MODERN DREDGE SIMULATORS & TRAINING-MEANS TO GET A DREDGE CREW MORE EFFICIENT

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ABSTRACT

We are using more and more efficient dredging technology, applying advanced designs, dredging components and integrated systems. This allows dredging operations with high efficiency for projects at high accuracy while operating in more difficult soils and site constraints. The use of advanced automation and control systems enables efficient and sustainable use of the innovative dredging equipment in these circumstances, but final performance is still determined by the operational crew and project staff organization. Without a high level of crew and staff competence – best described as a combination of proper dredging knowledge, skills and experience – it will be difficult to take advantage of the available modern dredging technology.

Current competence improvement is based more and more on specific training and educational programs using modern means like dredge simulators. Use of simulators allows practical training without production losses. Furthermore, the right combination of practical simulator training and learning theoretical background will not only teach a trainee the dredging trick. But also why it should be applied and to be self supporting within the ever more complicated dredge jobs, due to ever more required accountability, also due to environmental rules.

In modern dredge simulators for excavators, cutter suction and hopper dredgers, all related dredging processes including sensors, actuators and the dynamic relationship between the processes are simulated to obtain a realistic virtual dredge operation. The virtual dredge can be controlled using real control means installed in commercial type of consoles. Depending on the execution of such a console, trainees can also be trained on the use of automation systems and on-board diagnostics and data logging. Use of the latest state of computer technology, central monitoring and data logging allows a three dimensional virtual view of the outside world. Not only what is normally seen from the control room or bridge, but if required also as an underwater view.

Adding monitoring systems, as used in practice, to the dredge simulator like an eXcavator Position Monitor (XPM), Dredge Profile Monitor (DPM) or Dredge Track Presentation System (DTPS) enables training programs on the use of these systems.
And several surrounding issues like positioning, dredge job preparation and progress and operational enhancement.

In this paper the latest state of the art dredge simulators and their possibilities in training programs for excavators, cutter and hopper dredgers are described. Emphasis is given on how this improves the operational competence of dredger crews and dredging company staff members for efficient and sustainable use of modern equipment.

INTRODUCTION

The last years several simulators came to use to train dredging crews in the operation of hopper- and cutter dredgers. The type of dredge simulators emphasized in this paper are the ones with full realistic controls, software and presentation as developed by IHC Systems.
These modern simulators are mainly located in Belgium and the Netherlands and are all linked with permanent training programs, mostly for individual contractor's use, but also for public educational use.
At this moment the recent deliveries list shows 2 hopperdredger- and 3 cutter-simulators. Jan de Nul owns a hopper simulator and a cutter simulator, whereas DEME uses the last year installed cutter simulator, All installations are in use for the contractor's own training programs.
Another hopper dredger simulator is in use in Zeebrugge for public educational training whereas TID (Training institute for Dredging) has the availability of a cutter simulator being used for her training programs.
Further we conclude the 4 largest dredging contractors have all a dredge simulator aided training facility in place with a capability of (re)training each about 100 crewmembers a year in the use of hopper and cutterdredgers.

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Last but not least there is also a more than 10 years running training program for excavator operators to incorporate the use of modern positioning, monitoring and datalogging in the ever more complicated dredge jobs were they are mobilized.

Last 5 years there is an increasing awareness the human resources of a dredging company are vital.
The position in human resources seems straight after her financing capability.
Her financing capability to be able take on large projects and sustain investments in an innovative new building program for ever more efficient large sized cutter and hopper dredgers.
However with such capital involved an effective human use of the investments is a must.
Above mentioned is especially valid for the 4 largest dredging companies in the world, however on a lot of other companies we see the same training behaviour with their dredging excavators.

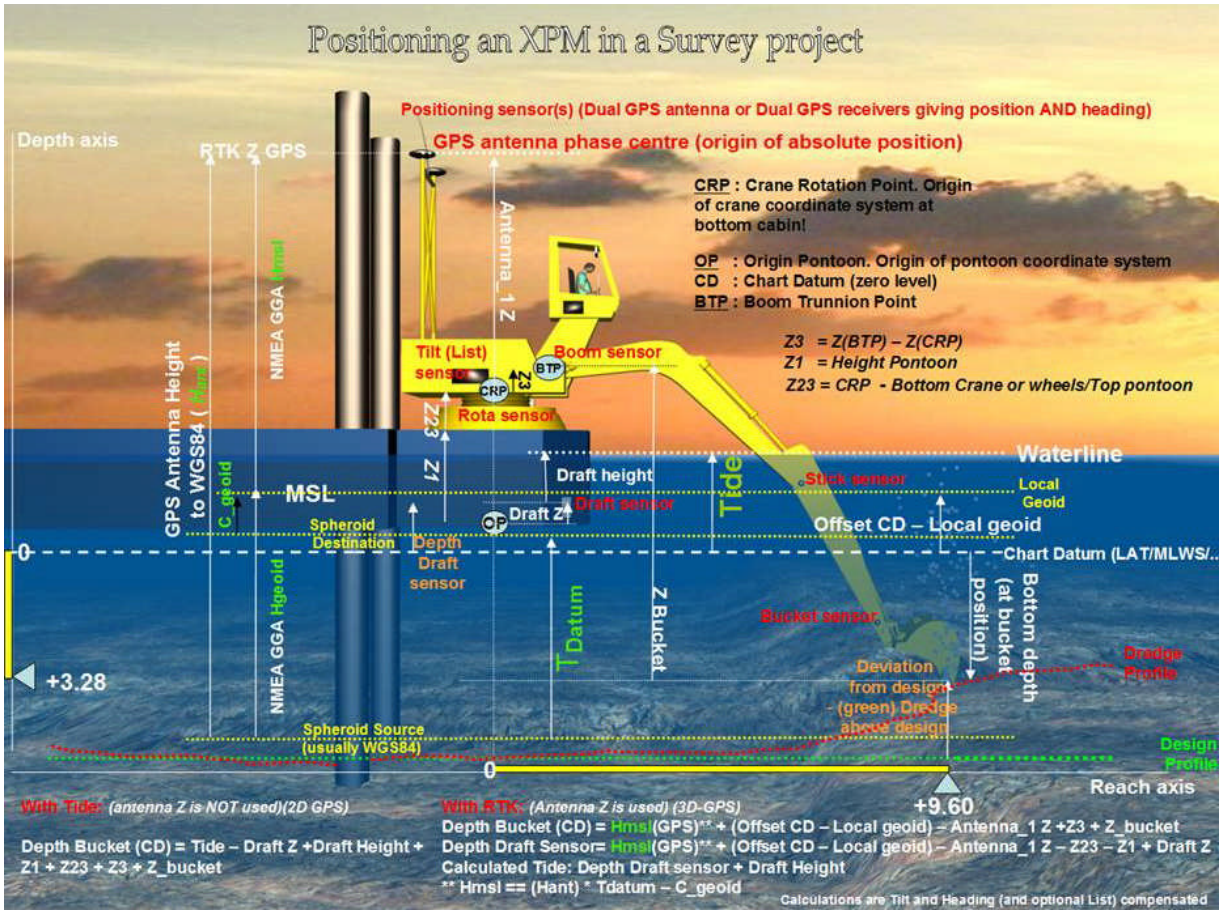

Figure 1. The theory behind something simple as excavator simulation

CHANGING TIMES, FROM SAND TO SILICIUM

In the old days of hydraulic dredging a depth meter and or vacuum indicator was all that was available, he needed more, but reliable instruments were not on the market for the dredge master to indicate the sand moving performance of the dredger.
And in case of sufficient practical experience of the dredgemaster the operations went relatively smoothly, so head office far away, even at the other side of the world sometimes, was happy enough.
Even with broken meters and the personal weekly assurance of the dredgemaster the pump or grab was still running the home office was not really in disorder or motivated for immediate action.
Nowadays, things are totally different.
The dredging equipment is evolved continuously with the latest technological possibilities, resulting in high-tech, high-capacity, high-investment machines with quite a complicated "user manual".
With fast internet communication and data logging capability and the high investment figures for dredge equipment the management in the home office is sitting on the shoulder of the dredgemaster.
Jointly teaming up day by day to run as efficient as possible with the large investment in a complicated project.

The labour market is drastically changed, with fewer lifetime and gradually advancing careers and much more influx of people required to perform at key positions after only a short education period.
All together, for the crew members and the dredger it is "show time" all the time, with no time to learn on-the job or to experimentally discover the best performance on a dredging project.
The virtual reality of a dredge simulator makes a fast track training program possible, being a playground and very serious education platform at the same moment.

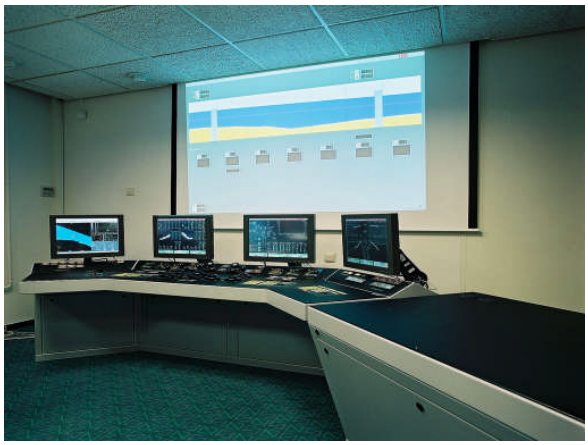

Figure 2. 50 million (or more) Euro playground? or 1 million Euro playground!

From experience the authors are convinced that the investment in a simulator combined with the operational costs of the training sessions is quickly paid back by the increase of the dredgers performance.
And the developments in the industry won't change this truth shortly.
The 3 main drivers for a dredging company to make use of -and or invest in a simulator aided training program are:

- 1) Requirements, like safety and efficiency, are more emphasized on the ever larger investments
- 2) Dredge equipment becomes more complex and crew numbers are reduced
- 3) To counter the more and more dynamic job rotation and internationalization of dredge fleet personnel

Due to these 3 main facts there is an imminent need for faster learning curves to come in a short time to a better quality of dredging personnel.
Because of the competitive character of the dredging market, the equipment is required to perform close to the limits, with high production, within strict tolerances and short execution times.
Performance as designed and paid for.
Aided by the latest fast changing technology of silicium based computer and communication systems, as found in all modern industries

HUMAN RESOURCE ASPECTS IN DREDGING

In the end all investments in technological improvements and control systems on board are wasted if not used to their capabilities.
So the crew members who operate the machines and systems have to understand the working of the systems (including limitations), to make full advantage of the possibilities and by doing so achieve the best possible result in terms of dredger output.

The number of machines, systems, controls and processes acting on one single dredger is increased to such numbers, that even for experienced crewmembers a regular knowledge update or upgrade is required, to be sure the operators use the equipment to the full potential.
For less experienced crewmembers (either youngsters at the start of their professional career, or personnel changing profession from related industries like mariners or fishermen) the challenge is even bigger: learning the dredging processes themselves, as well as the possible ways to improve the results by operating the machines and controls available.

Figure 3. A host of differently educated people, finally to be trained in the art of dredging

In general the dredging business is a highly specialized activity and incorporates a lot of people who have a non-dredging education, different cultural backgrounds and, after several years, a host of dredging experience.
Main reason, for this high amount of practical people, seems to be the relative small scale and global spread of the dredging industry, if compared to other industries.
Further there is a increasing globalization of the crews on a dredger.
Last century we still had a majority of dredgers with only 1 or 2 nationalities, nowadays we can easy find even more than 10 nationalities on 1 dredger.

This is countered by relative few educational institutes in the world where dredge knowledge can be obtained as prime technical education for the people willing to work in the dredging industry.
All together this requires in a later stage of a career of a dredge employee the need to review the approach to the dredging process, to come to its full potential for himself/herself or his/her employer.
Matters like the use of modern measurements, controls and monitoring as well as dynamic influence of changing slurry flows, density, soil type and pipe lengths or diameters can easily be learned with the help of a simulator that is almost a copy of the “real” dredger.

It’s very clear that this kind of training for crew members on a real dredger during operations will be far more costly due to production losses than doing this in a virtual simulator environment.
Especially with the latest dredgers hovering around a capital investment of 100 million Euros or more this is of importance.
The actual dredging situations demand optimum production and safety of equipment and owners do not like any compromise on that optimum.
The idea to have some non-experienced people doing some experiments will not have a relaxing effect on the people responsible for the expensive investments in dredge equipment.
In general it is very difficult to train safety events and calamities in reality without real danger and loss of production.

CREW ERGONOMICS

To come close to the best ergonomic way to train a dredge crew it is important to use the latest technology as it is used on actual real dredgers.
This in combination with an individual training mode on the dredge-simulator to give all trainees the opportunity to learn in a short time all kind of events, like:

a. The limitations of the simulated dredger and her safe use
b. Operational aspects
c. Preferable working methods
d. Inter dependency of the different parts of the dredging processes
e. The limitations of the simulated dredger and her efficiency

In practice this means that there will be a mutual training program for a group of dredge employees assisted by several trainers in an environment as realistic as possible.

Figure 4. A realistic cutterdredge environment, with outside presentation

We also know due to last years experiences in the dredge industry a bit more about the effectiveness of education methods
The days of learning by sitting in classrooms and collectively repeat what the teacher says are long gone.
It is beyond doubt that there are far more effective ways of learning, especially within a modern high-tech industry that requires a considerable amount of understanding instead of simply "knowing facts". Looking at the long-term impact of educational methods, the following sequence can be seen:

- telling (and have repeated)
- explaining (followed by learning from a textbook)
- explaining with the use of examples and visual aids like sketches and graphs
- experiencing by oneself
- experiencing by oneself, combined with understanding of the phenomena (by having the backgrounds of the experience explained).

Two well known examples from the dredging industry will show clearly the power of a simulated reality when trying to achieve an effective way of knowledge transfer:

Example 1, Diesel driven dredgepump

The rpm of a diesel-driven dredgepump becomes too low in a certain situation, yielding rising exhaust temperatures and a nervous chief engineer.
Trying to explain the theory of dredgepumps, the influence of the mixture density on the pump revolutions, the interaction of the dredge pump and diesel drive including the governor range (constant speed) and the full fuel range (constant torque) will require quite some hours. And still it has to be seen how many students will understand the

backgrounds of the most elegant solution to the problem: reduce the impeller diameter (or the number of blades if possible).
Having students experiencing the initial situation in a simulator will convince them how unfavourable it is, and of the need for immediate action. A subsequent simulation with a reduced impeller installed will convince them immediately and beyond any doubt of the efficiency and effectiveness of the solution. And now the students can be bothered with a theoretical explanation of the matter at hand, possibly getting the theoretical background of the message through as well.

Example 2, Flow control

Flow control (or, for that matter, any other computer controlled part of the dredge, like swing control, speed control, depth control) is sometimes looked at as "suspicious". Reality is, that modern dredgers have become such high-performing machines because of the aid of computer controlled subsystems on board. But at the same moment the dredger has become far too complex to be operated manually by a couple of crewmembers. But reluctance towards the use of a system is not easily overcome.
However, the working of various subsystems and the aid they provide to the dredgemaster can be shown very directly in a simulator test, using a realistic but troublesome dredging situation both with and without the aid of some computer-controlled subsystems. Monitoring the performance in both cases is probably not even necessary: the difference is overwhelming and will solve any unrealistic scepticism to the value of control systems. Seeing and experiencing is believing.

Figure 5. The look a like start of currently existing 15 years of integrated controls technology in dredging

SIMULATOR TECHNOLOGY IN DREDGING

Simulator technology has been advancing fast during the last 3 decades.
Both hardware and software developments make it possible to create virtual reality environments that are experienced by the users as a "real-life" situation instead of only a computer game.
Various high-tech industries make extensive use of simulator environments.

Below some examples are mentioned:

Example 1, Aviation Industry

The aviation industry for instance has very elaborate training programs, using the simulator for the whole range of standard and non-standard landing and take-off possibilities, including the most extreme emergency situations.
Moving the complete simulation cabin is a key feature here to achieve a high level of reality.

Example 2, Port Design

Port design including shipping lanes, access channels and basins is created in the virtual world of a shipping simulator, and full scale tests on the manoeuvrability of design ships during the entrance procedure are executed. Furthermore, training sessions with interactions of pilots, VTS (Vessel Tracking System)-operators and towing vessels are done, either to check the behaviour of the people in sometimes stressful situations, or to check on safety limitations on traffic density or environmental conditions.
A computer-animated 360 view from the ships bridge adds to the reality (sometimes even causing seasickness to visitors).

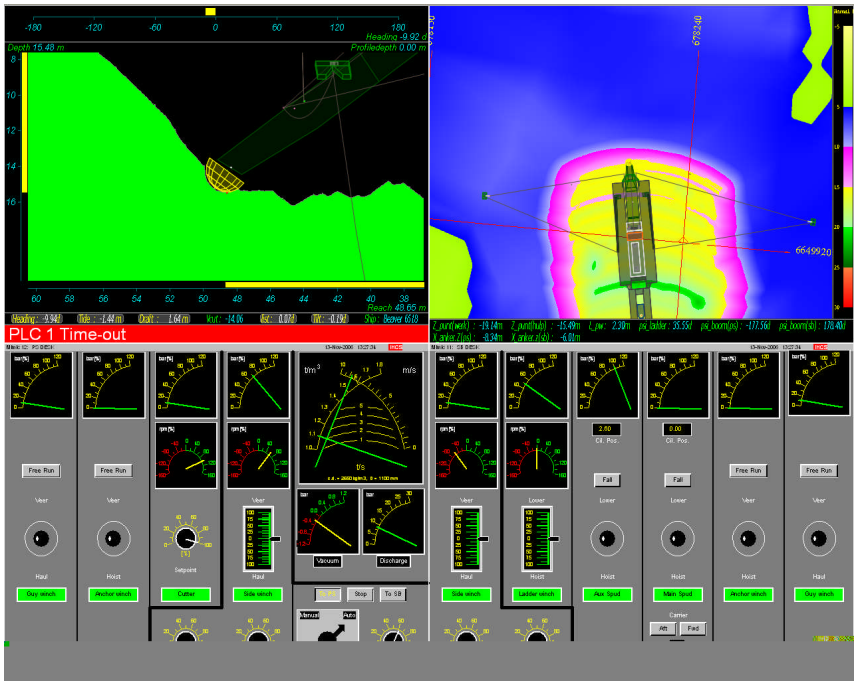

Figure 6. The presentation on the latest simulatorsis a "as on the dredger"

Within the dredging industry the simulator technology has evolved in a slightly different direction.
With the dredge simulators we see the interest mostly limited to the relative small group of people within our industry and the simulator platforms are mostly copies of a real dredgers bridge
Main attention is given to develop a realistic virtual dredge system, in which all physical dredging processes are mathematically integrated and are to be controlled by the trainee.

The various automation possibilities of the dredger are present, including the usual control means.
All control switches and handles used in the simulator line up are the ones available in commercial type of consoles, so commonly in use in the industry.
Fact of fashion is the latest hopper and cutter simulators as ordered by the large Belgian dredge contractors are so closely related to the latest build dredger the consoles are a copy.

Process parameters and system information is nowadays almost completely presented on a series of computer TFT (Tin Film Transistor) flat screens, as this information is available digitally in the central control computer.
Page formats for the operator are preset, usually designed mutually by shipbuilder and ship-owner.
This way separate panel indicators for every single process parameter have become redundant (and are phased out during refits, even on dredgers of high age).
Exactly the same components are used in the simulator, which boost the instant acceptance of the virtual world by dredge operators.
Adding to the level of reality, a 3D view of the outside world is shown, and if required an underwater view with the excavating tool position relative to the pre- and post dredged bottom can be generated by beamers on full window view covering screens. (something that would be priceless to have in real life!).

Figure 7. A realistic cutterdredge environment, with outside presentation

The core of the current dredge simulators is the computer network processing the data.
Calculation modules are developed, using the extensive existing knowledge of dredging processes and experience with the way to control dynamic behaviour of the dredgers hull, engines and a host of dredge particular parts.
Unique to the dredging simulator compared to more known and existing nautical simulators are also the following selection of calculation modules:

- Soil module, comprising as well soil characteristics and profiles, shown on the Dredge Track Presentation System
- Dredger Position Module (including excavator mathematics position shown on the eXcavator Position Monitor XPM)
- Hydrodynamics module (water level, currents, waves)
- Dredge hull dynamics module (based on forces from excavation process and the environment)
- Excavation module, specific for every type of dredger (like cutter module, draghead module, excavator bucket module)
- dredge pump module, including dynamic diesel or electric drive behaviour
- hydraulic transport module

Research continues on the modules that are especially critical to dredge processes and operational limits, being the excavation module and the vessel dynamics.

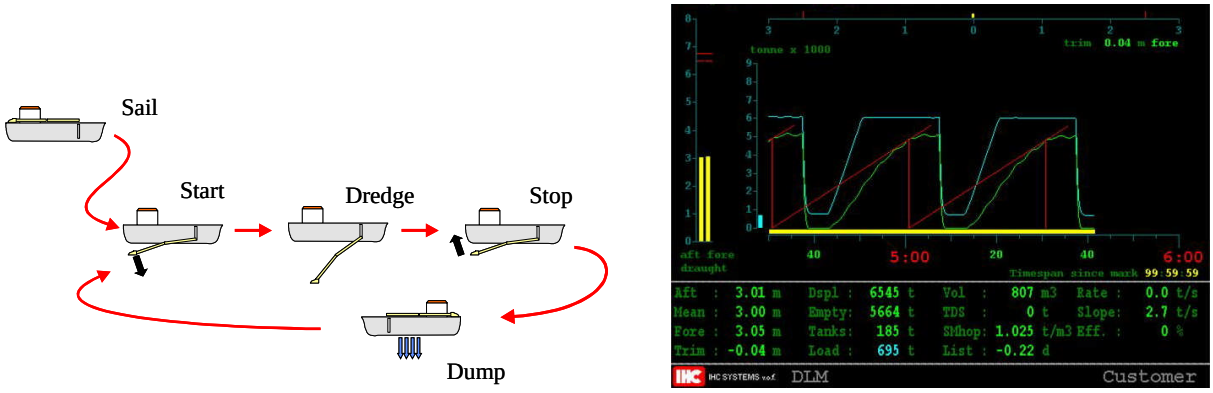

Figure 8. Translating the hopperdredging process to a Draught and Loading Monitor (DLM) as found in a hopper simulator

PRACTICAL USE OF DREDGE SIMULATORS

The advantages of computer controlled subsystems as aid for the crew in dredging is beyond doubt.
However, during the development of the system for a new or existing dredger it is quite an elaborative tasks to get the settings of those systems right.
Even more complicated is the interaction of various subsystems that act and react on the dredging process on board.
During the execution of dredging projects there is hardly the time, nor the patience, nor the right conditions to fiddle out the best system settings, very likely resulting in a underperforming system or even reluctance to make use of it.
In this way some dredge companies have on a few dredgers their own coffee-can table of more than a million Euro, professionally hidden under a table cloth on the bridge.

The dredge simulator offers the right environment to prevent this kind of dredge crew behaviour and do a lot of initial testing using the conditions as difficult as seems realistic.
After the design phase and during the actual building stages, the anticipated crew can already familiarize with the brand new vessel and or installation on the simulator.
This can significantly increase the learning process and decrease the learning time whilst on board, hence a steeper curve towards optimum performance of the dredger and crew.
And as long as the testing operator is not satisfied with the system performance, the same test can be rerun with slightly improved settings, as often as needed to get satisfied with the result. With this a flying start can be made with the test on board of the real dredger, saving lots of time, frustration and production losses due to testing.

Whereas the original tool for the simulator is the education and training of dredge crew members, it is also a very useful tool to create awareness with the company staff.
For them it is not a simple anymore to understand the working of all systems on board, along with their interdependencies and dynamic behaviour.
As well as for the technical department, estimators, research engineers, superintendents and project managers alike, a reasonable level of operating knowledge is paramount to perform their own task within the organization and stay connected to where the money is made.

Dredging is not an exact science with only one single truth of the office against one single truth of the dredger and its crew far away.
This is especially true when considering possible working methods for a specific job.
To find out the difference of various methods on-the-job is costly, time consuming, or even impossible. The simulator offers the possibility to test various methods subsequently, with exactly the same starting situation for every trial run.
Paramount for the value of these tests is the correctness of the module that evaluates the resulting soil profile beyond the excavation action, including the spillage from soil that is removed from its original position but not included in the excavated production.
Development of this technology is especially the last years strengthened and incorporated in 3D views.

Figure 9. The question of spillage estimation is close to be resolved!

During development stages of innovations to dredge parts, the majority of the work (both testing and calculating) is done in separation of the remainder of the dredge installation.
The simulator offers an environment to try within certain limits the newly developed tool within a complete dredging environment, and is for this an important technological step ahead.
A lot can be learned from this additional step in the development process, offering optimizing possibilities and eliminating some of the risks.
This way the basis to decide on the actual investment and implementation of the tool is increased further.
Similarly, during the design phases of new built dredgers decisions on the capacity of the numerous components do not come easy and can do with some substantiation.
Each part in itself can be perfectly ok, but the question remains whether all parts work together the way expected by the designers.
Especially in case of innovative designs, rather extreme conditions and/or stretching technologies beyond the limits, it is paramount to evaluate the behaviour (and production capacity) of the complete dredger as opposed to the various parts themselves.

By evaluating the complete picture, the money can be invested on the elements that will yield the biggest increase in overall production rate.
Especially for cutter suction dredgers vessel motions resulting from waves and swell impose a serious cap on weekly production rates.
Much research is done on this subject, ranging from test basin experiments to field logging tests. Getting the physics into mathematical models is a difficult task, especially so because of the simultaneously performed excavation process.
In fact a dredge simulator is the only environment that can be used to evaluate the correctness of the modelling, subsequently, with a satisfactory ship motion model, downtime analysis can be made for various circumstances. This enables estimators to reduce the risks involved in assessing the workability and is for this a very valuable tool for the latest investments by dredge contractors in high-tech, high-capacity, high-investment cutter dredgers.

PRACTICAL USE OF DREDGE SIMULATORS IN DREDGE TRAINING PROGRAMS

There are now several extensive descriptions of the goals of a simulator program, the role of the instructor, as well as an outline of a crew training program by educational institutes.
Any dredge organization using a simulator as a tool in the education system, shall have to make initial assessments on these issues, considering a.o. the following questions:

- What is the current status of knowledge of the crewmembers and staff?
- How much time can be made available for training sessions?
- What are realistic objectives, both instant and long-term?
- Who is capable of running training sessions?
- Do we combine practical and theoretical knowledge in the sessions?
- Is there a need for dedicated sessions for individual crew members based on their level of knowledge and experience?
- Can we incorporate combined sessions with various crew and staff members alike?

Based on the general objectives of the educational program, and decisions on training duration, group size and the diversity of participants, the various sessions can be composed.
Obviously some sessions are useful for any participant (irrespective of the position and experience), while other sessions are specifically designed for only a small part of the likely participants.
Basic rule in any education program is to offer the student learning material that touches the boundaries of knowledge and capabilities: too simple and students get bored, too difficult and students will drop out. A nice feature of a simulator is that the precise level of the learning material is not too critical.
Because the virtual reality of the simulator is experienced as "real life" instead of a "classroom", students have an increased span of attention.
To bridge the gap most training systems incorporate at least one person who combines theoretical and educational skills and a person who combines long term practical experience with educational skills.
On the existing simulators we see a combination of former teachers and former dredge masters, to assure a good contact with the trainees and optimum transfer of knowledge.
The first brings in the knowledge about theoretical background, learning methods and the mathematical knowledge behind the complex dredging processes.
The second brings a host of experience about practical do’s and don’ts and the practical focus on matters like safety and production efficiency.

It is beyond doubt that training sessions for specific crew members or other groups of participants with a similar level of knowledge and experience are valuable.
However, working also with combined teams of crew and staff in the virtual world of the simulator offer a valuable bonus to the team spirit within the organization.
With combined teams doing simulator sessions, a (dead serious) playground is created to bridge the gap between the everyday reality of dredging works as experienced by the crew, and the theoretical knowledge of dredging processes by R&D engineers, estimators and superintendents.
Both sides can do with some help: dredging reality often needs understanding of "why" and "how" things work out the way they do, whereas mathematical calculations have to be seen in the context of full swing operations of the dredge to really assess the value and/or the shortcomings.
Bringing this together in the simulated environment, with the possibility to test to the limit and beyond, is in itself very helpful for participating professional from both ends.
Equally important might be an increased mutual understanding of the work and difficulties encountered by the colleagues working towards the same goal: to achieve continuously a top performance of the dredge vessel.

EXISTING TYPES OF DREDGE SIMULATOR AIDED TRAININGS

Seen over a 10 years period we see developments in 3 major types of simulators as used and integrated in training programs for the dredging crew and related staff functions:
- Hopperdredge simulators
- Cutterdredge simulators
- Excavator simulators

Hopper dredge simulators have a rough split in those who are integrated with a nautical simulator and those who are on their own.
The first means in general the hopper dredge education module is part of a larger training target.
In general more biased to trainees who have also an interest in navigational training.
And the second is a typical solution for a “dredging only” training or with, of course, additional aims like mentioned in this paper.

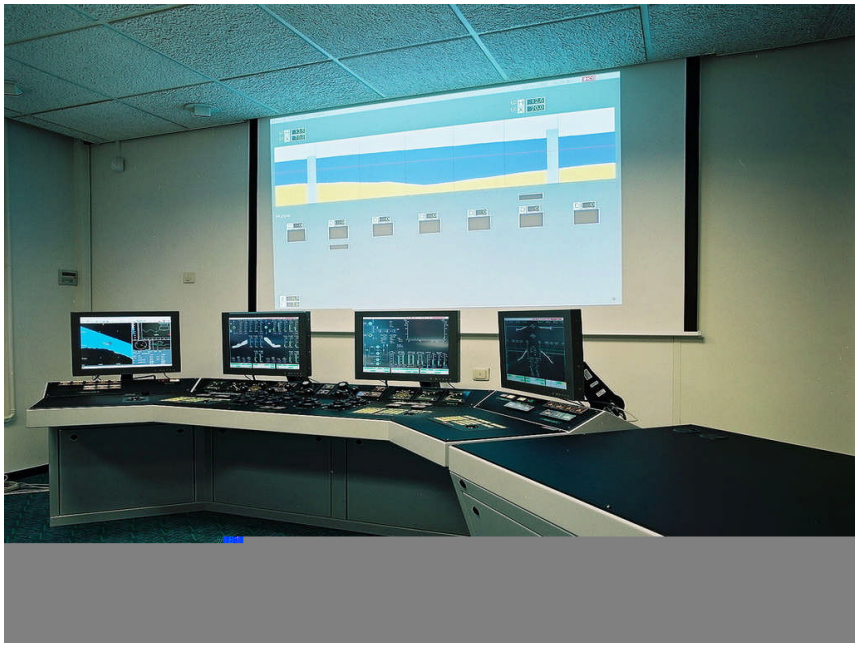

Figure 10. Hopperdredge simulator in test presentation

Overall impression is this kind of simulator is becoming more and more popular with the larger dredging companies.
Main driver to own your own hopper simulator is the fact nautical educations can be obtained easily and are less dredging specific, while the dredge technology part is more strategic to them.

Cutterdredger simulators are in fact the oldest simulators in dredging, going back as far as the seventies in last century when the first cutter automations were developed and used on several large cutter dredgers.
Especially this type of dredger is very suitable for automation of the complicated dredging job because it is basically an ever rehearsing repetitive task.
For this it is no surprise also the most recent generation of cuttersimulators is directly related to the last build large Belgian cutter dredgers like the 27.190 kW “JFJ de Nul” and the 26.100 kW D’Artagnan.
The simulators are in this case especially used to shorten crew learning curves to be in a position to use the submersible earth moving machines as soon as possible to their full capacity.
For the world of training programs and simulators it was a good exercise to have them designed, build, operated and transferred to the educational departments who exploit them today.
All in a limited timeframe.
The focus of development was especially on flexibility to model all different types and sizes of cutter dredgers, different soil types, cutting forces, anchor types, retaining forces and adhesion of the spuds and, of course, behavior of pumps and pipe lines.

With the dredging excavator training programs we see a 15 years development around the use of excavators on pontoons, guided by monitoring of the work-tool (bucket, grapple, hammer) and DGPS.

In general the crews on those dredgers have no or less dedicated nautical, technical and survey education than an average crew on a hopper or dredger.
Main cause is the very flexible attitude of dredge management with this type of crew.
A lot of times the dredgers is created temporarily by placing an excavator on a spud-legged pontoon for the next job of about 6 months.
However the job requirements, especially for environmental dredging, are though and disposal of contaminated dredged material is expensive.

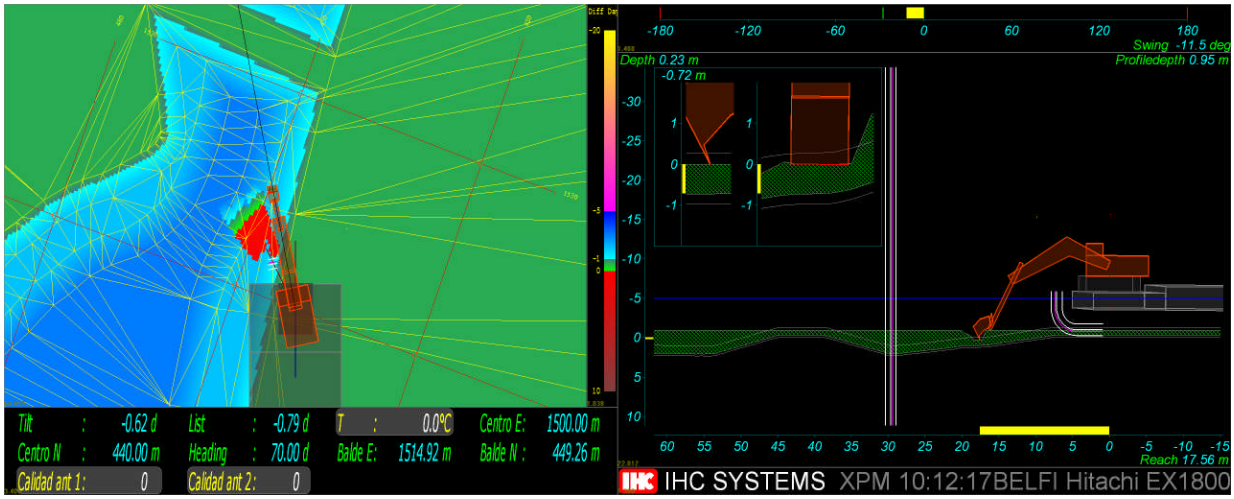

Figure 11. 10 cm (4inch !) accurate dredging is todays manageable requirement

All this is translating in the use of monitoring, positioning and datalogging and the short term requirement for high speed education about “how to use this gear”.
This type of training is especially focused on the use of ground model related software like the eXcavator Positioning Monitoring (XPM) and Dredge Track Presentation Software (DTPS).
And how to translate the dredge job requirements to easy understandable animated ground models and a good view on the jobs progress by datalogging of the actions.
In general this is type of training is done by means of 1 teacher for a class of about 6, with the aid of simulation software and focus on the real project as it could be done in the best way.
In this way the training comes very close to a project start up and, for this alone, the trainees are extremely motivated.

CONCLUSION

The use of simulators in training programs for dredging have a firm place in dredge education.
Development of ever more realistic features and benefits will continue to develop over the coming years, especially within companies with a large fleet of dredgers.

REFERENCES

Cox c.s., *Terra et Aqua - number 63 - june 1996*

Keizer, C. de., J.D.P.A Peters and L.L.J. Verdoodt (2003). “Training Simulator for Trailing Suction Hopper Dredgers with a Dynamic and Realistic Dredging Process.” *The first Chinese International Dredging Congress and Exhibition.* Shanghai – China.

Miedema, S.A. (1987). Paper in Dutch: “Berekening van de snijkrachten bij het snijden van volledig met water verzadigd zand” (“Calculation of the cutting forces for with water saturated sand”). *Delft University of Technology, Faculty of Mechanical Engineering and Marine Technology*, The Netherlands.

Muijen, H. van., C. de Keizer, D. Westelinck and K. De Winne (2003). “Experience with a Training Simulator for Trailing Suction Hopper Dredgers with a dynamic and realistic dredging process.” *CEDA Dredging Days 2003,* Amsterdam.