ENHANCED SAFETY THROUGH THE USE OF REAL-TIME DYNAMIC CHARTS OVERLAYS

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ABSTRACT

In today's economic climate, ports need to maximise their efficiency while ensuring safety of passage. As vessels increase in size, the dilemma facing many ports is that their existing static underkeel clearance (UKC) rules are inflexible, thus deeper vessels cannot transit without compromising safety.

As static rules do not change with the environmental conditions, the actual clearance and the potential of vessel grounding varies on any given day; for this reason static rules need to be conservative.

In contrast, dynamic UKC systems, calculate the required UKC depending on the prevailing environmental and vessel conditions; this ensures every transit satisfies appropriate risk standards. With safety assured, economic and efficiency benefits are realised when conditions allow deeper draughts and/or extended tidal windows.

This dynamic information can now be relayed to the pilot, via a chart overlay, to provide real-time 3D displays of the safe navigational areas, thereby ensuring continued safety of navigation.

STATIC V DYNAMIC SYSTEMS

The majority of authorities' in the world use static rules to determine the safe underkeel clearance of a vessel. These static rules often use the vessel's draught as the baseline to determine the underkeel clearance; however it is contended that this method can be erroneous as they are based on the assumption that this clearance is sufficient regardless of the prevailing environmental conditions.

In practise, the actual safety clearance is determined by the conditions on the day, and under static rules the clearance for a vessel varies for every transit. Most of the time the static rules will be conservative, but evidence shows that up to five percent of transits are marginal, even unsafe[1].

By contrast, a dynamic under keel clearance system (DUKC®)[2] calculates real time under-keel clearances in ports and shallow waterways to maximise channel safety and also productivity. The DUKC® considers all factors that affect the UKC of a vessel transiting a channel to determine the minimum safe UKC requirements. The system does not use the vessels draught as the baseline, but

[1] **OMC's historical records show approximately 95% of vessels are conservative, 4% marginal and 1% potentially unsafe**

[2] **DUKC® is the trademarked product of OMC International to determine dynamic underkeel clearances**

a pre-determined safety limit which must not be breached; added to this limit are the vessel's dynamic movements which are modelled using the predicted environmental conditions and this gives the minimum water level that is required to ensure safety at all times throughout a planned transit.

The methodology behind dynamic underkeel clearance has been internationally recognised, and the improved certainty and information that dynamic systems can deliver, has seen regulatory bodies, i.e. IALA and PIANC[3], regarding such systems as an essential Aid to Navigation (AToN).

These bodies are now developing standards for dynamic underkeel clearance systems because of the significant benefits, which dynamic determination of underkeel clearance provides, as a risk mitigation tool. They have identified DUKC® as a core e-Navigation concept, which is available and operational today. For the same reasons many authorities' have become increasingly interested in installing DUKC® for safety and risk management purposes.

However, DUKC® systems have also been widely recognised for the enormous economic benefits provided to waterway owners and users by reducing the inefficiencies inherent in the static rules when allowed; Inefficiencies which are caused by the conservatism required to manage the worst case scenario[4]. Therefore benefits can be realised when environmental conditions allow, and safe transits outside the restrictive static rule boundary can be undertaken.

STATIC RULES

Traditionally, authorities' have utilised static rules to govern the minimum under keel clearance (UKC) to ensure the safe transit of a vessel. These static rules were devised when vessels were smaller, their speeds lower, ship/shore communications poor and technology generally unavailable to determine ship motions accurately.

Therefore, there needed to be a simple method of calculating a safe underkeel clearance, and the accepted practise, was/is to calculate the underkeel clearance as a proportion of the vessels draught. Whilst any ratio could be used, most authorities' use ten percent unless conditions dictated otherwise. PIANC[5] guidelines reference this ratio, but it is often forgotten that this is a minimum suggested safety clearance and is for calm waters only, and that twenty, even fifty, percent may be better, especially for areas that are subjected to wave motions.

[3] International Association of Lighthouse Authorities and Permanent International Association of Navigation Congresses

[4]

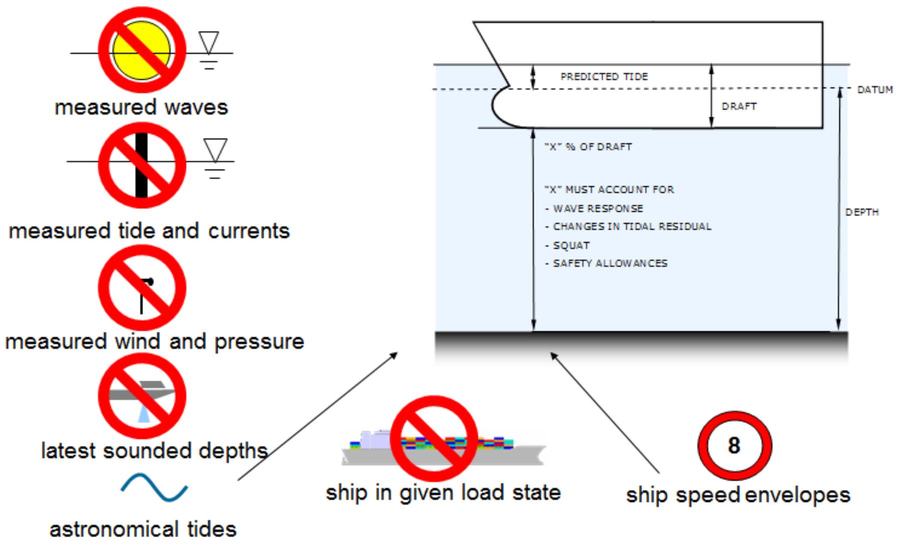
[5] Underkeel clearance for large ships in maritime fairways with hard bottom; Supplement to Bulletin No51 (1985);

The static rule tries to capture all anticipated factors[6] in a single allowance. Essentially the only controllable factors are the tide height (and therefore transit time) and speed (which determines the amount of squat[7]). Where depths are critical and conditions more variable, there may be times when the allowance is marginal. It could be suggested that the **"static rule" approach is a "top-down" approach**, where the gross clearance is determined from the draught and the actual net underkeel clearance is unknown.

Some ports do try to assess some of the factors, and this could be viewed as an advanced static rule. But whilst some of these factors can be pre-calculated, predicted wave response (in real time) is impossible to calculate without significant processing power and access to environmental data; so in practical terms wave motions are undeterminable once a transit commences. To address this issue, some ports apply a pre-determined roll/pitch angle to give the ship-handler an indication of loss of underkeel clearance due to wave motion[8].

Speed is an absolutely critical element in maintaining safe UKC. Evidence has shown that vessels' do not always maintain the planned, or proceed at an appropriate speed for the transit. If the transit is too fast, the ship will squat and heel in excess of the predicted amounts; both effects are approximately proportional to the square of the speed. By contrast if the vessel transits slower than planned, it will not reach way points at required times and, in tidal waterways, may therefore have less water than predicted and the transit may now be unsafe.

Once underway these elements can be difficult to assess and can often be overlooked. Most authorities' will use a single squat formula, but there are many formulae in existence and the most appropriate formula will depend on the bathymetry, channel design and the type of vessel. Often the navigator will calculate the squat for a single critical point, but in practise the vessels squat is continually changing throughout the entire length of the transit.



[6] Factors include: Tidal residual (difference between predicted and actual tides); Tidal change during transit; Allowance for unfavourable metrological conditions; Water density; Squat (from ship speed); Wave response; Sounding errors; Sedimentation, Localised phenomena such as standing waves.

[7] Squat is an hydrodynamic phenomenon by which a vessel moving through water creates a localised area of lowered pressure that causes the vessel to "apparently increase in draught" and be closer to the seabed than would otherwise be expected. It is approximately proportional to the square of the speed of the ship. http://en.wikipedia.org/wiki/Squat_effect

[8] Loss of UKC = Tan Roll * Beam. However it should be remembered that two vessels, of the same dimensions, but with differing stability will react differently in the same environmental conditions

The biggest drawback with static rules is that they are wholly dependent on the environmental conditions. If they are too optimistic safety could be jeopardised; too conservative and they become uneconomic; so they are blunt compromise, and for safety reasons will often be derived for the worst case scenario. The actual net clearance is proportional to the environmental and transit conditions, but at the same time unresponsive to change; this means an authority cannot maximise efficiency when conditions allow. More worryingly, an authority will not be aware when conditions are actually unsafe[9], because when static rules are used, the level of risk is variable and the net underkeel clearance on any particular transit is unknown.

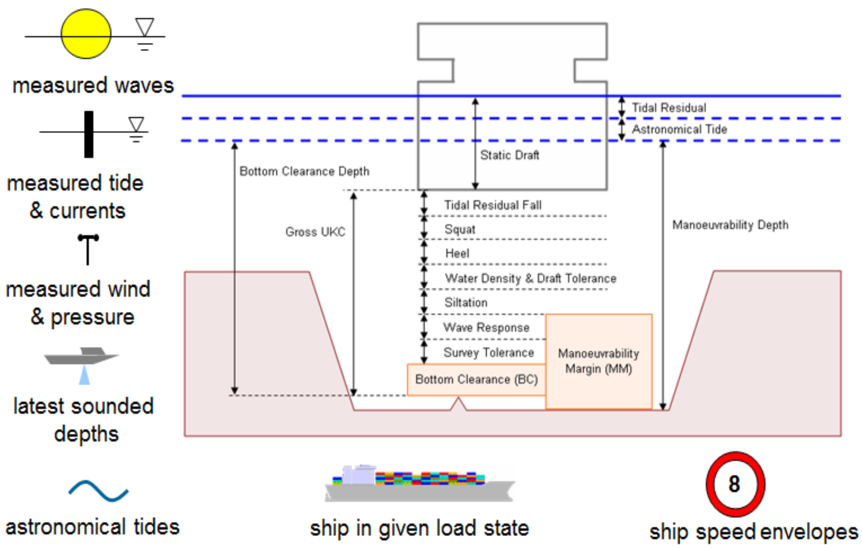
DYNAMIC ALLOWANCE

By contrast, dynamic underkeel clearances 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 the system. With respect to squat, individual ships and the pertinent characteristics of the complete approach channel are modelled in each dynamic system, using the most appropriate squat formula, and include the effect of temporal and spatial variation of tidal currents during the transit.

Dynamic systems can be considered as a **"bottom up" approach** and the system has, at its core, a minimum limit[10] that must not be breached. Each of the factors are computed in real time and then added until the minimum tide height is found that ensures a safe transit. Thus when the conditions are favourable vessels may have greater tidal windows and/or can sail with a deeper draught; but when conditions are not then tidal windows are reduced, and may even be closed, or a vessel may be able to proceed but with a reduced draught.

The systems are predictive, so if a navigator wishes to adapt his transit plan (especially the transit leg speeds), or if there is an unforeseen event (e.g. an engine issue or berth congestion), or there is a change in the environmental conditions the system will



[9] Whangarei, 2003. Two vessels "Capella Voyager' and 'Eastern Honour' ground under existing static rules, which were considered safe.

[10] The limit/s can be found in PIANC, 1985 (Underkeel Clearance for Large Ships in Maritime Fairways with Hard Bottom. Report of a Working Group of the Permanent Technical Committee II. Supplement to Bulletin No. 51 (1985)). The limits used in a dynamic system are the PIANC's Bottom Clearance and Manoeuvring Margin limits, but any stipulated minimum limit could be used.

automatically update the safe transit windows.

The day-to-day operation[11] of DUKC®, in preference to static rules for UKC, has moved the system from academic theory into a best practice in the real world.

Integration of the sophisticated numerical calculations (the "engine") with real time environmental data (wave, current and tide) ensures integrity and quality at the critical interface between the UKCM system and the dynamic data. Validated accurate numerical models[12] are used to ensure accurate vertical displacements for any vessel type, size and stability condition and vessel speed, in any channel width, configuration, lengths and wave condition, tidal regime and current speed. Each installation is customised using these numerical models to calculate the UKC requirements of the particular ship sailing in the particular waterway in the environmental conditions at the particular time. For this reason a dynamic system satisfy and often exceeds the internationally-accepted levels of risk for safely managing the UKC of vessel transits[13].

By conducting extensive comprehensive analysis of raw sounding data[14], the system can accurately quantify minimum depths and manoeuvrability depths on a much finer resolution than a standard DUKC calculation. This results in allowing 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.

DYNAMIC UNDERKEEL CLEARANCE SYSTEMS (DUKC®)

DUKC® is a proven safety and risk management technology and is a recognised core e-Navigation concept, which is available and operational today. OMC, the developers, created the first DUKC® system for Hay Point coal terminal in 1993. The technology has now been installed in over 20 ports and has ensured the safety of over 100,000 transits to date.

[11] **DUKC® was first installed in Hay Point, 1993. To date it has been operational in 22 ports for over 20 years with 100,000+ sailings without incident.**

[12] **Accurate, and validated, numerical models are fundamental to the assured safety of a DUKC® system. This is done through full-scale measurements of vessel speed, track and vertical displacements, using survey grade DPGS units. OMC has undertaken on more than 300 ship transits in a wide variety of channel widths, configurations and lengths, vessel types, sizes and stability conditions, vessel speeds, wave conditions, tidal regimes and current speeds.**

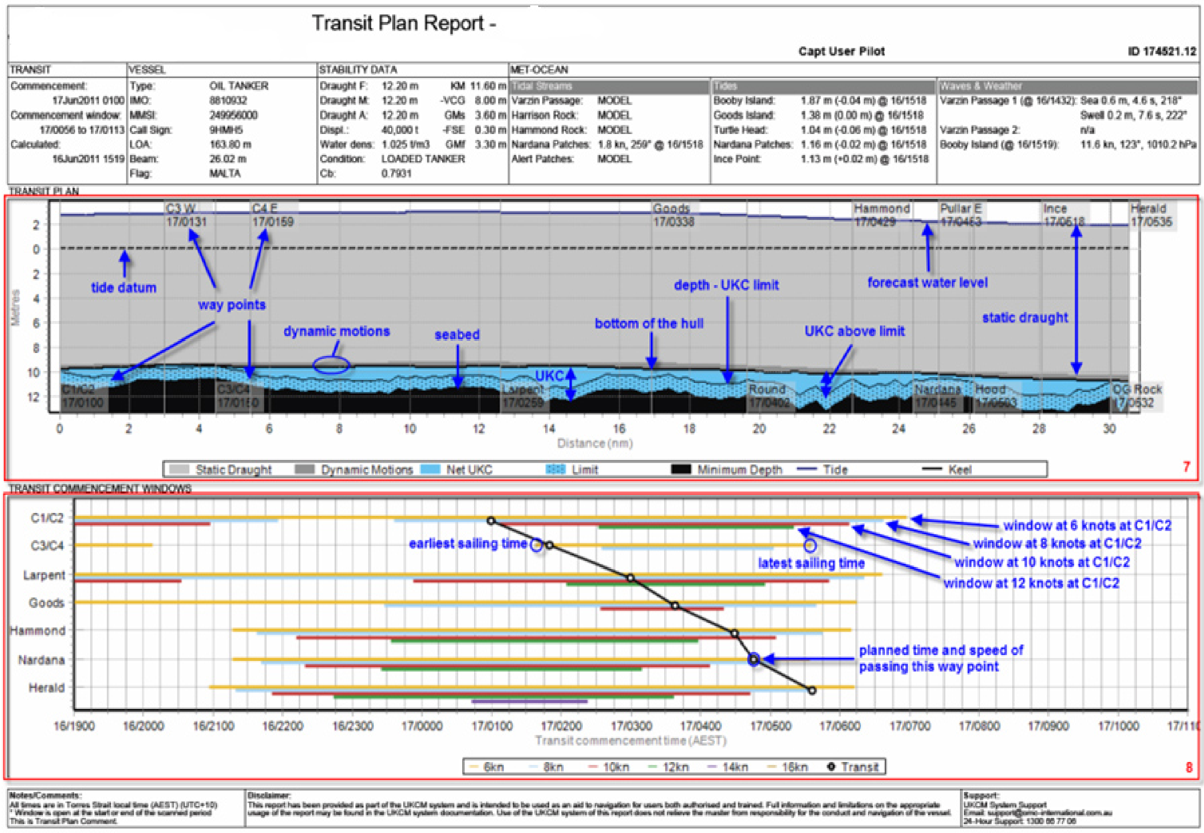
[13] **The system has also been rigorously and independently tested by specialist risk management consultants to ensure that it satisfies internationally-accepted levels of risk for safely managing the UKC of vessel transits. The Port of Melbourne also undertook two independent risk assessment studies and these extensive risk management studies concluded that the full complement of DUKC® navigation software would significantly reduce the risk of large vessels grounding in port approach channels.**

[14] **This is done through the use of sophisticated geospatial analysis software and combined with extensive research to accurately quantifying manoeuvrability depths.**

The system is customised for every port and implements the "dynamic allowances" mentioned above. 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

The system provides comprehensive reports for ports and pilot's which improves the decision making process and enhances the master pilot information exchange. It also serves as a historical database for auditing and risk analysis purposes. The system is now at Version 5 and is a fully interactive cross-platform web based system.



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. One such development is the delivery of the dynamic information to the pilot (and vessel), in a format that is readily understandable. Chart overlays were identified as the most appropriate method, which can be readily incorporated into the pilots' portable pilotage unit (PPU). Chart overlays present a simple visual indication on which areas meet UKC limits and are therefore safe for traversing, and which areas do not meet UKC limits and should be avoided.

One of the key areas to implement chart overlays is a comprehensive understanding of the channel and relies on extensive depth analysis[15]. 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. High resolution multi-beam survey data is used to describe the sea bed in much greater detail than is typically available from a standard ENC or navigational chart.

CHART OVERLAYS

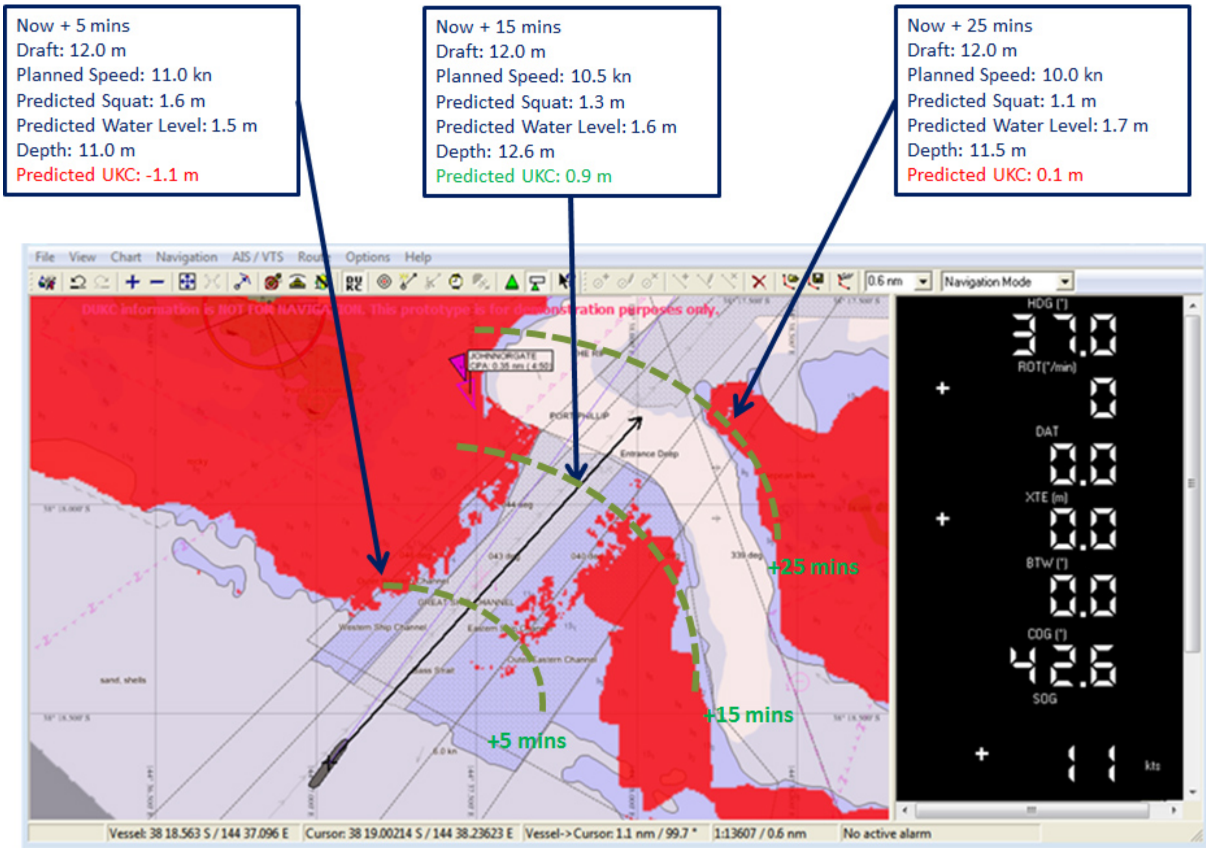
DUKC® Chart Overlay was specifically designed for pilots and mariners and displays under keel clearance information geospatially through a Marine Information Overlay (MIO) on a compatible Electronic Charting System (ECS) such as one running on a Portable Pilot Unit (PPU) carried on board to monitor the passage in real time. Alternatively the overlays can be displayed on the web within the DUKC portal, allowing a shore station to view the same dynamic overlay that the pilot is viewing. As every vessel has a unique dynamic UKC plan each overlay is vessel dependant; this is different to a tidal or weather overlay that is generic to all vessels. Thus there may be numerous vessel specific chart-overlays in existence at any one time.

The overlay is based on the latest available high-resolution bathymetry data, prediction of tidal and non-tidal water levels, waves and currents, knowledge of the recorded vessel load state (draft, trim, and stability), the pilot's submitted passage plan (speeds and expected times at waypoints) and predictions of the associated dynamic vessel motions (squat, heel, and wave response).

The DUKC® overlays are also predictive in nature. Therefore tide heights, currents and environmental conditions are being predicted for the actual time of transit (i.e. at a waypoint) which makes DUKC overlays unique when compared to other products.

An example of the chart overlay is displayed in Figure xx. The simple presentation of predicted Go / No Go areas for the time of the vessel arrival in those areas allows the pilot to anticipate required deviations from the transit plan. This anticipation allows time for various options to be considered and enables proactive rather than reactive navigations.

[15] **El Mejoramiento De La Seguridad De La Navegacíon Utilizando El Sistema Dukc®, M.R. Turner , M.A. Villella and P. W. O'Brien, VI Congreso Argentino de Ingeniería Portuaria Seminario Latinoamericano " Desarrollo Sustentable de la Infraestructura Portuaria Marítima y Fluvial en América Latina.**



KEY BENEFITS AND FEATURES

Dynamic chart overlays, and the predictive capabilities, have a number of key benefits over existing navigational systems.

- It allows rapid identification of channel (or adjacent) areas that must be avoided and allows identification of potential UKC hazards at the passage planning stage.
- It allows pilots and masters to make informed tactical navigational decisions about the vessels route which can be adjusted to ensure safety of navigation is maintained.
- It offers optional fine-tuning and optimising of passage plans for long or complex passages while underway.
- In emergency conditions it offers informed escape options and lowers the risk of channel blockage. As the overlay is computed ashore, and is available to the port authorities, it allows the Harbour Master, or similar, to assess the same situation. This also allows the pilot/master to stabilise the situation whilst contingency plans are assessed.

The key features of the system are:

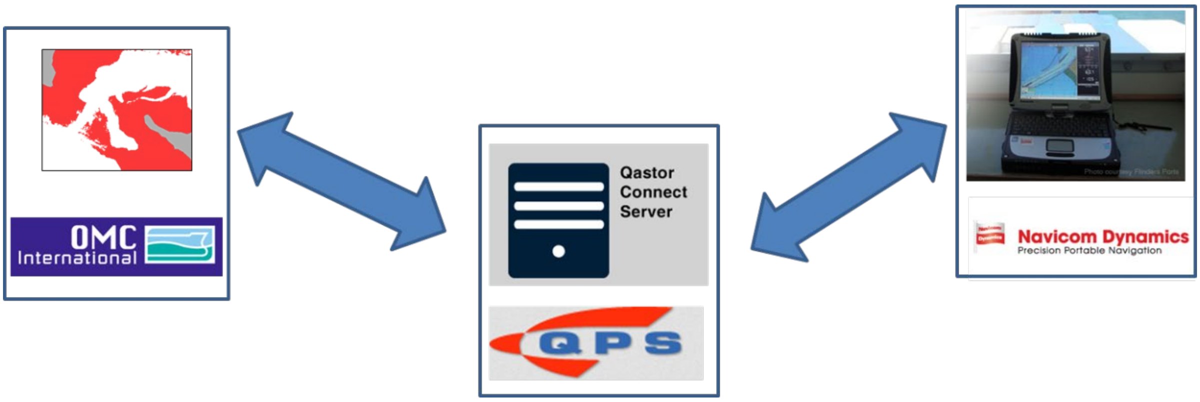
- Display of safe and unsafe transits (go/no-go areas) at the passage planning stage.
- Display real-time safe and unsafe transit areas (go/no–go areas) whilst underway.
- Updates go/no-go areas automatically based on the latest available met-ocean conditions and actual vessel speed and position.

- Go / no-go areas are based on dynamic under keel clearance calculations and include the impact of dynamic ship motions on navigational safety.
- Go / no-go areas are computed on-shore by powerful computers and are transmitted to the vessel, allowing relatively lightweight & low spec on-board devices.
- The go/no go areas are predictive, i.e. predicts the conditions ahead of the time of arrival.
- The go/no-go areas can be displayed within compatible ECSs.

CHART OVERLAY DELIVERY

The delivery of a chart overlay to a pilot requires a number of technologies to be integrated. The concept of overlays is not new[16] but dynamic content delivered in real-time is a world first and true e-Navigation solution. The first live application is at Port Hedland, Australia, and involved three[17] principal companies, these were:

- OMC International: DUKC® system delivering dynamic chart overlays in real-time.
- QPS BV: Received the chart overlay, interpret the data and deliver to the PPU via their Qastor Connect server.
- Navicom Dynamics: PPU manufacturers running Qastor navigation software which receives the Qastor Connect data and displays on the PPU.



The key steps to producing an overlay are:

1. At the planning stage, prior to the transit, the administrator calculates a safe transit window for the vessel and the time of sailing, based on a default speed profile, and promulgates this to the pilot organisation. The pilot can then interact with the system (via the web) and customise the transit. In essence this means the pilot can optimise/adjust the speed profile, to match the vessels manoeuvring characteristics and any changes that negatively impact on the safety are visually[18] apparent to avoid unsafe transits.

16 MARNIS project ************************ ADD

17 A fourth company, Telstra, was used for dedicated 3G broadband but newer technologies like marine broadband could be used when available.

18 At the planning stage, the transit is displayed as a vertical graph of the water column taking into account the dynamic components for the whole transit.

2. When a DUKC calculation is performed the results are spatially combined with the high resolution bathy grid (as described earlier) and areas of Sail / No Sail are determined. This data are stored as a single band geotif. There are four options for each cell (Sail, No Sail, No calculation or Calculation Error). These geotifs are vessel and transit specific i.e. customised for each vessel using the system.

3. The computed geotifs are placed on a local file server. The chart overlays are now ready for display. For passage planning where pilot has ready broadband access (before departure on land) overlays can be displayed on map server within DUKC® system.

4. The overlays are continually updated and file sizes are reduced by splitting transit into tiles and only updating the required tiles by overwriting. Once a transit commences historical tiles are not recalculated, thus reducing file sizes further (and this significantly reduces data transfer costs).

   Once transit has commenced the other Chart Overlay partner companies take over.

5. Qastor Connect server regularly pole the OMC file server for new chart overlays. These are pulled down from the local server, interpreted and broadcasted via a dedicated communications channel to a receiver running the Qastor software, normally being the pilot's PPU.

6. The Qastor navigation software has been modified to allow the pilot to load the applicable transit from the server. Once loaded the software continually downloads the revised chart overlays (updated tiles) and these are displayed as a layer on the PPU display by over laying the standard ENCs and other layers used. The chart overlay is on by default but can be turned off if the full chart needs to be viewed.

FUTURE DEVELOPMENTS

Dynamic chart overlays are expected to revolutionise navigational practices and the new S100 standard are well suited to being able to deliver this to a ship's ECDIS or other navigational system's rather than just the pilot's PPU.