Computer Aided Assessment for Engine Room Simulator

Stefan Kluj, PhD (Eng.),
Associated Professor, Gdynia Maritime Academy, Poland.

This paper presents the Computer Aided Assessment (CAA) applied for the full mission engine room simulator developed in Gdynia Maritime Academy. The simulator named ER-SIM has been based on the modern low-cost hardware architecture. This architecture enables on-line analysis of the engine room parameters and control signals. This data is used for specialised analysis designed as the assessment support. The different kinds of CAA tests have been described in detail. The example of the several CAA static tests and their application results have been given. Finally, the article describes also the idea and measures of the CAA dynamic tests.

INTRODUCTION

The discussion at ICERS 2 in Rimouski [1,2,3,4] has proved that an engine room simulator can be used not only for a training but for an assessment as well. The author experience and research has shown that it is very hard to achieve an objective and reliable assessment when only an instructor is responsible for it. It means that the simulator used for the assessment should provide the assessor not only with all necessary information about student actions, alarms and the parameter records but with a lot of additional special pre-processed assessment data as well. The author would like to propose the term ‘Computer Aided Assessment’ (CAA) for the technology which will be the main subject of this paper.

SIMULATOR

In order to explain the hardware and software environment necessary for CAA implementation, the short description of the simulator used for tests, will be presented. The full mission engine room simulator called ER-SIM has been developed, built and installed in Gdynia Maritime Academy (Poland) by the team under the author’s leadership. ER-SIM is the ship engine room simulator aimed for cadets and marine engineers training. The simulator includes a model of the typical low-speed marine diesel engine and its auxiliary systems. The main target of the development team was to achieve the parallel processing at many co-operating workstations instead of mainframe or minicomputer machine (see also [5]). The result should be:

- lower hardware cost,
- flexibility of the hardware configuration,
- lower software development cost,
- possibility of the constant simulator software improvement due to the ongoing research.

The team of 8 persons needed about 2 years for the simulator development, programming and basic testing. The simulator operation started in March 96 and has been continued together with its intensive testing by users.

HARDWARE

The simulator hardware consists of the computer network, several engine room hardware consoles, printer and the Internet connection (see Fig. 1). This has been implemented for the future simulator extension. It is planned to offer simulator services for the interested users (maritime academies, ship owner training centres) via Internet. The user will be able to operate simulator remotely using the standard PC hardware as a simulator terminal.

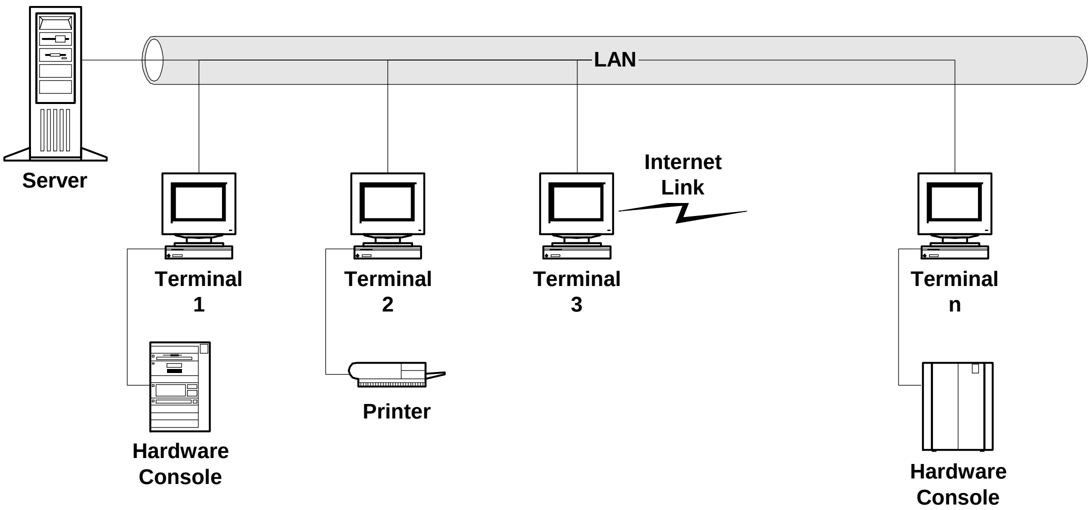

Fig. 1. The modular simulator hardware.

The computer network has a typical LAN architecture and consists of a dedicated server and several terminals. The server and the terminals are PC class machines with 80486 and Pentium processors, equipped with 17” colour monitors running at the resolution 1024 x 768 pixels. Most of the terminals are equipped with Sound Blaster compatible sound cards in order to provide sound capabilities.

The engine room hardware consoles include switches, lamps and gauges necessary for the selected engine system control and co-operate closely with the appropriate computer terminals where the system mimic diagrams are presented. The combination of the virtual system presentation and the hardware system control provides both; the realistic look and feel, and the comfortable operation. The main engine console is equipped only with the actual controls (levers, switches, gauges, telegraph) in order to provide the very realistic feel of the engine manoeuvring, typical for today’s (but not totally computerised) control rooms. The hardware consoles and the main engine console are connected with computer terminals via AD/DA interfaces and that gives the possibility to communicate with a computer network. Several sound cards and the sound amplifier with high power speakers are responsible for the digitised sound effects like the engine noise correlated with the engine speed, the starting air sound and many others.

SOFTWARE

Simulator software consists of many independent modules which have been installed at different workstations or at the server (see Fig. 2). Each system module was developed and tested separately, however, keeping its future connectivity in mind. The appropriate communication protocol and the common module interface enable close co-operation between single components and parallel processing of the data. This means that the simulator can be tailored according to the customer specific needs and its cost can be optimised. On the other hand an incomplete configuration can be extended in the future without any complications (see also [6]).

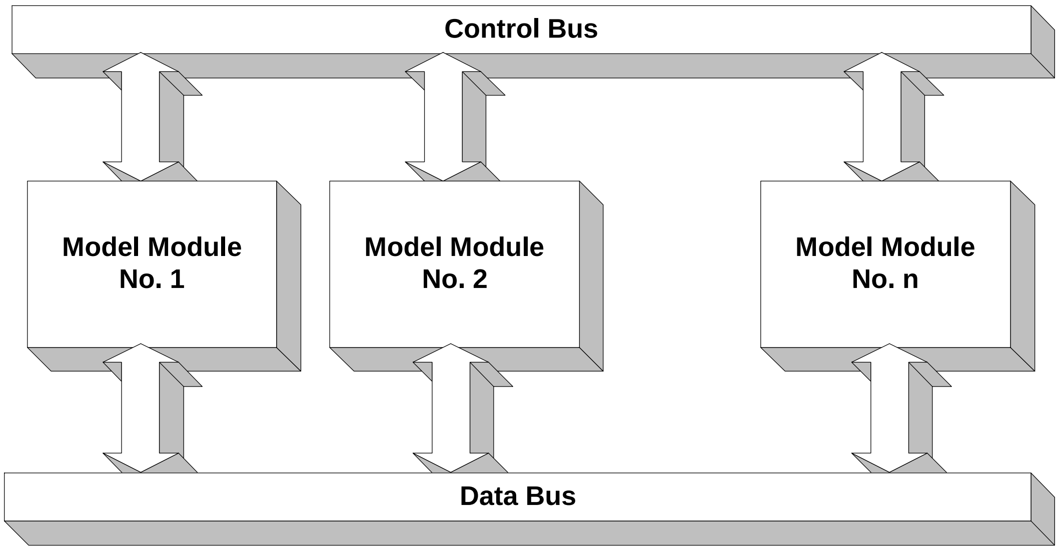

Fig. 2. Logical layout of the modular simulator

The data and control buses are responsible for the communication between modules. This communication has very important meaning for the proper co-operation between parts of the simulator mathematical model especially because of its real time operation. The special software interface standard has been developed and implemented in order to provide the communication between the module kernel and the buses (see Fig. 3). The additional advantage of that approach is the independence of the single modules which means that the module kernel can be written in different programming languages, with the use of different programming techniques and have different purposes.

The experience of the development team has shown that such a specification can be very useful (if not necessary) for the co-operation of many modules developed by many persons. The author’s opinion is that it would be reasonable to elaborate and establish similar interface standard in ship engineering software industry. It should simplify the software development and provide the necessary background for the future development of the standardised simulator test procedures and assessment methods, what will be discussed below.

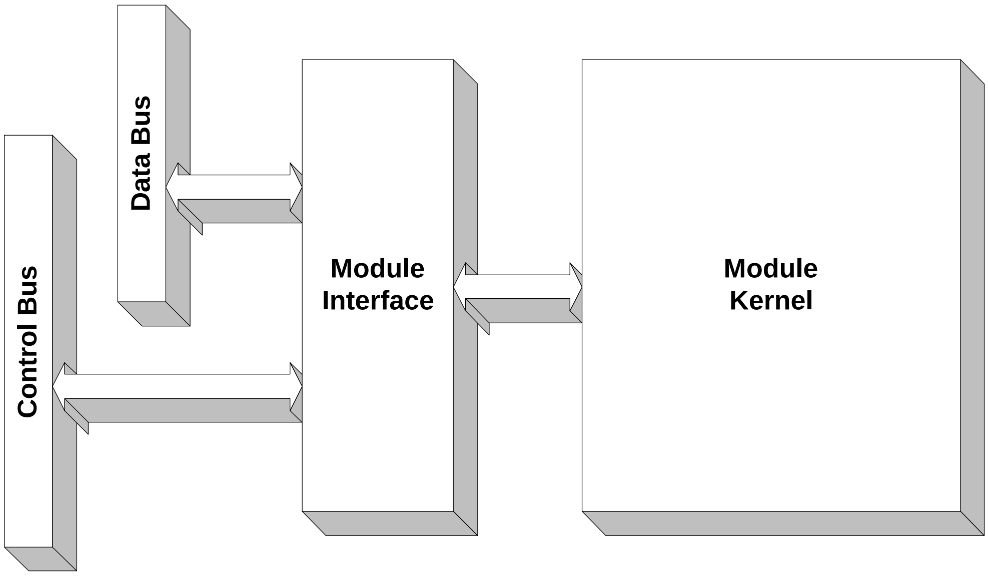

Fig. 3. The co-operation between the single module and the buses.

The graphic user interface has been selected as a simulator shell in order to provide the comfortable operation and the realistic presentation of the engine systems (Fig. 4.). As mentioned above; the engine room sound is generated from many sources and synchronised with the situation. That gives the useful information feedback for an engine room operator, that is very important especially for the engineers with some experience at sea.

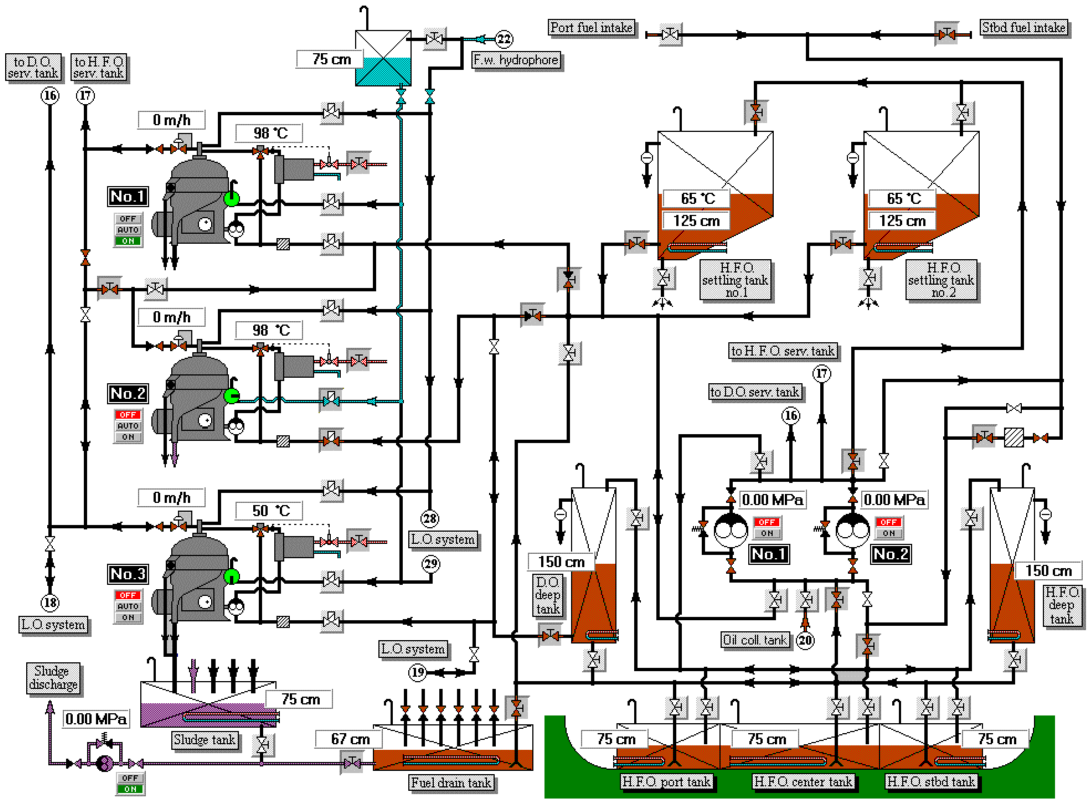

Fig. 4. The example of the simulator user interface.

The high speed and high accuracy of the software modelling enables observation of differences in combustion between single combustion cycles at a single cylinder.

DEFINITIONS

Computer Aided Assessment is not an assessment at PC-based simulator. CAA means the computer evaluation of the data obtained from the engine room simulator where the assessment takes a place. Theoretically it means that the engine room simulator should be able the deliver all necessary data to the CAA computer and the assessor will be provided with special 'assessment data'. The term 'assessment data' is much more appropriate in author's opinion than 'assessment results' because according to the discussion at ICERS 2, only the instructor should be responsible for the final assessment results. The mentioned assessment data could be especially useful for the self-assessment done by students in a stand alone mode.

Two modes of CAA operation are possible:

- <u>on-line</u>: the assessment data delivered from simulator will be elaborated in the real time and the analysis results could influence further assessment progress. This mode is especially important for the operation errors monitoring.
- <u>off-line</u>: the assessment data delivered from simulator will be stored in the real time and analysed after the end of the test. This mode can be used for operation optimisation analysis.

On the other hand using different approach two kinds of CAA tests can be specified:

- static tests are based on the 'snap-shot' picture of the engine room systems and the requested engine room status. The purpose of a static test is to check if the trainee is able to achieve the requested engine room status (for example: prepare it for main engine start).
- dynamic tests are based on the continuos registration and analysis of the user behaviour in the selected situations. The purpose of a dynamic test is to check the trainee ability to follow random changes in the engine room operating conditions (for example: respond to the engine telegraph commands during manoeuvring)

The assessment criteria and operation quality measures are very important problems closely connected with CAA. In order to compare and evaluate the operator's proficiency the quantitative measures are taken. Several proposals of such operation quality measure can be found in the publications [1,2,3,4]. However, only the intensive practical tests can prove the real quality of such a measure. The author would like to propose his own operation quality measure which has been tested at ER-SIM simulator.

Several conditions should be fulfilled before the CAA can be implemented:

- the computer where CAA software has been installed has to be connected with the simulator in order to provide the continuos operation data transfer. Depending on the simulator architecture the serial/parallel interface or the computer network can be taken into account.

- the classification of the operation errors is necessary. This difficult problem has been mentioned before by many experts. The author of this paper would like to propose very simple and flexible classification of operation errors:
  - fatal errors: i.e. errors which can cause direct danger for the ship and her crew or which can cause that the ship will be out of operation for a longer time. ***(Example: The engine shut down because of the low lubricating oil pressure caused by an improper operation.)*** The test should not be passed if even a single fatal error occurs.
  - serious errors: i.e. errors which can cause serious damage in the engine room in the near future ***(Example: the engine automatic slow-down because of too high cooling water temerature. caused by too fast engine speed increase.)*** The test should not be passed if to many serious faults have happened.
  - minor errors: i.e. errors without any direct consequences in the observed situation but which could cause a serious problem if the situation were slightly different. ***(Example: The student had switched on lubricating oil pre-heater just before the circulating pump was started.)*** The test should not be passed if the frequent repetition of minor errors can be observed.
- the operator proficiency measures are required. The CAA should be able to calculate those qualifiers but the accompanying analysis will be welcome as well. The author would like to propose the measure for quality of the main engine manoeuvring. The description of that qualifier and the appropriate test results will be presented.
- the CAA software has to be developed and tested. The author has developed and tested several CAA modules. The experience collected on ER-SIM full mission simulator during the tests with cadets has shown that CAA can offer an useful support for an assessor, but the final decision if the test has been passed or not, should be rather taken by an instructor. Some examples of that research will be shown in the paper.

In order to test the assessment quality three different groups of simulator users have been selected:

- Simulator Experts (8 persons) - i.e. the members of the simulator development team, all with experience at sea. The main task of this group was to establish the evaluation measure limits and set the engineer operation behaviour standards.
- Experienced Chief Engineers (4 persons) - i.e. the engine room operation experts, but usually without any computer or simulator experience. The main task for that group was to confirm the simulator fidelity and confirm the limits and standards developed by the previous group.
- Maritime Academy Students (60 students from the final semesters) - most of them without any watchkeeping engineer experience at sea. The members group was used for the assessment with and without CAA. This was done in order to prove if the CAA application can improve the assessment quality when compared to the traditional methods.

IMPLEMENTATION

The full mission engine room simulator ER-SIM in Gdynia Maritime Academy has been equipped with CAA prototype. Only several software modules have been implemented and tested until now. The present version of the CAA software package called ER-SIM Check consists of three main test modules:

- START TEST - is the static test of the engine room prepared for the immediate main engine start (for example when leaving the harbour).
- STANDBY TEST - is the static test of the engine room prepared for the short break in the operation with the ability to be operational in the short time (for example when waiting for the pilot at the anchor).
- STOP TEST - is the static test of the engine room prepared for the longer break in the operation (for example when laying at the quay for several days).

Two other dynamic test modules are under development:

- MANOEUVRING TEST - is the test of the trainee reactions to commands from the bridge during manoeuvring.
- POWERUP TEST - the test of the load increase strategy when passing from the manoeuvring FULL AHEAD to the navigational FULL AHEAD.

The core of each test module is the knowledge base developed by the group of engine room operation experts. This base consists of many rules which have been written as a special syntax single text line being the part of the text file. The rule syntax is different for Data Rules and for the Control Rules. This classification is closely connected with a simulator architecture (data and control buses) described above.

The task of the Data Rule is to check a single engine room parameter value in the moment when the test takes place. All parameter and control state information has been stored in the central repository of the simulator and can be accessed and edited as a typical data base. Every parameter possible change range has been divided into five sub-ranges divided by the corresponding limits (Fig. 5). Please note that different parameters can have different active limits what changes definitely the way the parameter will be evaluated. For example the lubricating oil pressure before the engine has only 3 limits active: Low Alarm Limit, Low Slow Down Limit and Low Trip Limit so the appropriate rules for different static tests look as follow:

- in START TEST and STANDBY TEST the lubricating oil pressure value should be between the Low and High Alarm Limits what means the proper lubrication oil flow.
- in STOP TEST the lubricating oil pressure value should be below Low Trip Limit what means that the circulating pumps have been switched off.

The Control Rules are more complicated, mainly because the required state of the control device depends usually on the state of other control devices. For example the recommended state of the lubricating oil circulating pump number two depends on the state of the pump number one switch. Every engine room control state has the set of associated possible states described by the standard values which can be accessed any time at the control bus. For example states associated with the circulating pump switch are: ST_OFF, ST_ON, ST_AUTO and states associated with the air compressor priority switch are ST_PRIOR_1-2 and ST_PRIOR_2-1.

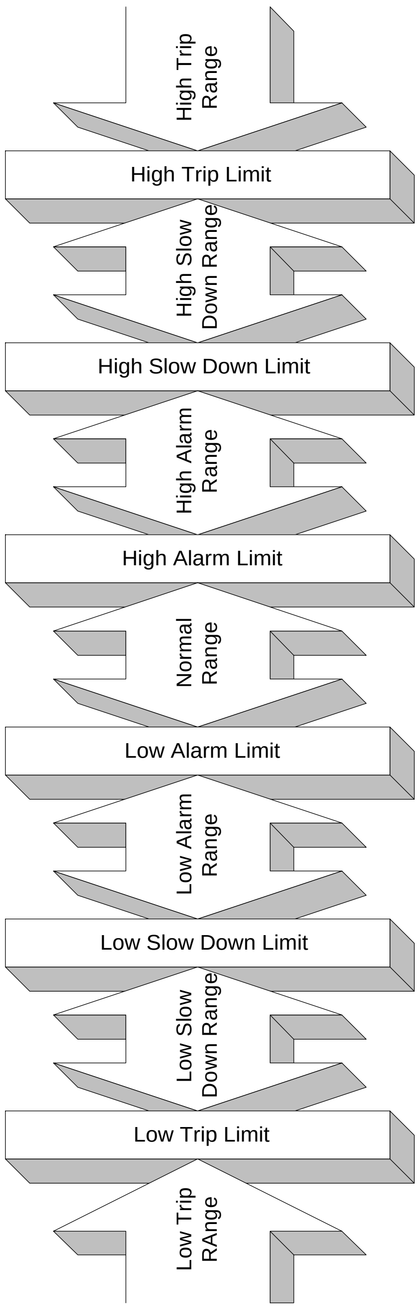

Fig. 5. The engine room parameter range classification.

The Control Rules development has been simplified significantly, by the standardisation of all possible control states, but even so they can look quite complex. The rule for lubricating pump number two will have different forms in different tests:

- in START and STANDBY tests the rule says the control switch of this pump should be in ST_STANDBY state if the switch of the pump number one is in ST_ON state, but the pump switch should be in ST_ON state if the switch of pump one is in state different than ST_ON.
- in STOP TEST the rule says that the switch has to be in ST_OFF position without looking at the state of the pump one switch.

The rule for the switch of the pump number one will of course check the state of the pump two. Those combined rules will commonly describe the very well known practical rule which says that in the normal operation or in stand-by at least one circulating pump should be switched on and the other has to be in stand-by status. On the other hand, in the harbour both pumps should be off.

In both cases: Data and Control Rules it can happen that the rule can be either fulfilled or not when tested. In the second case the appropriate number of penalty points will be added to the test score. The number of penalty points connected with the certain error, depends on its classification (see above chapter). The different error importance have been tested but finally the following assessment strategy has been chosen:

- every fatal error will be punished with 100 penalty points.
- every serious error will be punished with 10 penalty points that means that 10 serious errors are equivalent of one fatal error.
- every minor error will be punished with 1 penalty point.

All penalty points will be added and if the number of penalty points will be higher than 100, the test is not passed.

The presented strategy has been based on following principles:

- the fatal errors are absolutely unacceptable so the test cannot be passed,
- the significant number of serious and minor faults has the same weights as fatal error because it proves that the tested person acts randomly without the proper knowledge and in other case the fatal error could happen as well, so the test cannot be passed.
- passing the test with fewer penalty points means better proficiency of a tested person.

Those principles are arbitrary of course and can be a subject of a further discussion and improvement but looking at driving licence tests in many countries the similar approach can be observed.

However, the presented assessment strategy has one weak point which should be discussed in detail. The assignment between certain rules and the error classes is the key problem of the proposed methodology and requires a lot of analysis and expert work. Let’s take into account the case of the lubricating oil circulating pump switches as an example illustrating the problem. The case when none of the pumps has been started in START or STANBY test is rather easy and can be classified as a fatal error, but the case when one switch is ST_ON state and the other in ST_OFF is more delicate. The engine will start of course, but it is hard to describe such a situation as wise and good practice, so the question is: is it a serious or a minor error? The difference is quite important taking into account that serious error means 10 time more penalty points. The experts from ER-SIM team have decided that absence of stand-by pump can lead to the danger if the working pump is faulty so this error has been classified as ‘serious’. The slightly different situation takes place when both switches are in ST_STANDBY state (what is possible only in some remote control systems). The pump switched as first will start automatically and the second will be actually in stand-by status. At first everything looks all right because one pump works and the necessary stand-by is also provided, but on the other hand it is hard to treat this way of a pump starting as a recommended practice. After a long discussion, we decided to classify it as a minor error. This is only one and even not most complicated problem connected with the error classification and it proves the necessity to develop a commonly recognised and approved assessment standard.

EXPERIENCE

As mentioned above the presented CAA software had been tested on the development team members and on experienced chief engineers before it was applied to students.

The experience has shown that the simulator team members discussed deeply many controversial situations and after some software debugging were able to pass such tests without any problem. The best score in the simulator expert group was below 10, the worst below 20 penalty points what is quite obvious taking into account that the members of that group have developed the knowledge base for al the test. But even they were not able to avoid some minor errors what shows how much concentration such a test at simulator requires.

The group of experienced chief engineer concentrated mainly on testing the simulator fidelity, but after some familiarisation they acted quite automatically. The best result from that group was below 5 penalty points, the worst below 40. The interesting experience from that test was that in some cases the chief engineers were not ready to accept certain rules from the knowledge base. In most cases the matter of discussion were minor errors, which were no errors at all in the opinion of several chief engineers. This confirms that the definition of the good practice in the engine operation is required.

False FUEL OIL VISCOSITY BEFORE M.E. status: is HIGH ALARM level and should be NORMAL level (100).
Wrong M.E. SLOW TURNING AIR VALVE POSITION: is CLOSED and should be OPENED (100).
Wrong LUBRICATING OIL HEATER STATUS: is ON and should be OFF (10).
Wrong LUB. OIL HEATER BY PASS VALVE POSITION: is CLOSED and should be OPENED (1).

Fig. 6. The CAA example printout.

The most interesting however, was the comparison of traditional and CAA assessment on the big group of maritime academy students from final semesters. Here is the list of conclusions based on that test of 60 students:

- an instructor without computer support is not able to provide high quality assessment for many hours of a test. He will never be able to offer the same level of attention and concentration at the beginning and at the end of his working day and the improper assessment results can be a consequence of this situation.
- many minor errors were reported by CAA in almost any situation when the instructor has fully accepted the engine room setup presented for assessment as correct. It means that even well trained and fully concentrated instructor is not able to find some very subtle errors in engine room setup,
- several serious errors have not been found by instructors. It means that the lack of concentration or the problems with the situation evaluation can cause difficulty in everyday simulator assessment practice.
- only two fatal errors were not found by the instructors, but they were identified quickly later, when the student tried to start the engine. Even such a low number of

the omitted fatal errors can be described as a serious problem of the traditional assessment.

- the CAA is perfect tool for the instructor assessment.

The CAA printouts (see Fig. 6) are not only necessary for the test documentation but they are also very useful for the after-test debriefing and evaluation of the week points in the students education.

DEVELOPMENT

Three static tests described above are only the first step in the CAA prototype development project. Several dynamic test should be the second important part of that project. The example of the dynamic test being under development and testing will be presented in this chapter.

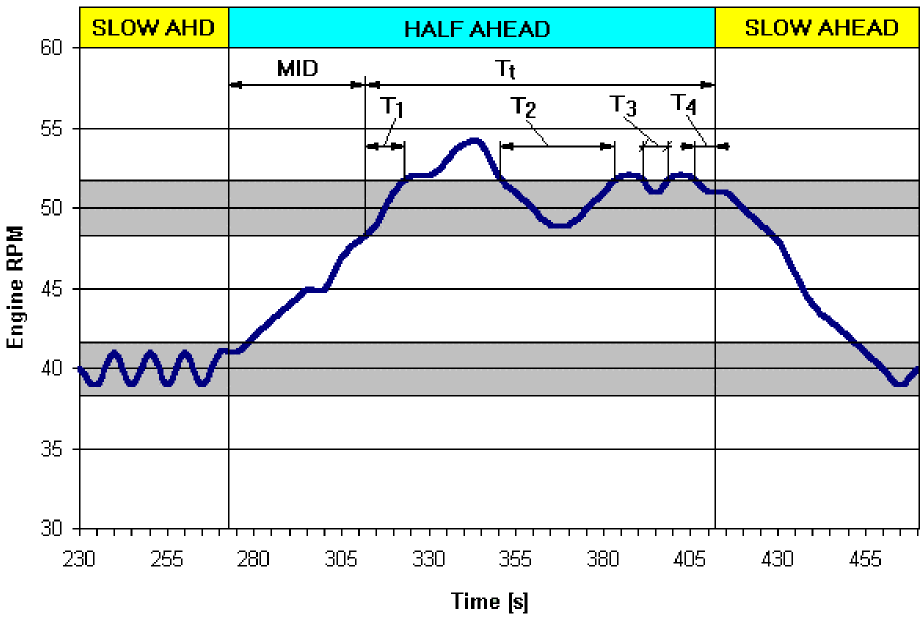

Fig. 7. The manoeuvring analysis example.

The MANOEUVRING TEST has been designed in order to test how a trainee is able to follow the commands from a bridge during the manoeuvring. The test has been based on the following principles:

- The engine speed during manoeuvring should be kept in a certain range depending on the telegraph position.
- When a telegraph position is changed, the engineer responsible for the manoeuvring from the control room, should correct the engine speed as soon as possible. The time between the moment of the telegraph position change and the moment when the engine speed has reached the destination speed range will be called MANOEUVRE INITIAL DELAY (MID) and will be one of two evaluation criteria in this test (see Fig. 7).
- The engine speed should be kept inside of the required range until the new telegraph command comes. However, it is sometimes difficult to keep the engine speed inside

of the required range, especially when the control lever has been set too quickly. In such a case only the time until the next command will consists of periods when the engine speed is inside and outside of the range (see Fig. 7). The relation between the sum of all time periods inside of the range and the time until the next command will be called MANOEUVRE RELIABILITY COEFFICIENT (MRC) and can be defined as below.

$$MRC = \frac{\sum_{i=1}^{i=n} T_i}{T_t}$$

where: *MRC* - Manoeuvre Reliability coefficient
T_i - time period when the engine speed is inside the range
T_t - time until the next manoeuvring command.

It has been planned that the reference values for the MANOEUVRING TEST will be based on the statistical analysis of the manoeuvring done at the simulator by the experienced engineers. The values obtained that way should be later corrected taking into account all possible kinds of telegraph position changes. If the tests described here are finished until the time of ICERS 3, the appropriate results will be presented.

CONCLUSION

CAA cannot replace the instructor and should be considered only as a valuable assessment tool. The number and range of the presented CAA test is very limited and will be completed in the near future. The author is convinced, that despite of the different simulators architecture, the CAA test and the evaluation criteria should be widely discussed and standardised. Only this can lead to the simulator assessment compatibility and the simulator assessment standardisation. However, even now CAA can significantly improve the quality of the assessment at the engine room simulators.

REFERENCES

1. M. Percier, M. Caillou, L. Wagemann, ‘Adapting Simulators for Training and the Evaluation of Operator Performance’, Proceedings of ICERS 2, Rimouski, (1995).
2. D. Nieri, ‘Certification and Licensing of Mariners Based on Performance Assessment’, Proceedings of ICERS 2, Rimouski, (1995).
3. J. Perry, ‘Engine Room Simulation Evaluation and Assessment’, Proceedings of ICERS 2, Rimouski, (1995).
4. D. Bichat-Gobard, ‘Ongoing Research into the Use of Simulators as an Assessment Tool to Check an Applicant’s Competency as an Engineer’, Proceedings of ICERS 2, Rimouski, (1995).
5. S. Kluj, ‘The Role and Mission of the Engine Room Simulator’, Proceedings of the 9th Ship Power Plants Symposium, Gdynia, (1996).
6. S. Kluj, ‘The Modular Engine Room Simulator’, Proceedings of 11th Ship Control Systems Symposium, Southampton, (1997).