Impact of Radar Integration with Electronic Charting

Helmut H. Lanziner
Canstar Navigation Inc.

When electronic charts were first introduced, there were many objections to the idea of incorporating radar imagery on the chart. This has changed significantly over the years. Today, most sophisticated charting systems, such as those classified as the Electronic Chart Display and Information Systems (ECDIS), have the ability to display radar information together with that of the chart. From the users' perspective, this combination offers a powerful tool providing safer and more efficient navigation. The benefits of combining chart and radar are far greater than the sum of the two parts, because they provide new insight and awareness of problems that were previously not so obvious. At the same time, they offer new solutions to old navigation problems that neither developers, nor users anticipated.

This paper outlines some early efforts to combine radar and chart information, together with lessons learned. It also deals with the discovery of enabling techniques that have made the integration of chart and radar technologies the marine navigation tool of the future.

Other radar-based technologies, which have emerged along with electronic chart development, are also briefly discussed. Apart from the direct integration with charting systems, these technologies also apply modern computer power to turn marine radar into a precise positioning tool.

Early Experiments

The idea of combining radar and chart information for the purpose of aiding in the interpretation of radar data during coastal navigation is not new. Experiments to modify navigation charts so that they could be optically projected onto a PPI (Plan Position Indicator) radar screen took place as early as 1949 (Satow, 1949). R. F. Hansford first conceived the concept of a Chart Comparison Unit (CCU) in an attempt to achieve positive identification by direct visual comparison of the chart with the echoes on the PPI (Dickson, 1952). There have also been attempts to modify charts by overprinting radar images to indicate radar prominent targets (Day, 1954).

In the mid 1980's, when the first sophisticated electronic charting systems arrived on the market, it became obvious that the integration of other navigation sensors was an important aspect of this new technology. One of the main elements in this concept is that the navigator no longer has to be concerned with the task of collecting information from a variety of sensors. Radar, in particular, the most significant navigation device in use, had to be considered. Logically, and from an ergonomics standpoint, it does not make much sense to display data on a number of independent screens, when the information can be shown more effectively on a single display. The ability to superimpose one picture on the other is much more effective than mentally comparing two side-by-side displays. In addition, the user may be looking at one screen, while missing significant information on another. The omission of critical sensor data during demanding navigational situations has the potential for disaster. Of course, there is always the argument about information overload, but this can be dealt with through selective means and innovative display concepts.

A problem in the early days was that low-cost computers were not available and accessible hardware was not powerful enough to handle radar data on the chart with adequate performance. Some early radar interface attempts turned out to be very expensive as there was limited processing capability. The presentation and manipulation of chart information requires a vastly greater capacity than that required for radar only.

The first attempt to combine chart and radar on a personal computer was initiated by Mortimer Rogoff of Navigation Sciences Inc. in 1983. M. Rogoff, a recognised pioneer in electronic chart development, probably has the right to be called the father of electronic charting. At the time, this was truly an ambitious undertaking, as processing power was lacking, chart data was not readily available and positioning with differential Loran-C, which Navigation Sciences Inc. offered as a positioning source, did not always provide the required position stability. However, the system, which included most of the essential features of the present ECDIS, was successfully demonstrated on a number of occasions.
The first official recognition of radar integration was provided by the Canadian Hydrographic Service "Electronic Chart Testbed" on the Norwegian "North Sea Project" of 1988.

Problems Revealed

Although at first it seems as if radar integration consists simply of adding another layer of information over the chart, experience has shown that, in order to do it correctly, a number of new factors had to be considered. The combined set of information demands that each be independently calibrated to a degree of accuracy previously not required. Both sets of data have to match perfectly on the screen to be of real value; otherwise it can result in confusion and lack of confidence, which will seriously impede the mariner's acceptance of this new technology. When applied correctly, radar overlay can bring a variety of existing problems, which are difficult to determine independently, to the immediate attention of ship's officers. Of course, whenever there is disagreement between two methods of observation, it is only natural to trust established tools and procedures before accepting any new technology.

Radar Range Errors

Offshore Systems Ltd. of Vancouver, Canada conducted an interesting demonstration of radar overlay of an electronic chart on the St. Lawrence River in 1988. During the demonstration, the radar image on the screen did not match the shoreline of the river. Although the river shoreline on both sides was steep and clearly radar conspicuous, the radar image overlay on the display appeared wider than the chart outline. After a brief analysis, the company's engineers assumed that there was a scaling error applied to the radar data within the system. In the end, it turned out that the time delay setting between the trigger and the return signal on the ship's radar was in error by 40 m. The interesting part about this observation is that the vessel's radar had been in operation like this for a long time and no one seemed aware of the problem until both sets of data were combined on a single display.

Ship's Heading Errors

In a similar fashion to that of range distance calibration, the radar image has to be perfectly aligned in rotation with the chart, even though the radar antenna may not be perfectly oriented along the axis of ownship. A related problem, which is due to lag in the gyrocompass, became obvious in 1990 on board the MV "*Joseph and Clara Smallwood*", a 27,614 GRT passenger ferry operating between Newfoundland and Nova Scotia, Canada. The combined chart/radar display brought a heading error of three and one-half degrees to the attention of the navigation crew (Heathcote et al, 1990). During the ferry crossing, this vessel would run at 18 knots for several hours until its arrival at the destination, Port aux Basques, in Newfoundland. Prior to docking, it had to come to a halt to execute a 180-degree turn so that it could be backed into the berth. Upon arrival at the dock, the display showed a mismatch of radar and chart, with the stern of the vessel overlapped onto the dock. After approximately 15 minutes, the display correctly showed a match of chart-to-radar and the vessel appeared perfectly aligned with the dock. The effect of rapid deceleration, together with a 180-degree rotation, resulted in significant temporary gyrocompass errors governed by the rate of both manoeuvres. However, after docking, a period of 15 minutes allowed the gyrocompass to precess to its correct heading relative to true North. Ship's officers stated that they were not previously aware of the magnitude of this error until they saw it on the combined chart/radar/ownship display. Under normal operating conditions, the gyrocompass phenomenon does not create a problem for this vessel, since the turnaround takes longer than 15 minutes due to discharging of passengers and vehicles, as well as loading. Nevertheless, these vessels operate in some of the worst weather conditions and in reduced visibility conditions. They rely heavily on the accuracy of the gyrocompass upon departure from the berth at Port aux Basques. During this departure, while accelerating, a critical course change is required less than two ship's lengths from the dock in order to clear a narrow, rocky passage leading out of the harbour. In an emergency situation, when a quick turnaround might be required with less than 15-minutes in duration in the presence of the frequent Newfoundland fog, a considerable correction has to be applied to the compass heading. This problem occurs on all vessels to varying degrees whenever turns are executed during normal operations. Depending on the situation, there may not be an easy way to check this without the overlay.

Position and Chart Datum Errors

One of the problems that became apparent early on was that of horizontal chart datum errors. When the radar image appeared offset to one side, while overlaid on the chart, it was first assumed to be a position error. Further investigation would sometimes result in the discovery of a chart datum error of significant proportions. Even ports that were frequented by bulk carriers on a regular basis showed datum offsets in excess of 80 m.

A further problem is that in pre-GPS days the hydrographer could always be confident that he had a more accurate positioning system than the mariner and that the mariner would give hazards a wide enough berth to avoid any danger of grounding. Consequently, less effort was spent on examining areas close to hazards than is required now that the DGPS/ECDIS combination has given the mariner the same navigation capability as the hydrographer.

Here again, one has to assume that hydrographic authorities responsible for these charts were not aware of these problems, or they would have corrected the errors. In most cases, the large scale remedy of these problems through re-surveys and other means did not begin until complaints from electronic chart users in the marine industry commenced. On the other hand, the use of paper charts, which were the source documents for electronic charts in most cases, did not pose a problem due to the manner in which they were utilised. Electronic charting, together with radar overlay, revealed a number of chart related problems over the years.

Benefits Revealed

The problems mentioned are only representative of a larger list of findings. It is also important to point out that the incidents referenced did not occur in isolation. Over the years, manufacturers and national hydrographic offices have learned to deal with most of them. The result is an improved and more accurate operational environment. During this period of experimentation, it became apparent that this new integration of technologies offered other significant benefits, which were not necessarily planned at the design stage of these systems.

Position Confidence

One of the greatest benefits of combining radar imagery with electronic charts in confined waters is a significantly increased confidence level in ownship position. Since radar information and ship's position come from different sources, it is difficult to imagine a close correlation of the two sets of information unless they truly represent the actual position of ownship [Figure1]. However, care has to be exercised and there should be an understanding of the process in situations where a good match may not be possible due to low terrain, ice or changes in water levels. In cases where they do not match due to chart or position errors, a chart-offset utility within the system allows the user to align the two sets of data to correct ownship position and to accurately determine the magnitude of these errors.

Radar overlay is not a replacement for the ship's radar. It offers an entirely new element to the position determination process. Never before has the mariner had the kind of information available, which permits reliable position checking at-a-glance. This increased level of confidence results in reduced stress for the navigator. Reduction in bridge workload was an important finding reported in the results of both Bridge Simulator experiments and at-sea trials conducted at the U.S. Merchant Marine Academy at Kings Point, New York in conjunction with the U.S. ECDIS Test and Evaluation Program (Gonin et al, 1994).

No Longer Committing Charts to Memory

During piloting or navigation operations, the advantage of a combination chart/radar over stand-alone marine radar is quickly recognised. The common practice of fixing positions by laying off bearings from the ship's radar for transfer to the paper chart always requires carrying a mental picture of the chart to the radar screen. This was also recognised a long time ago. In his presentation, J. Home Dickson addressed this issue: "In many instances, however, the pilot will con the ship directly from the PPI, using his local knowledge, which is equivalent to using a chart impressed on his mind" (Dickson, 1952). Specific points on the radar image have to be identified and correlated with the chart for the transfer process to make any sense. Without such identification, the radar image is of no value as a positioning source. Looking at this closely, it seems that memorising chart features for correlation with the radar image and then transferring range and bearing information from the radar back to the chart is a poor and error prone way to do it, when it is possible to present the two in a common scale on a single display in the first place.

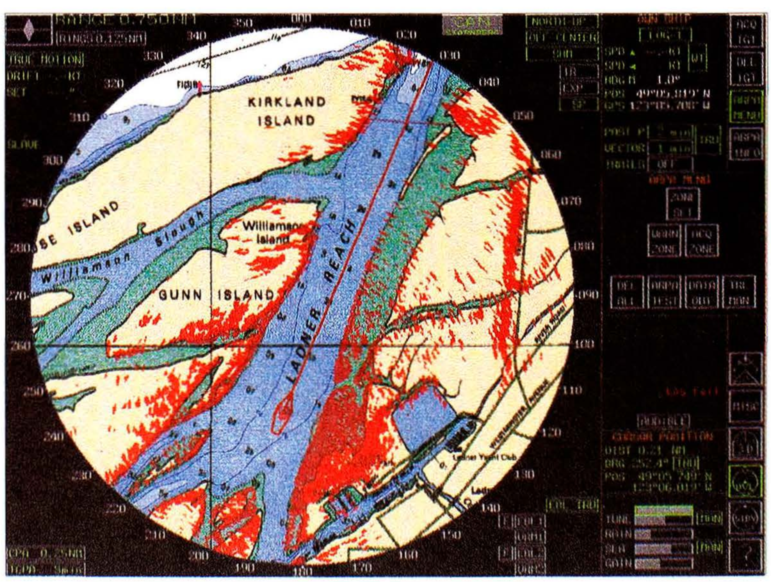

Figure 1: *Close "match" of chart and radar image (red) translates to accurate position as well as correct chart information. Position shown on the chart is determined by satellite positioning, while the radar image stems from echo returns relative to ownship*

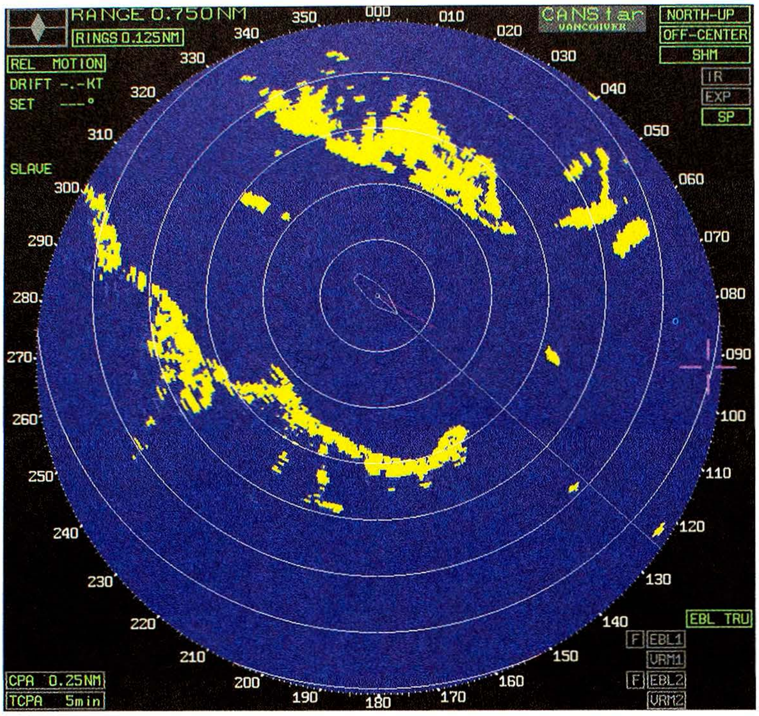

Figure 2a: *This radar image shows well-defined echoes from shore, but it does not provide information on shoal waters. With the radar image alone, the identity of three small radar targets ahead of ownship is not immediately clear*

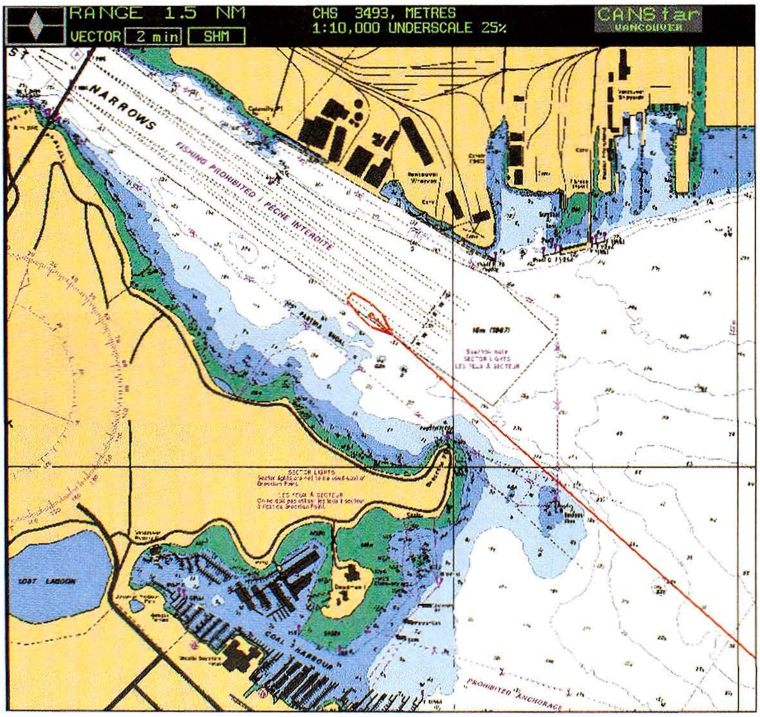

Figure 2b: *When switching to the chart mode, the relationship to shoal waters is clear, but without the benefit of viewing the relationship to other traffic*

Of course, radar manufacturers came to this conclusion some time ago, which is evidenced by the chart-like features usually shown on ARPA (Automatic Radar Plotting Aid) displays. Unfortunately, most of these charts are not detailed enough to allow replacement of the paper chart. However, it could be argued that not all radar information (video) is required on electronic charts and that ARPA information, with the inclu-

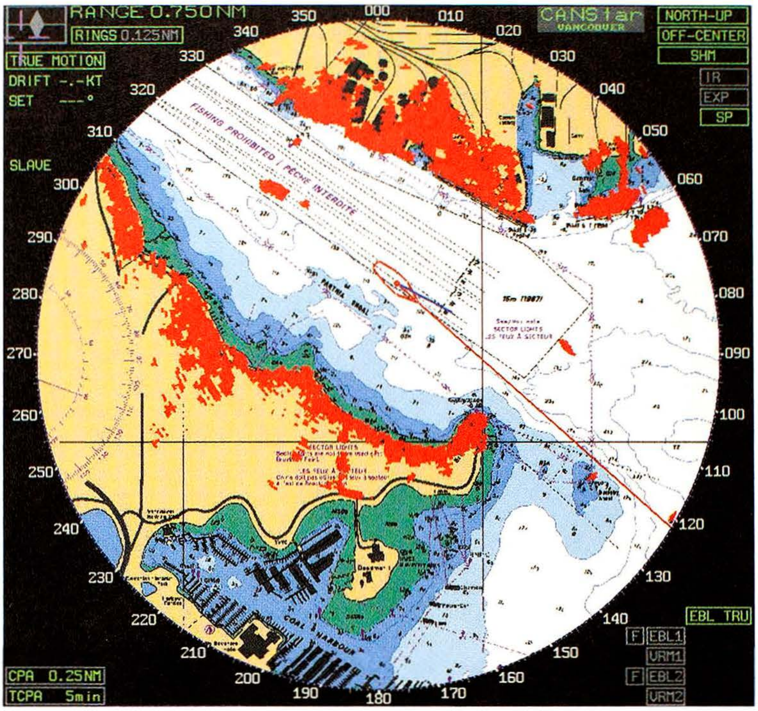

Figure 2c: *The chart with radar overlay (red) shows the relationship to all surrounding hazards. It also assists in the interpretation of the three small targets ahead. The one just to starboard of the heading line is clearly that of a fixed aid to navigation, while the two on the port side are most likely small craft*

sion of key landmarks, is sufficient to aid in chart alignment. But simulator tests have shown that "A-less-than-complete radar overlay on ECDIS is potentially unsafe as it may reduce the watchstander's attention to the more capable radar/ARPA displays on the bridge" (Gonin et al, 1993).

Reducing the Number of Displays

The watchstander's attention problem is rooted in the fact that more than one display has to be monitored. Officers, who routinely operate ECDIS without a radar overlay in reduced visibility conditions, have expressed serious concerns about the fact that the ship's radar sometimes does not get the attention it should, due to the fact that they are concentrating on the ECDIS display during difficult maneuvres in shoal waters.

Improved Radar Interpretation

The proficient operation of stand-alone marine radar requires a significant amount of training and experience. The operator must fully understand how the interaction of controls affects displayed information, particularly during inclement weather. Yet, many serious marine accidents are due to misinterpretation of radar (is that small echo a buoy or a yacht, is that faint line the coast line or the ice edge?).

With the use of stand-alone radar operating in rivers and harbour approaches during poor weather and visibility conditions, there is a strong reliance on the skill of the operator to be able to interpret the radar image correctly. Geographic features often appear quite different and almost unrecognisable on the radar when compared to the chart. In the presentation "Radar Chart-matching Devices" (Dickson, 1952), it states: "In such cases it is necessary to identify immediately and unambiguously the PPI paints (*PPI is explained previously under 'Early experiments*) [radar video], which often bear little resemblance to the shape on the chart of the feature which is producing the echo". This is usually due to projections at higher elevations close to the radar, which are causing shadowing of low terrain features behind. In unfamiliar waters, a situation like this leads to time delays, which cause increased stress with the potential of misinterpretation. When combining chart and radar images, data missing on the radar image are "filled-in" by chart features, which makes it easy to confirm a "match".

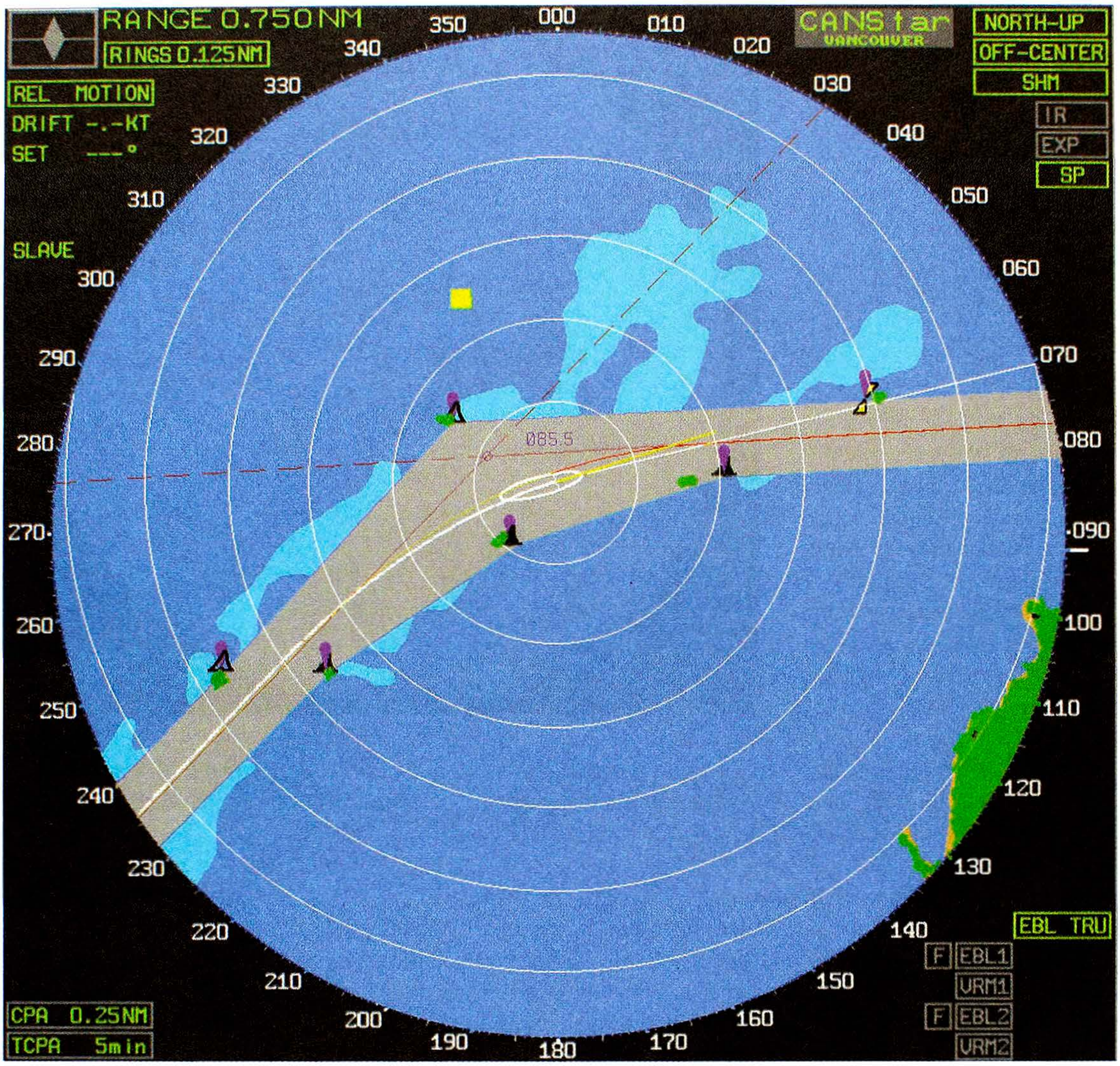

Figure 3: *Buoy position verification is easy when chart symbol positions coincide with that of radar echoes (green)*

In view of the fact that the vertical beam pattern of marine radar is relatively wide (20+ degrees), it is impossible, for example, to tell if radar echoes originate from radar reflectors attached to overhead power lines or from obstructions on the water. Looking ahead on the ship's radar screen without visual confirmation, such contacts have to be taken seriously. On a charting system with radar overlay, the picture becomes very clear when the radar image coincides with the power line shown on the chart.

During river navigation at night, one of the most serious concerns for vessels of all sizes is the presence of small isolated radar contacts. The mariner's predicament is always the ability to determine if it is a moving small craft, some other obstruction on the water, or an aid to navigation. Radar overlay usually answers this question immediately, when the display shows the position of the radar contact overlaid on a charted floating aid symbol [Figures 2a, 2b, 2c & 3].

Buoy Position Verification

Using the buoy identification feature in a different way, it has the additional benefit of being able to easily and quickly verify the correct position of floating aids to navigation without the requirement of coming alongside the aid. Discrepancies may arise during buoy replacement, or even between the buoy's position on the

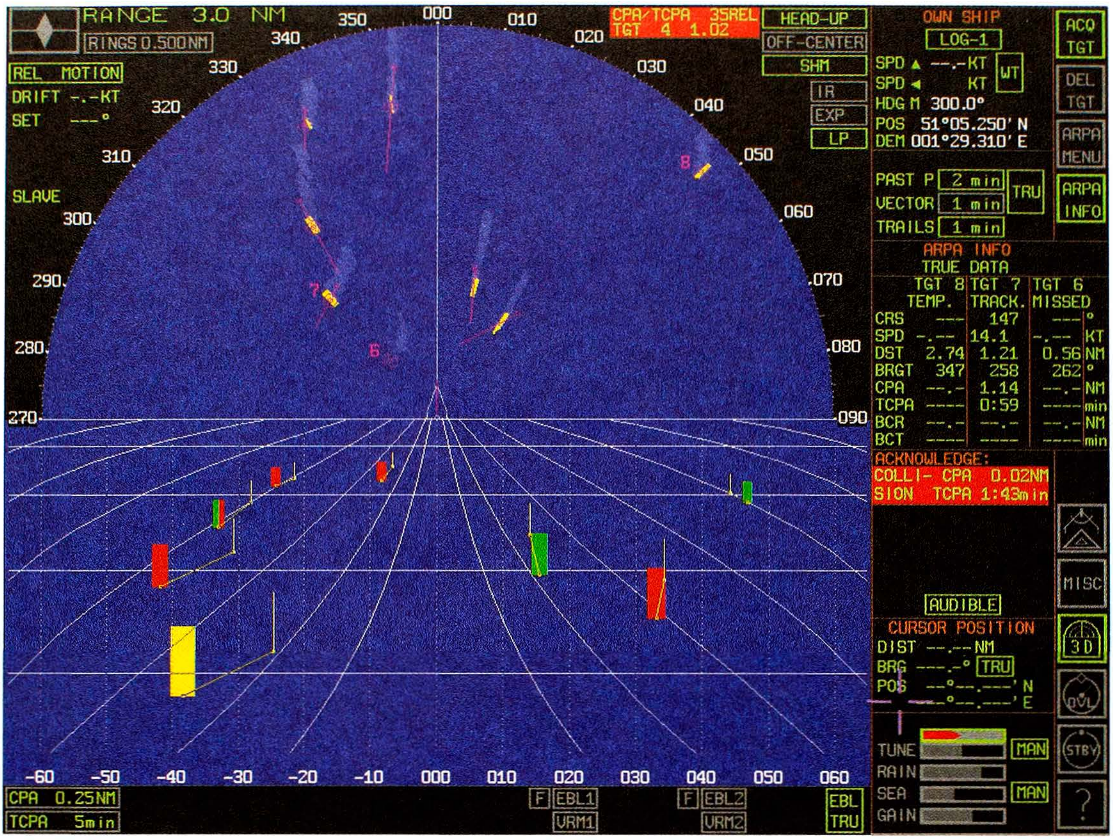

Figure 4: *The top half of this screen is presented in the standard radar/ARPA mode (yellow), while the bottom half shows a perspective view of the traffic ahead. Ownship is presumed to be centered at the very bottom*

flood and ebb tidal streams when the chart is displayed at large scale. As part of this process, the mariner is again able to measure the distance between the charted and the radar-determined position of the buoy and, through the use of a charting utility, place a temporary symbol on the buoy's actual position. This is particularly useful to organisations maintaining such aids, and to vessels that rely on them [Figure 3].

Combining Collision Avoidance with Grounding Avoidance

Most serious marine accidents involving large vessels are the result of collisions or groundings. Automatic collision avoidance with radar/ARPA has been in use for many years. Yet, effective automated grounding avoidance came into being only with the advent of electronic charting technology. The logical "next step" is to combine the two technologies. Although the advantages and disadvantages of electronic charts and radar/ARPA integration were at one time somewhat controversial, this matter was thoroughly investigated by Deutsche Gesellschaft für Ortung und Navigation E.V. (DGON) Germany. In 1993, DGON conducted a comprehensive study on "Superimposition of ECDIS and radar/ARPA" (Deutsche Gesellschaft, 1993). The results of the investigation clearly indicated when ECDIS and radar/ARPA are superimposed, they form a single system that can be used both as a primary navigation system and as a primary collision avoidance system. The ability to show chart related hazards below the water's surface, together with moving traffic on top of the water –all on the same display– provides ship's masters the ability to determine an optimum safe path for both collision and grounding avoidance.

Often, it is important to determine the location/movement of vessels in terms of their geographic location. Many decisions related to collision avoidance are associated with both ownship and the other vessels' location in the channel or proximity to shoal waters.

Information Overload

Finally, valid concerns have been raised about information overload when combining radar and chart information graphically. Although the ultimate, practical display configuration has yet to be confirmed through user feedback, experience has shown that the user does not want to go back to getting the total picture from separate radar and chart displays. In the classic radar overlay presentation, where the radar image is opaquely superimposed on top of the chart, one of the problems has to do with radar video colour. For example, the International Hydrographic Organisation (IHO) Colour and Symbol Specifications assigned the colour green for not only radar/ARPA, but also for buoys and light sectors. In addition, there is concern that radar overlay will obscure essential chart information. After bridge simulator trials in 1992, to evaluate the use of electronic charts with radar overlay, "Several mariners suggested that the extent of the radar overlay, complete video or ARPA targets only, should be user selectable" (Akerstrom-Hoffman et al, 1993). However, a variety of presentation methods have demonstrated that neither radar nor chart information needs to be obscured. A number of different ideas have been successfully implemented.

- Rather than limiting the display to a standard plan view, ARPA information is also presentable in an isometric mode, whereby the top half of the screen is in the plan view, while the bottom half displays the contacts being tracked as seen through the ship's window. Vessels up close appear larger than the ones at a distance and colours are used to simulate running light colours [Figure 4].

- Some companies are using a method whereby only radar imagery over water is visible, while video beyond the shoreline is underlaid or masked by topographic features. This way it is still possible to match chart and radar images without concealing shore based chart features. However in this scheme, some chart information on the water, such as a floating aid to navigation, could still be masked by radar video.

- Another technique, which has been used successfully, shows radar video translucently, so nothing on either information set is lost. With an adjustable level of translucency, this method can provide an acceptable display under any condition, regardless of the amount of chart or radar information. Settings can be varied in fine increments from a totally opaque image to nearly full transparency [see Figure 5]. (However, the mariner must beware of losing small targets at high transparency settings).

- It depends on navigational circumstances whether radar or chart information should take priority. For this reason, and for the purpose of providing the most flexible option, one method has been introduced

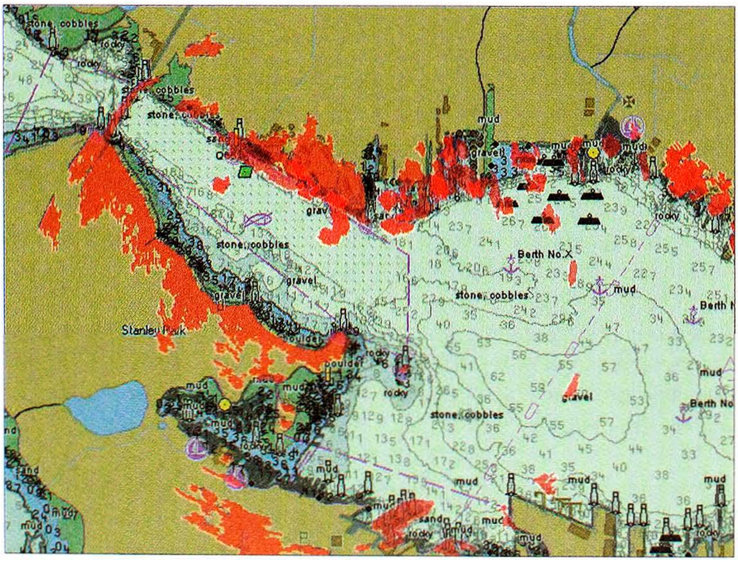

Figure 5: *Radar transparency (red) makes it possible to have an unobscured view of both sets of information*

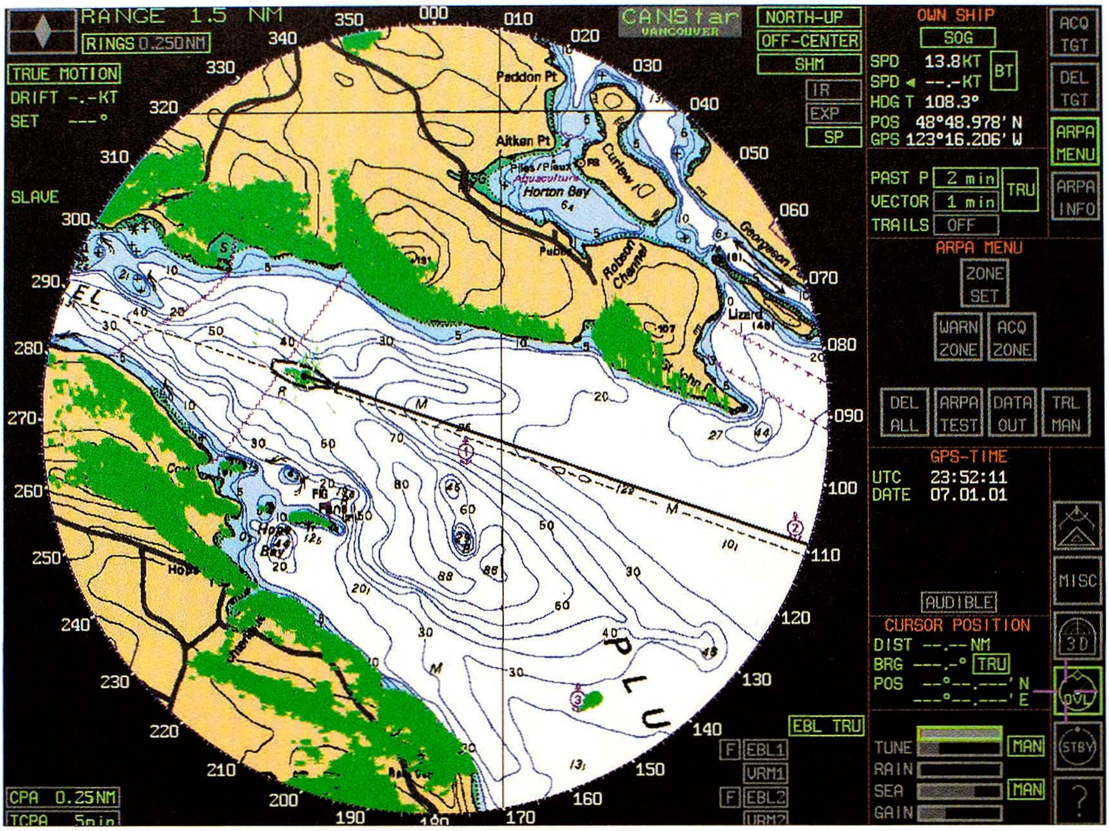

Figure 6a: *Some raster charts have numerous, heavy contour lines, causing a lot of clutter on the display, which could make it difficult to detect small radar targets (green)*

that allows the user to adjust translucency on the radar image, as well as the display intensity on the chart, in order to put emphasis on the radar. This intensity adjustment ranges from full chart display level to total background darkness [Figures 6a & 6b].

- Multi-windowing is an effective way to show radar independently from a radar/chart combination, although this necessitates displaying each window at a reduced scale as it requires sharing of the total screen area.

- An alternate method to multi-windowing is the sequential selection of chart-only, radar-only and chart-with-radar-overlay activated by single keystrokes. In this mode of operation, it is important that alarm-monitoring functions stay active in the background for chart and radar, regardless of the information shown on the display.

During the early days of electronic charting, graphics technology was limited to relatively simple displays, which did not permit a lot of necessary display innovation. The last decade has seen incredible advances in computer graphics, making it possible to meet today's stringent display requirements.

Radar Positioning, AIS and Other Applications

Universal Automatic Identification System (UAIS)

UAIS, or AIS, *is* a concept, similar to that used in air traffic control, whereby all participating vessels (or aircraft) are equipped with a transponder, which automatically provides detailed ship data to other AIS equipped shore stations, ships and aircraft, including safety related information. It includes ship's identity, type, posi-

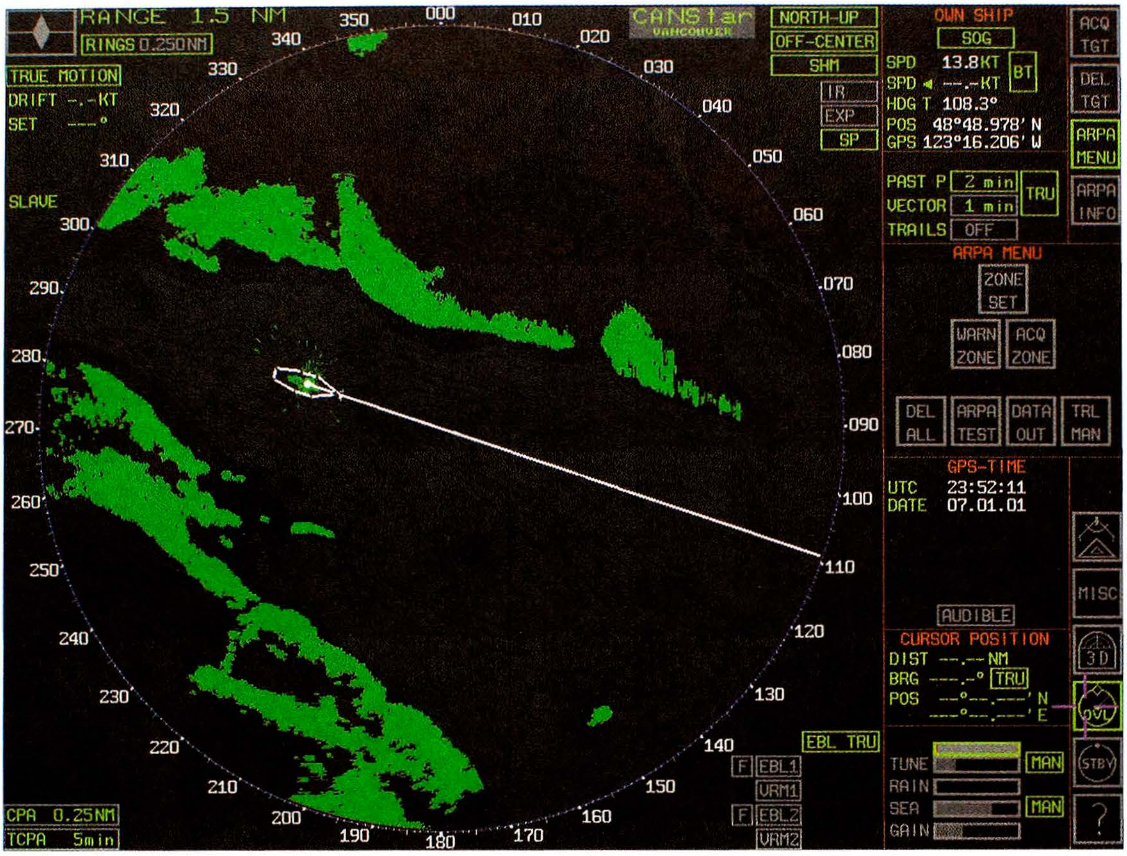

Figure 6b: *By providing separate display intensities for chart and radar (green), charts with the appearance of a lot of clutter can be displayed at reduced intensities. This is also an option where radar information must take priority*

tion, course, speed, and navigational status. It also includes the monitoring and tracking of ships in addition to exchanging data with shore based facilities. AIS will be mandatory for some SOLAS (Safety Of Life At Sea) vessels beginning in 2002 and for all SOLAS vessels by 2008. An early version of AIS, referred to as Automated Dependent Surveillance System (ADSS) was tested and implemented in Prince William Sound, Alaska in the early to mid 1990s (Radice et al, 1993). In investigating the grounding of the tankship Exxon Valdez, the National Transportation Safety Board (NTSB) in the United States recommended that such technologies would be required in order for the U.S. Coast Guard to provide a Vessel Traffic Service for Prince William Sound commensurate with the nature of the maritime commerce which exists there (NTSB, 1990). The mandatory installation of AIS on SOLAS vessels will have a major impact on all types of vessels, in terms of how navigation and collision avoidance information will be viewed.

Although AIS is not directly linked to radar or electronic charting systems, the only effective way to display AIS information is in conjunction with radar/ARPA and either ECDIS or ECS.

AIS consists of ship–to–shore/shore-to-ship and ship–to–ship communication, which provides a number of services, including the following:
- Ship–to–shore: Fleet Tracking, Asset Management, Silent reporting.
- Ship–to–shore/shore–to-ship: Vessel Traffic Services (VTS), Vessel Traffic Control (VTC), Surveillance and monitoring, Information dissemination.
- Ship–to–ship: Navigation information exchange. From the mariner's perspective, it permits locating and accurately tracking other marine traffic in relation to ownship where a direct path via radar and visual means may be obstructed.

The major drawback with AIS, and certainly with the more expensive UAIS, is cost. Smaller vessels will not be able to afford participation in this scheme, particularly recreational boats, until an affordable concept emerges. The interesting part about AIS is that, for the most part, large vessels do not cause unforeseen problems for other major vessels. Professional mariners man these ships, with full knowledge of navigation rules and regulations, and where applicable, of international rules. One can also assume that these experienced professionals generally follow the rules. In most cases, the problem stems from smaller, non-participating vessels made up of predominantly recreational boats that are causing the more serious obstructions for large ships in rivers, harbours and harbour approaches. They are usually not operated by professionals, which often means that they do not know the rules and consequently, they do not follow them! This means the true benefits of AIS will not be realised until vessels of all classes are able to participate.

Radar Video Broadcast

A interesting project called RATAN (Radar And Television Aid to Navigation) was launched in New York City in 1961-1962 to demonstrate the use of a television broadcast of radar images of the harbour, which originated at the Vessel Traffic Services (VTS) center, to any vessel large or small (Dean, 1962). These broadcasts were transmitted on an unused broadcast channel for delivery to all vessels equipped with an inexpensive television receiver. The most important aspect of this concept is the fact that it offers a birds-eye-view of all moving traffic covered by VTS radar to all non-participating recreational boats that may not even have radar, as well as vessels outfitted with AIS. A modern day RATAN would have a number of significant benefits over the 1961 experiment, since the radar imagery could be combined with electronic charts and other enhancements prior to the broadcast, which would make the task of interpretation and ownship identification a lot easier.

IALA and the IHO have since worked on procedures for overlaying VTS information on ECDIS.

Radar Positioning – Pattern Recognition

As soon as the general-purpose electronic digital computer became a practical, reliable device, it was thought that it would soon be programmed to achieve pattern recognition. Unfortunately, electronic recognition systems of this type are progressing at a much slower pace than scientists ever imagined. Advances in digital signal processing during the 1980s resulted in the emergence of a number of objective pattern-recognition based endeavors designed to determine ownship's position through an automated chart-to-radar matching process. Essentially, this concept is based on first establishing a database of radar imagery during repeat transits and then comparing and matching this data with the chart. There are two major challenges in this approach. The first is to determine if required position accuracies are achievable from images of land clutter by comparison with a digital map obtained from charts. The second is the problem of navigating from radar images that are stored in the computer from earlier voyages through the same region (Austin et al, 1985). With this approach, an extraordinary level of processing power is required even under ordinary conditions. In addition, the radar image is strongly affected by water level changes, such as tidal fluctuations, as well as ice build-up, which present considerable problems.

Radar Positioning – Passive Reflectors

The most successful application of radar as a positioning tool was demonstrated in the late 1980s, spanning into the mid 1990s. A system called *Radarfix*, which was developed for the purpose of establishing ownship position in a dynamic environment, takes advantage of existing conspicuous radar reflectors, such as buildings, towers and fixed aids to navigation, rather than coping with the entire radar image. Through the application of sophisticated proprietary image processing techniques on individual areas of interest, this system is capable of differentiating specific radar targets in the presence of strong surrounding radar clutter. System performance depends on the number and shape of radar prominent features, as well as the size and geometry of the operating environment. In order to remove any ambiguities concerning its operation, particularly in surroundings with scarce and unsuitable radar targets, the prospect of combining this system with special purpose-built, passive reflectors was investigated by Offshore Systems Ltd. The addition of trihedral corner reflectors has major benefits. The most significant is that the system is able to perform optimally in any environment, because position and the number of reflectors is chosen as required. Corner reflectors inherently yield very high radar cross sections relative to their size and, due to their structure, they form a reflective point source, which is desirable for use as a position reference. In order to obtain even higher target discrimination, polarisation diversity was employed, by modifying the linearly (horizontal) polarised marine radar antenna to circular polarisation and with the addition of a "twist-grid" in the reflectors. The resulting effect is a vastly improved ability to detect these "co-operative" radar reflectors in a strong background clutter environment. After the initial development, the system was first tested and evaluated in the St. Lawrence River in 1990, with support from Transport Canada and the Canadian Coast Guard under the project name RANAV (Radar-Assisted Precise Navigation). During these trials, position accuracy in static conditions, expressed at the 95% confidence level (2-sigma), was found to be 2.5 meters (Transport Canada, 1992). Later trials conducted by Canadian Coast Guard found the system well suited for buoy positioning operations. After the first operational trials in 1989 on the East Coast of Canada, on board the cargo ferry *MV Atlantic Freighter*, the system was installed on the *MV Joseph and Clara Smallwood* in 1990, where it was used for many years in an all-weather operation, particularly for harbour navigation and docking in two different ports with challenging approaches. The passive polarimetric reflectors are constructed of corrosion resistant aluminium and require little maintenance. Nevertheless, it was decided in 1997 to replace them with the Differential Global Positioning System (DGPS), which was by then fully operational and did not require any shore-based maintenance at all. Another unique aspect of RANAV is that ownship's orientation in relationship to the reflector network is known within 0.2 degrees and the system, unlike the gyrocompass, is not affected by lag. Ships docking with RANAV would have the benefit of a display, which presents the true relationship to the berth instantaneously, as the vessel manoeuvres alongside. An updated version of the concept of radar positioning could offer a totally independent position and heading backup in confined water operations where GPS and DGPS have proven to be unreliable due to blockage of satellites by tall buildings or steep slopes, as well as weather conditions and radio interference and where position reliability and heading accuracy is critical.

Conclusion

Experience over the last few years has shown that mariners in general prefer radar overlay on the chart, rather than charting alone, for the many reasons already stated which include:

- having radar and chart on one screen avoids replacing a collision with a grounding, or vice versa.
- Errors in own-ship position immediately become evident.
- Chart errors and datum errors also become evident.
- Radar interpretation is aided.
- Problems such as the significant gyro errors encountered on changing course after a long straight run become recognised.

Virtually all of the Great Lakes bulk carriers, that initially purchased electronic charting systems and rejected radar image overlay, had this feature retrofitted on their vessels later. Similarly, all of U.S. Coast Guard's new "Juniper" and "Keeper" class buoy tenders now have radar overlay capability, although the first of these ships did not have this feature included. At the same time, it is also clear now that the mariner does not want to operate without an independent, familiar marine radar display. It will be interesting to see how this plays out once all radar and electronic chart systems are offered in a common housing with dual purpose controls, and when these multi-purpose consoles allow instant inter switching from "radar" to "electronic chart" or an "electronic chart with radar overlay" combination.

It was relatively easy for the commercial user to recognise the advantages of a chart/radar combination through the use of these systems under difficult conditions. On the other hand, the recreational boater, who is becoming very much aware of radar overlay, usually cannot afford systems which offers such features. This also applies to the smaller commercial vessels. Nevertheless, recent years have shown a shift of marine navigation technology from expensive commercial hardware toward inexpensive personal computer based platforms. Some of the modern consumer navigation technology now displays capabilities, such as electronic charts with radar overlay, including full radar functionality and ARPA, that were reserved for only the most sophisticated of the big-ship systems just a few years ago.

References

Akerstrom-Hoffman, Robin A., Myriam Witkin Smith, Steven I. Siegel, Todd E. Schreiber, Carmine M. Pizzariello, Irene M.Gonin (1993) "*A Closer Look at Mariners' Use of Electronic Chart Display and Information Systems (ECDIS)*", ECDIS '93 Baltimore, Maryland, March 8-9.

Austin, G.L., A. Bellon, M. Riley and E. Ballentyne (1985) "*Navigation by Computer Processing of Marine Radar Images*", The Journal of Navigation, No.3.

Day, Sir A. (1954) "*PPI Pictures on Charts*", The Journal of Navigation, No.7.

Dean, Ralph D. (1962) "*An Introduction to Ratan*", Coast Guard Engineers Digest No.134, May-June, pp. 28-32

Deutsche Gesellschaft für Ortung und Navigation E.V. (1993) "*Superimposition of ECDIS and Radar/ARPA, Version 2*", Hamburg, Germany, April 2.

Dickson, J. Home (1952) "*Radar Chart-matching Devices*", Ordinary Meeting of the Nautical Institute, Royal Geographical Society, May 16.

Gonin, I.M., M.W. Smith, R.M. Akerstrom-Hoffman, S. Siegel and C.M. Pizzariello (1993) "*Human Factors Evaluation of Electronic Chart Display and Information Systems (ECDIS)", The Institute of Navigation, 'Evolution Through Integration of Current and Emerging Systems'*, January 20-22, 1993.

Gonin, I.M. and M.K. Dowd (1994) "*At-Sea Evaluation of ECDIS*". Proceedings: Institute of Navigation, National Technical Meeting, January 25.

Heathcote, Peter, D.R. Williams, Capt. John M. Taylor (1990) "*The Use of Precise Integrated Navigation System (PINS) in Marine Atlantic*", Seaways, The Nautical Institute, November.

NTSB (1990)" *Marine Accident Report – Grounding of the U.S. Tankship EXXON VALDEZ on Bligh Reef, Prince William Sound, Alaska, March 24, 1989*".

Radice, J.T. and W.R. Cairns (1993) "*The Prince William Sound Automated Dependent Surveillance System", May 5.*

Satow, P.G. (1949) "*Charts and Chart Matching Devices*", The Journal of Navigation No.2, 125.

Transport Canada (1992) "*Performance Evaluation and Demonstration of the RANAV (Radar-Assisted Precise Navigation) System in the St. Lawrence River*", Transportation Development Centre, Transport Canada, TP11326E, April.

Biography

Mr. Lanziner is the Chairman and Founder of the Canstar Navigation Inc. He is actively involved in product planning and development of personal computer based radar/charting systems, for he has an in-depth knowledge of Electronic Charting, including ECDIS. For the last eight years, he has been directly involved in setting ECDIS standards through his advisory role as a member of the Canadian delegation to the IMO/IHO in the development of international standards. He developed the use of polarised radar returns for precise navigation.

As founder of Offshore Systems Ltd., Mr. Lanziner pioneered the development of the first electronic chart system in the Canadian Arctic in 1979. He has over thirty years experience in precise navigation, ranging from vessel docking to drill-ship positioning and intimately understands customer requirements in marine navigation. At a time when electronic charts were more a concept than a reality, Mr. Lanziner championed the use of these early systems to navigate ships through narrowly dredged channels in the Canadian Beaufort Sea.

Mr. Lanziner is recognised internationally for his expertise, and has been sought out for his advice by Government and industry alike. He contributed to making Canada a leading nation in electronic charts.