Forum

Waypoint Navigation for Rivercraft?

D. Breedveld

Anticipating that transport on the West European inland waterways will increase in volume, in ship size and in speed, experiments are being carried out to investigate whether safety of navigation – including traffic management – can be improved by the employment of GPS or DGPS, electronic navigation charts, river radar and computer technology. Although waypoint navigation and collision avoidance systems are generally accepted in the maritime world, these methods could cause problems when applied on inland waterways.

1. introduction. The difference between open-water navigation and navigation on inland waterways, canals and rivers, is mainly due to the difference in distance between successive waypoints and compensation for the effect of currents. In open-water navigation, a current compensation system can easily be introduced into the overall navigation control system. On rivers, this turns out to be much more complicated. A river is a confined waterway. River currents meander in the riverbed. In other words, the main current oscillates between the river banks. This is in contrast with tidal currents in open sea. Using current compensation systems makes little sense in river navigation. Trying to eliminate river current influence using such a system would result in the need for rather drastic course changes every few hundred metres in order to keep the vessel on the pre-planned track. Furthermore, although for a certain water depth the turn-radius is a fixed, known value and consequently the required vessel speed can be established, estimating the influence of the centrifugal accelerations and of the upper and bottom currents is a very difficult process.

When steaming down-river, the principle of river navigation is to make use of the main current and thus to follow the meandering current pattern to achieve the desired trajectory: extreme course changes are not necessary to keep the vessel on the desired track. The same principle applies when sailing-up river, but then meandering courses are steered in order to avoid as far as possible the main current. This means that for both up and down river-sailing, a kind of ideal trajectory does exist. Moreover, it appears that when, under such circumstances, a vessel is navigated according to the above-mentioned principles, it will follow a trajectory with minimal path width. It also requires minimal rudder movement to keep the vessel on the desired trajectory. Additional factors to consider are river depth and the fact that, often, river navigation means shallow-water navigation with very little underkeel clearance. Underkeel clearances of 40 cm (16 inches) and even less are no exception. This, of course, influences steerability of the vessel and its speed. River depth is at its maximum in the outside river bends. In between consecutive outside river bends, depths can reduce considerably. In these river sections, locally called 'Ubergang' or, in English, 'transit', the phenomenon of so-called current dunes may also occur in the longer stretches. The helmsman of a vessel consequently has to react to all these factors and not just the influence of the current. In addition, the other external conditions that influence navigational behaviour have to be considered and compensated for. A skilled and experienced skipper is well aware of all these factors, and will determine speed and course of vessel in accordance with all possible circumstances.

Clearly, knowledge and experience of the geographical conditions is of prime importance for safety of river navigation. That is why, in order to obtain a certificate of competence for a river

https://doi.org/10.1017/S0373463398008194 Published online by Cambridge University Press

or part thereof, proficiency is tested through an examination. River navigation is more than simply drawing lines through waypoints. It requires a dynamic approach to follow the main current, account for current direction and strength and for shallow patches, etc. Moreover, we are not alone in this world and that holds true for rivers. Depending on existing water levels, the number of ships navigating a river can increase considerably, and passing distances can consequently decline to values of approximately 20 metres. A condition that will also occur under reduced visibility and fog when navigating with the aid of 'river radar'.

2. prospects for automation. In the development of a fully computerized river navigation system for inland waterway craft, the following conditions will have to be satisfied. The computer program will have to be able to account for, and thus contain, the following basic data: ship characteristics, speed, influence of wind forces, centrifugal forces, sideways resistance, upper and bottom current predictions, and draught and underkeel clearance variations. Also needed is the influence of overtaking and meeting vessels on trim and rotation around the z-axis and the mutual sideways displacement of the vessels involved. In the computer program design, a certain tolerance should be built in, otherwise there will be a risk that the system runs away with itself and gives too many commands.

The simplest way to develop the ideal main current trajectory is by having various experienced skippers of comparable inland river craft sail over the specified river section to be computerised. This should be done for a number of different water levels in order to account for seasonal changes. It does make a difference whether the river flows in its summer bed or in its winter bed; in other words, there is a best route for every water level and every ship draught. The trajectories developed by such an exercise would be average trajectories and would not deviate too much from the main current and ideal ships' paths for the different water levels. This concept was verified by the Soesterberg Institute of Sensory Perception & Physiology, who investigated the possibility of six barge pushtows with dimensions of $280 \times 22{\cdot}80 \times 4{\cdot}50$ metres.

Work is also needed to determine whether, in the specified river section, navigation data will be accurately and constantly available from GPS or DGPS. With this in mind, it must be realized that a river is not only bound by its natural river banks which, depending on the geographical environment, can be either meadows or mountainous country. Man has added to this natural environment houses, office buildings, factories, bridges and other constructions, such as high-tension cable crossings. All these objects and constructions can be an impediment for the undisturbed reception of navigation and communication satellite signals. It will consequently be necessary to provide for a close network of booster stations in order to guarantee 100% reliable navigation data.

Furthermore, as opposed to a canal, the water level in a river may vary considerably. This in turn means that the visual aspect of the surroundings as seen from a river barge can change drastically. For example, on the River Rhine, differences in water levels of nine metres may occur between average and highest navigable water levels. Of course, it is a very nice idea that the ship's position can be indicated on the electronic chart display with a small dot of light, but what happens when chart display, radar display and visual image differ? Doubt may arise, but this need not be so if electronic charts can be made to conform to the following requirements. Starting from the bank of the summer bed, the chart should display over a distance of at least 2000 metres inland the differences in height, including buildings and similar constructions. Charts should provide an accuracy comparable with ordnance maps with a scale of at least 1:25000, but preferably a scale of 1:10000. In the river bed, continuous depth contours, shallows and type of soil should be shown. Like river pilots, an inland barge skipper does not navigate by compass courses but by heading points on the river banks. These heading points should also be shown on the charts.

In the early days of development of radar navigation on the River Rhine, the author used just such a chart. This chart was mounted on two cylinders and could be rolled up or down with adjustable speed. The system made it possible for the ground speed of the barge to control the

https://doi.org/10.1017/S0373463398008194 Published online by Cambridge University Press

roller chart speed and so keep chart speed in concurrence with barge displacement over the ground.

In case the intention is not only to keep the vessel on the right trajectory, but also to have give-way operations computer-generated, strange things can happen. Based on practical experience with the reliability of shore-based radar installations, a certain amount of prudence will do no harm. Radar towers of shore-based installations are immobile. The composition of the synthetic radar picture is, in general, based on three different measurements, and tracking to provide a speed vector is no problem. Problems do arise when two or more ship targets get very close together. Then the radar picture often goes haywire, and ships' positions become interchanged. Moreover, the markers and annotations around the echoes hamper proper observation of echo position, track history and passing distances of the ship targets. The problem of filtering out false echoes is often underestimated when synthetic radar displays are involved. With the radar on a moving vessel, the false echoes are even more difficult to filter out, due to their non-stationary nature. Consequently, this may cause the computer program designed for give-way operations to make wrong conclusions. As mentioned earlier, meeting and overtaking vessels not only occasion changes in trim, but also a rotation around the z-axis and a sideways displacement; clearly, these phenomena may easily be responsible for further computer program problems.

Let us take for example an inland waterway vessel upon whose radar display, under certain circumstances, more than ten vessels may be displayed within a radius of 1600 metres. With a minimum acceptable passing distance of 20 metres (quite a normal condition), a computer now has to draw its conclusions based on data from one single radar to initiate a collision avoidance manoeuvre. Collision avoidance and deviation from the ideal trajectory, the control over own-ship trajectory, while maintaining continuous tracking of other vessels in the immediate vicinity, will not be easy to programme.

Inland waterway craft are very manoeuvrable, but they too require a safety zone. The size of the safety zone is not only determined by the manoeuvring characteristics of the vessel, but also the conditions of the river trajectory. On trajectories with a river bend radius of 1000 m or less, the safety margin is perforce smaller than that with large radii. On the other hand, ship speeds are too great and passing distances too small to allow other vessels to enter the safety zone uncontrolled. The latter may happen due to erroneous conclusions of the computer system. If penetration of the safety zone does occur, an accident can hardly be avoided.

3. conclusions. There is no doubt that electronics can be, and are, a welcome aid to navigation and have meant progress. As system users, the skippers on inland craft have to be well-trained in the proper use of the system and have to be made well aware of its weaknesses. However, navigation decisions must remain with the skipper, because, based on professional knowledge, he can fulfil a very valuable filter function, and because the ultimate responsibility for the vessel and navigation safety rests on his shoulders.

key words

1. Navigation practice. 2. Rivers and canals. 3. Safety.

Vertical Sextants Give Good Sights

W. W. Huybrecht

For most ship navigators, this discussion is now purely academic – which does not make it less interesting.

https://doi.org/10.1017/S0373463398008194 Published online by Cambridge University Press

A sextant is a simple instrument but the use of it requires a lot of practice. In the 1950s, navigation reached a high level of accuracy because the technology was there (good instruments – daily radio signals – good bridges) and because the will and interest of the seafarers was there as well.

In my company, no sextants were provided (against the Rule), and a cadet/midshipman joining the fleet and wishing for promotion to 4th Mate had to work hard (10 hours/day) for six weeks to be able to acquire his own sextant. If he wished to discern the suspicion of approval in the eyes of his 1st Mate, he could not board with less than a Plath with a 6×30 telescope. The day that his observations and calculations were good enough to be relied upon, he was ready for promotion. Some had the knack of it after a few months, some needed 6–8 months, some still had problems a long time after this.

Practice was all day long in his spare time, 10–12 shots in the morning or afternoon depending on his watch (watch was for working, not for practising). If he got the sympathy of the Officer of the Watch, they took sights together – the quickest way to find errors and learn from mistakes. Once the Sun was mastered, the boy spent every evening on the bridge shooting stars (cutting hours off his sleep). Today, people cannot realise the application and the will necessary to earn any promotion.

The 3rd Mate took at least three Sun sights in his morning watch of 0800–1200; all Officers joined together for Noon; the 2nd took a last Sun around 1600; the Ch/Mate and 4th took a star at evening and at dawn. When you came on the bridge, the first sight you had was of a battery of sextants, from three to five, ready for use. As in other trades before industrialization, a very high level of skill and craftsmanship was achieved (as in cargo handling/care). The Sun was tracked between and behind clouds, the horizon between showers; a few seconds was enough to get a workable sight. The best Officers knew up to 70 stars; 30 stars was the minimum. Stars were identified through the telescope so that you were sure you had the right one.

In the beginning, calculations were made the long way, all by hand. Later, some Officers bought their own HO214. With these tables, I could regularly put seven stars on the plotting sheets within 15 minutes of the first observation, and I was not the fastest. The NP401 were slower. On the plotting sheet, a fine-pointed pencil was used to give very high precision. It was expected that from these seven stars, sights between four and six would cross at *one* point – on a good day, all seven. The three or four stars, of first magnitude nearly always crossed at one point; the fainter stars might be slightly away, but their lines of position would give a 'mean' very near the 'crossing' (Figure 1).

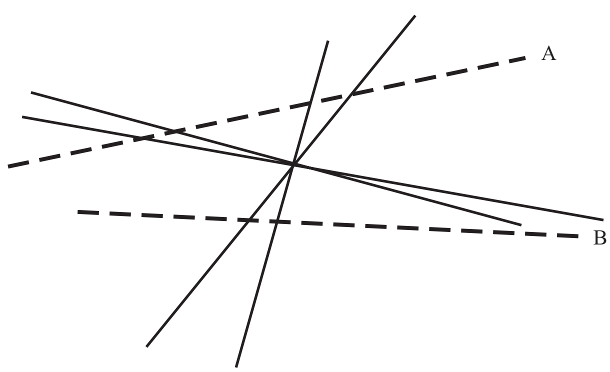

Fig. 1. A&B being outside the position was attributed to 'dip', never to a sextant out of vertical.

https://doi.org/10.1017/S0373463398008194 Published online by Cambridge University Press

At Noon, when at least three Officers were observing (up to six on passenger ships) the senior officers *always* achieved the same results to within $\frac{1}{4}$ min. Which means there was no, or negligible, 'personal' error. The same could be said when more than one Officer took stars; they came to the same position within one sea-mile.

A marine sextant should be heavy (Plath), the telescope clean and adapted to the sight of the observer (personal sextant). The way a person takes a sextant out of its box and keeps it in *both* hands will tell you who he is.

Most cadets had problems with technique: (1) eye sight-keeping (adapting telescope to the eye); (2) the way of 'kissing', light or too heavy; (3) swinging body and sextant around 'spine', finding the vertical plane; (4) rocking the sextant to keep it vertical. Points 2 and 3 give big errors, 1 and 4 very small ones. Ship movements should have no influence on the quality of a sight. Rhythmic movements like rolling, pitching, heaving are compensated by the body – that is why they are seamen. Unexpected surging can hamper, and heavy airing of the propeller can make a sight very difficult; but then, so is reading and writing in such conditions. Wind can be a problem, but that is why a marine sextant should be heavy, having more inertia.

In hazy weather, the 2nd Officer took a sight on the maindeck, as low as possible, and in many cases a reasonable fix was obtained. Poor fixes were attributed to poor horizon (dip), sometimes taking the Sun through clouds or in a 'flash' between two clouds. But the experienced Officer had a very good idea of the quality of his sight. At that time, any good Officer could take a sight 'with his eyes closed'.

The best sights were between 30 and 60° above horizon. Below 15° there were some doubts, below 10°, it was not worth taking. Above 80° you needed a minimum of experience and at 89°, correct Noon positions were always possible. One day I had 90°!

The vertical edge of the horizon glass will give no clue, as it will be not discernible. But no Officer should have doubt about the verticality of his sextant; that is why the 'kiss' should be light. Verniers (1/10 min) were seldom used or fitted and did not improve position. Sights were rounded to $\frac{1}{2}$ minute, calculations to one mile. This precision is more than enough for ocean navigation, and closing a danger to less than five miles (ocean) is poor seamanship. Coastal navigation is a different thing.

Special shades were considered as gadgets, and never did improve the sight. On the other hand, choosing the correct shades for both mirrors could make the difference between a good and a poor sight. Astro positions by sextant were very accurate – less than a mile out. This was proved over and over again by correct landfalls within less than six hours. Officers (and ratings) were proud of their trade, and sights and calculations were regularly compared and analysed. Job satisfaction was the result of lengthy application.

Satellite navigation systems were the beginning of the end of the art; dead reckoning became sloppy, radio signals were forgotten, chronometers were not wound, etc. It was also the end of 'sea sense'; currents and meteorology were no longer studied.

The coming of GPS put an end to it all. The sextant (one per ship) is hidden in a lower drawer; the chronometer is not connected to its battery. Time is given by the GPS. If one day the satellites should be switched off, 99% of the ships would be 'lost'. In the 1950s and 1960s, a good ship had at least two mechanical chronometers. The 'top' was taken daily at the same time, and they were compared with each other. Some ships had lamps in the chronometers to keep them at an even temperature. If one of them stopped working it was a major event, and the Master informed. The daily rate was quite correct. Later came battery-operated chronometers. To the general surprise of all, they were no better; only one was provided. With the coming of GPS, the younger Officers took time from the set; some were using their wristwatch (Seiko), which was often steadier than the chronometer! Older Captains lost their health. Nowadays 'a 2nd engineer' can get a position by pushing a button.

The last 10 years have seen a revolution in water transport of the same importance as during the demise of the sailing ship the change from steam tramp to cargo liners which occurred in the '50s. It is another trade, another job. Let us hope the new 'sea-men' obtain the same level of satisfaction and pride as we had. Seven sights in five minutes was the norm.

https://doi.org/10.1017/S0373463398008194 Published online by Cambridge University Press

reference

Dixon, M. and Richey, M. W. (1997). Vertical sextants give good sights (Forum). This *Journal*, **50**, 137 and 464.

key words

1. Sea. 2. Astro. 3. Navigation practice. 4. History.

Feedback from Users of Electronic Chart Technology

David Edmonds

(*PC Maritime Ltd*)

This paper was presented at the Third Electronic Chart Technology Conference, SASMEX International, Brighton, 22–23 April 1998.

Electronic Chart Systems have been used by mariners across the entire user spectrum without official standards or specifications for 10 years. In the last three years, the debate has centred on chart data and the merits of differing cartographic technologies. There is little new that can be said for or against raster or vector technologies except what actual users might say to support the requirements of their day-to-day operations. Today, we approach a new stage as ENCs start to become available but only for limited areas. This in turn means that ENCs are capable of supporting the only approved electronic chart system, ECDIS, in a limited way. There is an urgent need for alternatives to ECDIS to cover those areas where ENCs will continue to be unavailable for the foreseeable future. This paper therefore summarizes a feedback from users of RCDS and ECDIS-type systems to demonstrate the benefits which can be secured from official recognition of RCDS systems as the legal equivalent of paper chart navigation.

1. what is the navigator looking for? It is so easy to forget that the end user is simply looking for a benefit. He is not concerned so much with the type of chart, the producer of it, the advanced nature of the system's capabilities and so on, as in how the system will help him perform his daily tasks, with improved safety and efficiency. The real requirement for a navigation system could not be put more clearly than in the following statement.

> [I want] 'a reliable, accurate and continuously updated position related to charted features, with a simple method of ascertaining from the display the distance from perceived hazards without involving too much distraction from the task of conning the vessel. Plus a simple means of checking the accuracy of GPS position against other fixing methods.'[1]

and

> 'A reliable and simple to use passage planning tool.'[2]

2. the necessity for the 'dual fuel' system. The 'raster vs. vector' debate seems to have carried itself well beyond the fundamental needs of safe navigation, spreading confusion and uncertainty about different chart and system standards. As a consequence, many users are being needlessly denied access to efficiencies, safety checks, and better navigational strategies.

What is not made clear by the proponents of vector charts is that there is vector and vector – i.e. official ENC vector data (see Appendix for a glossary of terms and definitions related to electronic charting) produced to an international standard, and privately produced vector data produced to a proprietary specification. You may have heard the phrase 'vector is best'. Well, which vector? There is only one approved vector chart, the ENC, and ENCs can only be issued by, or on the authority of, national Hydrographic Offices. The irony is that the debate is often rendered irrelevant by the simple lack of ENC vector data. There are no commercially available ENCs as I write. Meanwhile, there are available now safe, accurate and consistent Raster Nautical Chart (RNC) services developed to a product specification, and a detailed performance standard has been set out to control the navigation systems which use RNCs, known as the Raster Chart Display System (RCDS).

To recap briefly on the RCDS draft performance standard: it largely mirrors the already approved ECDIS specification, but it states that in areas where there are no ENCs available (currently, the whole world, but in the future, parts of the world), then official updateable raster charts may be used to fill the gaps in the chart coverage. We all know that ENC data will not be available for the foreseeable future for those parts of the world where the original survey data is not good enough. New surveys would have to take place first, and there is limited funding for major new survey work. So the 'dual-fuel' system, using part ENC, part official raster charts, is now a necessity. And since RNCs for the non-ENC areas are already available, mariners are justifiably questioning the lack of approval for the RCDS specification with RNCs. Why wait, they ask, until some ENCs become available, when the RNC part of the system is already available and would give them many safety and accuracy benefits over paper chart navigation?

The feedback I am reporting in this paper is from Marine Superintendents and senior Masters onboard SOLAS registered vessels using RCDS systems safely and with increasing confidence.

3. rcds benefits. Two Hydrographic Offices, the UK HO with ARCS (since March 1996) and the Australian HO with Seafarer (since December 1997) provide charts to Raster Nautical Chart product standards. My company, along with others, has been able to supply systems using RNCs for over two years. This has enabled a large number of systems to be supplied to a very wide range of vessel types and for mariners to get genuine long-term experience in the use of such systems.

The experiences reported here fall into the following main areas, and the paper will be divided accordingly:

(i) Charts
(ii) Chart correction
(iii) Position plotting and monitoring
(iv) Safety benefits and the removal of risk of human error
(v) Limitations.

4. charts. The following comments were made in support of the quality of ARCS:

[we like the] 'accuracy of reproduction and clarity of display.'[2]

'The fact that [ARCS] are direct reproductions of their paper equivalent means that it is easier for the user to relate to them rather than to other possible electronic chart aids.'[2]

[we like] 'the fact that all chart features are displayed with no option to remove layers of information.'[2]

'ARCS charts do not wear out and necessitate costly renewals on the issue of new chart editions.'[2]

'There is nothing which the paper chart provides that is not provided for in some way by the raster chart, always assuming that the charts are issued by a Hydrographic Office.'[1]

'The display makes it easier to see small chart details, especially at night.'[2]

4.1 *Physical Chart Availability*. An obvious limitation of the paper chart is that it has to be physically delivered to its destination. In practice this means that vessels may have to navigate without the charts required for a new destination if they do not stop en route. This safety issue is resolved by RNC; ARCS and Seafarer raster charts allow chart permits to be sent by voice, fax or email, so that charts already resident on the library CDs held on-board can be unlocked for use. This benefit is recognised by users who have commented.:

'Due to the ease with which new charts can be obtained via a chart permit, one is less dependent on chart suppliers if one receives a sudden change of voyage orders to areas for which charts are not carried.'[2]

'Since one can obtain permits and user entry codes for additional charts whilst at sea, the shipowner does not need to carry such an extensive chart folio to cover all eventualities – he can add to them at sea if unexpected voyage orders are received.'[2]

An incident reported on by the Australian Marine Incident Investigation Unit highlighted that vessels are routinely trading without the necessary charts on board. This was in the context of the grounding last May of the *Western Winner* on Tiparra, South Australia, where the master of the *Western Winner* said that he had four sudden changes of orders in the loading port and claimed to be unable to obtain the necessary charts before proceeding to sea.

4.2 *Chart Management*. There is a physical benefit to electronic chart management. Electronic chart data requires virtually no storage space and any of the charts, once installed into the system, can be viewed after a few keypresses. The following benefits are reported:

'ARCS do not require bulky storage space on the bridge and the display can be located with the needs of the navigator, as a prime consideration, rather than where there is sufficient space for a chart table.'[2]

'Automatic chart correction, organization of electronic charts without physical effort/distraction, calling up charts for examination without physical effort/distraction.'[2]

'The changeover from chart to chart is less time-consuming, and there is no risk of error in transferring position.'[2]

'The ease of … chart management.'[2]

5. chart corrections, electronic charts and the ism code. All commentators highlight the automation of electronic chart corrections as a very substantial improvement in vessel safety management, which alone should impel the adoption of the RCDS performance standard at the earliest opportunity.

'The most noteworthy advantage of an RCDS displaying ARCS charts is the ability to efficiently and accurately correct charts in a timely manner with little effort on the part of the operator.'[1]

[RCDS provides] 'a much more reliable and consistent method of chart correction compared to manual methods.'[2]

'There is a considerable time-saving with regard to chart correcting, the Update CD taking, at the most, minutes.'[4]

'The chart update method saves many hours work for the navigator, reducing fatigue, and probably enhancing the quality of visual lookout since it is inevitable that a lot of manual chart correction is done during watchkeeping time.'[2]

[There is] 'no risk of human error, inefficiency or ignorance of proper chart correcting procedures. This ought to be a very important plus-point for shipowners, since it fulfils their legal responsibility for having adequate chart management systems in place with minimum training costs.'[2]

Captain S. K. Joshi, Marine Superintendent of Teekay Shipping (Canada) Ltd, provided a summary of shipowners' responsibilities:

'The ISM code is all about changing the safety culture present at sea and ashore. Historically, the ships were blamed for everything that went wrong at sea. Today this is changing and there is a realization that owners, managers or operators have to take some, if not all, of the blame for what goes wrong on the ships.

There is a long list of items where management is responsible for taking care of ships' activities in a safe manner. A major responsibility is to supply the ship with up-to-date navigational equipment, including approved navigational charts for the area where the vessel is planning to navigate and adequately qualified and trained staff.

The ISM code expressly requires the management to provide the vessel with resources and personnel for safety and environmental protection. SOLAS Chapter V Regulation 20 requires that "all ships shall carry up-to-date charts... necessary for the intended voyage".

This brings us to two fundamental issues: firstly, the ship must have the charts onboard for the intended voyage and secondly there must be a reliable system for keeping the charts corrected *at all times* with the latest corrections available.

The major problem on ships trading worldwide is the sheer number of charts which must be corrected up-to-date from the latest Admiralty Notices to Mariners. It is an extensive task for any average second officer. In addition to his other duties (watchkeeping, cargo watches and provision of medical attention), he has to correct all charts and publications. In practice, this job is quite likely done in his own time. With on average over 3000 charts on a worldwide trading vessel, this job is not the most exciting or entertaining task in the world. Fatigue, boredom and the repetitive nature of the work take their toll on chart correction.

The reliability of chart correction is vital to the safe navigation of the ship. Yet the Master is unable to verify that the second officer has made appropriate corrections and maintained a proper log due to the sheer size of the task. There are three basic reasons for the unreliability of chart corrections. Firstly, due to work overload on the second officer, the job is done at the end of the day when he is tired, so the corrections may not be applied accurately. Secondly, on a number of ships the second officer may be ignorant of the importance of chart corrections and is not trained in chart correcting. Chart correcting is not a subject in any syllabus for examinations nor is it taught in schools. It is learned on-board by observing the senior officer doing the job. Thirdly, and most regrettably, the officer may be too lazy to correct the charts, instead making false entries in the log and in the left bottom corner of the chart without actually correcting the chart itself. Occasionally, one comes across a second mate who does this at sea. The Master cannot physically check all the charts for correction. He has to delegate and rely on his officers.

Under Rule 7 of the ISM Code, development of plans for shipboard operations is an essential part of the Safety Management System. This includes identifying all operations affecting safety. These can be classified in four categories namely: normal, special, critical and emergency operations. Chart corrections fall under the critical category. The totality of corrections, accuracy of corrections and record-keeping of corrections are all critical to the safe navigation of the ship. If one has to look into the functional requirements of Safety Management Systems (SMS) related to safe navigation of the vessel as a pro-active measure, there has to be a check list to ensure availability of an up-to-date corrected chart for navigation.

The foregoing discussion establishes the necessity for corrected charts under the ISM code. This can only be achieved with current reduced manning on ships by an automatic electronic process. This in turn is only possible with electronic charts (whether they are raster or vector is not of the greatest importance). The human element is avoided in electronic chart correction, thereby increasing safety and saving a considerable amount of time to devote to other safety measures.

If there is an accident and the root cause is traced to inadequately corrected charts, the ship will be held to be unseaworthy.

This alone in my view should prove the case for compulsory use of electronic charts onboard in the near future.'[3]

6. position planning and monitoring. All navigators have the same fundamental requirement for accurate and, in the modern age, automatic plotting of position. Comments included:

'Full navigational information is available at the position of control without the need to move to a separate chart table/chartroom.'[1]

'The risk of operator error in plotting positions is eliminated.'[2]

'Instant real-time display of current position with up-to-the-minute course made good and speed trend indication.'[2]

'Position relative to chart features, at that instant, is readily available to the navigator without the distraction, and time required, to plot a fix.'[2]

Fast ferry operators where vessels are moving at speeds over 40 knots and where position will have changed significantly in the time it takes to plot onto paper, commented in particular on:

'The ability to note at a glance any impending dangers relating to position.'[4]

'The operator does not have to leave his chair to plot a position and, combined with DGPS, approaching danger and potential manoeuvres to avoid traffic are much more easily identified.'[5]

6.1. *Chart Datums and Offsets*. The RNC product specification requires that the RNC provides a quality-checked shift from WGS84 to the RNC's local datum. This enables GPS positions to be accurately plotted on non-WGS84 charts. This is not a concern for ECDIS since all ENC data should be referenced to WGS84. This capability is a great benefit of RCDS, which will have geodetic datum management built in because:

'It eliminates the need for the navigator to check each chart for datum corrections, and to apply the manual updates to the GPS receiver.'[2]

'It simplifies watch handover procedures, in that less time is spent by the incoming OOW in checking his predecessor's actions.'[2]

'It eliminates the risk of erroneous positions if the foregoing precautions have been forgotten or misapplied.'[2]

'It is very beneficial when changing charts in busy waters where safety considerations dictate that the time could be better spent monitoring the ship's planned passage and traffic situation.'[2]

7. safety benefits and the removal of risk of human error. Several commentators highlighted direct safety benefits as follows:

'Because most of the inputting of courses etc. is automatic, there is much less risk of human error whilst inputting the route.'[2]

'The speed at which routes can be planned and modified, and then downloaded to printer and GPS receiver [as back-up in monitoring cross track error].'[2]

'It is easier to check the planned route for hazards by just scrolling along the track without having to physically pull out the next chart.'[2]

'Courses are automatically calculated so there is a much reduced risk of human error compared to the transfer of conventional passage plans to paper charts.'[2]

'Data concerning speed and course made good is available at the chart without having to consult different equipment for the information, thereby reducing workload on the navigator who is conning the vessel.'[2]

'[improved]...position fixing capability of a navigational watch manned by ill-trained, inefficient, fatigued, or poorly motivated navigators – unfortunately a very real and important consideration nowadays.'[2]

'The automatic application of known datum errors to WGS84 means that the risk [with paper charts] of the user forgetting to apply these corrections is eliminated.'[2]

8. limitations

8.1. *Backup.*

'Due to the nature of the equipment (both hardware and software), the possibility of failure exists, which is not the case with the paper chart. The provision of a back-up system does, however, overcome these problems.'[1]

The draft RCDS performance standard has allowed for this and requires that 'adequate back-up arrangements shall be provided to ensure safe navigation in case of RCDS failure'.

8.2. *Look Ahead.*

'Occasionally, look-ahead facility can be restrictive.'[1]

'The difficulties associated with portraying a large chart on a small screen...makes it time-consuming finding the 'out of immediate area' features of the chart you wish to examine.'[2]

The foregoing points can be solved by the chart viewing software, either through multiple chart windows (allowing small and large scale views to be displayed simultaneously), or by the system being capable of over-riding the normal vessel-centred display when necessary.

9. conclusions. A number of the points made in this paper relate to the general benefits of an electronic system over paper, rather than specifically to the use of RNCs, but without the necessary approvals, these users are unable to use RCDS to its fullest extent. And the vast majority of ship operators will not even purchase such systems, despite their benefits, whilst they are obliged to run full paper systems as well.

Those companies who are using RCDS are very positive about the safety and accuracy gains from using ARCS, and unanimous in their desire for the draft RCDS specification to be approved. Here are some comments in conclusion which pinpoint RCDS advantages:

'RCDS is a great aid to navigators in that it applies known errors, and given the automatic presentation of a reliable fix on a corrected chart display, will probably reduce the frequency of navigational error. This is an important point in an era when a large percentage of the world's navigators are insufficiently trained.'[2]

'RCDS is also an incredibly efficient time-saver for the navigator. Very few ships now are not under-manned in some respect and anything which reduces workload and fatigue of the navigator, and provides a more effective method of working, should be given very serious consideration.'[2]

'At present, the 300 paper charts carried on each of our ships have to be corrected manually. The ARCS charts on board the same ships, however, are corrected each week from an Update CD issued by the UK HO. Provided the Update CD is loaded into the computer, which can be documented and takes about five minutes, the ARCS charts are automatically corrected. Indeed, one can justly argue that ARCS is not just the equivalent, but better than the paper chart, since one is no longer relying on hard-pressed ship's officers to correct all their charts each week.'[6]

'It was widely assumed within all sectors of the maritime industry that once an electronic equivalent of the paper chart was available, equivalency would be measured in terms of any improvement which was provided by the newly developed system. I believe that all interested parties would agreed that the ARCS system, with back-up provision, is in all ways at least equal to the paper chart, with the exception of correction facilities which are in themselves a demonstrable improvement.'[1]

For myself, I would like warmly to thank the small, but growing, band of users who are providing such thoughtful real-time testing of RCDS and giving the shipping industry in general, and my company in particular, such valuable feedback. The resulting improvements in systems and understanding of RCDS are due to these pioneering companies whose input will benefit the entire industry in the longer term.

appendix – GLOSSARY OF TERMS AND DEFINITIONS RELATED TO ELECTRONIC CHARTING

ARCS *Admiralty Raster Chart Service* – the UK HO proprietary RNC.

ECDIS *Electronic Chart Display and Information System* – the performance standard for ECDIS approved by the IMO assembly in November 1995. The standards are defined in documents of the IHO and IEC: IHO Special Publication S-52 Provisional Specifications for Chart Content and Display of ECDIS; IHO Special Publication S-57 IHO Digital Data Transfer Standard; and IEC 1174 ECDIS Performance Standards. Note: The ECDIS standard is designed for use by vessels governed by SOLAS and requires data meeting the above standards which, at the time of writing (October 1997), is not commercially available.

ECS *Electronic Chart System* – a chart system which does not meet the requirements of SOLAS V/20 and is not defined by official standards.

ENC *Electronic Nautical Chart*.

EPFS *Electronic Position Fixing System* – GPS, Loran, Decca etc.

HCRF *Hydrographic Chart Raster Format* – this is the format developed by UK HO and used (at September 1997) by the UK HO for its Admiralty Raster Chart Service (ARCS) and the Australian HO for its Seafarer Chart Service. Other HOs are also expected to adopt HCRF.

IEC *International Electrotechnical Commission*.

IHO *International Hydrographic Organisation*.

IMO *International Maritime Organisation*.

NMEA *National Marine Electronics Association* – NMEA 0183 version 2·01 is the standard which is defined to permit the ready data communication between electronic marine instruments, navigation equipment and communications equipment when interconnected via an appropriate system.

RCDS *Raster Chart Display System* (*RCDS*) – means a navigation information system which can be accepted as complying with the paper version of the up-to-date chart required by regulation V/20 of the SOLAS Convention, by displaying RNCs, with position information from navigation sensors to assist the mariner in route planning and route monitoring and, if required, display additional navigation-related information. A draft performance standard for RCDS is being considered by IMO.

RNC *Raster Navigational Chart* – means a facsimile of a paper chart. Both the paper chart and the RNC are originated by, or distributed on the authority of, a government-authorised Hydrographic Office.

S-52 IHO standard which defines the presentation of chart data on an ECDIS display.

S-57 IHO standard which defines the chart data format (DX90) and encoding for ECDIS.

references

[1] Captain E. W. Lyons, Marine Superintendent, F. T. Everard & Sons Ltd (SOLAS I V Trial).

[2] Captain David Picking, Master of Euplecta, Shell International Trading and Shipping Company Ltd (SOLAS I V Trial).

[3] Captain S. K. Joshi, Marine Superintendent, Teekay Shipping (Canada) Ltd.

[4] Captain C. Clare, Master, Stena Line Ltd.

[5] Captain A. C. Humphreys, Senior Master, Stena Line Ltd.

[6] David Williams, Coastal Operations Manager, Shell (UK) Ltd.

key words

1. Sea. 2. Maps/Charts. 3. Electronics. 4. Displays.