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# NAVIGATION DECISION SUPPORTING SYSTEM (NAVDEC) — TESTING IN REAL CONDITION

**ABSTRACT**

The known navigational systems in use and methods of navigational decision support perform information functions and as such are helpful in the process of safe conduct of a vessel. However, none of these known systems provides a navigator with ready solutions of collision situations taking account of all the vessels in the proximity of own ship, where the Collision Regulations apply. This paper presents testing results of NAVDEC — new Navigational Decision Supporting System created by research team from Szczecin Maritime University both for ocean going ships and pleasure crafts Tests were carried out in real condition on board container vessel. Testing results were presented on example encounter situation between Hammonia Berolina (own ship) and FR8 Fortitude (target ship). Encounter parameters were compared with data received from Full mission simulator.

**Keywords:**
Navigational Decission Suport System, Colreg, anticollision.

## INTRODUCTION

Supporting the navigator in making decisions may significantly enhance the safety and effectiveness of the transport process. The presented Navigational Decision Supporting System NAVDEC was created by research team of prof. Pietrzykowski from Szczecin Maritime University both for ocean going ships and pleasure crafts [Pietrzykowski Z. et al., 2012a; Pietrzykowski Z. et al., 2012b; Pietrzykowski Z. et al., 2012c]. The system is to supplement the shipborne navigational equipment, while in the future it may be a part of Integrated Bridge System (IBS). The correct operation of the system requires co-operation with other devices and systems onboard ship and the external ones in order to acquire navigational information automatically. The navigator able to use a system that correctly qualifies a situation in compliance with the COLREGs and submits possible solutions would not make errors as was in cases presented in papers [Banachowicz A. et al., 2007], [Magaj J. et al., 2007; Magaj J. et al., 2010]. It goes without saying that the implementation of such systems would enhance the safety of navigation.

## TESTING IN REAL CONDITION

There were following aims to verify during testing period:

1. Correctness of encounter parameters (CPA, TCPA) calculation [Banachowicz A. et al., 2008b] — to be verified by ARPA and Full mission simulator.
2. Correctness of new courses (which lead to pass other targets on presumed CPA) calculation [Banachowicz A. et al., 2008a; Wołejsza P., 2012] — to be verified by radar and Full mission simulator.
3. Reaction of the system for changing initial settings [Magaj J. et al., 2008a; Wołejsza P. et al., 2010] — to be verified by Trial manoeuvre.

Developed decision supporting system was tested on m/v Hammonia Berolina between 16.05–10.09.2012. Vessel was on fixed route from Algeciras in Spain to West African ports i.e. Lome, Onne, Douala, Tema, Takoradi, San Pedro.

Computer with installed system was connected to ship's AIS transponder (Saab R4). Data from AIS were transferred to portable computer via pilot plug/RS 232. Due to technical limitation, the system was not connected to radar/ARPA. This is why correctness of encounter parameters (CPA, TCPA) calculation was verified only visually on the radar screen. Later, basing on registered data, encounter situation was replayed on Full mission bridge simulator at Maritime University in Szczecin. All hardware and software forming the Polaris System was delivered by Kongsberg Maritime AS which was granted DNV certificate for compliance or exceeding the regulations set forward in STCW '95, section A-I/12, section B-I/12, table A-II/1, table A-II/2 and table A-II/3) [Gralak R. et al., 2010]. The CNT (Centre of Navigational Technologies) has been also accredited as an DP Operator Training Centre in accordance with the Nautical Institute standards.

Obtained accreditations, confirm the full compatibility of simulated events, interactions and behaviors and allow for a reliable verification of the system's operation in relation to reality. Vessels' parameters recording functionality was used in anti--collision analysis and to carry out the validation of calculation algorithms, implemented to the NAVDEC system.

## CALCULATION OF ENCOUNTER PARAMETERS

Basic criteria for the assessment of the navigational distance are Closest Point of Approach (CPA) and Time to Closest Point of Approach (TCPA). They are commonly used in Automatic Radar Plotting Aids (ARPA) [Kazimierski W., 2011].

$$CPA = \frac{X_{wz}\, VY_{wz} - Y_{wz}\, VX_{wz}}{V_w}\,; \tag{1}$$

$$TCPA = \frac{X_{wz}\, VY_{wz} - Y_{wz}\, VX_{wz}}{V_w^2}\,, \tag{2}$$

where:

$VX_{wz}$, $VY_{wz}$ — relative speed vector components;

$X_{wz}$, $Y_{wz}$ — distance between vessels counted along $x$ and $y$ axes, respectively;

$V_w$ — relative speed.

Determination of the ship's own course for the passing of an object at a given distance is possible depending on the analytical [Lenart A., 1999]:

$$\mathrm{tg}\,\frac{\psi}{2} = \frac{A_{CPA}\, V \pm \sqrt{(A_{CPA}^2 + 1)\, V^2 - B_{CPA}}}{B_{CPA} - V}\,; \tag{3}$$

$$A_{DCPA} = \frac{X_{wz}\, Y_{wz} \pm CPA\sqrt{D^2 - CPA^2}}{X_{wz} - CPA^2}\,; \tag{4}$$

$$B_{DCPA} = A_{CPA}\, V_x - V_y\,, \tag{5}$$

where:

$V$ — own ship speed;

$X_{wz}$, $Y_{wz}$ — distance between vessels counted along $x$ and $y$ axes respectively;

$V_x$, $V_y$ — components of the velocity vector of own ship;

$D$ — distance between vessels;

$\psi$ — new course which enables to pass other targets on presumed CPA.

In a similar way it is possible to determine the speed of own ship, which enables to pass other targets on presumed CPA.

## SCENARIO

Following figures show screen shots of decision supporting system. Collision situation took place on August 8, 2012 in the Gulf of Guinea. Target ship is FR8 Fortitude. When ships were at a distance greater than 8 nm (fig. 1), the system considered the situation to be safe, as indicated by a green symbol denoting that our vessel should keep her course and speed. This distance can be freely changed by the navigator e.g. on restricted area can be considerably reduced.

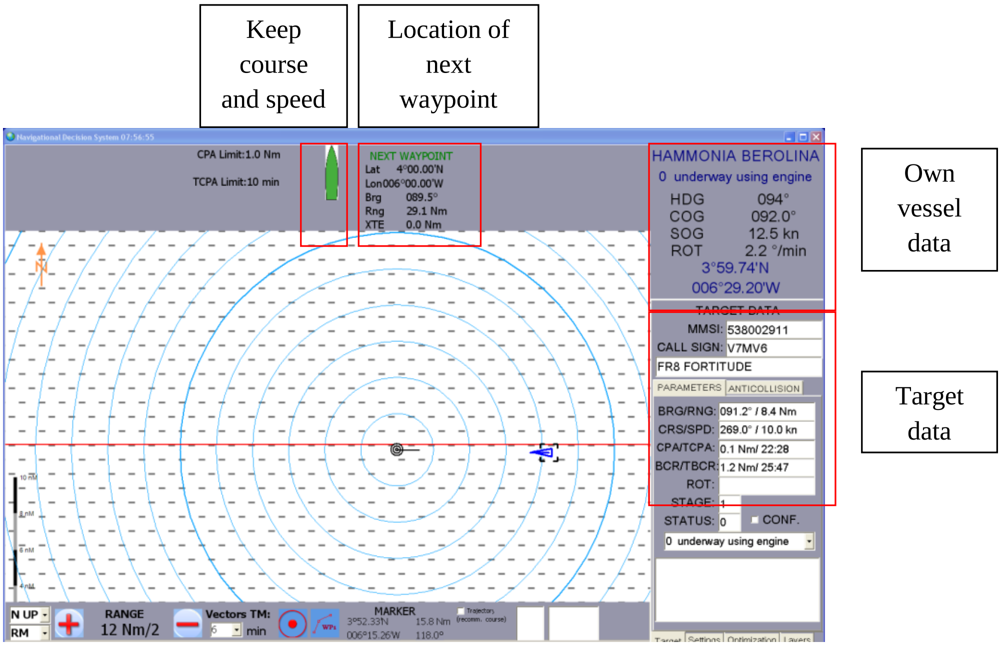


Fig. 1. Collision situation, first stage

When the distance between the vessels was less than assumed, the system qualified encounter situation according to COLREGs [Magaj J. et al., 2008b; [Wołejsza P. et al., 2012]. In this particular case it is Head on situation, so, according to COLREGs, two ships should alter their courses to starboard to avoid collision (fig. 2). In addition, rosette is displayed where courses from red sector are dangerous courses i.e. in extreme circumstances can lead to a collision or CPA will be less than assumed. Courses from yellow sector guarantee, if other objects keep their courses and speeds, safe passage for at least assumed CPA. Additionally, blue highlighted is the optimal course that meets the criteria of a safe distance, is consistent with the provisions of COLREGs and enables to reach next waypoint on the shortest route. This course, in the form of numbers, is also displayed next to the rosette (fig. 2).

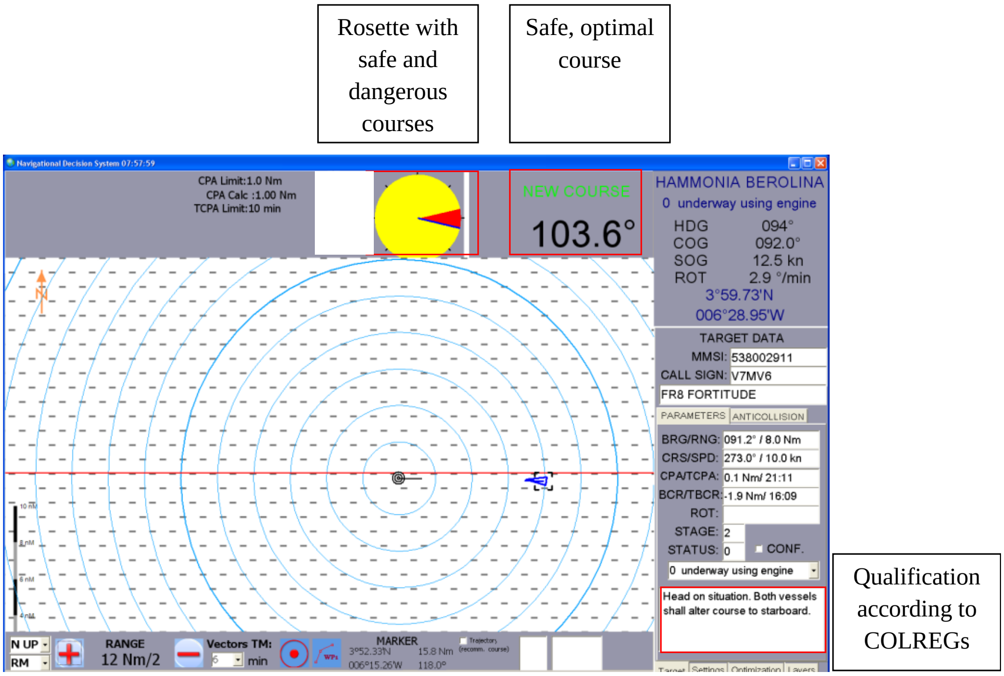


Fig. 2. Collision situation, secondo stage

After executing manoeuvre by own vessel, rosette disappeared because CPA is 1.0 Mm, which meets minimal safety requirements set up by navigator (fig. 3).

## RESULTS

To verify correctness of CPA and TCPA calculation, results received from NAVDEC and Simulator (radar strings RATTM) were compared. Total number of 1157 records were registered. In 70% cases CPA calculated by NAVDEC and ARPA were identical. Only in 1.5% cases (19) difference was bigger than 0.2 nm. All 19 cases were registered when target ship started manoeuvre. In the first phase of manoeuvre (30 seconds) difference ranges between 0.6 to 1.1 nm. At this time difference in TCPA reached over 11 minutes. Later CPA difference backed to range 0–0.1 nm and was in this range up to the end of experiment. At the distance of 5.5 nm, own vessel made an anticollision manoeuvre suggested by NAVDEC and altered course to starboard (fig. 3) to new course (COG = 097°). Thanks to this, CPA increased up to 1 nm (safe, assumed CPA) and remained unchanged, until TCPA was positive.

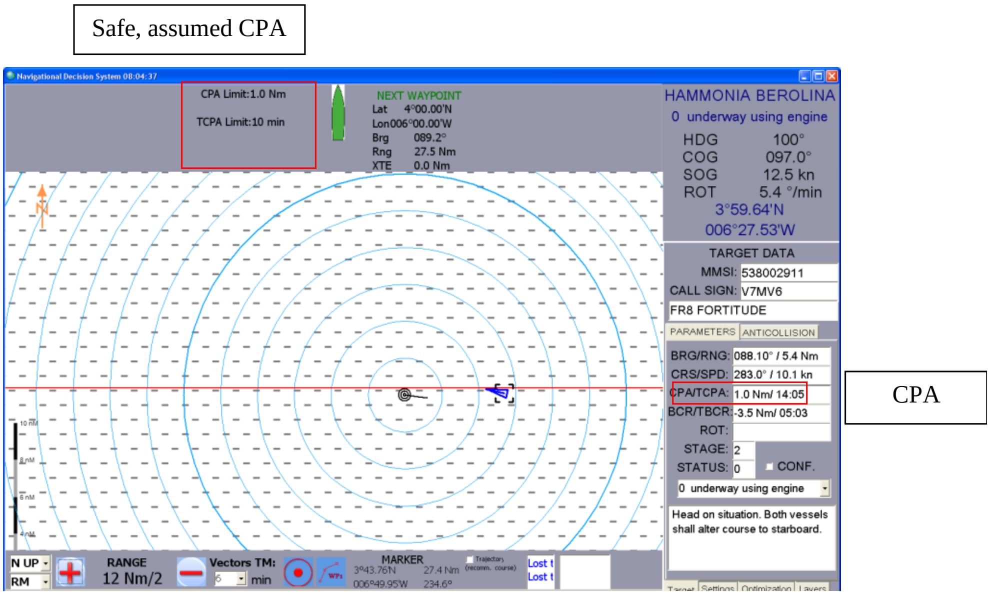


Fig. 3. Collision situation, third stage

On figure 4, rosette appeared again and presents ranges of safe and dangerous courses. This is because navigator increased required CPA to 2 nm. System responded correctly which was verified by trial manoeuvre on ARPA.

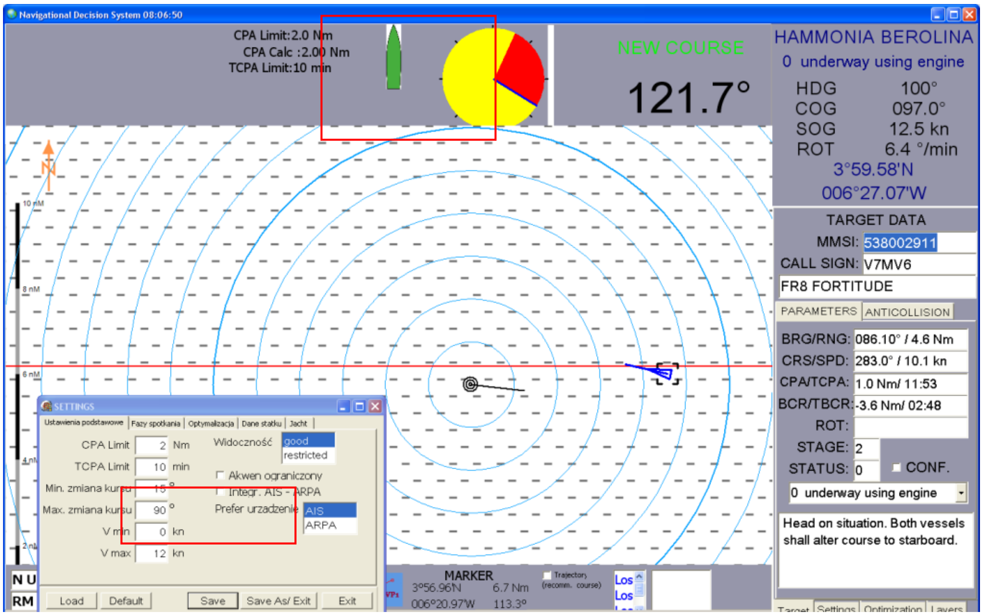


Fig. 4. Collision situation after increasing CPA limit

The system correctly calculates new, safe courses which lead to pass FR8 Fortitude on assumed 1 or 2 nm (fig. 3 and fig. 4). Passing distance was verified by radar and on Full mission simulator. CPA, at the moment when TCPA was equaled zero, was exactly 1 nm (fig. 5).

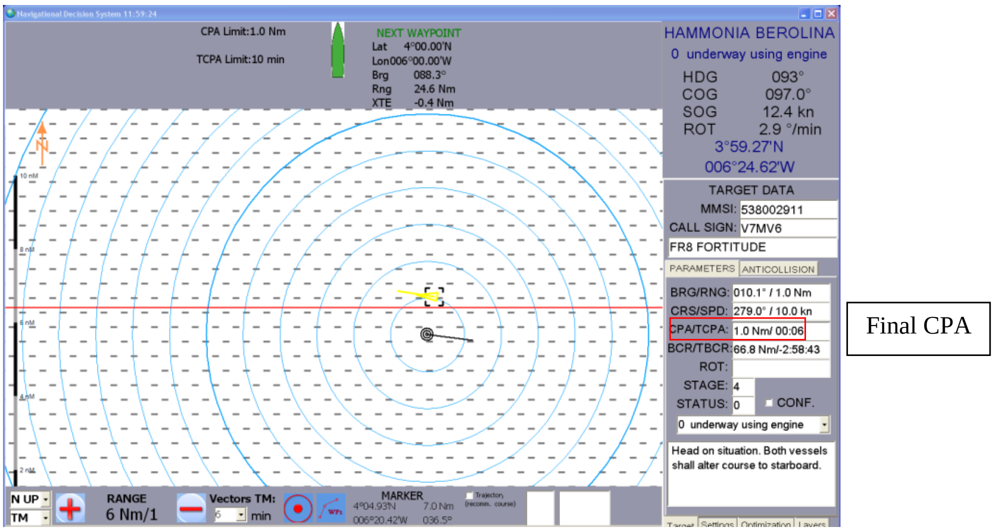


Fig. 5. CPA at the moment of passing by

## SUMMARY

Testing of NAVDEC on m/v Hammonia Berolina was carried out on open sea in the period of four months. Results, in general, are positive. In details system correctly calculates encounter parameters like CPA and TCPA. Displayed parameters were each time compared with ARPA. Additionally CPA and TCPA calculated by NAVDEC were compared with encounter parameters calculated by Full mission bridge simulator. Results show that NAVDEC is more precisely than ARPA particularly when ships are manoeuvring. In the first phase of manoeuvre CPA and TCPA presented by ARPA are useless and should not be taken into account in evaluation of encounter situation as it could lead of its misjudgment. Moreover NAVDEC informs navigator that targets have started their manoeuvres. In such situation target ship is flashing yellow. This function is not available in ARPA.

The system responds correctly after change of initial settings i.e. when required CPA was increased up to 2 nm. It calculated new, safe courses, which were verified by Trial manoeuvre on ARPA.

The system correctly calculates new, safe courses which were verified by radar and on Full mission simulator.

Results show that system is helpful and effective in solving collision situation. Particularly it can be very useful for inexperienced navigators like those who took part in collision between m/v Gotland Carolina and m/v Conti Harmony.


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**STRESZCZENIE**

Znane systemy nawigacyjne, a także będące w użytkowaniu metody wspomagania decyzji spełniają funkcje informacyjne i jako takie są pomocne w procesie bezpiecznego prowadzenia statku. Żaden ze znanych systemów nie dostarcza jednak nawigatorowi gotowych rozwiązań w sytuacji kolizyjnej, z uwzględnieniem ruchu wszystkich statków w otoczeniu i przepisów o unikaniu zderzeń. W artykule przedstawiono wyniki testów funkcjonowania systemu NAVDEC — nowego systemu wspomagania decyzji nawigatora, wykonanego w Akademii Morskiej w Szczecinie z myślą o statkach profesjonalnych i nieprofesjonalnych. Opisane badania przeprowadzono w warunkach rzeczywistych na statku kontenerowym. Rezultaty zostały zaprezentowane na przykładzie Hammonia Berolina (statek własny) i FR8 Fortitude (obiekt manewru). Uzyskane parametry porównano z wynikami symulacji uzyskanymi na symulatorze mostka.