investigated. The results show a clear dependence of the optimal interval on the mission program of the frigate and the subsystem failure behaviour. See: The interplay between deployment and optimal maintenance intervals for complex multi-component systems, *Proceedings of the IME, Part O: Journal of Risk and Reliability*, 227 (2), 2013. [Journal of Risk and Reliability]

7. A Game theoretic attacker-defender ASW model

In transit to an operating area or in a sea base situation an expeditionary RNLN task group can be threatened by enemy SSKs. The task group is presumed to consist of one or more HVU's, defended by a number of assets, including an M-frigate equipped with LFAS and possibly one or more organic NH90 helicopters.

Subject of this study by LTZ1 ir. R. Jutte (CZSK, MATLOG), conducted for the MDTC, is to model the behavior of an enemy SSK which threatens an RNLN task group. This model is expected to provide insight in how to employ the defending forces in order to minimize chances on an attack on the HVU's.

A game-theoretic approach is chosen: the interplay between the defending forces and the attacking SSK can be seen as a "two-person zero-sum game". In this concept, the defender tasks platforms to minimize the probability that the enemy can reach the HVU, while the enemy observes and intelligently reacts to these defenses by routing SSKs to maximize this probability.

At the Naval Postgraduate School (NPS), Monterey, California these type of attacker-defender ASW models are also subject of study. They have developed a model called BASTION ([Military Operations Research]). It can optimally merge activities of different types of ASW platforms and is relatively easily adaptable to extend (e.g. with sonobuoys). The BASTION model appears to be applicable to the RNLN situation and the NPS has been forthcoming in providing details. Therefore, instead of developing a model from scratch, the focus is on developing a derivative model for the RNLN case.

8. A planning tool for submarines in transits

Submarines want to operate undetected. However, submerged is a state that cannot be sustained over time. This is, for example, due to the capacity of the batteries. Therefore, in transit, it will also have to sail at periscope depth (PD) at regular intervals, and fresh air is added to the boat. During these intervals, the diesel engine is used to recharge the batteries. Of course, this increases the probability of detection of the submarine and also severely limits the maximum speed. The submarine will therefore try to minimize the time spent at PD. For a given desired speed of advance, one plans the periods of sailing at PD. This plan divides the transit into several blocks, each with its own speed and status (underwater navigation or sailing at PD). The desired result is a maximum speed of advance, or the shortest period at PD.

Finding an optimal plan is very difficult, due to restrictions such as desired air quality in the submarine, maintenance of diesel engines, rest periods of several officials involved in returning the boat to PD, ability to send messages, etc. And of course, for obvious reasons, there may exists areas where the submarine does not want to sail at PD.

In this project, LTZT2 ir. T. Stuivenberg (Zr.MS. Walrus) aims at developing a planning tool that also takes into account several technical characteristics of the batteries. Given a desired speed of advance, it identifies the periods of sailing at PD. Conversely, also, the highest possible speed of advance can be determined. This planning tool uses advanced mathematical optimization methods and methaheuristics.

9. Convoying against piracy

The last couple of years have shown an alarming increase in the incidence of piracy near Somalia. Both the Somali East Coast and the Gulf of Aden are high-risk areas. The Gulf of Aden is an important shipping lane due to its location. Convoying merchant vessels through the Gulf of Aden is one of the solutions to the problem of piracy.

With the help of Operations Research we can quantify the effectiveness of protecting merchant vessels by a warship. A model that has been developed, in close cooperation between TNO (ir. J. Vermeulen) and NLDA (drs. M.P.A. v.d. Ven), can be used to investigate the influence of the number of merchant vessels, lateral distance, convoy speed, (relative) position of the warship and intercept strategy of the warship on the maximal response time to a threat by pirates.

The model assumes that the convoy system has a simple configuration, namely a group of merchant vessels in two lines, with an escort sailing warship in-between (see Figure 1).

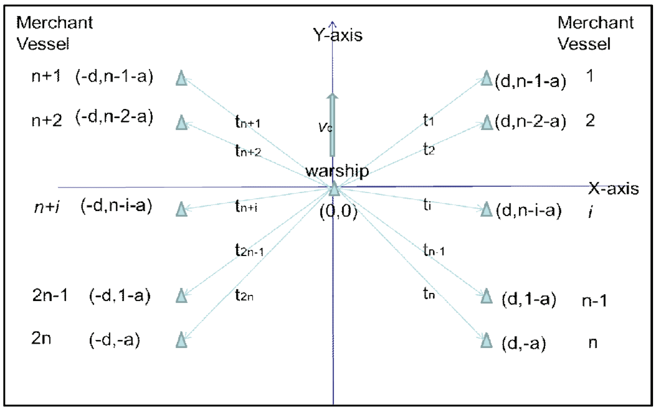

Figure 1: Illustration of a convoy configuration.

In order to ensure a timely interception of the pirate, the warship has to reach any merchant vessel within the predefined maximum response time. The intercept procedure is modelled realistically and considers, among others, the capabilities of the warship in terms of acceleration and the limitations in the course change.

This research has shown that, for example, a convoy with size equal to 24 merchant vessels, with speed 15 knots can be protected by a single warship assuming a response time of 15 minutes, that the warship navigates in-between and in front of the convoy and that the lateral distance between the two lines of merchant vessels is in-between 1.5 nmi and 2 nmi. It also provides tactical advice on the optimal convoy length given the convoy speed and maximum response time.

10. Analysis of Terrorist, Insurgent and Cyber Networks

Networks permeate every aspect of everyday life in general, and our military operational environment in particular. Abroad and sometimes at home we face insurgent, terrorist and criminal networks. Additionally our infrastructure contains certain critical components whose destruction or incapacitation would have a detrimental effect on our nation's economy, public health, or safety and security. This critical infrastructure consists of (technical) systems that transport energy, information, water, goods and people. Such systems can be considered to consist of, and are controlled by networks.

In his research dr.ir. R.H.A. Lindelauf develops game theoretical and graph theoretical models that help understand the complex nature of networks relevant in a military operational environment. Can we quantify the structure of a terrorist network and predict which one is most likely to occur in a given environment? Can we identify relevant subgroups in insurgent networks? See Social Networks. Which actors should be targeted to minimize the insurgent's 'project' of conducting an IED attack? Which nodes in our infrastructure are most critical when under cyber attack? How can we detect cyber-attacks in large volumes of network data and how can we attribute those events and cyber-attacks to the criminals that perpetrate them? Is it possible to quantify secure network design patterns to minimize losses against attacks?

11. New PhD-project: Deploying Security Measures to Intercept Multiple Simultaneous Threats *(cooperation TNO DV, NLDA and University Twente)*

The effects of terrorist and piracy activities, or generally speaking activities of intelligent opponents can have a