to-peer negotiation, self-synchronization, and agility. As the terms NCO and NEC suggest, C2 systems are regarded as networks, rather than a hierarchy. Accordingly, it is appropriate to view the C2 process and C2 systems through the lens of network theory. The book will consist of a collection of peer-reviewed chapters. The overall objective of the book is to connect the fields of C2 and network science; both fields share the need to face adversaries, but until now have been studied separately. While there are some books on C2 and others on network science, this book will bring the two fields together for the first time in print. Regarding a C2 system from the network viewpoint enables one to think about issues such as the robustness and evolution of C2 systems. For network science, C2 is a new, demanding, real-world application area.

3. Research on Network Science

In recent years, a variety of models have been developed that evaluate the structure, stability, robustness and dynamics of social, information, inter-alliance or military C2 networks. To be able to evaluate these models, at the NLDA we are involved in research on Network Science. See, for example the book chapter on an application to cyber warfare (Asser publications). We are also developing stochastic actor-based models to study the dynamics and evolution of, for example, a social or C2 network. We apply our work to the problem of identifying key players in social or terrorist networks. For more information, we refer to our papers in several scientific journals. (European Journal of Operational Research, Mathematical Social Sciences)

4. Spare Parts Inventories for Air Force Missions

As part of the operation Ocean Shield two RNLAF AS532U2 Cougar helicopters were tasked to support Zr. Ms. Rotterdam in the anti-piracy campaign off the coast of the Horn of Africa. During this operation one of the Cougar helicopters lost its availability due to a failed oil cooler. A spare part was not readily available on board and therefore this spare part was air dropped from a Danish military aircraft in a carefully planned action. A fast but costly solution. Better would be having this spare part already available in the spare part inventory, which would have saved additional cost and downtime. This shows that choosing the right spare part inventories will lead to both cost reduction and higher system availability.

In this research, ELT ir. A. Schuitmaker (Defence Helicopter Command) and dr.ir. R.H.P. Janssen (NLDA/ Expertise Centre Military Operations Research), are working towards a quantitative model to select the optimal spare part inventory. This is based on life-time distributions of components and mission properties. These lifetime distributions were found analyzing historic maintenance data.
In the literature models can be found to calculate spare part inventories but this model assumes exponentially distributed lifetimes. However, the Weibull distribution is more commonly used in modelling lifetimes in maintenance engineering. In this research we therefore extend this model to accommodate the more flexible (and realistic) Weibull failure distribution. This model can also be applied in much broader applications in logistic risk analysis.

5. PhD-project Robust and Agile Planning *(cooperation TNO DV, NLDA and Erasmus University Rotterdam)*

The PhD research by Lanah Evers is a collaborative research project between TNO, the Netherlands Defence Academy (NLDA) and the Erasmus University of Rotterdam and aims to develop robust and agile planning methods for military operations. This PhD research is supervised by Dr. A. Barros (TNO), who is also affiliated at the NLDA as a senior research fellow, Dr. H. Monsuur (NLDA) and Prof. dr. A. Wagelmans (Erasmus University).

Current military operations have grown increasingly complex over the past several years. Due to the rapidly changing environment, quick reaction times and an increasing uncertainty in the operating environment or theater area, traditional military planning does not offer the required solutions. New military planning methods should therefore explicitly consider uncertainty and not to blindly optimise a certain criterion. Such new planning methods should be adaptive (agile) and adjust to changing operational circumstances and/or provide good solutions for a variety of operational circumstances (robust), increasing therefore the effectiveness and efficiency of military operations.


General Atomics MQ-9 Reaper

The PhD thesis presents new robust and agile planning methods to improve the efficiency and effectiveness of UAV mission planning. (For a recent paper, see Annals of Operations Research). UAVs are often used in reconnaissance missions to capture both motion and still imagery of potential 'targets' on which up-to-date information is required. Such targets might include important infrastructure, possible locations of Improvised Explosive Devices (IEDs), and insurgent locations. The goal of the UAV mission is thus to gather as much information as possible given operational constraints related to the UAV endurance capabilities. Obviously, some locations might be more relevant than others in terms of information gathering for the military operation. In order to optimize data collection, the UAV mission should include target locations of higher relevance, starting and ending at the UAV recovery point. Existing mathematical models could be used with the aim of optimizing this UAV mission planning problem. However, these models do not take uncertainty and dynamics of the problem into account in the planning stage, and might therefore result in infeasible or suboptimal flight plans. The PhD thesis introduces new mathematical models for the UAV mission planning problem which explicitly consider uncertainty in fuel consumption, flight and recording times and a dynamically changing set of targets during the flight.

The new ideas and results presented in this thesis could also be adjusted and extended the other military and safety and security applications to develop plans that can better deal with the increasingly complex, uncertain and rapidly changing environment.

6. The interplay between deployment and optimal maintenance intervals for complex multi-component systems like a Navy Frigate

In corporation with the research and expertise center maintenance led by Prof. dr.ir. T. Tinga, dr.ir. R.H.P. Janssen and Prof. dr.ir. T. Tinga published a paper about optimal maintenance intervals for a navy frigate. Instead of performing maintenance at fixed intervals, the operational efficiency of assets can be improved significantly by taking into account the variations in usage and operating environment of the asset. In that way, the traditional static maintenance policy is replaced by a dynamic maintenance policy. This concept is demonstrated by modelling the failure behaviour of a rather complex multi-component system, i.e. a navy frigate. For this system, several non-identical subsystems are included. Some of the systems are unique on board, while others have been made redundant, which means that the criticality of the subsystems to the mission capability of the frigate varies. Moreover, the variation in deployment of the frigate in terms of mission types and operating environments is translated into various usage profiles for the subsystems. Simulations are then performed to obtain the optimal maintenance policy in terms of interval length and preventive maintenance threshold, given certain requirements for the deployability of the frigate in a certain period. Moreover, the sensitivity of the results for different subsystem initial service life times and variations in usage profile are