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ERIC KULBIEJ, PIOTR WOŁEJSZA
Maritime University of Szczecin, Poland

AN ANALYSIS OF POSSIBILITIES HOW THE COLLISION BETWEEN M/V 'BALTIC ACE' AND M/V 'CORVUS J' COULD HAVE BEEN AVOIDED

ABSTRACT

The report presents the simulation results of collision between m/v 'Baltic Ace' and m/v 'Corvus J'. The analysis was performed by means of navigation decision support system (NDSS) in collision situations. This system (NAVDEC) works out anti-collision manoeuvre using AIS (Automatic Identification System) and ARPA (Automatic Radar Plotting Aids) data. Then they are processed by specialized computing algorithms and presented to the operator on a display in the alphanumeric and graphic forms. The data on the specific navigational situation from the report of Bahamas Maritime Authority was used for the generation of signals transmitted to NDSS as a sequence of NMEA strings.

Keywords:
AIS, collision, decision support system, Navdec.

INTRODUCTION

The navigational decision support system NAVDEC is the first navigational tool worldwide that performs information functions as well as those typical of decision support systems. Its innovative functionalities, significantly extending the performance of devices generally carried by ships, have now a status of patent applications filed internationally.

The presented Navigational Decision Supporting System NAVDEC was created by research team of prof. Pietrzykowski from Maritime University

of Szczecin [Pietrzykowski et al., 2012a], [Pietrzykowski et al., 2012b], [Pietrzykowski et al., 2012c].

The NAVDEC complements the navigational equipment of the ship. It is a real time system handled by the navigator. The system observes its ship and the environment and records information on the present navigational situation. On this basis the system identifies and assesses the navigational situation (processing) and works out solutions (decisions) assuring safe navigation. For the system to function correctly it has to co-operate with standard equipment and systems installed on board (often used on leisure craft as well) such as: log, gyrocompass, ARPA (Automatic Radar Plotting Aids), GNSS (Global Navigational Satellite System), AIS (Automatic Identification System), ENC (Electronic Navigational Chart), sources of current navigational data. Similarly to the ECDIS system (Electronic Chart Display and Information System) the NAVDEC performs information functions — on one screen it presents bathymetric data from an electronic chart, an image of surface situation from a tracking radar, positional information from the AIS and GNSS receivers. Finally, it determines and presents to the navigator movement parameters of targets in vicinity. Schema of data operation pyramid in Navdec is shown in Figure 1.

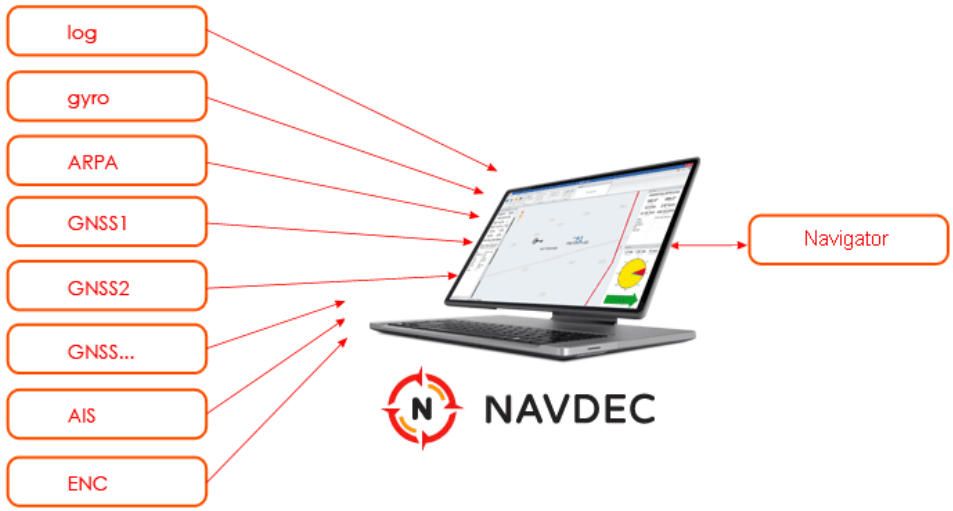

Fig. 1. Sources of data used in NAVDEC
[http://www.navdec.eu (access 01.09.2016)]

NARRATIVE OF THE EVENTS LEADING TO COLLISION

The collision occurred at 18:15:00 (UTC) on the 5th December 2012 in position 51°51,9'N 002°53,9'E, located within the Noordhinder Junction area of the southern North Sea.

At 18:08:00 'Baltic Ace' and 'Corvus J' were 3 Nm apart, with a CPA of 0,5 Nm. The bearing from the 'Baltic Ace' to 'Corvus J' was moving very slowly right, indicating that the 'Corvus J' was intending to cross ahead of the 'Baltic Ace'. Both vessels remained at service speed giving a relative approach speed of 31 kts.

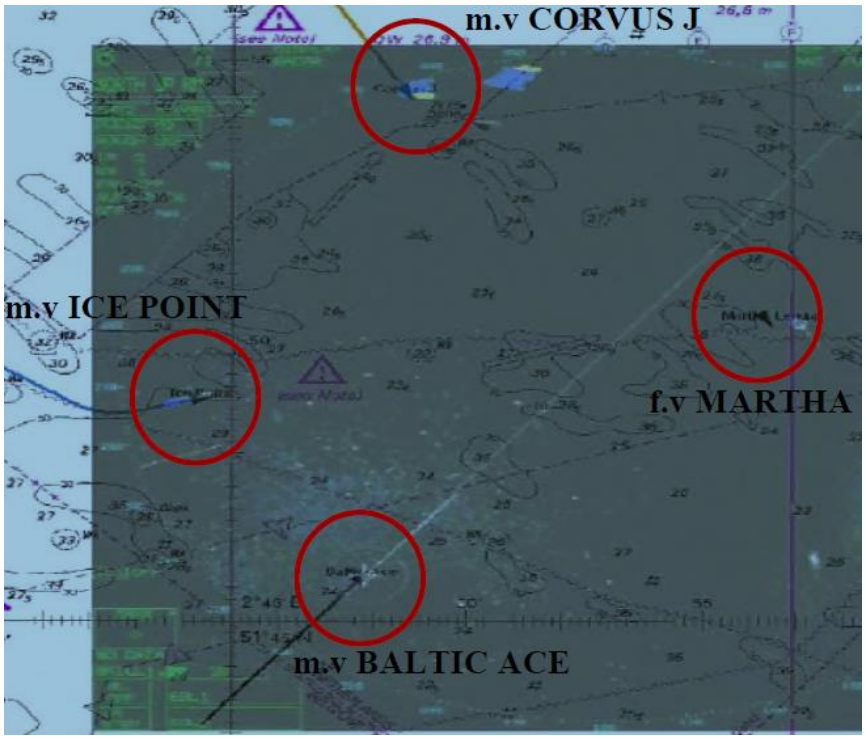

Fig. 2. Reconstruction of vessel location on the electronic chart screen
[Bahamas Maritime Authority, 2016]

The Officer On Watch (OOW) on 'Baltic Ace' had identified the 'Corvus J' and acquired the vessel on ARPA at approximately 12 Nm and later visually by the sight of her masthead lights. The first acknowledgement by the OOW on board the 'Baltic Ace' as to the CPA and the developing situation with the 'Corvus J'

came at 18:08:45, when the OOW was heard to say on the bridge audio recorder 'it's close, 5 cables before my bow' [Bahamas Maritime Authority, 2016].

Having recognised that a close quarters situation was developing with the 'Corvus J', at 18:09:31 the 'Baltic Ace' called the 'Corvus J' on VHF CH 16 to establish a working channel. Whilst the OOW on board 'Baltic Ace' establishes communication, the 'Corvus J' commenced an alteration of course to starboard from 129° to 152° in what is believed to be in accordance with the vessel's passage plan [Bahamas Maritime Authority, 2016].

Between 18:09:40 and 18:11:28 the 'Baltic Ace' altered course to port by 2° from 037° to 035° and maintained a speed of 18,5 kts. Over the same period, the 'Corvus J' commenced altering to a new course of 152° and maintained a speed of 12,5 kts having altered from 129° at 18:09:55 [Bahamas Maritime Authority, 2016].

Between 18:11:28 and 18:12:27 the 'Baltic Ace' altered 4° to port whilst the 'Corvus J' maintained its course and speed. At 18:13:18 the 'Corvus J' attempts to make VHF contact with the 'Baltic Ace', however, due to a conversation taking place on the bridge of the 'Baltic Ace' at the time, the OOW did not respond to the 'Corvus J'. The 'Corvus J' repeats the transmission and successfully establishes communications with the OOW and asks the 'Baltic Ace' 'you keep your course like that', the 'Baltic Ace' replies 'yes I keep like that' [Bahamas Maritime Authority, 2016].

At 18:13:26 the 'Baltic Ace' began an alteration of course to port, starting at 021° and by 18:14:40 had reached a heading of 010°. In the same period the 'Corvus J' commenced a turn to starboard using 15° of rudder, from 152° to 207° which was the recorded heading at the time of impact. No reduction in speed was evident on either vessel as the distance between the two vessels closed at a speed of 31 kts [Bahamas Maritime Authority, 2016].

At 18:15:04 the OOW on board the 'Baltic Ace' placed the rudder hard over to port. At the same time the OOW on board the 'Corvus J' reversed the rudder from 15° starboard to hard to port and reversed the propeller pitch from 65% ahead to 55% astern [Bahamas Maritime Authority, 2016].

At 18:15:17 the 'Corvus J' collided with the starboard side of the 'Baltic Ace' in vicinity of frame 165. On impact the 'Baltic Ace' was traveling at a speed of 15,1 kts on a heading of 322°, the' Corvus J' was traveling at a speed of 9,2 kts on a heading of 207°. The 'Corvus J' rotated clockwise as it travelled along the starboard side of the 'Baltic Ace' penetrating the side shell plating with the bulbous bow and bow structure [Bahamas Maritime Authority, 2016].

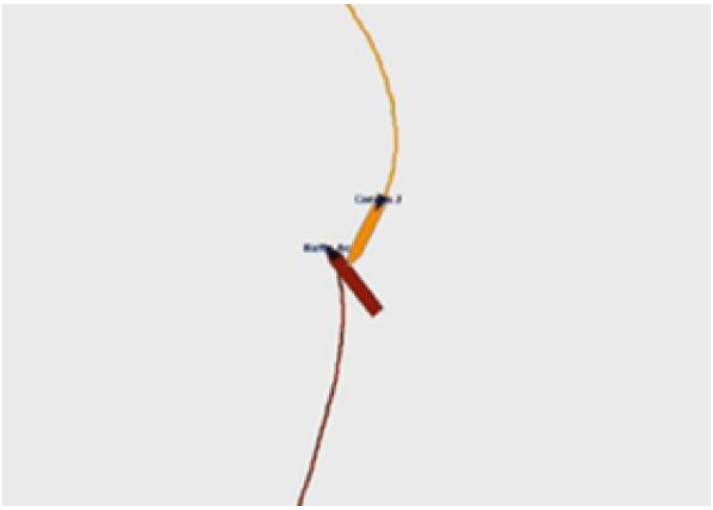

Fig. 3. Collision [Bahamas Maritime Authority, 2016]

ASSUMPTIONS FOR SIMULATION

The intel used for simulating the collision encounter of two vessels is derived from the report by The Bahamas Maritime Authority placed at their web page. The data was processed in order to develop a sequence of NMEA messages that was then implemented into Navdec.

Taking relative geographical positions of both vessels into account and their movement parameters at 17:50:00, the system qualified this encounter as **crossing courses** and labeled 'Corvus J' as the give-way vessel, which is in compliance with Rule 15 of COLREGs. Consequently, a recommended maneuver was generated for the ship 'Baltic Ace', with an assumption that the stand-on ship is actually maintaining its course and speed (Rule 17 of COLREGs).

Following general parameters were assumed to provide the simulation:

- CPA (Closest Point of Approach) = 1852 m (1 Nm) or 926 m (0,5 Nm);
- good visibility'
- length overall m/v 'Baltic Ace' — 148 m;
- length overall m/v 'Corvus J' — 134 m.

The velocity intervals were determined on the basis of both vessels' manoeuvring data. Ships' headings as well as their speeds and positions in function

of time are stated in Table 1. On the basis of data contained in the Table 1 simulation was carried out in order to determine encounter parameters and possible collision-prevention manoeuvres at particular moments of time. Vessels physical dimensions and equations of kinematic movement were not taken into account in regards to the solution.

Tab. 1. Data used for simulation. Source [Bahamas Maritime Authority, 2016]

Time	**'Baltic Ace'**				**'Corvus J'**			
	Latitude 51N [minutes]	Longitude 002E [minutes]	Heading [degrees]	Speed [knots]	Latitude 51N [minutes]	Longitude 002E [minutes]	Heading [degrees]	Speed [knots]
17:50	45,20	47,08	35	19	55,30	48,17	150	12,5
17:51	45,47	47,39	35	19	55,12	48,41	150	12,6
17:52	45,74	47,70	35	19	54,95	48,65	150	12,7
17:53	46,01	48,01	35	19	54,77	48,89	150	12,8
17:54	46,28	48,32	35	19	54,58	49,13	150	12,9
17:55	46,54	48,63	35	19	54,42	49,37	149	13,1
17:56	46,81	48,94	35	19	54,32	49,66	129	13,1
17:57	47,08	49,25	35	19	54,21	49,94	129	13,1
17:58	47,35	49,56	35	19	54,11	50,23	129	13,1
17:59	47,62	49,87	35	19	54,00	50,52	129	13,1
18:00	47,88	50,18	37	19	53,90	50,80	129	13,1
18:01	48,15	50,49	37	19	53,79	51,09	129	13,1
18:02	48,42	50,80	37	19	53,69	51,38	129	13,1
18:03	48,69	51,11	37	19	53,59	51,66	129	12,5
18:04	48,96	51,42	37	19	53,48	51,95	129	12,5
18:05	49,22	51,73	37	18,9	53,38	52,23	129	12,5
18:06	49,49	52,04	37	18,8	53,27	52,52	129	12,5
18:07	49,76	52,35	37	18,7	53,17	52,81	129	12,5
18:08	50,03	52,66	37	18,6	53,06	53,10	129	12,5
18:09	50,30	52,97	37	18,5	52,96	53,38	140	12
18:10	50,56	53,28	35	18	52,78	53,54	152	11,5
18:11	50,83	53,59	35	17,5	52,60	53,70	152	11
18:12	51,10	53,90	35	17	52,42	53,86	152	10,5
18:13	51,25	54,00	21	16,5	52,20	54,00	152	10
18:14	51,50	54,10	10	16	52,05	54,10	179	9,7
18:15	51,75	54,00	355	15,5	51,95	54,05	193	9,4
18:16	51,90	53,90	322	15,1	51,90	53,90	207	9,2

SIMULATION RESULTS

On the basis of assumptions and the direct vessels' data derived from the report [Bahamas Maritime Authority, 2016] a simulation was composed in order to provide parameters of the encounter and to determine possible anti--collision maneuvers at certain moments of time.

When the simulation was commenced TCPA (Time to Closest Point of Approach) equalled 22 minutes, CPA (Closest Point of Approach) equalled 1,1 Nm and the velocity of 'Corvus J' was 12,6 kts.

A reconstructed situation at 17:59:00 hours can be seen in Figure 4. Recommended anti-collision maneuvers for the vessel, that is the range of courses assuring safe passing at the preset CPA or larger, is marked yellow on the circle whilst the most optimal course is tagged with blue color. The recommended maneuver is indicated with green arrow labeled with particular course value and enables the ships to pass each other at the pre-defined CPA. On request, alterations to rudder and engine may be displayed by the system based on the generated solutions.

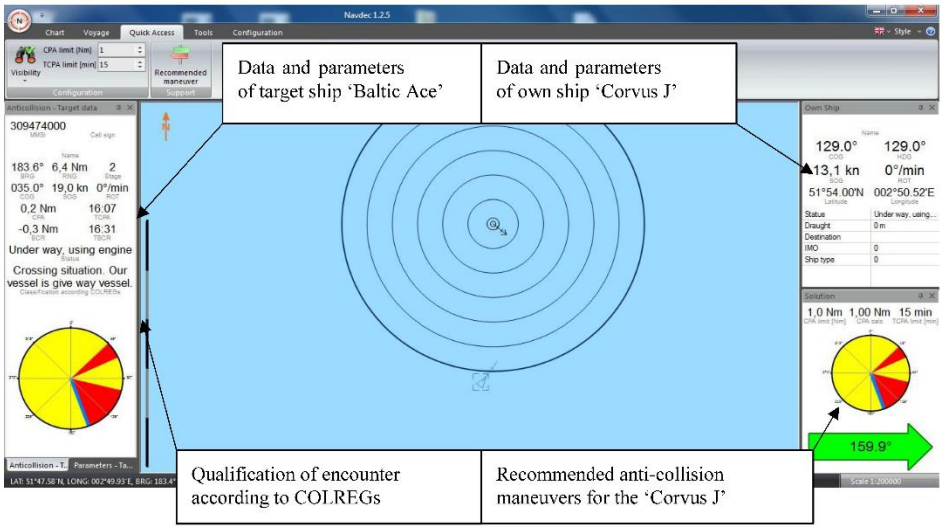

Fig. 4. Location of the ships at 17:59:00 hours

If the navigator does not take a preventive action, the system will continue to work out maneuvers to be performed. If a collision cannot be avoided by altering course to starboard (since course alteration to port is not recommended

by COLREG),the system automatically divides the assumed CPA by two and proceeds to obtain solution for a new set of alphanumerical parameters (Fig. 5). That being insufficient the proposed course alterations will be replaced with a sign saying ‘DANGER Ships too close’ (Fig. 6).

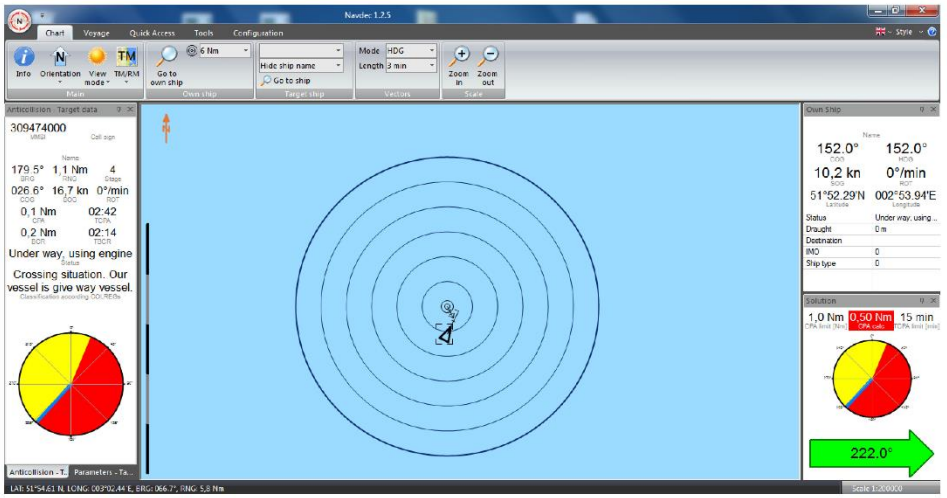

Fig. 5. Automatically enhanced CPA limit

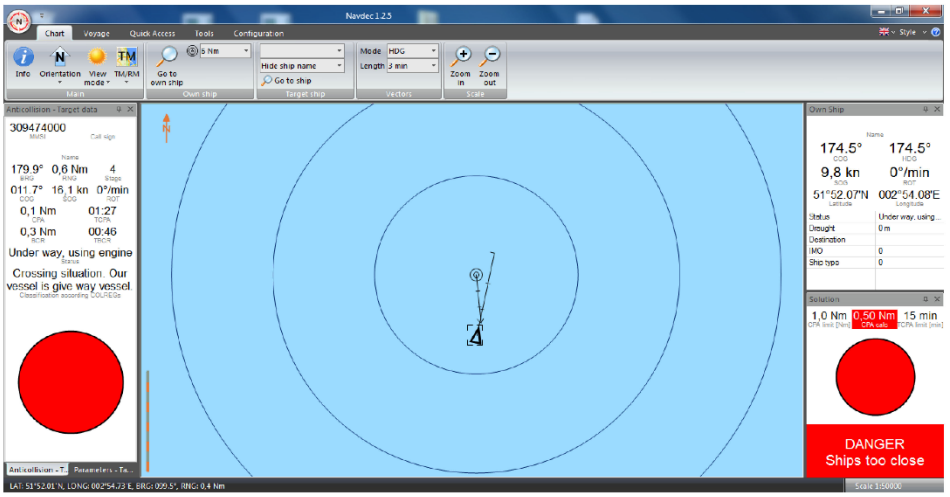

Fig. 6. Close quarters situation labeled with ‘DANGER Ships too close’ note, 18:15:00

If the information note shown in Figure 6 has emerged, failure to take a preventive action, which means failure to execute the action recommended by the system, will lead to a close quarters situation. Then only a concerted action by the two ships may save them from a collision.

Having further the case investigated and mathematical calculus taken into consideration a theoretical scenario could be generated. It bases on the very premise that since 18:08:00 both of vessels cease to alter their velocities and courses.

Introduction to this solution is shown in Figure 7. At 18:10:00 Navdec suggests to alter the course to starboard for then it will meet the expected predetermined CPA of 0,5 Nm.

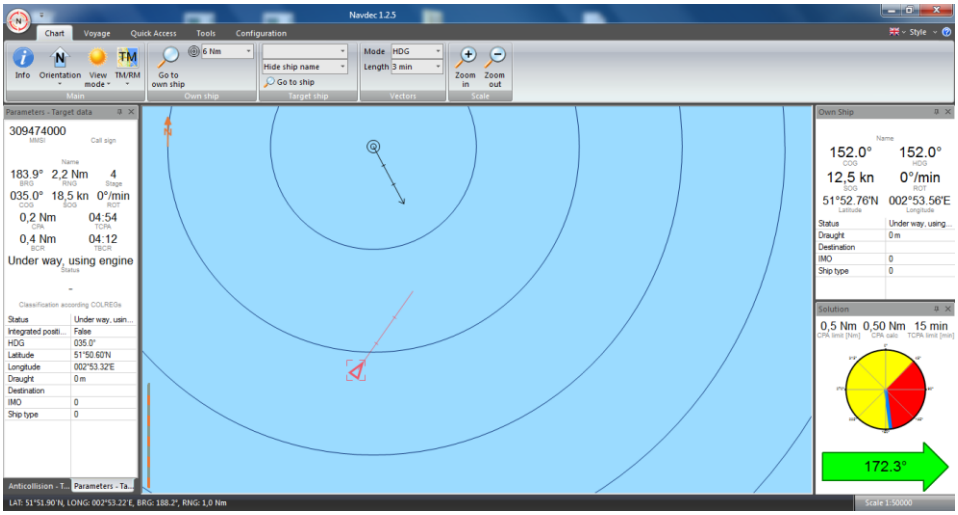

Fig. 7. Hypothetical situation of non-altering the course, 18:10:00

Nonetheless, according to the simulation at 18:15:00 'Baltic Ace' has already passed through the crossing point (Fig. 8), with minimal CPA of 0,2 Nm.

Eventually at 18:16:00 both vessels would stay at relatively safe position. Moreover, the display of Navdec would change from 'DANGER: ships too close' to 'Keep course and speed'. The classification of situation according to COLREGs has been expanded by providing label 'vessel passed by' (Fig. 9).

Simulation of hypothetical situation presented on Figures 7, 8 and 9 is the proof, that collision could have been avoided should both vessels keep their parameters since 18:08:00. Small alteration of courses carried out by 'Corvus J' after the aforementioned time and unpredictable port alteration of 'Baltic Ace' after 18:13:00 caused that manoeuvers mutually abolished. These can be seen in

Figure 10, which is a bare recreation of the routes actually taken by both vessels. The hypothetical situation on the other hand basis on variation in which from position at 1810 the track would be linear in the set direction, respectively 037° for ‘Baltic Ace’ and 152° for ‘Corvus J’.

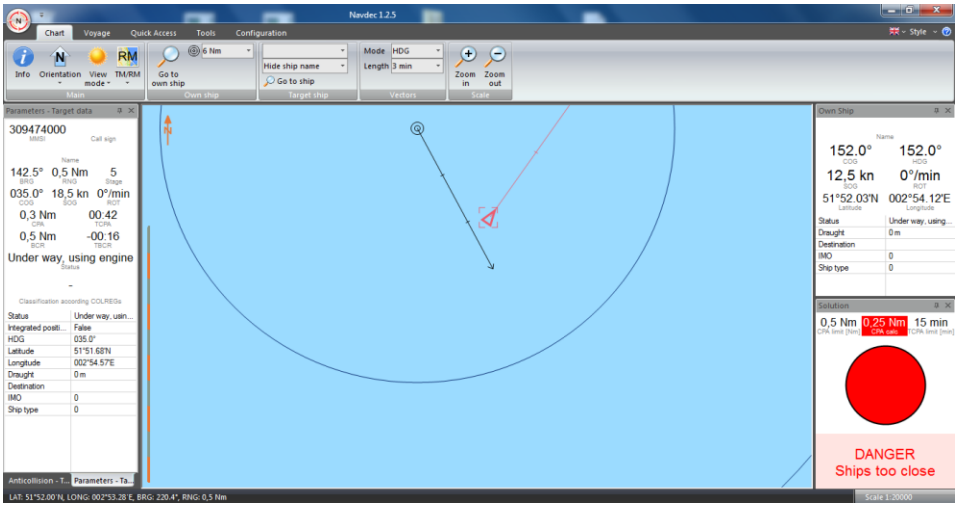

Fig. 8. Hypothetical close quarters situation labeled with ‘DANGER Ships too close’ note, 18:15:00

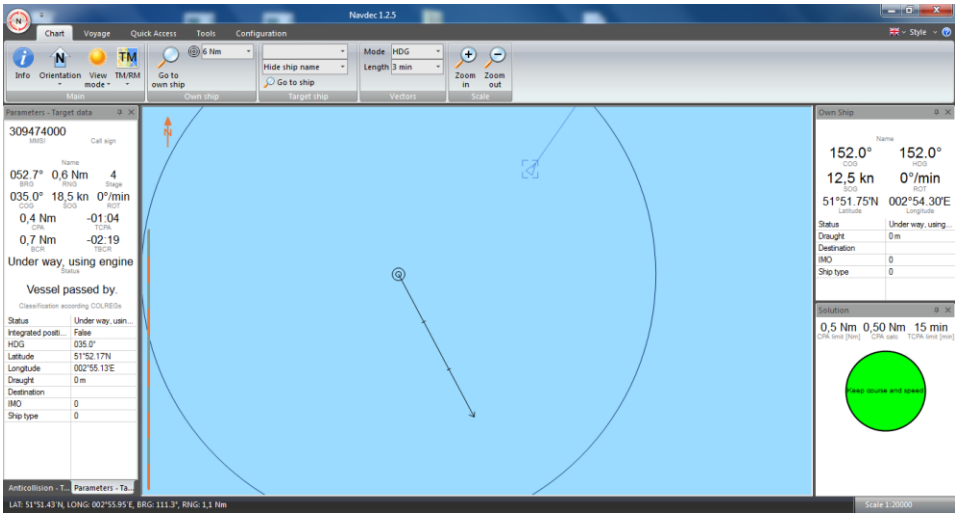

Fig. 9. Situation after the encounter, 18:16:00

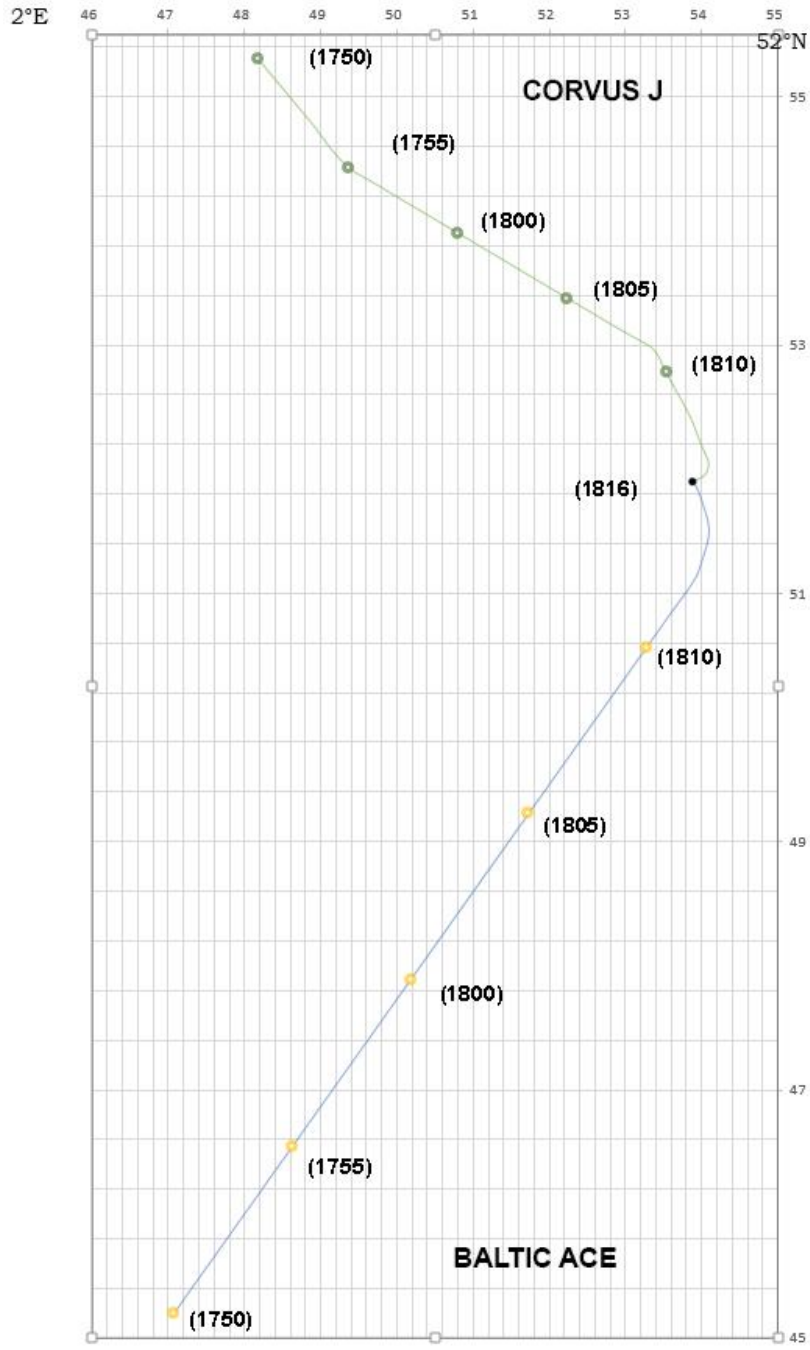

Fig. 10. Reconstruction of the vessels' location based on data from investigation report

ANALYSIS OF RESULTS

There were two separate simulations executed using Navdec. First of them is a replay of real movement of both vessels. Analysis of navigators' behaviour shows that both of them did not follow Collision Regulations. For instance 'Corvus J' executed few small alterations of course, which were really hard to observe by 'Baltic Ace'. Both vessels were communicating by VHF (Very High Frequency) continuously, which should be avoided in such situation. Despite of action carried out by navigators, Navdec continuously informed them about possible and effective anti-collision manoeuvres.

Second simulation were based on assumptions:

- both vessels do not communicate and they do not agree on any manoeuvres;
- both vessels tend to keep their courses and speeds.

In this situation (Fig. 8) 'Baltic Ace' passed 0,5 Nm ahead of 'Corvus J', with minimum CPA 0,3 Nm. Had not the navigators executed 'nervous' manoeuvres in last minutes, the collision would not have happened. This is a clear example that so called Last Moment Manoeuvre (LMM) should be coordinated automatically by, for example, anticollision systems. In such a case, Navdec would have commanded both vessels to keep their course and speed, since it had been the alteration of them that led to the fatal encounter. Provided that majority of ships had an intelligent anticollision system installed, the number of collisions would definitely decrease with a matter of years.

CONCLUSIONS

Report of investigation [Bahamas Maritime Authority, 2016] was published 3,5 years after collision. It shows how complicated and time consuming is the reconstruction and evaluation process. Basing on data recorded by VDR (Voyage Data Recorder) Navdec is able to meticulously reconstruct encounter situation, analyse priority and manoeuvres executed by both vessels. Thanks to it, Navdec can significantly reduce time used for collision analyses. But what is much more important, Navdec was generating reliable solutions until the distance between vessels reached 0,5 Nm i.e. 2 minutes before collision. When the distance between vessels is smaller than 0,5 Nm, Navdec qualifies such situation as LMM i.e.

suggests that avoiding collision is possible only by coordinated manoeuvre of both vessels. This assumption is based on manoeuvring standards for ship, which says that during executing circulation, the advance could not be bigger than 4,5 length of the vessel. The second assumption is that average length of the vessels is 200 meters. After multiplying both parameters, we receive 900 meters, which is close to 0,5 Nm. These are obviously a considerable simplifications and will be thoroughly investigated in subsequent publications. LMM was elaborated during execution of Horizon 2020 research project: Navigational Decision Support System for Improved COLREGs Safety Management, grant number: 684803, Activity: IT-1-2015-1-P, Call: H2020-SMEINST-1-2015_18-03-2015.

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ERIC KULBIEJ
Maritime University of Szczecin
Wały Chrobrego 1 Str., 70-500 Szczecin, Poland
e-mail: ekulbiej@gmail.com

PIOTR WOŁEJSZA
Maritime University of Szczecin
Wały Chrobrego 1 Str., 70-500 Szczecin, Poland
e-mail: p.wolejsza@am.szczecin.pl

STRESZCZENIE

Celem artykułu jest zaprezentowanie wyników symulacji przebiegu kolizji pomiędzy m/v „Baltic Ace" oraz m/v „Corvus J". Analiza została przeprowadzona przy użyciu nawigacyjnego systemu wspomagania decyzji (NDSS) w sytuacji kolizyjnej. System ten wypracowuje propozycje manewru antykolizyjnego przy użyciu danych z AIS (system automatycznej identyfikacji) oraz ARPA (system automatycznego kreślenia nakresów radarowych). Następnie propozycje te są przekazywane użytkownikowi w formie graficznych rozet i danych alfanumerycznych. Informacje wykorzystane do analizy tej szczególnej sytuacji nautycznej zostały zaadaptowane z raportu Bahamas Maritime Authority jako ciąg sekwencji protokołu NMEA.