
* friction coefficient increase
* engine speed
* engine load

Aim: To learn how the engine parameters change when a single fault occurs. The typical fault symptoms should be collected as a final result.
Time: 3 * 90 min.

4.5. Multiple simulations (mixing every single simulation with other single simulations)

* air filter fault with all other simulations
* air blower fault with all other simulations
* gas turbine fault with all other simulations
* air cooler fault with all other simulations
* gas leak through the piston rings with all other simulations
* fuel effective quantity decrease with all other simulations
* injection advance angle change with all other simulations
* decrease of cooling efficiency with all other simulations
* friction coefficient increase with all other simulations
* engine speed with all other simulations
* engine load with all other simulations

Aim: To learn how the typical fault symptoms change when other faults occur.
Time: 6 * 90 min.

4.6. Live Run mode exercises.

* the first 20 steps and the saved Run (discussion),
* the next 20 steps and the saved Run (discussion),
* the next 20 steps and the saved Run (discussion),
* general maintenance strategy discussion based on the examples.

Aim: To learn the maintenance strategy rules.

Time: 3 * 90 min.

4.7. Live Run mode assessment.

* the first Live Run assessment,
* the second Live Run assessment,
* the results discussion.

Aim: To test the diagnostic and maintenance knowledge level.
Time: 3 * 90 min.

Total estimated time: 18 * 90 min. = **27 hours**.

5 CONCLUSIONS

The diagnostic simulator, based on the mathematical model of the high power, medium speed, four stroke diesel engine is particularly suited to the diagnostic engineering education, providing the teachers with a powerful teaching tool and the students with an increased understanding of the relation between the engine technical state and its operating parameters

The very important feature of a presented simulator is its low cost and the possibility to be used also for stand-alone education. This makes such a kind of a simulator very attractive for low budget colleges in developing countries, and for the ship owners, because of the possibility to be installed also on board. The well cut, complete teaching program and a set of pre-prepared lessons should be always a part of a simulator package

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BIOGRAPHY

Dr. Stefan Kluj is an associate professor in Gdynia Maritime University (Poland). He graduated from the Technical University of Gdansk (Poland) in 1974 and received a Ph.D. degree in the engineering eight years later. Stefan Kluj has developed several engine room simulators like Argus, Turbo Diesel or Virtual Engine Room. and was responsible for the software development of the full mission simulator called Unitest Engine Room.