# New generation of Electronic Card Systems:
# The 4-D Card

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## Context

In the present context of globalization and competitiveness, it is essential for the players in the marine domain to exploit in a durable and optimal manner the possibilities offered by shared waterways. To this end, it is essential to maximize transportation capacity while at the same time minimizing the accompanying risks. It is then absolutely necessary to provide access to all the pertinent information in an adequate format to the users and managers of this waterway.

Let us mention three facts. First, with the introduction of new navigation equipment, such as the DGPS, AIS, and the electronic card, the navigator is much better equipped than he was 10 years ago. Next, it is important to note that much progress has also been made with regards to data acquisition useful to navigation. We have only to consider the use of multibeam sounders in bathymetry, the modeling of marine currents, the studies on the dynamic sinking of vessels, etc. Finally, one must take into consideration the fact that the computers now available on the market are by far much more powerful than those used at the time of the implementation of electronic card systems aboard ships.

These facts lead us to make the following observations: navigators utilize electronic card systems similar to those first introduced on the market, technical advances permit access to information that did not exist at the time these electronic card systems became available, and that the computers currently available on the market allow this information to be processed and displayed adequately on a system of electronic cards.

These observations have led to the development of applications that allow us to utilize information provided by the new technologies via electronic card systems. These applications offer the navigator in a work situation more powerful tools than those currently available. It is thus possible for him to optimize the transit of vessels in navigable waterways.

## Problematic

The majority of the estuaries are affected by the phenomenon of tides. This creates cyclic variations in the currents and water levels. These cyclic variations will significantly alter transit in two ways. First, the currents will directly affect the speed of the ship, thus making it difficult to estimate its times of transit and arrival. Next, the variation in water levels affects the keel clearance of the vessel, and in this way restrains its draft or its speed.

The interaction of the currents, the variation in water level, and the bathymetry renders planning the optimal voyage using a conventional electronic card extremely difficult. Given the available means, the navigator who attempts to do so comes face to face with a type of puzzle that can only be solved adequately through intuition by experienced pilots.

The St. Lawrence River is confronted with this problematic, since downstream from Trois-Rivières it is the tides that dominate. Note that the currents as much as the water levels are dependent on the tides, and that to this is added navigation zones of limited depths. If we take into consideration all the operational implications (draft, dynamic sinking, ETA, etc.), it is evident that the currently available navigation systems do not permit planning an optimal voyage.

## The approach

The electronic card systems allow navigators to control well the positioning of the vessel in a two dimensional system, i.e., in latitude and in longitude (x, y) in real time. With the utilization of the applications developed, the same system allows positioning the vessel in four dimensions, i.e., in addition to the latitude and longitude it is possible to have the keel clearance (z) for a precise moment (t). In short, we pass from a system (x, y) to a system (x, y, z, t). Note that in integrating the time dimension, the system permits planning the voyage by simulation.

### *Model for calculating the dynamic speed (t)*

To arrive at planning an optimal voyage, the first input to control is the movement of the vessel, i.e., its speed over the bottom. This speed includes the vessel's own speed (speed on the water) as well as the current (movement of the water) that affect it. In short, this is the speed of the vessel relative to the ground. To this end, one must obtain the vessel's own speed as well as the current that affects it in real and projected time.

Based on the AIS data of a vessel, it is possible to obtain its speed over the bottom. It is also possible to obtain the actual and projected tide current using mathematical models. Since the vessel normally maintains its own speed during transit, knowing the planned transit it is possible by adding the vector current dynamically to obtain the speed over the bottom for the complete transit, and thus predict precisely the transit and arrival times.

The manner in which the application was developed for the calculation of the times of transit and arrival is based on three operations. The first consists in having the planned transit of the vessel (course and change of course). In the channels, since in the absence of particular circumstances the vessels proceed in confined waters, they follow the same courses and carry out the same transit.

The second operation consists in obtaining the vessel's own speed, i.e., without the effects of current. Using the AIS data, it is possible to determine the vessel's speed relative to the ground for a precise segment and at a precise time. By modelling the current, it is also possible to obtain the existing current over this segment at that moment. It then suffices to calculate the vessels own speed. Since (absent particular circumstances) the vessel proceeds at constant propulsion power, the vessel's own speed (on the water) remains constant all along the transit. In this way we obtain the vessel's own speed for the transit.

The third operation consists in obtaining the tide currents. As far as the St. Lawrence is concerned, the currents are available from the Canadian Hydrographic Service. It is also possible to use modelling for other waterways. Finally, the last step consists of integrating the vessel's own speed over a known distance over which we apply the anticipated currents for a time of departure with an incremental calculation.

In this way we obtain a dynamic calculation model that allows us to determine the hour of passage of the vessel at any point on the transit. An application was generated from this model that allows the hour of passage of the vessel at all points on the transit to be determined using an electronic card system.

### *Keel clearance (z) calculation model*

With the present electronic card system, the dimension depth (z) is indicated statically as a minimal water depth for a zone. What is important to the navigator is not the minimal depth relative to the level zero of the card, but rather the keel clearance of his ship. In order to optimize planning a transit in confined waters, it is necessary to have all the information on the keel clearance of the ship. To obtain the keel clearance, one must first have the depth of water at a precise place and time. Afterwards, this depth is used to deduce the draft of the vessel and the dynamic sinking.

$$Nuk = \left(De + Wl\right) - \left(Dr + Sq\right)$$

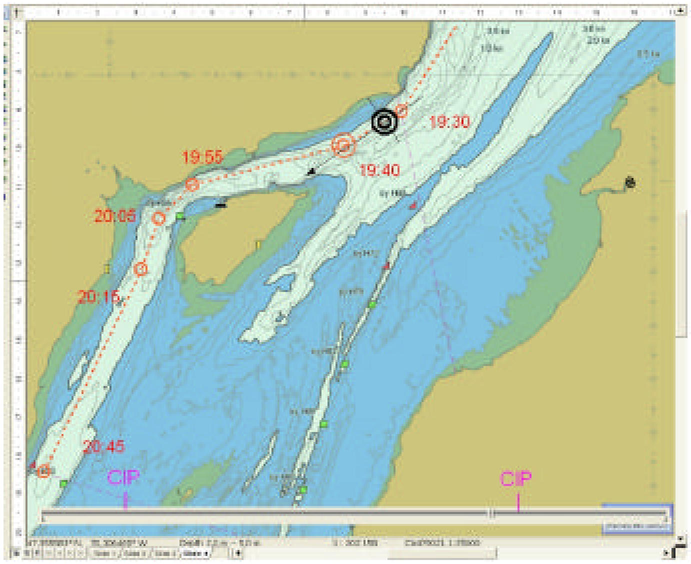
| | |
|---|---|
| Nuk | Keel clearance |
| De | Dept reading |
| Wl | Water level |
| Dr | Draft of the vessel |
| Sq | Dynamical sinking |

To generate an application that yields the keel clearance, the calculation module must access the following data: high density bathymetry, water levels in real and projected times for the position of the vessel, and finally the vessel's dynamic sinking.

The keel clearance calculation module operates jointly with the dynamic speed calculation module. The dynamic module allows us to obtain the predictable water levels all along the transit. With the water level (in real time and in predicted mode) and the high density bathymetry, we obtain the available water column. Subtracting the draft of the vessel as well as its dynamic sinking from this water column, we finally obtain the keel clearance for every point of the transit.

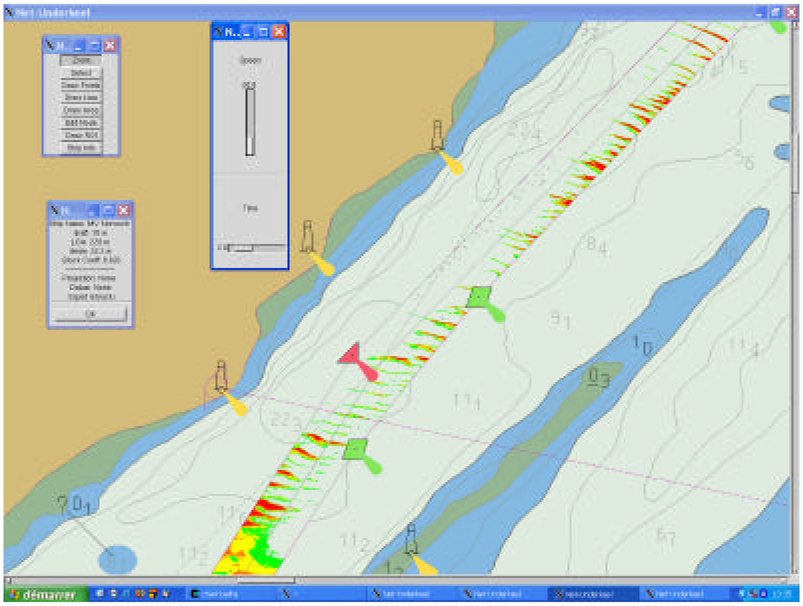
## Presentation

The results obtained from the applications can be presented as tables, with the help of geographical and temporal references, or again integrated graphically in the presentation of the electronic card system. On matters like the results of the dynamic speed calculation module, they can be presented in the following manner:

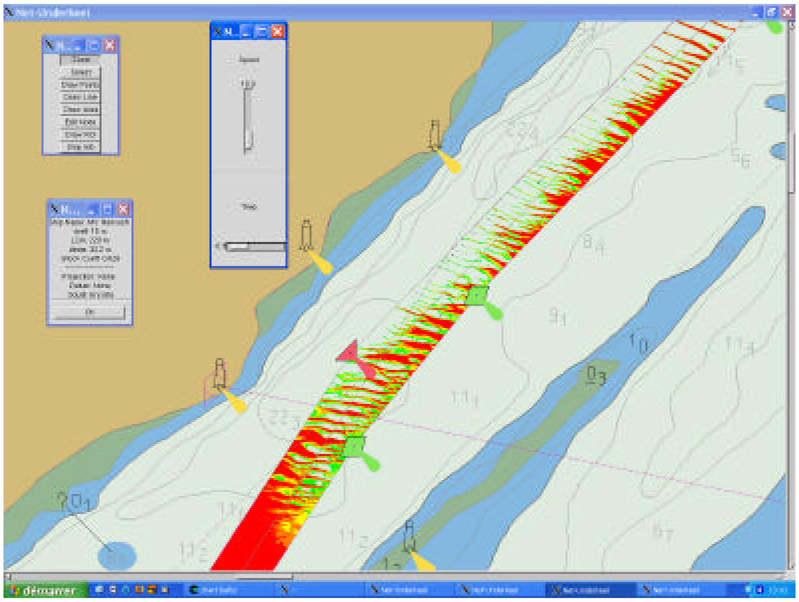


Graphical presentation of the application clearance under keel

🟥 Less than 0.4 meter.
🟧 Less than 0.8 meter.
🟨🟩 Less than 1.2 meters.
⬜ More than 1.2 meters.



Condition: two hours after low tide at 20 knots



Condition: one hour after low tide at 19 knots

## Validation

The results obtained by the calculation modules of the applications were validated for the St. Lawrence River. The following result was obtained during a transit carried out between Québec and the pilot station at des Escoumins on September 15, 2005, with the tanker M.T. Emerald Star. The times calculated were obtained by the dynamic speed calculation module in steps of six minutes, and the real transit data used in the validation were provided by the AIS system of the vessel. In spite of the fact that this transit involves variable and intensive tide currents, the difference between predicted and real transit was only one minute.

| Point of passage | Calculated transit | Real transit |
|---|---|---|
| Departure | 00h 25m | 00h 25m |
| Beauport | 00h 27m | 00h 28m |
| Lévis | 00h 31m | 00h 32m |
| CIP Ste-Pétronille | 00h 43m | 00h 44m |
| Beaumont | 00h 51m | 00h 54m |
| CIP - St-Laurent | 01h 14m | 01h 16m |
| Pointe St-Jean | 02h 03m | 02h 05m |
| Traverse Nord | 02h 15m | 02h 18m |
| CIP Cap Brulé | 02h 32m | 02h 34m |
| Anse aux Bardeaux | 02h 49m | 02h 51m |
| Sault aux Cochons | 03h 04m | 03h 07m |
| CIP - Cap Maillard | 04h 09m | 04h 16m |
| Île aux Coudres | 05h 05m | 05h 08m |
| CIP-Cap aux Oies | 06h 32m | 06h 31m |
| Cap à l'Aigle | 07h 54m | 07h 59m |
| CIP - Île Blanche | 08h 26m | 08h 30m |
| CIP - Haut Fond Prince | 09h 00m | 09h 10m |
| Bergeronne | 09h 33m | 09h 32m |
| Total transit time | 9h 08m | 9h 07 m |

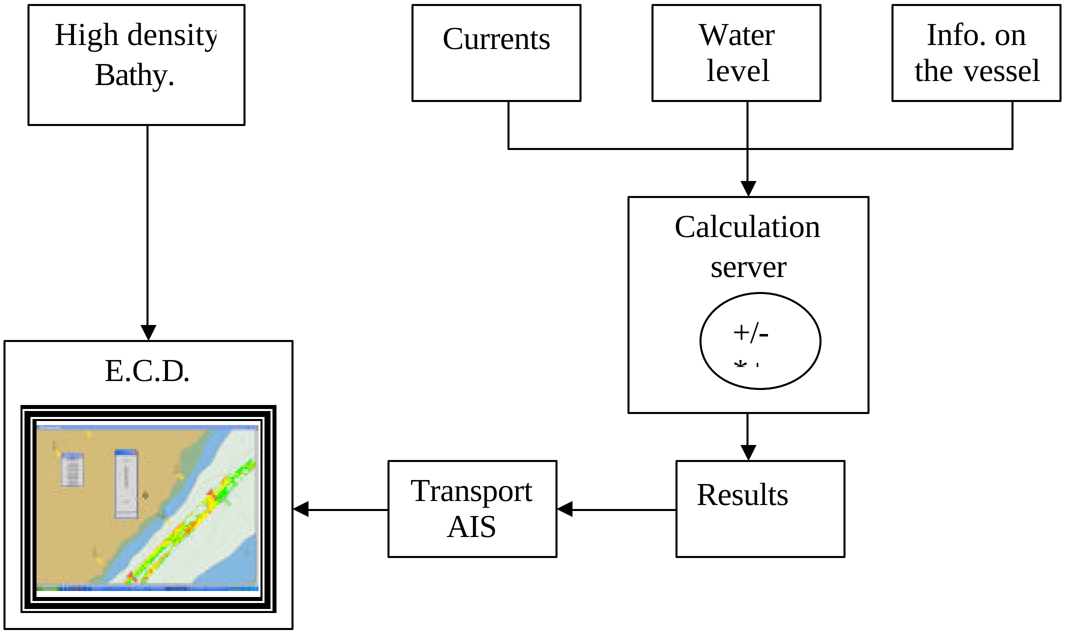
From the observed sample, having the vessel's precise speed over water, in following the preestablished transit without deviation, and in carrying out the transit without changes in speed, the model allows a mean deviation of about 1.5%. This represents an error of 8 minutes for a voyage of 9 hours.

## Operational functioning

The applications can be set in motion on a platform dependent on an electronic card system. However, it is important to take into consideration that a significant number of data must be processed by the dynamic speed calculation module and that an equally important number of data are required for the keel clearance display. The electronic card system may have in its menu an applications option that allows calling the application results in various forms and also permitting upgrades to be made.

The most effective way to obtain a convivial operation of the applications in an electronic card system consists in implementing a dynamic information exchange structure based on the types of data. The data are of two types: variable data obtained from the currents and water levels (different for each transit) and fixed data, i.e., bathymetry (constant for many transits). It is in using this principle of variability of the data as a basis that the operational diagram of the applications on an electronic card platform was developed. Thus, the fixed data, i.e., the high density bathymetry, will be entered into the electronic card system beforehand. As to the variable data, processing as well the mathematical manipulations will take place at the data supplier to then be entered via AIS into the electronic card system.

Schematically



## Conclusion

The evolution of technologies and navigation systems is entering a new phase: that of integration. The integration of the data will permit taking advantage of all the information useful to the navigator who must proceed in confined waters.

The introduction of the AIS system aboard vessels brings a new dimension to navigation in confined waters. This dimension modifies the role of the vessel in the system of marine traffic management, since this system in no longer simply a consumer of information, but becomes an emitter of data.

The fact of integrating the information from the AIS data of the vessel into a system of other available data allows making predictions on the precise movement of the vessel. This modifies current marine traffic management since it is now possible to take into account not simply the vessel's position but many passages in real time, and to thus come in a precise manner, as well as the keel clearance both present and to come.

Note that the elements of information making it possible to carry out this type of traffic management can, after adapting the AIS communication network, be available to the navigator in real time and in projective mode. Besides, it would be incoherent not to allow navigators, who are the primary users, to have access to this information.

This new approach to the dissemination of information relative to a transit will allow, when all is said and done, the use of a 4-D card on board. In a tangible way, this utilization of available information will allow the navigator to effect transits in much greater security, all the while optimizing his passage.