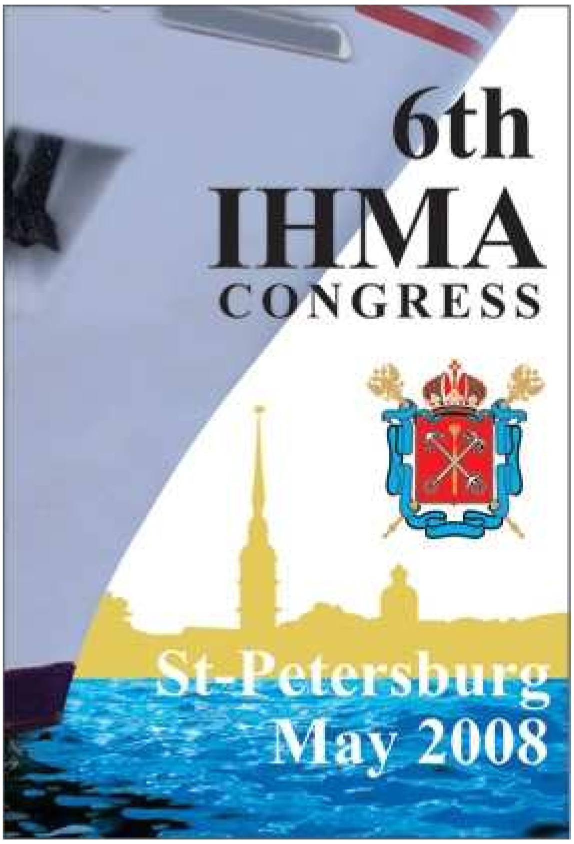

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Recent Developments and Applications of DUKC® Technology

By

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ABSTRACT

The Dynamic Under Keel Clearance System (DUKC®) has been the leading real-time UKC system in the world for more than 15 years. It has assisted more than 35,000 vessel movements without incident and has directly generated for shippers and stakeholders many billion of dollars in decreased freight costs and increased cargo throughput, while increasing port safety. These gains have been achieved at a small fraction of the cost involved in gaining equivalent increases in productivity by dredging, without incurring any adverse environmental effects.

OMC has continued to tailor the DUKC® system to better meet the under keel clearance needs of its customers. The resultant products provide integrated vessel management and monitoring tools from port of origin to port of destination.
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The presentation first introduces three recent developments in the core DUKC® Dynamic Passage Planning System: WaSP (Wave Spectral Predictor) to integrate swell forecasting outputs out to 48 hours directly into DUKC® planning computations for maximising vessel drafts and tidal windows; modeling the effect of wave-current interaction on ship response, and use of Raw Data Depth Analysis (employing detailed electronic sounding data) for calculation of under keel clearances.

The presentation then describes recent innovations and applications which allow DUKC® technology to be taken onboard ships by pilots equipped with the DUKC® Portable Pilot Unit (PPU) and to be integrated into Vessel Traffic Services (VTS) with DUKC® VTS. Both applications allow monitoring and control of under keel clearance by management of vessel speed during transit. Both applications are configured to provide a seamless transition from the shore-based DUKC® Dynamic Passage Planning System.

A brief description is presented of the DUKC® Scheduler, a new development recently commissioned at Port Hedland. This system integrates the DUKC® Dynamic Passage Planning System with Port Management and Information Systems (MIS) to facilitate the management of vessel scheduling activities, berth planning, conflict resolution and cargo agent tracking.

The presentation concludes with a summary of the author's involvement in recent activities by PIANC and IALA with regard to concept and detailed design of channel depths, use of hydro/meteo data in channel operation and provision of analysis tools for management of under keel clearance. A brief description is also given of the use of DUKC® PPU technology as a key component in the MarNIS (Maritime Navigation and Information Systems) Project being undertaken by the European Union.

1. INTRODUCTION

Traditionally, ports have operated under fixed rules which govern the minimum under keel clearance (UKC) to permit safe transit along port approach channels. To ensure safety, these fixed UKC rules are determined by requirements under extreme swells and negative tidal residuals.

If the requirements are too conservative, ships carry less cargo than they could, and the operation is not as cost-effective as it might be. At the other extreme, inadequate criteria could jeopardise safety and cause a grounding to occur.

The Dynamic Under Keel Clearance System (DUKC®) developed by OMC uses customised numerical models to calculate the UKC requirements of the particular ship sailing in the particular waterway in the environmental conditions at the particular time.

DUKC® modelling guarantees accuracy and applicability. UKC requirements are determined based on the actual vessel and its stability parameters, real-time met-ocean conditions (wave height, period and direction, water levels, currents, tidal plane, wind), vessel transit speed and waterway configuration, including detailed bathymetry, at the time of sailing. Wave spectra, ship speed and water depths vary along the transit and the effect of these variations is computed by the numerical ship motion model used in each DUKC® system. In addition, wave spectra and tidal residuals will change over time, and these effects are accounted for in each system. With respect to squat, individual ships and the pertinent characteristics of the complete approach channel are modelled in each DUKC® system, including the effect of temporal and spatial variation of tidal currents.

The accuracy of the numerical models used in the DUKC® System has been validated by undertaking more than 200 ship transits to obtain full-scale measurements of vessel speed, track and vertical displacements. These validation tests have been undertaken for a wide variety of channel widths, configurations and lengths, vessel types, sizes and stability conditions, vessel speeds, wave conditions, tidal regimes and current speeds.

The system has also been rigorously and independently tested by specialist risk management consultants to ensure that it satisfies internationally-accepted levels of risk for safely managing the UKC of vessel transits.

DUKC® has assisted more than 35,000 ship transits over the past 15 years, without incident. It is now used by 15 ports in three countries and by piloted vessels transiting Torres Strait. The Port of Lisbon installed DUKC® in 2007 for their deep draft container vessels. By the end of 2008 it will be extended to the Outer and Lower Weser River in Germany as a pilot project of the Waterways and Shipping Directorate, Aurich, and will be operational in the VTS centres at Bremerhaven and Bremen.
On average, there is now a DUKC®-assisted ship movement every two hours, somewhere in the world.

DUKC® is supported 24/7 by an experienced staff of engineers, naval architects and software engineering/IT personnel, employed full-time on the development, implementation and support of DUKC® systems, including ongoing system maintenance, training of operators and regular audits.

What are the benefits?

The three key areas of benefit from an operational DUKC® system are safety, environmental protection and economic.

Safety – DUKC® systems greatly reduces the risk of ships running aground. Some examples of groundings that might have been avoided with DUKC® include two large tankers that grounded in the channel leading to New Zealand's only oil refinery at Marsden Point in 2003 where it was later shown that a DUKC® would have prevented both these near environmental disasters. The Maritime Safety Authority of New Zealand imposed significant draft limits on the port following these groundings – these restrictions were not lifted until a DUKC® System was implemented at the Port in a record time of 4 months!

Environment – DUKC® has been developed and is currently being trialled to ensure adequate under keel clearance for piloted ships transiting through Torres Strait and the Great Barrier Reef, one of the great natural marine wonders of the world. The ecological consequences of a ship running aground here, or anywhere, are clearly serious.

Economic – In port operations, the estimated economic benefits of DUKC® in increased vessel drafts, widened tidal windows and reduced demurrage charges exceeds US$5 billon to date.

2. DYNAMIC PASSAGE PLANNING

The core functions of DUKC® systems have always been to provide ports and users with dynamic passage planning advice on:

- maximum draft for tides
- earliest and latest sailing times (tidal windows)
- UKC for specific transits

These core functionalities remain but user needs in specific waterways often drive new developments in the way in which they are computed for those waterways; sometimes these developments find general application for all waterways.

Three examples are given below.

- **WaSP** (**Wa**ve **S**pectral **P**redictor) has been developed to integrate wave forecasting outputs into DUKC® passage planning advice up to 48 hours prior to sailing. This is particularly important for those waterways which are subject to rapid change in swell conditions, such as occur at port entrances in southern Australia, New Zealand and Portugal.

  DUKC® passage planning calculations usually commence between 24 hours to 36 hours prior to sailing. These calculations attempt to predict future environmental conditions to allow efficient operation of the port. If these predictions are too conservative, then the predicted drafts will be too low.

When the time comes to sail, the vessel will have a much greater maximum draft available and very wide tidal windows.

If the environmental predictions are not conservative enough, then the risk of a vessel loaded to the predicted draft being unable to sail will be high. This outcome will cause problems for port operations as vessels tie up berth and loading space.

Traditional DUKC® systems have used a conservative model of swell growth to predict future swell conditions. WaSP improves the DUKC® swell forecasting models by combining spectral forecasts from wave models. These combined spectral forecasts are generated by breaking various forecast model outputs into frequency bands (Sea Waves, Short Swell, Long Swell and Infra-Gravity). The forecast bands are then re-combined based on the general historical accuracy of each forecast in each band. Error allowances are also made based on the historical accuracy of forecasts in each band.

By varying the error allowance made with forecast horizon (the period between calculation time and forecast time), the risk of a forecast being exceeded can be tuned to give the desired planning and sailing behaviour. This ability, along with WaSP's transition between measurements and forecast values, retains the DUKC®'s traditional safety record by transitioning to use only measured spectra for calculations performed at the time of sailing.

An example plot of WaSP forecasts up to 48 hours ahead is given in Figure 1

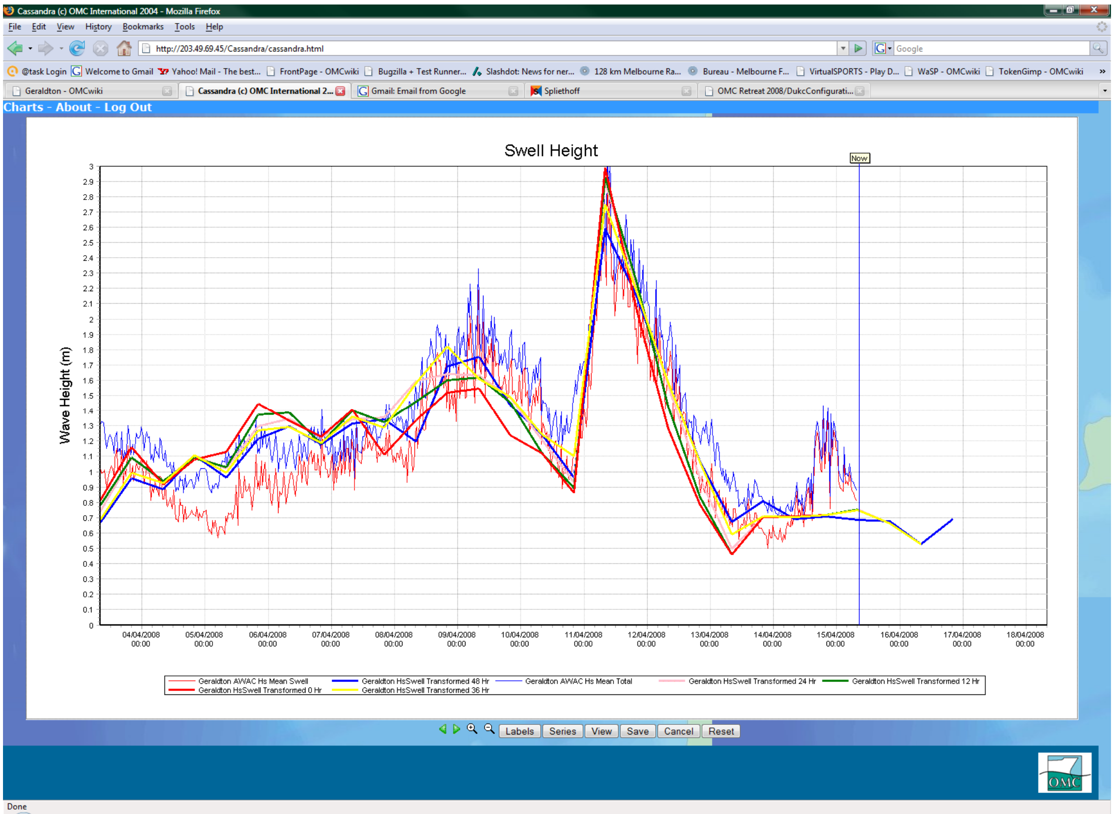

Figure 1 – Example of Swell Forecast using WaSP

- **Effect of wave-current interaction on ship response.** This is particularly important for those waterways subject to large swells interacting with currents.

The current has two effects on the resulting vessel wave response: firstly, influencing the encounter frequency of the vessel to the waves and secondly, altering the wave length (and height) of the waves, both of which can have a significant effect on resulting vessel motions.

OMC has developed and integrated wave-current interaction predictions into the DUKC®, utilising the 1-D action balance equations and loss terms dependent on offshore wave height and tidal phase. These have been extensively and successfully validated at the Port of Melbourne where, at the entrance channel at Port Phillip Heads, deep-draft vessels navigate through a difficult body of water where tidally driven currents exceeding 6 knots interact with very large swells rising from the south west over a complex bathymetry. The validation showed clearly the importance of wave-current interaction, with motions for some vessels at ebb tide double those for the same vessel at flood tide.

- **Raw Data Depth Analysis.** In recent years, survey techniques, data processing and computing power have progressed to the point where detailed electronic sounding data can be readily provided in place of paper charts. In response to this progress, OMC has recognised an opportunity to conduct a more comprehensive analysis of raw sounding data and thus better quantify minimum depths and manoeuvrability depths. To this end, OMC has invested in sophisticated geospatial analysis software and conducted extensive research to develop and test methods of accurately quantifying manoeuvrability depths. This investment has yielded results with significant benefits to DUKC® clients. In effect it allows vessels to load deeper by performing dynamic passage planning analyses based upon actual channel depths derived from raw sounding data rather than from a usually conservative estimate of channel depths. For channels that have major siltation issues and require regular sounding, these can now be readily input the DUKC® as soon as they are made available. The DUKC® is therefore always operating on the latest available hydrographic depths, with an allowance for siltation where appropriate from the date of the latest survey.

3. DYNAMIC PASSAGE MONITORING, ADVICE AND DIRECTION

Recent innovations allow DUKC® technology to be taken onboard ships by pilots equipped with the DUKC® Portable Pilot Unit (PPU) and to be integrated into Vessel Traffic Services (VTS) with DUKC® VTS. Both applications allow monitoring and control of under keel clearance by management of vessel speed during transit. Both applications are configured to provide a seamless transition from the shore based DUKC® Dynamic Passage Planning System.

DUKC® PPU and DUKC® VTS Systems provide Pilots and Vessel Traffic Operators, respectively, with look-ahead predictions of minimum under keel clearances during transit from berth to deep water (or vice versa).

The DUKC® PPU provides marine pilots with real-time under keel clearance management advice through vessel speed optimisation.

Specifically the DUKC® PPU allows the pilot to:

- Monitor that the actual speeds are within the speed envelopes generated by the DUKC® Passage Plan.
- Determine where it is safe to travel at speeds outside those generated by the DUKC® Passage Plan and to what extent it is safe to do so.
- Investigate alternative speed/sailing options in situations where the passage does not proceed as planned. This could include situations such as vessel breakdowns, vessel delayed leaving the berth, vessel loaded in excess of its planned passage draft, vessel not performing as expected or deterioration in the environmental conditions.
- Identify speeds that will maximise UKC or minimise transit time without exceeding safe UKC limits.

The DUKC® VTS System provides VTS Officers with a tool to monitor the effect of vessel speed on under keel clearance during transit. If shore-based pilots have access to this system, they can use it to advise on-board pilots (who may not have access to a DUKC® PPU unit) to adjust speed as necessary, especially when problems develop with maintaining planned passage speed.

The VTS application has been operational at Port Hedland, Western Australia, since mid-2007. It was used on at least three occasions during the first four months of operation to help on-board pilots determine the best option in dealing with UKC issues arising from engine breakdown during transit.

Both PPU and VTS applications are currently being implemented at several ports where DUKC® Dynamic Passage Planning systems are in place.

4. INTEGRATION OF DYNAMIC PASSAGE PLANNING AND CONTROL FOR MULTIPLE VESSELS AND PORTS

An integrated DUKC® system for Dynamic Passage Planning and Control is currently under development for the Waterways and Shipping Administration (WSA) in North-West Germany. The project is being undertaken as a pilot project of the Waterways and Shipping Directorate, Aurich.

This system is being configured for the Outer Weser and Lower Weser River, between Bremerhaven and Bremen to assist safe and efficient movement of deep-draft container vessels into the Port of Bremerhaven (4.9 million TEU’s in 2007) and bulk carriers into the ports of Nordenham, Brake and Bremen on the Lower Weser.

The integrated system will be operated at the VTS centres at Bremerhaven and Bremen (as shown in Figure 2) for UKC management of vessels in their respective traffic control segments on the Outer and Lower Weser It will provide Vessel Traffic Operators with the capability to monitor and predict minimum under keel clearances of vessels as they pass through the two VTS control zones on the Weser and as they enter or leave one of the four ports on the river and its estuary.

Figure 2 – Outer and Lower Weser River, Major Ports and VTS Centres

5. INTEGRATION OF DYNAMIC PASSAGE PLANNING WITH PORT MANAGEMENT AND INFORMATION SYSTEMS

A new development recently commissioned at Port Hedland is the DUKC® Scheduler. This system integrates the shore based DUKC® Dynamic Passage Planning System with Port Management and Information Systems (MIS) to facilitate the management of vessel scheduling activities, berth planning, conflict resolution and cargo agent tracking.

The requirement for a complete scheduling system has become vital at Port Hedland for a number of reasons including:

- the port is undergoing rapid growth in iron ore export with trade predicted to triple in the next five years (to 300 million tonnes per year),
- addition of new customers to the port.

As such there will be significant commercial pressure on the Port Authority to get a number of vessels out efficiently during the high tide period. The DUKC® Scheduler will assist the port to manage the political, procedural and physical constraints and conflicts that will arise.

The DUKC® Scheduler seamlessly integrates with the scheduling modules of the MIS System, in the case of Port Hedland the *KleinPort MIS* System. The resulting DUKC® Scheduler System:

1. Seamlessly interfaces Port Hedland's DUKC® Dynamic Passage Planning System with the *KleinPort MIS* System through web mapping services to dynamically update scheduling advice while minimising user input for the two component systems;

2. Manage and record scheduling operations (vessels, tugs and pilots) based around shipping movement protocols developed and defined by Port Hedland Port Authority.

6. OPTIMISATION OF CHANNEL DESIGN

Ever increasing demands on ports to accept larger and deeper vessels on a frequent tight time schedule have required ports to become smarter in their under keel clearance (UKC) management. Yesterday's approaches in channel operation, based on mostly static rules with little scientific basis, and in blanket capital dredging, are becoming increasingly less acceptable in today's world of accountable budgets and increased emphasis on minimising environmental impacts.

DUKC® methodology quantifies the UKC requirements of each section of a transit; this information is used to create an optimal channel depth profile which matches the specified channel capacity whilst minimising the dredging requirements. The UKC profile is produced based upon statistical analysis of environmental conditions as well as the range of possible vessel types and speeds. The channel profile is designed for the full range of conditions under which a vessel may be required to transit the channel.

Optimisation with DUKC® can significantly reduce the financial cost of dredging as well as its environmental effects. The outcome of increasing sailing drafts and tidal windows is delivered at a greatly reduced cost and with minimal environmental effects.

The accompanying paper by Captain Eric Atkinson and Peter O'Brien summarises the application of DUKC® technology to optimise dredging profiles for deepening the approach channels for container vessels into the Port of Fremantle, Western Australia. This methodology has been applied at a number of other ports around Australia and New Zealand to minimise channel deepening costs.

7. INTERNATIONAL DEVELOPMENTS IN UKC MANAGEMENT

Two recent developments in UKC management by international navigation bodies are summarised below.

PIANC has established MarCom Working Group 54 to develop guidelines for the use of hydro/meteo data to optimise safe waterway access and determine the operational limits of navigational channels. This Working Group is being chaired by the author and is well advanced towards meeting its target of providing a draft report by late 2009. The guidelines will address the measurement, prediction and use of hydro/meteo data and give examples of current national approaches to these important tasks.

IALA – A meeting of IALA's e-Navigation Committee in Shanghai in February 2008 produced a Strategy Document and an accompanying paper on User Needs, which specifically include provision of analysis tools for management of under keel clearance and air draft.

These documents are to be reviewed and approved by IALA Council, for submission to IMO Nav 54 in late June 2008. If Nav54 approves the proposed strategy and user needs, the documents will then be referred to MSC (Maritime Safety Committee) of IMO for its meeting in October 2008.

In addition to the above developments, Dynamic Under Keel Clearance Management also forms an important component in the European Union **MarNIS** (Maritime Navigation and Information Services) Project.

MarNIS is an Integrated Research Project in the 6th EU Framework Programme, bringing together 50 partners to develop Maritime Navigation and Information Services on a pan-European basis.

OMC was sole-sourced by the MarNIS Project to integrate its DUKC® technology for Portable Pilot Units (PPU) into the POADSS (Port Approach Docking Support System). The integration of this technology with high precision IMU/RTK vessel motion sensors will be featured at the MarNIS Demonstration scheduled in Lisbon on 15-16 October, 2008.

8. CONCLUSIONS

This paper has summarised the work undertaken in recent years by OMC on the continued development of the DUKC® system.

The paper outlines the extension of the DUKC® system from its traditional use during the past 15 years in Dynamic Passage Planning to its new applications for Dynamic Passage Monitoring, Advice and Control through use in VTS Centres and by pilots onboard with Portable Pilot Units.

The paper concludes with a brief review on work presently being undertaken by international navigation and safety organisations relating to the management of the under keel clearance of large vessels in restricted waterways and the expanding role which proven Dynamic Under Keel Clearance systems are likely to play in the safe and efficient management of such waterways. OMC intends to maintain its position as the world leader in the provision of such systems.

9. ACKNOWLEDGEMENT

Since installation of the first DUKC® systems in the early 1990's, continued research, development and refinement of DUKC® technology has been undertaken by an expanding OMC team of talented and dedicated engineers, naval architects, software developers and IT personnel. They have been. greatly assisted by interaction with Harbour Masters, Pilots and port users. Without such continuing feedback and interaction, the technology could not have reached its present state of development and widespread application. The author is deeply grateful to all who have contributed their time, knowledge and experience to this innovation in maritime engineering, and especially to the two authors of the accompanying paper referenced below.

10. REFERENCE

Atkinson, Captain Eric and O'Brien, Peter, "Dredging Ports in Today's Environment: A Fremantle Ports Perspective", paper presented at 6th Congress of the International Harbour Masters Association, St Petersburg, 12 -16 May 2008.