STUDY GUIDE

MILITARY TECHNOLOGY, PROCESSES AND SYSTEMS (MTPS)

2021 – 2022

Faculty of Military Sciences

Netherlands Defence Academy

Disclaimer

The content of this study guide refers to the courses and the curriculum as offered in the academic years 2021-2022. Changes to courses or curriculum may appear in between. At the beginning of each year a new study guide will provide the latest information of the two academic years to follow. No rights can be obtained from the information in this guide.

Contents

Introduction

MTPS explores the complexity of modern military technical systems and processes. It analyses, evaluates and tries to create or invent improvements through modelling and simulation. The programme focusses both on the material and the software for all complex functions and on the (future) use of these systems in their operational environment.

This study guide provides you with information about the relevance of the programme, the curriculum structure, course details and the planning for Cohort 2021. Further course details, like preparations, assignment details, exercises and try-out exams can be found at the electronic learning environment Moodle.

For detailed information about teaching and assessments, see the Teaching and Examination Regulations (TER).

Relevance

MTPS is required for all those who seek to understand integration and optimisation issues of modern military systems including their operational use and maintenance. The programme is also of interest for those who are currently engaged, or seek a career, in the defence related industry, technical support agencies or research centres, national and even international.

The programme encourages initiative and independent learning abilities, required for professional development. It provides students with critical analytical and methodological skills. MTPS enables assessment of complex technical problems from several perspectives and effectively contributes to developing advice and solutions, concerning operational processes and materiel projects.

Programme focus

MTPS proceeds where the profiles of the academic bachelor Military Systems and Technology (MS&T) have ended. MTPS connects with the three MS&T profiles: Sensor and Weapon Systems (SWS), Command and Control Systems (C2S) and Operational Deployment and Deployability (ODD). It is also closely linked to FMS research in SRO3 (Clustering Unmanned Military Systems), SRO4 (Deployment and Deployability of Military Systems) and SRO6 (Cyber Operations and Cyber Security). MTPS takes the military technological perspective since military missions and operations are the essential drivers for the design, implementation and use of defence systems. These systems have to operate in complex, network enabled, constantly changing environments. This programme provides the students with quantitative skills using simulation and modelling for current and near future problems in these missions and the corresponding support. This requires deeper knowledge of and investigation into a range of military technological processes and systems. It is exactly this broad military perspective that defines the unique basis of MTPS.

MTPS aims at students who have experience and knowledge of the challenges one faces in the real military world and who are able to add this professional experience to their academic bachelor education in their commitment to solving real military problems. That's why they must have served in at least two functions after gaining their bachelor degree before they can enter the programme.

Regarding the curriculum, at least following topics will be addressed:

- *Cyber awareness*
- *Unmanned and autonomous systems*
- *Systems engineering*
- *System analysis and modelling*
- *Optimisation of military operations*
- *Life Cycle Management, Life Cycle Costs*
- *Reliability engineering, material behaviour and predictive maintenance*
- *Spare parts and inventory management*
- *Simulation of platform, sensor, weapon, C2 and communication systems*
- *Cyber threat simulation*

Programme objectives

Having successfully completed the MTPS program, and regardless of the track, each student:

1. has insight into the most important military operational-technical developments and scientific results including its relationship with other areas;

2. has the ability to apply this insight in the military operational-technical field;

3. is able to describe and explain the complexities and possibilities of operational-technical processes and systems in a military environment;

4. is able to apply modelling, simulation and decision support techniques that are used for understanding and problem solving in the field of study;

5. is able to describe and explain the complexities and possibilities of techniques for system engineering in the field of study;

6. is able to describe and explain the complexities and possibilities of techniques for optimising maintenance and logistics of military systems;

7. is able to systematically analyse and critically assess data;

8. communicates effectively about his own academic work in the English language, to both professionals and non-specialists, including presentations and reports;

9. is able to work both independently and in multidisciplinary teams, interacting effectively with specialists and taking initiatives where necessary;

10. demonstrates a professional attitude towards evaluating existing knowledge, acquiring and integrating new expertise, research and towards changing circumstances with an understanding of its incompleteness, ambiguities, limitations and ethical implications;

11. is aware of the importance of life-long learning in order to maintain his recently gained professional qualifications.

In addition to qualifications 1-11 and having followed the Processes track, the MTPS graduate:

12a. has technical knowledge and capabilities that enable the graduate to build new models and to expand existing models for problem solving in operations research, logistics and maintenance;

13a. is able to conduct research related to military operational-technical processes;

14a. is able to explain the influences of changing parameters on the model outcomes in the field of study;

15a. is able to assume management positions related to the materiel-logistic support of military systems.

In addition to qualifications 1-11 and having followed the Systems track, the MTPS graduate:

12b. has technical knowledge and capabilities to conduct integrated simulations of platform, sensor, weapon, C2 and communication systems;

13b. is able to conduct research related to the integration of military systems;

14b. is able to explain the influences of changing circumstances and cyber threats on the system's performance and effectiveness;

15b. is able to assume management positions related to technical integration for new and existing military equipment.

Who can apply?

All applicants possessing a certificate proving that they have successfully completed MS&T will be admissible. Applicants with an equivalent or higher technical degree, may also be admissible. Depending on their dossier and the advice from the Board of Examiners, the Executive Board will decide. For the first cohort, however, only Dutch defence personnel will be accepted.

All students must also have sufficient command of the English language. This means that they must possess a certificate, not older than 5 years, at described in the Teaching and Examination Regulations (TER article 3.4).

How to apply?

The enrolment period is from 1 February to 1 July 2021. To receive the necessary application documentation, one needs to contact the Faculty of Military Sciences via master.mtps@mindef.nl.

All defence applicants must have permission from their director or commanding officer. Military applicants must additionally have permission from the HRM department of their operational command (OPCO/P&O).

Proof of English proficiency must be submitted prior to 15 July 2021. With this exception, all documents for Class 2021 must be submitted before 1 May 2021. Before 1 July 2021, all applicants will receive notice on whether or not they have been (conditionally) accepted to the programme.

Library

The library of the Netherlands Defence Academy (NLDA) facilitates students and scientists in realizing their scientific goals. In addition to a large physical collection in the field of military science, staff and students of the NLDA have access to a large collection of online scientific resources. This digital collection is also accessible from outside the NLDA workplace. The search engine LibSearch provides access to the total collection of the library. You can log in with your @nlda-account.

Both in Breda and in Den Helder the library has a modern study and research environment with many opportunities for studying individually or in a group. These workstations are also open in the evenings.

In addition, training courses and workshops in the field of information literacy and the use of Zotero. The library also advises about copyright and publishing, and provides sustainable archiving and access to research publications.

More information: https://bibliotheeknlda.org

Programme Structure

See figure 1 for the MTPS curriculum. The five common and compulsory core courses are presented in green. The Processes track courses are shown in pink and the Systems track courses in blue. The next three paragraphs explain this structure in more detail and give a brief outline of each course.

EC	Processes track	Systems track
5	Advanced Technologies in Warfare (ATW)	
5	Systems Engineering Principles (SEP)	
5	Life Cycle Management (LCM)	
5	Modelling and Simulation (M&S)	
5	Command & Control (C&C)	
5	Optimal Deployment (ODT)	System Modelling and Integration (SMI)
5	Sustainment of Military Systems (SMS)	Military System Specialisation (MSS)
5	Topics in Logistics, Maintenance and Operations Research (TLMOR)	System In Context (SIC)
20	Thesis (TSS)	
60		

Figure 1: MTPS curriculum

The curriculum core

The increasing importance of unmanned systems and cyber aspects are the main topics in the ***Advanced Technologies in Warfare (ATW)*** course. This creates an important part of the necessary mind-set of the students. In parallel, students begin to study ***Systems Engineering Principles (SEP)***, also a subject of increasing importance. Then, ***Modelling and Simulation (M&S)*** and ***Life Cycle Management (LCM)*** provide another part of the necessary academic basis for each of the tracks. Finally, regarding the core, ***Command and Control (C&C)*** ensures that students will be able to apply modelling, simulation and programming skills in an operational setting at an advanced level in both tracks.

The Processes track courses

The focus of this track is operational **effectiveness** and **sustainment**. The course ***Optimal Deployment (ODT)*** puts effectiveness of military force into practice by connecting to running research and operational problem solving. The course ***Sustainment of Military Systems (SMS)*** strongly applies a research approach to operational deployability (maintenance) matters. The final Processes track course, ***Topics in Logistics, Maintenance and Operations Research (TLMOR),*** challenges students on recent themes from both an effectiveness and a sustainment point of view.

The Systems track courses

The Systems track contains three courses elaborating on the SEP course. In the ***System Modelling and Integration (SMI)*** course students familiarise with modelling and simulating the integration of systems of interest. In the ***Military System Specialisation (MSS)*** course, students will enter more deeply in the architecture and in the outcomes of the chosen system. The final Systems track course, ***System In Context (SIC)***, considers the system(s) under consideration in the wider context such as enemy systems, cyber threats, weather influences and budgetary considerations.

The thesis

A 20EC thesis (TSS) including a final presentation integrates all acquired knowledge and skills. The thesis proceeds with the acquired track linked knowledge. The thesis is aimed at research in a problem that the student has chosen, coming either from his own job or from one of the existing MTS research programmes. The thesis concludes the programme.

Course structure, EC and level

Each course has a paragraph “course structure”. This contains the number of European Credits (EC), the level of the course and the number of teaching sessions. One EC means one credit in the European Credit Transfer System (ECTS) and corresponds to 28 hours of study. For each course the number of contact hours is given in the COURSE OUTLINE. With regard to the number of self-study hours, the ratio between the number of contact hours and the hours necessary for self-study is roughly 3:5 for each course.

The course level can be 400, 500 or 600. Level 400 means a specialised course using professional literature next to textbooks. Level 500 refers to a course with an academic orientation using professional literature meant for researchers. Level 500 usually involves tests aimed at problem solving by a paper or research and calls for reflection on the course materials. Level 600 corresponds to a highly specialised course using research papers, state-of-the-art academic thinking and an oral presentation of an original contribution to a yet unsolved problem.

Course descriptions

ADVANCED TECHNOLOGIES in WARFARE (ATW)

ADMINISTRATIVE DETAILS

Course director: Prof.dr.ir. E. Theunissen
Course instructor(s): Prof.dr.ir. E. Theunissen; ir. B. Lubbers; A. Dijk, MSc

COURSE DESCRIPTION

The introductory part of this course consists of characterisations of unmanned military systems that play an increasing important role in modern military operations. Topics that are discussed are requirement analyses when evolving from manned towards unmanned systems and a framework for unmanned systems when going from remote control through full and intelligent autonomy. Sheridan's Level of Automation taxonomy is part of this framework. Attention is given to challenges that occur when an increase in autonomy requires the transfer of decision authority from human to system. Both legal and ethical questions are identified. To be able to investigate system performance and potential trade-offs at the intended TRL, methods and techniques are discussed. Different types of simulation to support this process are addressed.

To fulfil their missions, unmanned systems operate in hostile environments and collect and process lots of data. The amount and kind of information enclosed make these systems an extremely interesting target for espionage and endangers them of theft, manipulation and attacks. In the second part of this course we discuss two possible threats: navigation warfare and cyber warfare. We show parallels in the evolution of these two serious threats. Technical aspects of jamming and spoofing satellite navigation systems as well as countermeasures are part of the course. Advanced Persistent Threats (APT's) are a major cybersecurity risk for military operations. Detection of APT's in the industry is more than 6 months on average. We need to understand how to detect and combat these threats as early as possible. With the Cyber Kill Chain we will visualize the phases of an attack and enrich the understanding of adversary's tactics, techniques and procedures.

COURSE OBJECTIVES

The student will be able to

1. Describe, understand and analyse relations between requirements, specifications, and automation levels of (unmanned) military systems;
2. Select the appropriate techniques for assessing relevant technology at TRL ranges 3 to 7;
3. Identify legal and ethical questions that may occur at higher levels of automation of the Decide function in the O-O-D-A loop;
4. Identify opportunities for use of unmanned platforms together with the associated challenges and limitations;
5. describe and analyse in a quantitative way acts of navigation warfare;
6. describe vulnerabilities and assess consequences of cyber warfare activities on military and civilian systems;
7. describe and identify attack phases with the Cyber Kill Chain;
8. identify the following cyber-attack vectors, among others: jamming, spoofing and hijacking;
9. synthesise countermeasures against known and unknown cyber-attacks;
10. make an assessment to evaluate operational cyber resilience and cyber security practices.

COURSE STRUCTURE

The course will be given at level 400 and is 5 EC. The course will consist of 3 themes that will be discussed in 11 teaching sessions. Attendance in the teaching sessions is compulsory.

EDUCATION METHOD

Lectures, self-study and application of knowledge to case studies.

LITERATURE

Hand-outs of book chapters and journal papers, a.e.,

- Parasuraman, R., Sheridan, T., Wickens, C.D., A Model for Types and Levels of Human Interaction with Automation, IEEE Trans Systems, Man, and Cybernetics, vol 30(3), 2000.
- Autonomous Systems, Issues for Defence Policymakers, 2015 (ISBN: 9789284501939).
- Oonincx, P., Theunissen, E., Navigation Warfare meets Cyber: Threats and Trends, NL ARMS 2017, Asser Press, aug. 2017
- Unmanned Systems Roadmap 2017-2042
- Ethically Aligned Design – A Vision for Prioritizing Human Well-being with Autonomous and Intelligent Systems. Version 2. IEEE.
- Intelligence-Driven Computer Network Defense Informed by Analysis of Adversary Campaigns and Intrusion Kill Chains, Lockheed Martin, 2011

ASSESSMENT

Accomplishment of two case studies on automation levels and threats for military systems.

COURSE OUTLINE

	Subject	Literature / assignment	# hours
Week 1	Introduction to unmanned and autonomous systems – definitions and framework: OODA, LOA, TLS, risk, safety, security, threat, integrity, continuity		4
Week 2	Multi-dimensional classification schemes for automation, LOA & system design: fault tolerance, redundancy, dissimilarity. Examples		3
Week 3	Above LOA 6 - transfer of decision authority: legal implications, ethical risk and moral dilemmas. Questions + examples	Assignment: Case study on automation	4
Week 4	TRL dependent methods and techniques, performance-based requirements and standards		4
Week 5	Use of simulation at TRL 3 to 7: testing, LVC environments, human-in-the-loop, hardware-in-the-loop, real-time vs. fast-time. Examples.		4
Week 6	Unmanned system examples, opportunities & challenges (classified using OODA and LOA) + history & examples		3
Week 7	Cyber 1: Detection of APTs, vulnerabilities and consequences	Assignment: Case study on APT's	4
Week 8	Excursion		8
Week 9	Cyber 2: Cyber resilience and countermeasures		3
Week 10	Cyber 3: Case study cyber; analyzing network data		3
Week 11	Principles of global navigation satellite systems (GNSS)		4
Week 12	Vulnerabilities of GNSS: jamming, spoofing. Countermeasures		3
Week 13	Methods and techniques relevant for GNSS research		4

SYSTEMS ENGINEERING PRINCIPLES (SEP)

ADMINISTRATIVE DETAILS

Course director: Dr.ir. H. Nikookar
Course instructor(s): KTZ(TD) b.d. Dr.ir. F. Bolderheij, Dr.ir. H. Nikookar, KLTZ(TD), Prof. Dr. R.vd Ketterij, Dr. E. Dado, Prof.dr.ir. T. Tinga, Prof.dr.ir. R. Heusdens.

COURSE DESCRIPTION

PART1: Systems Engineering (SE)

- What is a system, What is SE? Big Picture
- Systems Engineering fundamentals, Definition and characteristics of systems;
- Application areas of SE;
- SE phasing
- System development
    - Strategy, marketing, concept development [needs, requirement analysis, concept definition], Ethics
    - R&D; testing & evaluation; Ethics
    - Design synthesis, life cycle analysis, performance prediction, construction and verification
    - Operation, maintenance, adaption and dismantling
- Practical (military) systems engineering examples, Military development processes (Project management, system life cycle)
- Project management
- Students' problem within the SE cycle

PART 2: Systems Integration

- SE & development models (V, spiral, prototyping)
- SE methodologies (MOE/MOP);
- Sensor integration
- Balancing capacities

PART 3: Life cycle analysis

- Performance analysis
- Total cost of ownership
- Maintenance (in defence)

COURSE OBJECTIVES

The student will be able to:

1. Understand an SE approach and its importance in choosing and applying correct models, methodologies to solve a specific SE problem (HW, SW and combined);
2. Have insight in generic, military SE & development processes;

3. Apply SE in software tools (such as MATLAB or Simulink, Python, etc.) to realistic military problems.

COURSE STRUCTURE

The course will be given at level 400 and is 5 EC. The course will consist of several themes that will be discussed in 12 teaching sessions. Attendance in the teaching sessions is compulsory.

EDUCATION METHOD

Classroom sessions, carrying out Case Studies, self-study and working out exercises.

LITERATURE

Book: Systems Engineering Principles and Practice, 3rd Edition, A. Kossiakoff, W. Sweet, S. Seymour & M. Biemer, Wiley, 2020.
Professional literature and journal papers.

ASSESSMENT

Accomplishment of your own problem as case study including a written report, presentation and oral questions.

COURSE OUTLINE

	Subject	Literature / assignment	# hours
Week 1	Foundation and Landscape of Systems Engineering (Nikookar)	case study assignments	3
Week 2	Complex Systems (Nikookar)		4
Week 3	System Development Process (Ketterij)		3
Week 4	Needs Analysis, Concept exploration (Ketterij)		3
Week 5	Systems Development Example-1 (Bolderheij+ Heusdens)		3
Week 6	Systems Development Example-1 (cont'd) (Bolderheij+ Heusdens)	Deadline for defining case study assignments	4
Week 7	Systems Development Example-2		3

	(vd Ketterij)		
week 8	Excursion		—
Week 9	Systems Development Example-3 (Dado)		4
Week 10	Life Cycle Analysis & Maintenance, (Tinga)		4
Week 11	Systems Engineering Management (Nikookar)		3
Week 12	Topics in SE*: "Soft" Systems Engineering (Guest Lecturer)		4
Week 12	Case Studies in Systems Engineering		—
Week 13	Case Studies in Systems Engineering	Case studies presentations	7

LIFE CYCLE MANAGEMENT (LCM)

ADMINISTRATIVE DETAILS

Course director: Prof.dr.ir. T. Tinga
Course instructor(s): Dr.ir. C. Rijsdijk, Prof.dr.ir. T. Tinga

COURSE DESCRIPTION

Introduction

The life of a technical system may be defined in various ways. From a marketing perspective, the life of a technical system starts upon its introduction and it ends upon its obsolescence (ELOT). From a system engineering perspective, the life of a technical system starts upon its conception and it ends upon its disposal. From an operator perspective, the life of a technical system starts upon its acquisition and it ends upon its disposal. In addition, the life of a technical system depends on subjective decisions about whether and when to maintain the system, or to extend the life or not. Moreover, the various stakeholders (original equipment manufacturer, operator, maintainer, …) may decide differently at some stage which may evoke conflicts. Also, the various components and subsystems of a technical system may have different lives. Typically, the life of the structure of a military system exceeds the life of the software or of rotating equipment. This means that the technical system may need to be modified by replacing or updating some of the subsystems. All these decisions are part of the system life cycle management, which evidently is highly complex and can typically not be controlled by a single stakeholder.

A network of interacting stakeholders is not entirely predictable in its behaviour, and neither is the rate at which a technical system degrades. This highly complicates the system engineering premise claiming that the life of a technical system should be managed at the earliest stages of its life. However, at the conceptual design phase both the number of options and the uncertainty are large. Especially for military systems, the future operating profiles are highly uncertain. So, the choices at the concept phase are typically not optimal in practice. Then, adjustments during the operational phase may become viable. This module on life cycle management particularly covers these adjustments during the operational phase. Since a military organisation is predominantly an operator (rather than a designer) of highly advanced technical systems, the operational phase is highly relevant here.

Position in the programme

The LCM module provides a more holistic view on the maintenance and redesign activities during the operational phase. A selection of these activities will be deepened in the "processes track" of the MTPS curriculum. For students who attend the "systems track" of the MTPS curriculum, the LCM module intends to enhance the understanding about maintenance and redesign during the operational phase. An integrated approach to acquisition, maintenance and operations will be advocated in the MTPS programme.

SEP While LCM is predominantly about the operational phase and SEP about the concept and development phase, the development methods of SEP (requirements, system definition, development and validation) provide a full view of life cycle development with strong relationship with the LCM module.

M&S In the case study of the LCM module, simulation methods and techniques treated in the Modelling & Simulation (M&S) course will be used.

C&C The LCM module is predominantly about maintenance and redesign of assets which is important for the Command & Control and operations where these assets are deployed.

COURSE OBJECTIVES

The life cycle management (LCM) module will contribute to the following (academic) skills:

- Analytic thinking
- Interpreting
- Written and oral communication

The course objectives of the life cycle management (LCM) module are:

- Recognize and understand all the phases in the life cycle of a military system, the associated decisions to be taken, and the dependencies between these decisions;
- Collect data and apply numerical models (or simulations) to support the decision making process;
- Understand scientific papers on related topics and translate the principles to the Defence context.

COURSE STRUCTURE

The course will be given at level 500 and is 5 EC. The course will consist of several themes that will be discussed in 12 teaching sessions. Attendance in the teaching sessions is compulsory.

EDUCATION METHOD

Lectures, self-study and case studies.

LITERATURE

Books (core theory)

- Crespo Márquez, A. 2007. The Maintenance Management Framework - Models and Methods for Complex Systems Maintenance, Springer-Verlag London, ISBN 978-1-84628-820-3
- Tinga, T. 2013. Principles of Loads and Failure mechanisms. Springer.

Books (partly used)

- Emblemsvag, J. 2003. Life-cycle costing using activity based costing and Monte Carlo methods to manage future costs and risks. Wiley.
- Alfares, H., Duffuaa, S. (2009). Maintenance Forecasting and Capacity Planning, in: Handbook of Maintenance Management and Engineering, London, UK: Springer
- Dhillon, B.S. (2002). Engineering Maintenance. A modern approach. Boca Raton (FL, USA): CRC Press.
- Manzini, R. et al. (2010). Maintenance for industrial systems, London, UK: Springer.
- Haarman, M., & Delahaye, G. 2015. VDMXL: Value Driven Maintenance and Asset Management. Dordrecht: Mainnovation.
- Moubray, J. 2011. Reliability Centred Maintenance. Elsevier.
- Mulder, W., Blok, J., Hoekstra, S., Kokkeler, F. 2012. Design for maintenance - Guidelines to enhance maintainability, reliability and supportability of industrial products. University of Twente

ASSESSMENT

The assignments of the module LCM are:

Assignment 1: In this assignment, students are expected to formulate a maintenance model for a specific military system.

Assignment 2: In this assignment, students are invited to replicate some analysis from a scientific paper in their working environment.

A **written exam** to evaluate the knowledge of the students on the various topics in the course. Focus will be on the LCM decisions to be taken, and the dependencies between these decisions (objective 1). The overall grade of the course is the average of the grades for assignments and written exam.

COURSE OUTLINE

	Subject	Assignments	# hours
Week 1	**Introduction to LCM process** Different phases in life cycle, typical decisions and challenges, asset management		4 Tinga
Week 2	**Life cycle costing (LCC) and total costs of ownership (TCO)** Life cycles, costs, expenses, cost allocation, cost tracing, activity based costing.		3 Rijsdijk
Week 3	**Design for maintenance** Reliability, supportability, maintainability and their role in the design process, design philosophies.		4 Tinga
Week 4	**Maintenance concepts** Objectives of maintenance policy assessments, reliability centred maintenance (RCM), failure mode, effects and criticality analysis (FMECA), maintenance policies (time / usage / load / condition based).		3 Tinga
Week 5	**Maintenance modelling; quantitative decision support I** Basis maintenance models (constant interval / age based replacement, condition based maintenance)	assignment 1	4 Tinga
Week 6	**Maintenance modelling; quantitative decision support II** Advanced maintenance modeling and simulation, link with usage profiles.		3 Tinga
Week 7	**Data analysis and reliability engineering** Failure models, nonparametric predictions of failures, availability, reliability, evidence that supports predictions, data censoring.		4 Rijsdijk
Week 8	**Data analysis and reliability engineering** Parametric approaches to reliability and availability, life time modelling, hazard rate modelling, arrivals modelling.	assignment 2	3 Rijsdijk
Week 9	**Logistic processes** Spare parts management, planning and scheduling, level of repair analysis, total productive maintenance.		4 Tinga
Week 10	**Decision making and decision support**		3

	Scorecards to predict performance under varying operating conditions, data driven decision support, prima facie causality, causal/evidential decision theory		Rijsdijk
Week 11	**Performance indicators used for maintenance and logistics** Conventional scorecards to measure posterior compliance: industry standards and Mindef standards.		4 Rijsdijk
Week 12	**Questions**	Submit assignments 1&2	3 Rijsdijk& Tinga
Week 13	Written exam		3

MODELLING & SIMULATION (M&S)

ADMINISTRATIVE DETAILS

Course director: Dr.ir. R.H.P. Janssen
Course instructor(s): Dr.ir. R.H.P. Janssen; Ir. A.M. van Oers

COURSE DESCRIPTION

This course presents several approaches to modelling and simulation. Special attention is paid to probability models (Poisson process / Markov process) and discrete event simulation. Often, the goal of modelling and simulation is to find a good solution to a problem. To obtain these solutions we apply optimization techniques. We focus on metaheuristics, which can be applied to a broad range of topics, to solve these optimization problems. A novel technique in modelling is machine learning. When sufficient data is available a machine learning algorithm can be trained. After training, the algorithm can be used to make predictions or help in decision-making.

Course themes:

1. (Meta)heuristics
2. Machine Learning
3. Modelling approaches, discrete event simulation;
4. Probability models (Poisson process / Markov process).

COURSE OBJECTIVES

The student will be able to:

1. Solve optimisation problems with problem-specific algorithms;
2. Analyse and select a metaheuristic method to solve an optimisation problem;
3. Set up a simple simulation study, to implement this using a software platform, and then interpret the results;
4. Model stochastic systems as a Poisson process or a Markov process;
5. Perform calculations on stochastic systems modelled as a Poisson process or a Markov process;
6. Construct a Machine Learning algorithm.

COURSE STRUCTURE

The course will be given at level 500 and is 5 EC. The course will consist of several themes that will be discussed in several teaching sessions. Attendance in the teaching sessions is compulsory.

EDUCATION METHOD

Classroom sessions, self-study, theoretical and programming exercises, assignments and presentations.

LITERATURE

- Sheldon M. Ross, *Introduction to Probability Models*, 11th Edition, Elsevier 2014.
- M. Pidd, *Computer Simulation in Management Science*, 5th Edition, Wiley 2004.
- F.S. Hillier, G.J. Lieberman. *Introduction to Operations Research*. 10th International Edition, McGraw-Hill 2015, ISBN 978-1-259-25318-8.
- I. Goodfellow, Y. Bengio, A. Courville. *Deep Learning*. ISBN 9780262035613.
- Tutorial Enterprise Dynamics Software.

ASSESSMENT

Written exam (40%) and presentations & assignments (60%)

COURSE OUTLINE

	Subject/ Literature / Assignment	# hrs
Week 1	Optimization; Local Search & Simulated Annealing; Assignment 1 (10%)	4
Week 2	Computer simulation, discrete event simulation, random number generation.	3
Week 3	Optimization; Genetic Algorithms; Assignment 2 (25%)	3
Week 4	Practicum Enterprise Dynamics (discrete-event software)	4
	Assignment (pass/fail)	
Week 5	Presentations Optimization Assignments;	3
Week 6	Poisson Process	4
Week 7	Machine Learning; Assignment 3 (25%)	4
Week 8	Continuous-Time Markov Chains / Queueing Theory	3
Week 9	Machine Learning	3
Week 10	Continuous-Time Markov Chains / Queueing Theory	4
Week 11	Continuous-Time Markov Chains / Queueing Theory	3
Week 12	Presentations Machine Learning Assignments;	4
Week 13	Written exam (40%)	2

COMMAND & CONTROL (C&C)

ADMINISTRATIVE DETAILS

Course director: Dr. B. Lijnse
Course instructor(s): Dr. B. Lijnse, Dr. JM. Jansen, KTZ(TD) b.d. Dr.ir. F. Bolderheij

COURSE DESCRIPTION

This course shows the complexity of the "ORIENT" part of the OODA-loop.
The course focus is threefold:

- All elements of decision support in command decisions (Command);
- Optimum use of all available resources (Control) during military operations;
- The role of C2 systems in facilitating Command and Control.

Course themes:

1. C2 models: OODA, NEC
2. Intent/pattern recognition
3. Socio-technical systems
4. Information requirements
5. Common Operational Picture (COP) and Situational Awareness (SA)
6. Resource management
7. Task modelling
8. C2 Systems evaluation

Tools:
C2 Simulation Environment
C2 Design and Prototyping Tool Suite

COURSE OBJECTIVES

The student will be able to:

- identify, understand, model and simulate C2 aspects (i.e. risk analysis, intent/pattern recognition, human behaviour, COP, SA, cyber) of the military OODA loop;
- oversee the influence of operational use and C2 to the life cycle of a military system, the associated (design)decisions to be taken, and the dependencies between these decisions;
- design and evaluate a high-level C2 system for a given mission objective.

COURSE STRUCTURE

The course will be given at level 500 and is 5 EC. The course will consist of 12 teaching sessions. The first 6 sessions focus on fundamentals, the last 6 focus on application in a design and evaluation project. Attendance in the teaching sessions is compulsory.

EDUCATION METHOD

Lectures, assignments, (programming/design) exercises and self-study

LITERATURE

Selected research papers.

ASSESSMENT

Assignments (individual and in a small group) and a case-study report and presentation.

COURSE OUTLINE

	Subject /literature / assignment	# hours
Week 1	Introduction to C2 Theory and frameworks plus practical training in the design and evaluation of C2 systems. Series of lectures on C2 concepts and assignments.	4
Week 2		3
Week 3		4
Week 4		3
Week 5		4
Week 6		3
Week 7	Application of skills and theory to a case study of a C2 system of own choosing. Modelling and prototyping of the system followed by evaluation of its performance. Progress presentations, workshops and guest lectures dependent on the chosen topics. Final report and presentations.	4
Week 8		3
Week 9		4
Week 10		3
Week 11		4
Week 12		3

OPTIMAL DEPLOYMENT (ODT)

ADMINISTRATIVE DETAILS

Course director: Prof. dr. H. Monsuur
Course instructor(s): Prof. dr. H. Monsuur / Dr. M. van Ee

COURSE DESCRIPTION

To determine the optimal deployment of military systems, several (combinatorial) optimization techniques are used. In this course, we focus on the optimal deployment of military systems and innovations such as unmanned systems, taking into account scarce resources. Game theory is used to quantify and also minimize the effect of optimal acting adversaries, whose goal is to frustrate the operation of the systems. This will serve as an introduction to game-theoretic risk management.

Subjects: (Combinatorial) optimization (2.5 EC) Game theory (Security games) (1.5 EC); Applications/Case Studies (1.0 EC).

COURSE OBJECTIVES

The student will be able to:

- Apply several exact methods and metaheuristic methods for decision support to military (linear and nonlinear) planning problems of scarce resources.
- Apply game theory to take into account optimal reactions of intelligent adversaries in small scale (network) situations: game-theoretic risk management.
- Reflect on the decision making process, using a scientific attitude. Relate technical parameters of systems with operational effectiveness/efficiency.

COURSE STRUCTURE

The course will be given at level 500 and is 5 EC. Attendance in the sessions is compulsory.

EDUCATION METHOD

Lectures and computer assignment (in these assignments, the students apply the algorithms and methods to military operational problems).

LITERATURE

- Luenberger D.G. and Ye Y. (2016) Linear and Nonlinear Programming. 4th ed
- Washburn A (2014). *Two-person zero-sum games*. Springer. Parts from chapters 3,4,7.
- Alderson et al. (2014). *Assessing and Improving Operational Resilience of Critical Infrastructures and Other Systems.* Tutorials in Operations Research 2014: 180-215.
- Cares JR, Dickmann JQ (2016). *Operations Research for Unmanned Systems*. Wiley.
- Van Ee M. (2019) Lecture notes on combinatorial optimization
- Selection of papers from journals and/ or applications

ASSESSMENT

(Computer) assignments.

1. Assignment exact optimization + presentation 40%
2. Assignment network problems & game theory 40%
3. Review/discussion/presentation of application or scientific paper 20%

RELATION TO END TERMS

End terms 2, 3, 4, 10, 12a, 13a, 14a, 15a.

COURSE OUTLINE

Week	Subject	Literature	#hours
PART I	Optimization		
	Optimization within the Defence Organization: Applications in Deployment, Maintenance and Logistics. Introduction to optimization software, Lingo, Matlab, Python	Luenberger and Ye	3
	Pivoting and simplex method for Linear Programming Basic properties	Luenberger and Ye	4
	Integer Linear Programming Dynamic Programming Efficiency of algorithms	Van Ee	3
	Computational complexity Approximation algorithms	Van Ee	4
	Constrained optimization of convex functions, Karush-Kuhn-Tucker conditions. Applications for search theory and logistics	Luenberger and Ye	3
	Assessment exact optimization (plenary presentations)		4
PART II	Game Theory		
	Zero-sum game theory	Washburn	3
	Duality and complementarity in linear programming and networks Solving network problem in game theory Network interdiction	Washburn Luenberger and Ye Alderson et al.	4
	Logistic games Search games Bilinear games	Washburn Luenberger and Ye Alderson et al.	3
	Operations Research methods in Critical Infrastructure Protection	Case studies/guest lecture	4
PART III	Applications/ Case studies / …		
	Reading/discussing selected papers and applications		3
	Reading/discussing selected papers and applications		4

SUSTAINMENT OF MILITARY SYSTEMS (SMS)

ADMINISTRATIVE DETAILS

Course director: Prof. dr. ir. T. Tinga
Course instructor(s): Dr. ir. A.M. Homborg, Prof. dr. ir. T. Tinga

COURSE DESCRIPTION

In this course, the technical issues related to these advanced predictive maintenance policies are introduced and discussed. The basis for that is a thorough understanding of the material (failure) behaviour under various load conditions. This means that a general introduction in materials science will be provided. After that, the typical types of loads acting on various components will be treated, as well as the most common failure mechanisms like fatigue, creep, wear and corrosion. Moreover, quantitative methods to assess the time to failure at a specific loading will be discussed.
After this theoretical part, the topic of monitoring will be addressed, as the knowledge on material failure behaviour can only be applied for predictive maintenance purposes when the usage, loads or condition (evolution) of the systems and components is adequately monitored. The technical challenges in collecting, processing and interpreting the measurements will be discussed.
Finally, the development of predictive maintenance strategies will be discussed, as well as the application in design processes.

COURSE OBJECTIVES

The student will be able to:

1. Distinguish between the most important failure mechanisms (fatigue, wear, corrosion, overload, creep) and apply quantitative models to calculate the service life for a given load / usage profile;
2. Select and motivate (i) the application of a specific monitoring technique and (ii) the analysis method / way of interpretation of the obtained monitoring data to get insight in the system health / condition.

COURSE STRUCTURE

The course will be given at level 500 and is 5 EC. The course will consist of three themes, materials basics, loads & failure mechanisms and monitoring / predictive maintenance, that will be discussed in 17 teaching sessions. Attendance in the teaching sessions is compulsory.

EDUCATION METHOD

Lectures and assignments (in these assignments, the students apply the models and methods to military operational problems).

LITERATURE

- Tinga, T., Principles of Loads and Failure mechanisms, Springer, 2013 – Chapter 2-5
- Callister, W.D., Materials Science and Engineering, Wiley, 2011 - Composites, corrosion
- Jones, D.A., Principles and prevention of corrosion, Prentice-Hall, 1996
- Additional papers and hand-outs

ASSESSMENT

Presentation of a scientific paper on a relevant monitoring topic and writing a short research paper on a case study (failure mechanisms).

COURSE OUTLINE

	Subject	Literature / assignment	# hours
Week 1	Introduction to course		4
Week 2	Materials fundamentals I		3
Week 3	Materials fundamentals II	handing out ass. 1	4
Week 4	Failure mechanisms I		3
Week 5	Presentation assignment 1	Presentations ass. 1	4
	Summer break		
Week 6	Failure mechanisms II	handing out assignment 2	3
Week 7	Failure mechanisms III		4
Week 8	*No lecture*		
Week 9	Failure mechanisms IV		3
Week 10	Predictive Maintenance, design and failure analysis		4
Week 11	Stochastic life assessment/ role of uncertainty link with reliability engineering/ RFP		3
Week 12	*No lecture*		
Week 13	*No lecture*		
Week 14	Intro Health & Condition monitoring + Structural health monitoring + Sensors and sensing concepts	Presentation intermediate results	3
Week 15	*No lecture*		
Week 16	Condition monitoring: Oil analysis, Vibration analysis; Wrap-up & Questions		4
Week 17	*No lecture*		
Week 18	*No lecture*		
Week 19	Presentation of paper / assignment results	Final presentations	3

TOPICS in LOGISTICS, MAINTENANCE & OPERATIONS RESEARCH (TLMOR)

ADMINISTRATIVE DETAILS

Course director: Prof.dr. H. Monsuur
Course instructor(s): Dr.ir. R.H.P. Janssen, Prof.dr.ir. T Tinga, Prof.dr. H. Monsuur, Dr.ir. A.M. Homborg, Dr. M. van Ee, Ir. A.M. van Oers

COURSE DESCRIPTION

Topics related to Quantitative logistics: Logistics networks, Inventory management, Transportation problems, Operational Logistics.

Choice from several topics on OA and maintenance.

Subjects: Quantitative logistics, Integration of Quantitative Logistics, Maintenance and Operations Research (3.5 EC) (Assignment QL and TNO); Operations research / maintenance in context (1.5 EC) (Analyse, optimize, and visualize pedestrians crowds in any infrastructure with Pedestrian Dynamics/-).

COURSE OBJECTIVES

The student will be able to:

1. Calculate optimal inventory levels, ways of transport and logistic network;
2. Study an actual topic and critically report / present.

COURSE STRUCTURE

The course will be given at level 600 and is 5 EC.
The course will consist of lectures on quantitative and operational logistics, excursion to NLR and excursion to TNO and assignment at TNO, and 2 special topics from which students can choose (depending on the choice for OA or INST). Attendance is compulsory.

Topics can be:

- Big data, predictive analytics for maintenance
- Critical Infrastructure Protection
- Pedestrian Dynamics (year 2022)
- Additive manufacturing
- 3D printing (year 2022)

EDUCATION METHOD

Lectures and assignments.

LITERATURE

- Introduction to Logistics Systems Management - Gianpaolo Ghiani, Gilbert Laporte, Roberto Musmanno
- Operational Logistics: The Art and Science of Sustaining Military Operations. M. Kress
- Hand-outs and articles.

ASSESSMENT

Assignments and presentations.

COURSE OUTLINE

	Subject	Literature / assignment	# hrs
Week 1	Introduction to the course, and setup		3
Week 2	Quantitative logistics	Supplier Selection (presentations) Logistic networks (presentations)	4
Week 3	Quantitative logistics	Locating facilities (presentations) Transportation (presentations)	4
Week 4,5	NLR excursion for TLMOR		8
Week 6	INST: Guest lecture 3D printing OA: Pedestrian Dynamics	Apply selected paper to own organization Excercises	4
Week 67	Preparation for TNO assignment		5
Week 8,9	TNO excursion for TLMOR	Assignment and presentation	8
Week 10	INST: OA: Pedestrian Dynamics	 Excercises	5
Week 11	INST: OA: Pedestrian Dynamics	- Presentation of assignment	4

SYSTEM MODELLING & INTEGRATION (SMI)

ADMINISTRATIVE DETAILS

Course director: Dr.ir. H. Nikookar

Course instructor(s): Dr.ir. H. Nikookar; KLTZ dr.ir. F. Bolderheij; Prof.dr.ir. M. Voskuijl, Dr.ir. R. Nijboer, Dr.ir. R. Savelsberg

COURSE DESCRIPTION

1. Introduction to Modelling and Simulation
2. Statistical concepts for simulation
3. Discrete Event simulation
4. Modelling Continuous Systems
5. Error sources and uncertainties in modelling
6. Monte Carlo Simulation
7. Integration of simulation models

Currently NLDA foresees 5 simulation environments:

1. SEWACO simulator (military sensors and weapons systems in a threat environment)
2. Platform simulator (energy, propulsion, aircraft systems)
3. Cyber warfare simulators (DCC cyber range and a SCADA simulation)
4. Communications system simulation toolbox
5. C2 processes and task simulation environment

COURSE OBJECTIVES

The student will be able to:

- Understand fundamental principles of the simulator domain;
- Model the system-of-interest by combining system elements in accordance with the architectural design requirements and the integration strategy;
- Understand the architecture and use (scripting, initialisation) of the applicable simulation environments;
- Integrate own models into the simulation environments.

COURSE STRUCTURE

The course will be given at level 500 and is 5 EC. The course will consist of several themes and exercises that will be discussed in 14 teaching and working sessions. Understanding of the simulator domain will be acquired under self-study and expert support during these sessions. Attendance in all sessions is compulsory.

EDUCATION METHOD

Classroom sessions, self-study, simulation sessions related to exercises and case studies. The simulator activities will be executed in small groups (2-3 persons) on one simulator.

LITERATURE

1. J.A. Sokolowski and C.M. Banks (editors), Modelling and Simulation Fundamentals, Wiley, 2010.
2. Fok Bolderheij, Capt. (WE) RNLN, PhD, Benefits of integrating the management of combat and platform systems, Netherlands Defence Academy, NL
3. Papers from IEEE Systems Journal and Journal of System Engineering & Electronics
4. Book chapters, conference proceedings and digests.

ASSESSMENT

Take-home assignment (35%) and a case study research finalised by a report and presentation (65%).

COURSE OUTLINE

	Subject	Literature / assignment	# hours
Week 1	Introduction to Modelling and Simulation	Case study assignments	3
Week 2	Statistical concepts- Error sources and uncertainties in modelling		3
Week 3	Continuous and Discrete Modelling		3
Week 4	Performance evaluation techniques	Deadline for defining case study assignments	3
Week 5	Monte Carlo Simulation		3
Week 6	Simulation environments and software issues		3
Week 7	Advanced Topics in Systems Modelling & Integration		3
Week 8	Integration of simulation models		3
Week 9	Simulator session		3
Week 10	Simulator session		3
Week 11	Simulator session		3
Week 12	Simulator session		3
Week 13	Simulator session		3
Week 14	Simulator session		3
Week 15	Case study presentations		4

MILITARY SYSTEM SPECIALISATION (MSS)

ADMINISTRATIVE DETAILS:

Course director: KTZ(TD) b.d. Dr.ir. Bolderheij
Course instructor(s): Dr.ir. H. Nikookar; KTZ(TD) b.d. Dr.ir. Bolderheij; Dr.ir. R. Savelsberg; Prof.dr.ir. R. Heusdens; Prof.dr.ir. R. van de Ketterij; KLTZ dr.ir. R. Geertsma.

COURSE DESCRIPTION

In this course, modelling principles and techniques that were acquired in previous courses will be applied to construct a model of the (sub)system that has to be developed or improved upon during the thesis period. This course will mainly focus on the (sub)system itself and its properties, required performance and capabilities. Therefore, the student has to acquire a technical understanding of the military (sub)system to be analysed and has to describe the (sub)system in terms of its capabilities and Measurements of Performance (MOPs).

During the course, several experts will present their models and discuss the issues involved with the development, validation, verification, implementation and testing of these models. Furthermore, the student will be invited to discuss the problem that has to be investigated by means of the model, the modelling principles and techniques that will be used to construct the model and the requirements of the (sub)system. During the course, the student will use the model to provide proof of the validity and verify the performance of his/her model.

COURSE OBJECTIVES

The student will be able to:

1. Understand the technologies, architectures and underlying processes of the military (sub)system;
2. Describe the MS in terms of its capabilities;
3. Define MOP for MS capabilities;
4. Develop a model of the MS;
5. Discuss the techniques and methods used by the guest lecturers and the other students;
6. Critically examine the models developed by his/her colleagues.

COURSE STRUCTURE

The course will be given at level 500 and is 5 EC. The course will consist of 14 sessions consisting of (guest) lectures, presentations and discussion sessions. Understanding of the military (sub)system will be acquired under self-study and expert support during these sessions. Attendance in all sessions is compulsory.

EDUCATION METHOD

Expert presentations, presentation of the modelling approach, discussion sessions, self-study, progress presentations, final presentations.

LITERATURE

- Andreas Tolk, Engineering Principles of Combat Modelling and Distributed Simulation, John Wiley & Sons, Hoboken, New Jersey, 2012.
- John A. Sokolowski and Catherine M. Banks, Modelling and Simulation Fundamentals, John Wiley & Sons, Hoboken, New Jersey, 2010.
- Sterbenz, J.P.G., Çetinkaya, E.K., Hameed, M.A. et al. Telecommun Syst (2013), Evaluation of network resilience, survivability, and disruption tolerance: analysis, topology generation, simulation, and experimentation, Telecommunication Systems, February 2013, Volume 52, Issue 2, pp 705–736.
- Other technical papers, book chapters, conference proceedings and digests.

ASSESSMENT

Model assessment report, project report and presentations detailing the approach of the problem, progress and the final results.

COURSE OUTLINE

The number of sessions in a bullet point is depending on the number of students in the group

- Introduction (1 session)
- Expert Presentations (3 or more sessions)
- Presentation of modelling approach (1 or 2 sessions)
- Discussion sessions (3 or more sessions)
- Progress Presentations (3 or more sessions)
- Final Presentations (1 or 2 sessions)

SYSTEMS IN CONTEXT (SIC)

ADMINISTRATIVE DETAILS

Course director: KTZ(TD) b.d. Dr.ir. Bolderheij

Course instructor(s): Dr.ir. H. Nikookar; KTZ(TD) b.d. Dr.ir. Bolderheij; Dr.ir. R. Savelsberg; KLTZ dr.ir. R. Geertsma; Prof.dr.ir. R.G. van de Ketterij; Prof.dr.ir. R. Heusdens; Dr.ir. R. Nijboer.

COURSE DESCRIPTION

This course is a logical sequel of the course Military Systems Specialisation (MSS): the model that was developed within MSS is now tested against a realistic scenario. This provides an opportunity to observe the interaction of the MSS with its environment, being the natural environment and/or the systems of the opponent. By simulating the deployment of the system, its overall effectiveness can be analysed using a predetermined Measure of Effectiveness (MOE). The student therefore has to utilise the technical knowledge that was acquired within MSS to gain insight into the operational capabilities and restrictions (or *effectiveness*) of the system. During the course, several experts will present their simulations and ample room is provided to discuss these simulations, the underlying models and used methods and techniques.

COURSE OBJECTIVES

The student will be able to:

1. Integrate the (sub) system that was developed within the MSS course in a(n) (existing) simulation environment and analyse its behaviour in context of the expected threat and natural environment and its interactions;
2. Develop scenarios to model the operational behaviour and assess its effectiveness within a specified mission (MOE);
3. Apply tools to optimise the MOE(s) by adapting (sub)systems performance or requirements (MOP);
4. Asses the robustness on failure modes of the (sub)systems, capabilities and interfaces.
5. Discuss the techniques and methods used by the guest lecturers and the other students;
6. Critically examine the simulation results of his/her colleagues.

COURSE STRUCTURE

The course will be given at level 600 and is 5 EC. The course will consist of 8 sessions during which the effectiveness of the developed model is assessed in a realistic scenario within a specific simulation environment, followed by a demonstration and a presentation of the results. Attendance in all sessions is compulsory.

EDUCATION METHOD

Expert presentations, presentation of the simulation approach, discussion sessions, self-study, progress presentations, final presentations

LITERATURE

- Andreas Tolk, Engineering Principles of Combat Modelling and Distributed Simulation, John Wiley & Sons, Hoboken, New Jersey, 2012.
- John A. Sokolowski and Catherine M. Banks, Modelling and Simulation Fundamentals, John Wiley & Sons, Hoboken, New Jersey, 2010.
- F. Bolderheij, F.G.J. Absil, P. van Genderen, A Risk-Based Object-Oriented Approach to Sensor Management, IEEE, 2005.
- Conference proceedings and digests.

ASSESSEMENT

Simulator output report, project report and presentations detailing the approach of the problem, progress and the final results.

COURSE OUTLINE

The number of sessions is depending on the number of students in the group

- Introduction (1 session)
- Expert Presentations (2 sessions)
- Presentation of modelling approach (1 sessions)
- Discussion session (1 sessions)
- Progress Presentations (1 or 2 sessions)
- Final Presentations (1 or 2 sessions)

THESIS

ADMINISTRATIVE DETAILS

Course director: Prof.dr.ir. R. van de Ketterij

COURSE DESCRIPTION

The thesis is track-linked. Before starting the thesis, the student must have at least 35 EC and an Individual Thesis Proposal must be approved. For more details see the MTPS thesis guide.

The thesis subject preferably comes from the students' normal working environment. If this environment cannot provide a subject, the thesis supervisor will provide one.

COURSE OBJECTIVES

These are the same as the overall programme objectives and the track related exit qualifications (see pages 4 and 5).

COURSE STRUCTURE

The thesis is an academic graduation work at level 600 and is worth 20 EC.

ASSESSMENT

See the MTPS thesis guide for the assessment. In any case, the thesis must be approx. 50 pages, be presented in public and defended in front of an examination committee.

MTPS organisation

The MTPS programme has adopted the principles as laid down in the FMS Education Quality Manual dated May 2016. From these Plan-Do-Check-Act principles, following boards and committee ensure the overall quality of the programme and its organisation at course and curriculum level.

The programme has following boards and committees:

The **Board of Examiners** (BoE) is responsible for the quality of the testing, for the assessment procedure and for judging the admissibility of applicants. The BoE consists of:

- Prof.dr.ir. T. Tinga (Chairman)
- Dr. C. Rijsdijk
- Vacancy

The BoE has established Rules and Guidelines. These are published in appendix 2 of the Teaching and Examination Regulations MTPS.

The **Programme Board** (PB) is responsible for the quality of the programme. The PB manages programme organization and overall programme cohesion. Following people are members of the PB:

- Prof.dr.ir. R. van de Ketterij (Chairman)
- Dr.ir. H. Nikookar
- L. Verburg MA (Section Education)
- KLTZ ing. E. de Jong , programme coordinator
- C. Gille, student member cohort 2019 (vacancy for cohort 2021)

The **Programme Committee** checks the work of the PB and provides checks and balances in accordance with the Teaching and Examination Regulations (TER). The programme committee is a subgroup of the existing “Opleidingscommissie” (OC) for the bachelor programme MS&T. Following people are members of this committee:

- Prof.dr.ir. M. Voskuijl (Chairman)
- Dr. M. van Ee
- L. Verburg MA (Section Education)

- KAP L.A. van Mastrigt, BSc, student member cohort 2019 (vacancy for cohort 2021)
- Ing. A.D. Nederveen, student member cohort 2019 (vacancy for cohort 2021)

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	Aug-21				Sep-21					Oct-21				Nov-21				Dec-21						Jan-22		
wk	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	1	2	3
	4-aug	11-aug	18-aug	20-aug	27-aug	3-sep	10-sep	17-sep	24-sep	1-okt	8-okt	15-okt	22-okt	29-okt	5-nov	12-nov	19-nov	26-nov	3-dec	10-dec	17-dec	24-dec	31-dec	7-jan	14-jan	21-jan
class 2021					welcome day	Advanced Technologies in Warfare (ATW)							excursion	ATW				Pres		LCM				LCM		
						Systems Engineering Principles (SEP)								SEP					Pres	MS				MS		

	Feb-22				Mar-22					Apr-22				May-22				Jun-22					Jul-22			
wk	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
	28-jan	4-feb	11-feb	18-feb	25-feb	4-mrt	11-mrt	18-mrt	25-mrt	1-apr	8-apr	15-apr	22-apr	29-apr	6-mei	13-mei	20-mei	27-mei	3-jun	10-jun	17-jun	24-jun	1-jul	8-jul	15-jul	22-jul
class 2021	Life Cycle Management (LCM)							exams	C&C				Command & Control					C&C			Pres					
	Modelling & Simulation (MS)								ODT				Optimal Deployment					ODT			Case Study		SMS		
									SMI				SMI					System Modelling & Integration				Pres			
																							TLMOR			
																	Resit						MSS			

	Aug-22					Sep-22					Oct-22				Nov-22				Dec-22						Jan-23		
wk	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	1	2	3
	29-jul	5-aug	12-aug	19-aug	26-aug	2-sep	9-sep	16-sep	23-sep	30-sep	7-okt	14-okt	21-okt	28-okt	4-nov	11-nov	18-nov	25-nov	2-dec	9-dec	16-dec	23-dec	30-dec	6-jan	13-jan	20-jan
class 2021	Pres					Sustainment of Military Systems (SMS)										excursion	Pres									
	MSS					Military System Specialisation (MSS)							Pres					Thesis							Thesis		
	TLMOR					Topics in Log., Maint. and Ops. Research (TLMOR)						Pres															
						System In Context (SIC)											Pres										
									Resit																		

	Feb-23				Mar-23					Apr-23				May-23				Jun-23					Jul-23			
wk	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
	27-jan	3-feb	10-feb	17-feb	24-feb	3-mrt	10-mrt	17-mrt	24-mrt	31-mrt	7-apr	14-apr	21-apr	28-apr	5-mei	12-mei	19-mei	26-mei	2-jun	9-jun	16-jun	23-jun	30-jun	7-jul	14-jul	21-jul
class 202	Thesis																							colloquium		
	Resit																									