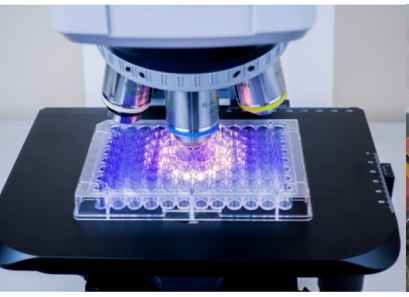
ROYAL HIGHER INSTITUTE
150-year think tank for DEFENCE

Department Scientific and Technological Research of Defence

# SCIENTIFIC RESEARCH
## IN THE BELGIAN DEFENCE FORCES




RMA Brussels
Royal Military Academy

# 2019

# Introduction

Dear reader,

This military scientific report provides you with an overview of all Defence research projects of 2019. Some of them are a continuation of projects conducted previously; others are newly started projects in new scientific areas. It is intended for a broad audience.

For the first time, this leaflet does not only contain projects ended in 2019, but shows the reader also the preliminary outcomes of on-going projects of 2019. As in previous years, the brochure includes also research projects partly done with external financial means, e.g. projects funded by the European Commission or sponsored by regional governmental institutes.

This is the fourth time this annual brochure is published and it is our intention to provide you each year with such a review to keep you informed about the outcome of our research.

While this brochure presents the result of the hard work performed by all the researchers and study directors of the different research institutes in the Belgian Armed Forces, we are confident that, while grasping through these final or preliminary reports, your interest in research will thrive.

We dear to hope that this document will be a stimulus for further military research and cooperation in order to obtain the necessary future capabilities for our Defence forces.

Sincerely Yours,
Filip Martel
Director of Scientific and Technological Research of Defence

## Main Defence Research Entities

Royal Higher Institute for Defence (RHID)
website: http://www.defence-institute.be

Royal Military Academy (RMA)
website: www.rma.ac.be

Defence Laboratories (DLD)
website: www.mil.be

Military Hospital Queen Astrid (MHQA)
website: https://www.mil.be/nl/eenheden/militair-hospitaal-koningin-astrid

# Executive summary

In this report, we invite you for grasping through a short overview of 51 running or completed research projects from different entities of the Belgian Armed Forces in 2019.

The first ones are presented to you organized by research area. The DAP (Data acquisition and Processing) projects with numbers DAP and SIC, the HFM (Human Factors and Medecine) projects with numbers HFM and RCDM and the MSP (Mobility, Systems and Protection) projects with numbers MSP and MB. They are all funded with budget from the RHID. Many of them, if not the majority, are conducted in collaboration with or as a national contribution to NATO STO or EDA projects since international cooperation is much stimulated.

Next are projects conducted under the auspices and with operational budget of the Military Hospital Queen Astrid. Many of them are oriented towards operational medicine.

To conclude you will find a number of projects run by Patrimony of RMA. Some of them like the TRIVALENT project are funded as part of an EU project H2020, others like SOLOMON are the BEL input to a PADR (Preparatory Action on Defence Research) EU project. The LLP project undertaken by the department of physics is fundamental fusion research for clean energy in the future.
For more information on any of these projects, contact can be taken with the director or the researcher of these studies.

# Table of Content


# DAP16-02 Study of cryptographic techniques with a focus on practical aspects of symmetric key algorithms and hash functions

Directors: Air Force Maj Helena BRUYNINCKX
Air Force Capt(sr) Julien PETIT
Researcher: Mr. Fréderic LAFITTE

# DAP16-02 Study of cryptographic techniques with a focus on practical aspects of symmetric key algorithms and hash functions

## Background

Computer security relies heavily on cryptography; any security solution built on top of poor cryptography is likely to offer no security at all.

The research in the field of cryptographic techniques and their applications is evolving fast and an independent expertise is required in order to assist Belgian Defence with crypto-related matters.

Since 1994, within the framework of multiple research projects, RMA-MWMW has developed and maintained an expertise in cryptography that has proven useful when supporting SGRS-SI/S/CIS & Cyber Security in the analysis, design and implementation of cryptographic solutions. Within the current project, RMA-MWMW also assists NVO/ANS in the development of national cryptographic algorithms to be used for the protection of EU and NATO classified information up to SECRET.

## Objectives

It is becoming increasingly obvious that off-the-shelf products should not be trusted for critical matters; even widespread collaborative open source efforts such as TLS should not be relied on, as suggested by disclosed governmental efforts to weaken cryptographic standards and implementations, or by hacker competitions whose goal is to design clever backdoors that can be deniably implanted.

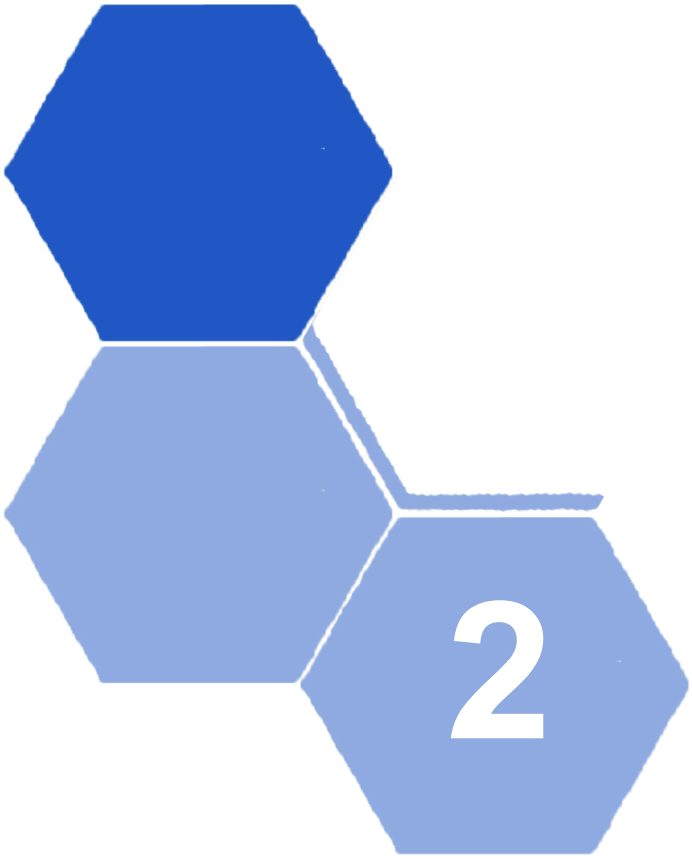
## Preliminary results

Products for SGRS-SI/S/CIS & Cyber Security developed within the frame of this project are:

- A taylored C++ library of symmetric key functions. “Permutation-based” cryptography is a rather recent hot topic within the cryptographic research community: it enables to obtain essentially all symmetric-key functions based on a single permutation. These functions are supported by a mathematical proof of security, based on the (unprovable) assumption that the permutation offers cryptographic strength. This separation of cryptographic strength and security functions enables a long-term modular implementation: the permutation module determines the security level as well as the performance of the functions and can thus be changed according to evolving needs (e.g. IoT), while the library that uses the module remains fixed on the long term making it worthwhile to invest in its hardening and external reviewing.

- A TRNG to produce all keying material for BEL Def, but also for national crypto. The design of the TRNG comes from the previous study (IS-06) and is based on the assumption that all off-the-shelf hardware random number generators are corrupted/backdoored, but by parties that have conflicting interests. Existing generators are combined in a manner that makes the output sequence unpredictable, even if these parties collude. In the frame of this project, the TRNG from IS-06 is partially re-designed in order to make it available for national use. This means, in particular, supporting a number of protocols for the secure handling of generated sequences.

- A prototype for deniable encryption. With crypto wars intensifying in recent years, the problem of border control continues to deteriorate: border agents are increasingly likely to search and seize travellers’ digital information and to compel travellers to reveal their encryption keys. The purpose of this product is to equip the traveller with “fake” decryption keys whose disclosure would only reveal chosen content (while the real key still reveals the real content).




# DAP16-03 Compromising Emanations of Video Display Units

Director: Dr. Ir. Col. Bart SCHEERS

Researcher: Ir. Pieterjan DE MEULEMEESTER

## DAP16-03 Compromising Emanations of Video Display Units

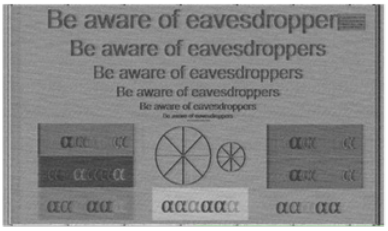
Electronic devices (e.g. personal computers, video displays, smartphones, etc.) leak electromagnetic signals either by radiation or conduction. These emissions or emanations can be picked up and under certain conditions the information can be reconstructed. In case of radiation leakage this means that even air gapped equipment can be spied upon. These methods are an attractive way to gain unauthorised access due to the fact that it is untraceable, no physical access is needed and that cryptographic protocols and authentication tokens are becoming more ubiquitous.

The aim of this research project is to investigate the feasibility of reconstructing the image of a leaking video display unit (VDU) solely from its emanations. This poses an informational integrity threat that could affect many devices. Therefore, it is of utmost importance to characterise and analyse this threat by firstly determining this eavesdropping possibility. The cause of these compromising emanations is investigated by closely examining the existing video signalling and processing technologies. This enables us to detect possible weak points in the security of the system. Consequently, this gain us new insights in how to develop countermeasures and security enhancement measures.

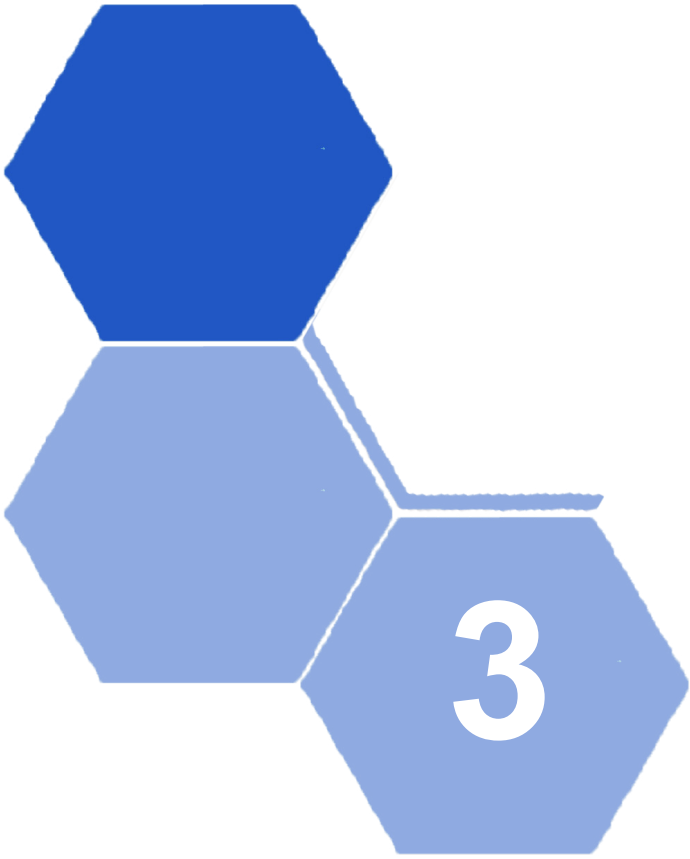
In this research work, the risk of a video eavesdrop attack at larger distances is investigated. A video leakage distance of 80 meters is examined for a video set-up consisting of an ultra-high-definition (3840x2160) and a high-definition displays (1920x1080) utilising HDMI cables for video signalling. By improving the instrumentation and video reconstruction methods, the video leakages of the tested set-ups are detected from an 80-meter distance. Furthermore, the original video image could be reconstructed from these leakage emanations. This confirms that (modern) video displays still suffer greatly from compromising emanations and form a risk of being eavesdropped (even at 80 meters…).

This research work also shows that the video leakage channels of co-located identical VDUs can be separated from each other. Consequently, the image of each VDU can be reconstructed exploiting the different leakage channels. This is realised by deploying a phased array system and an improved amplification stage and by an upgraded method of video image leakage detection and reconstruction. The phased array system enabled us to employ MIMO techniques such as spatial multiplexing to exploit the leakage channels, which resulted in an increase of quality of the reconstructed images.

Video display setup at 80 meters




Video image reconstruction at a distance of 80 meters




# DAP16-04 Non-lethal use of lasers on the modern battlefield

Director: Air Force LtCol Marijke VANDEWAL

Researcher: Mr. Christiani SANTOS

# DAP16-04 Non-lethal use of lasers on the modern battlefield

## Background

Law enforcement and military forces in many NATO countries are faced with a growing number of situations requiring non-lethal options. Laser illuminators can be used for effects ranging from unambiguous warning to reductions in combat and functional effectiveness.

This proposal will focus on non-lethal efforts in the visible domain for anti-personnel applications. The main objective would be the creation and implementation of a simulation model for the prediction and assessment of laser dazzler effectiveness (level and duration of functional disruption) at a certain range and in specific light conditions including the trade-off necessary for the safe use of the laser dazzler. For the validation of the model, results from testing of human subjects in the presence of a laser glare source will be used. These inputs will be delivered through the current participation in NATO SET198 and ongoing end of study works at RMA.

The performance prediction of laser dazzlers as a main objective will also lead to a better understanding of the protection measures necessary in the Belgian Armed Forces. Indeed, since adversaries have recognised the effectiveness of lasers to distract and diminish operational performance, the protection against these non-lethal weapons is of growing importance.

## Objectives

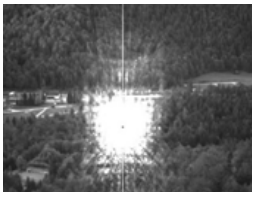
Laser dazzling of electro-optical (EO) devices has emerged in the last years as a powerful optronics countermeasure (OCM). In the activities developed during this period, we analysed the effects of laser dazzling in CMOS (complementary metal-oxide semiconductor) devices, which in the last years have enabled compact and low-cost microcircuits and imaging systems.

## Preliminary results

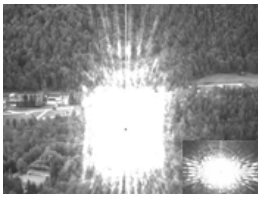
Two different small and lightweight cameras, hereafter CM1 and CM2, were used: a monochrome camera (CM1) where different lens systems can be added, and a colour camera (CM2) with integrated optics, equipped with a fisheye lens, which is commonly fitted to micro-unmanned aerial vehicles (micro-UAVs) providing a wide field of view imaging system. We present data acquired in the laboratory and during a field trial.

The influence of different parameters such as ambient illuminance, laser wavelength and irradiance were analysed. During laser irradiation, different physical phenomena appear, such as diffraction, multiple reflections and light scattering. Camera parameters such as exposure time play an important role on the resulting blurred images. The diameter of the dazzled area increases with increasing laser irradiance, and the dazzle is effective at irradiance levels around hundreds of μW/cm2.

Fig. 1 presents images acquired with the CM1 camera under laser illumination at D = 600 m ("Moonraker" trial). A green laser emitting at λ=532 nm and with nominal maximum power of 8 W was used. The average laser irradiance ($E_{avg}$) measured in the proximity of the camera position was $E_{avg}$=270 μW/cm2 (and peak irradiance $E_{peak}$=490 W/cm$^2$). In the dazzled images displayed in Fig. 1, the centre of the image presents an area where pixels are overexposed, leading to pixel saturation. Moreover, the blooming effect (a vertical column of saturated pixels), diffraction rings, lens flare and an interference pattern forming a regular array of bright spots can be observed.



(a)



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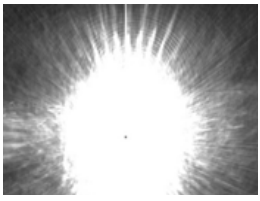

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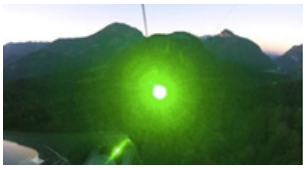

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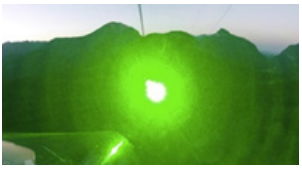


(e)

(f)

**Figure 1:** Dazzled images acquired for different exposure times ($t_{exp}$) and illuminance (I) for the CM1 and CM2 cameras at D = 600 m (field trial). CM1: (a) $t_{exp}$ = 10 ms (I ~ 900 lx) ; (b) $t_{exp}$ = 32 ms (I ~ 350 lx); (c) $t_{exp}$ = 40 ms (I ~ 44 lx); CM2: I ~ 900 lx (d-e) and I ~ 20 lx (f). The inset in (b) shows an image acquired during experiments in the laboratory for comparison (E ~ 287 μW/cm2, I=8 lx and $t_{exp}$ = 30 ms).

In the outdoor experiments, the illuminance varied from daylight (I = 5 - 900 lx) to nighttime (I < 0.1 lx) conditions, and was fixed at I = 8 lx for the laboratory measurements. In both cases, the dazzled area increased with increasing $t_{exp}$, as shown in Fig. 1a-c and Fig. 2a for $E_{avg}$ = 70 μW/cm2 (field trial) and E = 485 μW/cm2 (laboratory).

The total number of overexposed pixels under laser radiation was determined according to the Overexposed Pixel Counting (OPC) method, where a dazzle threshold pixel value vth is defined. Fig. 2a present the obtained results for laboratory (for both $v_{th}$ = 210 and $v_{th}$ = 255) and outdoor measurements.. For the outdoor measurements, a systematic analysis of the images showed that vth = 210 resulted in a better estimation of the saturated and overexposed area. Results obtained for overexposed pixels ($v_{th}$ = 255) are also presented in Fig 2a for comparison. The applied criterion in the choice of vth was the possibility to recognize vegetation and/or sharp features in the background scene. The pourcentage of dazzled pixels (Fig. 2a) varied in a set of acquired images due to turbulence effects (varying laser average irradiance and position impinging on the camera).

The dazzled images were also analysed using the Structural Similarity Index Method (SSIM), an image processing technique. The SSIM is an image quality assessment method, based on the degradation of structural information. Fig. 2b shows that the SS Index decreases as exposure time or irradiance increases, i.e. structural information is gradually degraded. Similar results were found in measurements performed in the laboratory, as shown in Fig 2b for $t_{exp}$ = 30 ms. As expected, the quality of the dazzled images (compared to a reference image with no laser illumination) degrades compared to the reference image, and dazzling is even more effective for a higher $t_{exp}$.

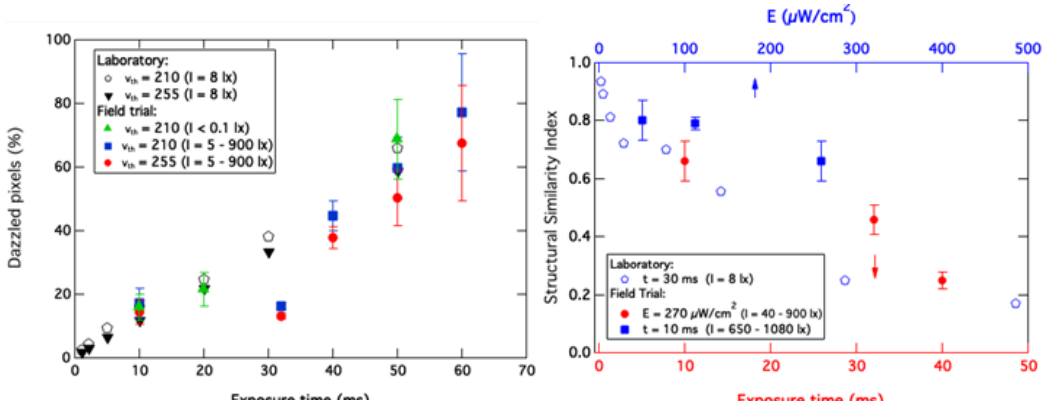



**Figure 2**: (a) Number of saturated (vth = 210) and overexposed (vth = 255) pixels for varying camera exposure time (texp) in the laboratory and at D = 600 m (field trial). The illuminance levels (lx) are indicated on the graph. (b) Structural Similarity Index (SSIM) vs texp (bottom axis, red data points) and irradiance E (top axis, blue data points). Illuminance levels are indicated for the corresponding data.

## Conclusions

To summarize, effective laser dazzling was demonstrated in two different imaging CMOS sensors in laboratory measurements and field trials.

As observed for laboratory experiments performed with controlled illumination, laser irradiance and beam position, the number of dazzled pixels in the images acquired during the field trials also increased with increasing exposure time and laser irradiance. The turbulence effects, involving rapid variations of the laser beam position and irradiance level, play an important role on the extent of the dazzled area. Nevertheless, for approximately constant average laser irradiance between acquired frames, a large part of the camera FOV was dazzled, resulting in nearly completely dazzled images. These results demonstrate the effectiveness of laser dazzling as an optronic countermeasure in an airborne scenario, as for small light-weight and wide FOV cameras commonly fitted to micro-UAVs.


# DAP17-01 Multi band efficient networks for ad hoc communication (MAENA)

| | |
|---|---|
| Director: | Col Bart SCHEERS |
| Researcher: | Mr. Vincent LE NIR |

# DAP17-01 Multi band efficient networks for ad hoc communications (MAENA)

## Background

The project on “Multi band efficient networks for ad hoc communications” is intimately linked to the EDA Cat B project called MAENA. This project consists of a consortium of 15 prime contractors and 5 subcontractors, representing 9 different countries (BE, FI, GE, FR, IT, NL, NO, PL, SE). The project leader is Thales Communications and Security from France. The prime contractor for Belgium is RMA for 36 months.

## Objectives

The aim of the MAENA project is to study the joint optimisation of the VHF and UHF bands by considering outer and inner dynamic spectrum management (DSM) loops. The outer-loop goes between the frequency management tool on the theatre and the tactical radio networks. The inner-loop is done at the network level and enables the networks to optimise the spectrum bandwidth they have been allocated. Each partner in the consortium studies some integrated solutions for the sensing, DSM, physical, data link, network layers, based on basic VHF and UHF waveforms and implements these integrated solution in a high-fidelity simulator similar to the simulator based on OMNeT++ of the EDA Cat B CORASMA project. OMNeT++ is a discrete-event network simulator providing C++ libraries and model frameworks to support various types of networks (e.g. wireless ad-hoc networks). However, the OMNeT++ framework abstracts significantly the physical layer, the channel and some parts of the data link layer. A high fidelity simulator is a simulator including realistic channel models and has no abstraction at the level of data link layer and physical layer. Therefore, all partners work in the same direction to build a common software (high fidelity simulator) which emulates tactical radio transmissions at the sample level (I-Q samples) with realistic channel models. The different partners work either on integrated solutions for VHF only, UHF only, and a combination of VHF and UHF (VHF+UHF) up to four radio interfaces. The UHF waveform is based on the waveform developed in the EDA Cat B CORASMA project, while the VHF waveform is based on the STANAG 5630 NBWF waveform.

The RMA contribution with this study develops and implements integrated solutions for the combination of VHF and UHF (VHF+UHF). Integrated solution means the combination of extended waveform, sensing, and DSM.

## Results

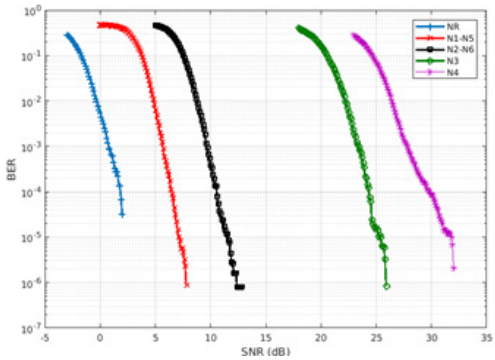
The roles of RMA in the EDA Cat B Project MAENA are to the following ones:

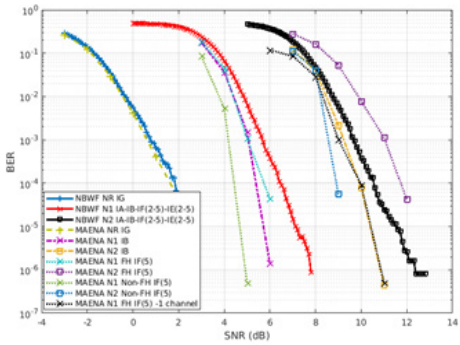
- Studying, developing and implementing a basic VHF waveform based on the NATO STANAG 5630 Narrow Band Waveform (NBWF).

- Studying, developings and implementsing integrated solutions for the combination of VHF and UHF (VHF+UHF). Integrated solution means the combination of extended waveform, sensing, and DSM.

**SSTANAG 5630 Physical Layer vs Basic VHF waveform – Simulation Results**

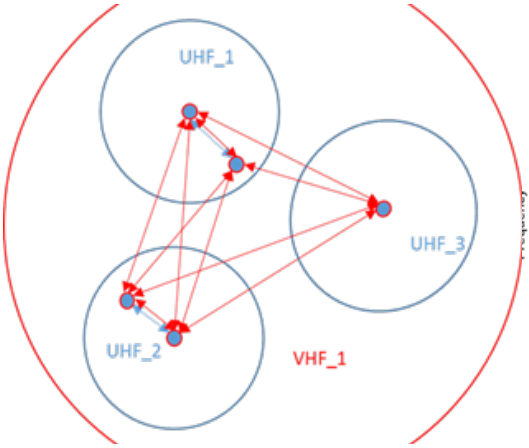
Based on RMA STANAG 5630 physical layer implementation (left), the basic VHF waveform has a new FEC (turbo code LTE) and frequency hopping of 44 hops/s (right).

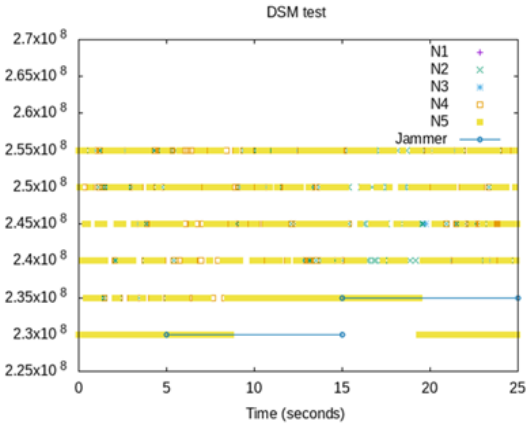


**RMA solution – Control VHF/UHF Frequency Hopping Sequence by VHF**

RMA has been studying and implementing so far the only VHF+UHF integrated solution in the consortium. This integrated solution consists of exploiting wideband sensing in the VHF and UHF bands and to use the VHF waveform as a bearer for exchanging messages to control frequency hopping sequences of the VHF and UHF waveforms whenever a jammer appears in the VHF and UHF bands.




# DAP18-01 Digital image steganalysis and forensics: exploiting the synergy

Directors: Air Force Maj Helena BRUYNINCKX
Air Force Capt(sr) Julien PETIT
Researcher: Mr. Dirk BORGHYS

# DAP18-01 Digital image steganalysis and forensics: exploiting the synergy

## Background

The aim of steganography is hiding information in innocent looking data. Criminals, terrorists and malware developers increasingly use steganography for covering up their activities. The used methods evolve constantly, forcing law-enforcement and intelligence agencies to have efficient solutions for detecting hidden information (steganalysis) at their disposal. In 2013, our intelligence service expressed a need to gain knowledge and have tools for steganalysis. For that reason, from 2014 on, successive scientific studies on digital image steganalysis were launched in order to answer this need. This study is a follow-on of a previous study titled “From prototype to an efficient framework for digital image steganalysis” which ended in 2017.

This first study acquired a solid knowledge on image steganography and steganalysis and a prototype of intelligent system for steganography and steganalysis was developed. The project succeeded in improving detection performance with respect to the state-of-the-art literature. The results in “laboratory conditions” were excellent, but when applied on “real world” images (images from the internet), the performance dropped considerably. This problem is known as the cover-source mismatch (CSM).

The second study (DAP/16-01), examined the factors determining the CSM and developed a detection strategy based on multi-detectors for mitigating the CSM. DAP/16-01 showed that knowledge about the acquisition and processing chain of the images under investigation (forensics knowledge) is crucial for improving detection performance in the real world.

## AIM

Hence, a new project was launched in 2018 to further exploit the synergy between digital image forensics and steganalysis and to further improve the operation performances of the developed framework.

The current study (DAP/18-01) aims at developing methods for exposing and exploiting forensics knowledge for steganalysis.

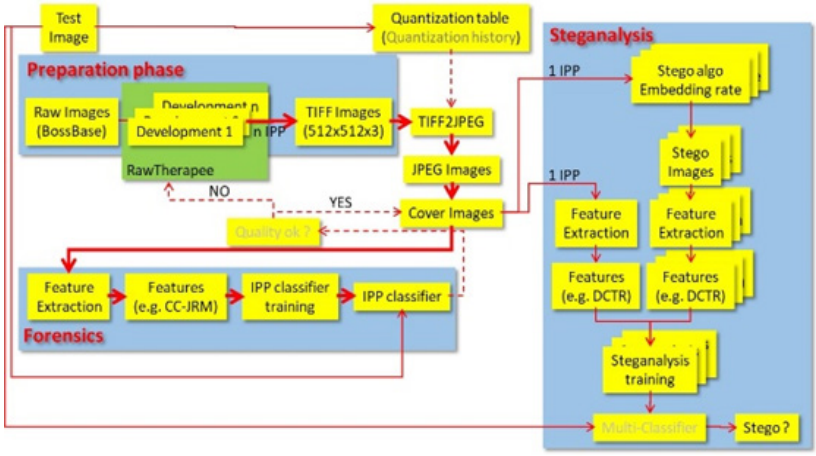
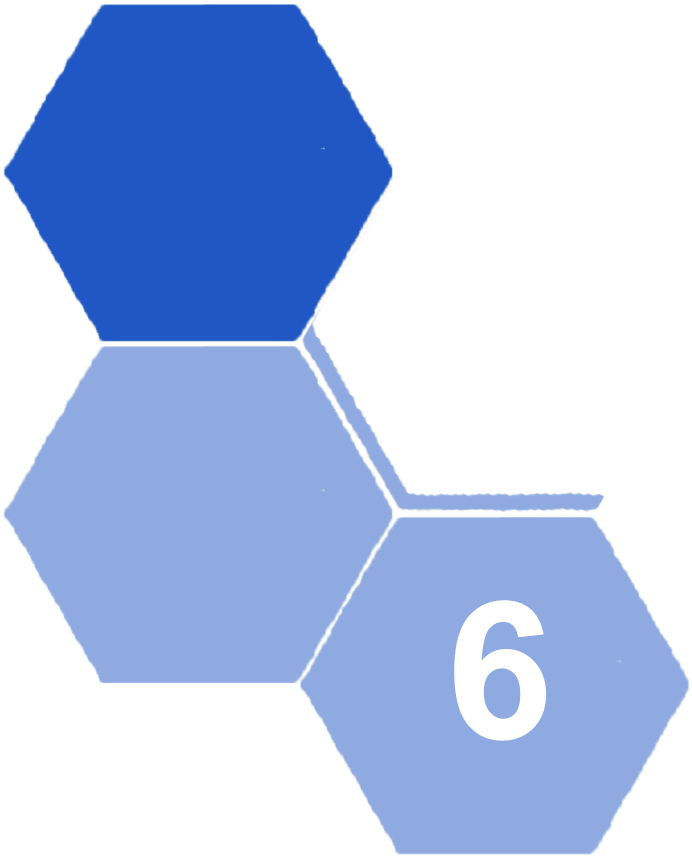



**Figure 1**: Overview of the atomistic approach based on Ensemble Classifiers (EC) and the detection of the image processing pipeline (IPP)

## Preliminary outcome

Within the framework of the study, we started a collaboration with two French research teams. The main goal of this collaboration is to develop and to compare methods for mitigating the impact of the CSM on steganalysis results. Two steganalysis approaches were implemented and evaluated on a large image dataset. The first is the “mixed” or “holistic” approach. It consists in blending as many sources as possible in order to enable the framework to learn the most general steganalysis rules. Hence, those rules will only loosely depend on the source. The second approach is called “atomistic”. It consists in splitting a large image dataset into small subsets with similar properties. The most successful work in this category have been referred to as “forensics-aided steganalysis”, see for instance [1-3] in which the authors used methods from digital image forensics to create clusters of “homogeneous training sets”. The atomistic approach, using a feature-based ensemble classifier (EC), was applied to the Alaska1 contest on “steganalysis in the real-world” in the spring of 2019. Analysis of our obtained results confirmed that our method does indeed outperform the other methods that use the feature-based EC. However, the competitors who used a steganalysis approach based on Convolutional Neural Networks (CNNs) obtained even better results. Thanks to the established network of contacts in the steganalysis community, we have access to the method that won the

Alaska1 contest. We are currently investigating the combination of our atomistic approach to this best performing CNN. The idea is to use a training set of images with properties close to the ones of the image under test, for fine-tuning a CNN (i.e. replace the steganalysis part in Fig 1 by a CNN). We hope that this method will achieve good results in the Alaska2 contest, which is to take place between March and May 2020.




# DAP18-02 Vulnerability of Mid-Wave Infrared Thermal Imaging Systems to Current and Future Laser Weapon Threats (Safeguard-FLIR)

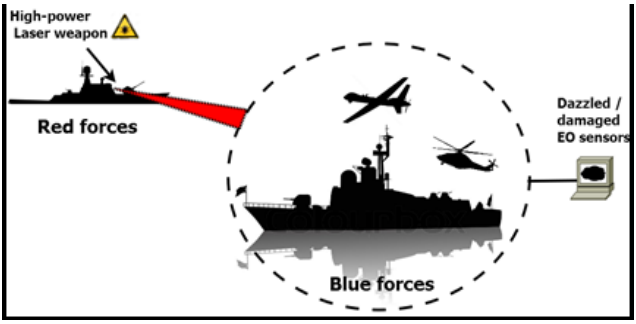
Director: Air Force LtCol Marijke VANDEWAL

Researcher: Mr. Gareth LEWIS

# DAP18-02 Vulnerability of Mid-Wave Infrared Thermal Imaging Systems to Current and Future Laser Weapon Threats (Safeguard-FLIR)

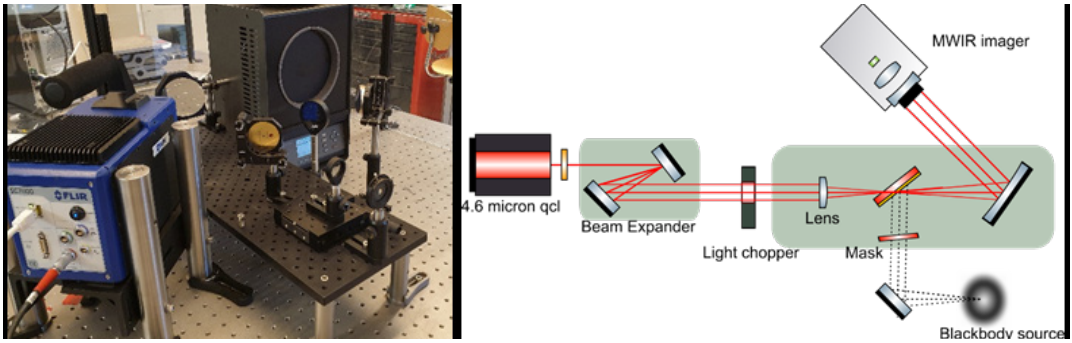
## Background

Today, no military or security platform can escape the risk of a laser weapon threat. This weapon will, at the very least, inhibit or damage the operational effectiveness of the onboard electro-optical (EO) and thermal infrared (IR) systems.




## Objectives

Conceivably the most disturbing use of such weaponry is during low-intensity conflicts (the grey zone), where a commander's reaction to such a threat is likely restricted to non-escalation of force despite the imminent damage to one's surveillance and tracking systems. Fuelling the growth of these weapons, the rapid development of compact and high-power multispectral laser sources are capable of damaging thermal imaging systems in all spectral bands, i.e. SWIR, MWIR and LWIR.




Laser Directed Infrared Countermeasures (L-DIRCM) research simulator (CISS/RMA)

## Preliminary outcome

The key results obtained for this year include a range of laser experiments, publishing results, and participating in a NATO research group:

- L-DIRCM test-bed: development of a table top laser directed infrared countermeasures test-bed for dual-purpose experiments: 1) Impact of in-band laser weapons on thermal imagers and 2) assessment of lasers as a means to neutralize incoming imaging seekers.

- Detector integration time: We demonstrated that we could partially mitigate the impact of laser radiation by reducing the detector integration time of the thermal imager. However, this also leads to loss of background contrast.

- NATO SCI-312 EO/IR Countermeasures: We contributed to the design of a surrogate L-DIRCM and provided results to the group on in-band laser dazzling of MWIR thermal imagers.

- Laser Tunnel: We assisted in the design and built of an 18-meter-long covered laser range in the CISS dept. Optronics lab, which will be used as a safe environment to test laser dazzling over longer distances in the laboratory.

- High Energy Laser (HEL) trial: We carried out several meetings and joint tests of a high energy laser (1 kilowatt at a wavelength of 1.07 micron) at

the facilities of the Netherlands Aerospace Centre (NLR).

- Publication: We published at the SPIE Defence and Security conference at Strasbourg on our results concerning the effect of detector integration time on the image dazzle.

## Conclusions

In summary, this was another successful year for the project DAP18-02 with new laser experiments, a new experimental facility, further scientific publication and collaborative trials.


# DAP18-04 Development and integration of a Military Augmented Reality System for Belgian Defence operations

Director: Air Force Maj Robby HAELTERMAN

Researcher: Mr. Charles HAMESSE

## DAP18-04 Development and integration of a Military Augmented Reality System for Belgian Defence operations

### Background

Asymmetric warfare situations and the continuous risk of terrorist attacks place Belgian Defence soldiers in dangerous situations where they have to correctly assess very complex situations in a minimum of time. Advanced sensors like visual and thermal cameras and sensing vectors like RPAS are being deployed to remedy this problem, but these also add to the information overload that soldiers need to process. This research study proposes to develop an augmented reality support system that assists individual soldiers in collecting, processing and analysing data without taking their eyes and attention from their environment and without causing cognitive overload.

### Objectives

The proposed study will research cross-domain scientific innovations in the fields of computer vision, robotics, human-system integration, machine learning to develop an augmented reality support system that will support the soldier in each phase of the sense-plan-act decision chain. Moreover, an augmented reality training system will be developed, enabling Belgian Defence to perform team training in the real world, with added virtual objects/enemies. As a result of this study, Belgian Defence will have at its disposal a proof-of-concept augmented reality system consisting of COTS/MOTS hardware and a custom software augmented reality toolbox, tailored to the needs of Belgian Defence clients.

### Expected outcome

As a result of this research study:

- Belgian Defence will have at its disposal a proof-of-concept augmented reality system consisting of COTS/MOTS hardware and a custom software augmented reality toolbox, tailored to the needs of Belgian Defence clients.

- Belgian Defence units will be able to directly evaluate the practical use of augmented reality technology on the terrain via operational field trials of the system, which not only can serve well for the direct improvement of soldier performance, but also indirectly in view of the foreseen future acquisition of high-tech combatant equipment.

- Belgian Defence will have at its disposal an augmented reality training system, enabling for team training in the real world, with added virtual objects/enemies.

Currently, we are in the development phase of a VR (Virtual Reality) Fire Trainer for DCC (Damage Control Centre of the Belgian Navy). An alpha version is expected in June 2020, with a beta version due later in the summer.
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# DAP18-05 Automation of Ship-Based Intelligence Gathering (ShipIntel)

Director: Air Force LtCol Marijke VANDEWAL

Researcher: Mrs. Cornelia NITA

## DAP18-05 Automation of Ship-Based Intelligence Gathering (ShipIntel)

### Background

Next to their policing tasks, the patrol vessels Castor and Pollux of the Belgian Navy play the important military role of naval intelligence gathering. We believe it is possible to expand this role, automating the fusion of ship sensor data with human intelligence, in order to generate reports on ship identity and signature, detected changes, ship activity and behaviour.

### Objectives

In the current project, an automated system will be proposed that attempts to generate reports on ship identity and signature, together with detected changes on naval vessels activity and behaviour.

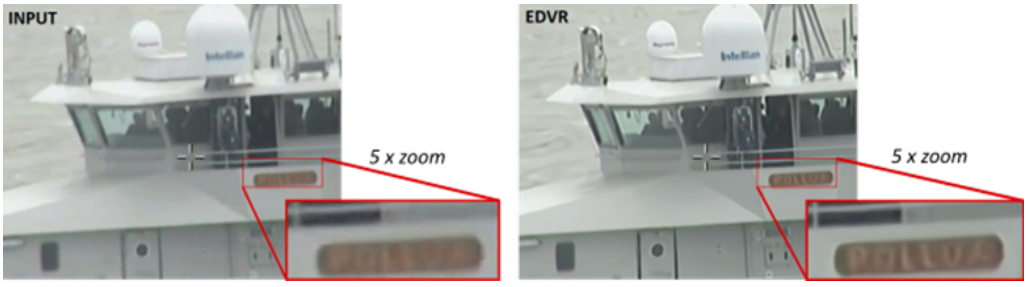



Fig.1 Qualitative results of EDVR method applied for image restoration (© Copyright Belgian Defence)

Two main topics are tackled in the initial phase of the project. These are the development of the required image processing building blocks and application of machine learning components. In the first step of the research, we apply the EDVR method for super-resolution and video deblurring tasks. Qualitative results on our data are presented in Fig.1. As can be seen from the figure, the method recovers some information, e.g. improvement of the text area and shape contours. Nonetheless, further investigations are needed in order to quantify the performance of the current method and to compare it with the state-of-the-art methods on video super-resolution.


Fig.2 Application of text recognition algorithm on VAIS and SMD dataset

A second objective of this study is to investigate the text recognition technique in order to identify ships from their markings. To this end, we implement a deep-learning method for text detection and recognition. In preliminary experiments, we show in Fig.2 that the method is quite accurate for some images from VAIS and SMD datasets. However, we find that more preprocessing of the input image is needed in order to correctly localise and recognise the text for other different image data. Overall, the findings reported here suggest that super-resolution and text detection process could be effective tools in enhancement of the information regarding the ship's configuration or signature. Next to that, in the first phase of machine learning components application, the Mask R CNN method, i.e. state-of-art framework for image segmentation task, is tested on SMD dataset.

## Preliminary results

The results, as shown in Fig.3, indicate that the detector performs well on large object, but training on a dataset that is representative of what you expected to recognise and detect is needed.

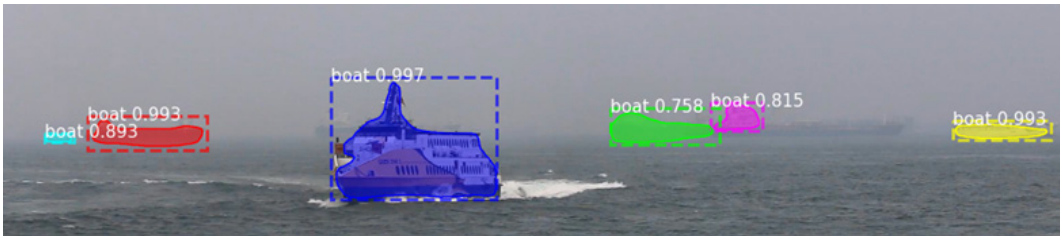



Fig.3 Application of Mask R-CNN method for ship detection on SMD dataset


# DAP19-08 Enabling operations with multiple heterogeneous unmanned maritime assets

Director: Air Force Maj Robby HAELTERMAN

Researcher: Mr. Geert DE CUBBER

## DAP19-08 Enabling operations with multiple heterogeneous unmanned maritime assets

### Background

Unmanned maritime systems are on the verge of becoming important assets for military operations, not only in tactical roles, but also in logistics and in supportive roles. This also means that an increased number of these systems are being deployed each with their own characteristics and specifications. This variety poses interoperability problems when deploying these assets together for operations, as there is to date no unified command structure for these unmanned assets and there are no standardised data interchange platforms that enables an easy transfer of sensory information between platforms. The result is that commanders have to work in most circumstances with custom-built solutions that may be good in performing one task, but that encompass little flexibility and modularity towards upgrading the task for future needs or towards interoperability with other deployed assets. This study proposal aims to remedy that situation by developing an interoperability concept for heterogeneous unmanned assets that enables the seamless integration of these tools into existing standard operating procedures.

### Objectives

Interoperability is the key to enable efficient multi-robot cooperation between the different units within the team. Seamless and non-ambiguous interaction between different robots of any provider and domain demands a common, well-defined interface. The ultimate goal of the work on the heterogeneous team is to consolidate a common command, control and payload interface to be agreed and adopted by all robotics platforms and control stations involved in an operation. This approach provides a common framework for the development of collaborative unmanned assets, minimising the integration time and costs by avoiding ad-hoc implementations.

As a key concept, we are developing a heterogeneous interoperability and collaboration framework that ensures seamless interoperability between the different agents. The interoperability concept consists of a highly modular system of carrier platforms and sensor payloads, enabling straightforward switching of

payloads from one system to another. This modular architecture will also ensure the future exploitability of the results of this project on other assets after the end of the project.

## Outcome

In terms of validation, three use cases are under preparation, each geared at a different application domain to maximise the exploitation potential of the IP developed within this study and to validate the proposed interoperability concept in a wide range of applications:

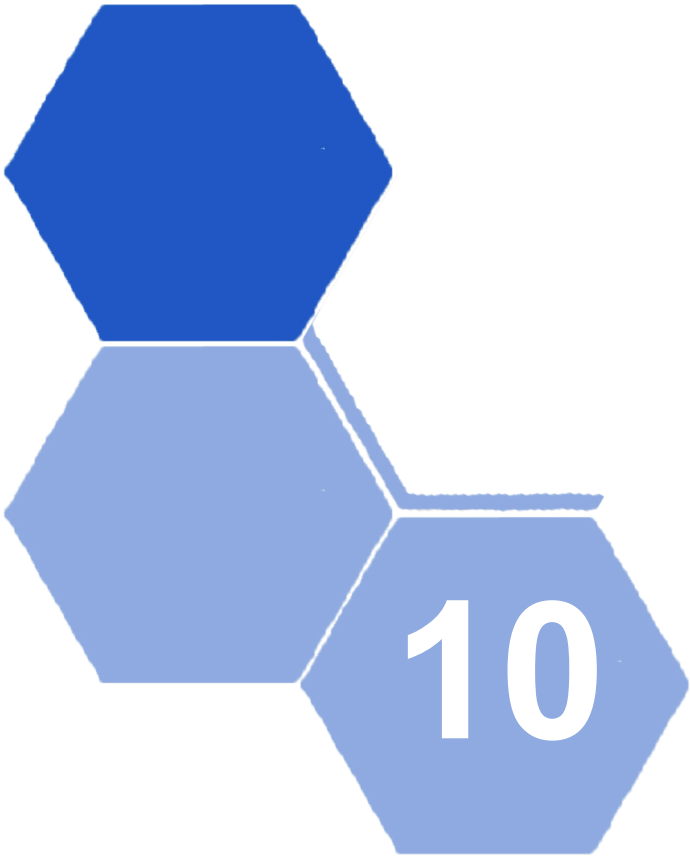
- *Shared situational awareness and data traffic management for unmanned dredging vessels*
  This fits into a VLAIO – Blue Cluster research and innovation project (SSAVE) studying the data management, cybersecurity and interoperability questions that are posed when (unmanned) assets start to exchange data on all levels (not only towards the cloud, but also between the edges). Preparatory work has been performed this year on unmanned surface vessels navigating autonomously within the port of Antwerp, as depicted in Figure 1.

- *Maritime surveillance of offshore windmill parks*
  Within the scope of this validation use case, an offshore windmill park has been outfitted with technology (hardware and software) to automatically detect trespassing vessels, as depicted in Figure 2.

- *Unmanned mine countermeasures*
  This validation use case fits into the much larger PESCO-MAS framework lead by Belgium.

Figure 1: Vessel used for validation trials in the port of Antwerp


Figure 2: Offshore distributed situational awareness for maritime surveillance




# SIC 11 Distributed semi-supervised clustering for APT detection


| | |
|---|---|
| Director: | Prof. Wim MEES |
| Researcher: | Mr. Alexandre CROIX |

# SIC 11 Distributed semi-supervised clustering for APT detection

## Background

Military organisations and civilian companies are becoming more and more dependent on their internal network (intranet) and on the Internet to achieve their objectives. In the same time, new types of attacks, called Advanced Persistent Threats target these networks. These attacks are committed by highly skilled attackers, who have the time and resources to act slowly and concentrate for a long period on a single target. Moreover, the objective of this kind of attacks is generally not to block the network, like a Denial Of Service (DOS) attack, but to silently steal valuable information. All these characteristics make these attacks very difficult to detect and combat.

Current detection techniques rely on manual analysis by a human expert of data provided by general-purpose network monitoring tools. These tools generate a lot of false alarms and thus produce a lot of data to be analysed by human experts, which makes detection very difficult.

## Objectives

The goal of this project is to develop a specialised tool that integrates human expert feedback into the detection algorithm to reduce false alarm rate. This approach is possible thanks to a recent kind of machine learning algorithms called semi-supervised clustering. To make interaction with human experts fluent, distributed semi-supervised clustering algorithms will be developed, to achieve near-real time processing.

## Preliminary outcome

To be completed (question asked to Wim (mees) and Alexandre (Croix))


# HFM 14-09 Modelling, simulation and optimisation of interacting military manpower planning processes for the Belgian Defence

Director: Air Force Maj Filip VAN UTTERBEECK

Researcher: Mr. Johan VAN KERCKHOVEN

## HFM 14-09 Modelling, simulation and optimisation of interacting military manpower planning processes for the Belgian Defence

### Background

Several manpower planning models are currently in use within the Department of Human Resources (DG HR), each with their own particular application domain and sometimes already including optimisation modules, which are used as decision aid models for the integrated HR-managers. However, further development is required. The customer of this project (DGHR-HRB-Integ/Mod) has identified the distinct need for a further operationalisation of these models and for a more profound integration of this suite of models into a model of models. New components may need to be added and further validation is required. There is a clear need to improve the existing capabilities in the domain of optimisation algorithms, which poses a highly complex challenge due to the interaction between the different models and the differences in considered time frame and objectives. At the same time, the model of models should present a user-friendly interface to the HR-manager and it needs to be able to condense complex results into clear and easy-to-interpret management reports.

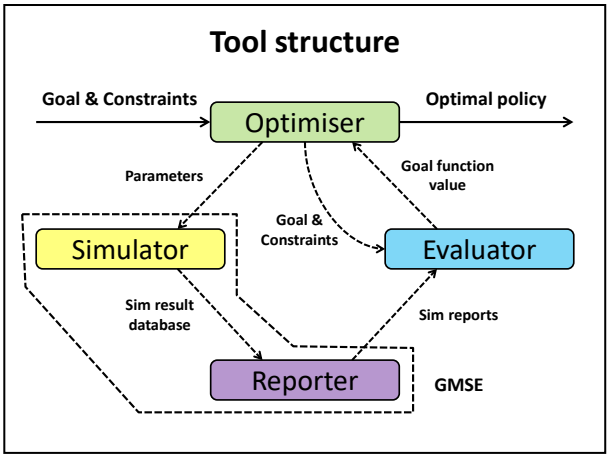
### Objectives

The original aim of the study is the development of a system of systems (or in this case more specifically a model of models) for decision support in military manpower planning. With the recent introduction of integrated manpower planning within the Directorate General Human Resources (DGHR), there is a clear need for decision support tools to assist the integrated HR-managers when they are confronted with complex “what-if” problems. These typically involve large amounts of (often interrelated) variables and parameters, with complex constraints, sometimes multiple objectives and often multiple time horizons.

### Outcome/Preliminary results

Quickly, it became apparent that making a model of models that unifies the various models currently in use by DGHR would be an incredibly complex and time-consuming task due to the disparity in how these models were implemented.

Hence, we opted to generate a new tool, a generic manpower simulation engine (GMSE), from scratch which can be easily configured to handle the demands of each of the separate models. This also enables us to separate the modelling of the military organisation from the decision-making process – i.e. the mathematical optimisation techniques – which enables us to use any desired optimisation technique without needing to change the underlying model of the organisation.




The GMSE enables the user to set up a hierarchical organisation by defining the following:

1. Attributes that personnel members can have,

2. Nodes, or “chairs”, that personnel members can occupy,

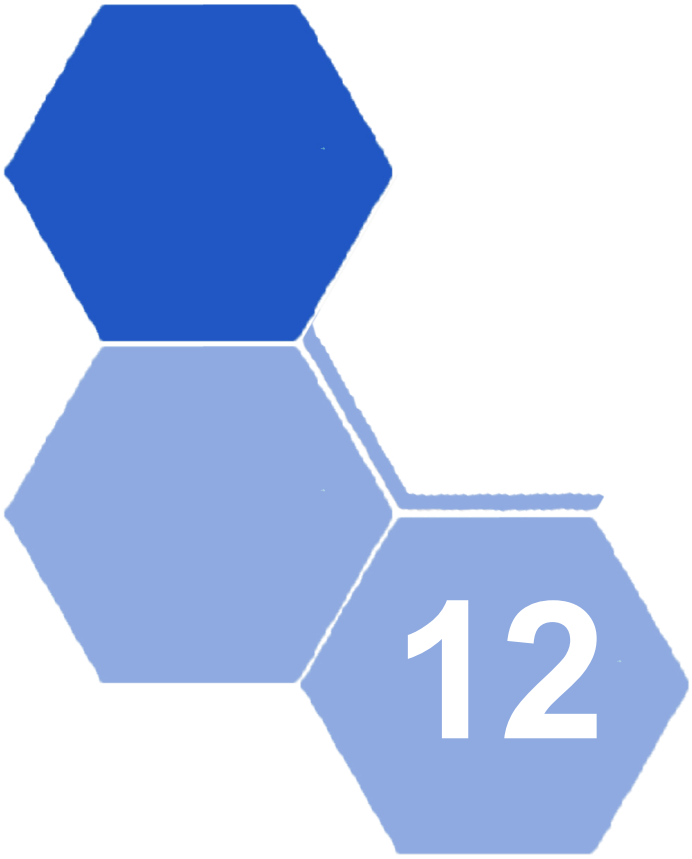
3. Transitions to enter the organisation (recruitment), to move from one node to another, such as promotion or mutation, or to leave the organisation, such as retirement.

4. Attrition, which cannot be controlled by the organisation’s policies, such as voluntary resignation.

5. All the parameters for any of these can be completely defined by the user, and then the user can ask a simulation to be run and request reports on the results of the simulation. This tool has been developed in Julia, using the SimJulia package created by Maj Ben LAUWENS.

Furthermore, the GMSE has been successfully integrated into a decision-

making routine where the results of the simulation runs were used as input for a mathematical optimisation algorithm, for which we have tested three different approaches. Although the initial results are rather disappointing both in computation speed and good fit of the resulting policy, we are confident there is room for improvement in both areas, even if the results for a single setting of the GMSE can vary widely due to the inherent stochastic nature of the simulation. This does not however need to be considered as a downside, as this provides valuable insights into the stability of a specific set of policies.




# HFM 14-10 Improving military selection: Psychological resilience screening (INSPIRE)

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|---|---|
| Director: | Dr. Maj Salvatore LO BUE |
| Researcher: | Own personnel |

# HFM 14-10 Improving military selection: Psychological resilience screening (INSPIRE)

## Background / Design

During this study, a complex design was developed in order to be able to take measurements at different moments in the military cycle. This required cooperation between HRB-R&S, the basic training centres (CIBE and CBOS) and the units of the Medium and Light Brigade.

## Objectives / Data collection

This study contributes significantly to the predictive validity study in the selection. Until now, data were collected only from the basic training. Thanks to this study, data from both the GPO and the internship period are now also available. These data will therefore not only be used for INSPIRE, but also for the validation of the other selection instruments.

INSPIRE 2 ran in 2018 as planned. The data collection that started in 2016 was terminated. The data were analysed.

After the data collection, work continued according to the pattern that was planned in 2016. There was cooperation with the centres for the basic training (CBOS, CIBE) and COMOPSLAND (Md and Lt Bde). During the 2018 data collection, some PoCs changed. The new PoCs had to be informed again. For the acquisitions, all services were visited individually and explained what was expected of them. The questionnaires that were collected were entered into a database with registration module that was developed in-house.

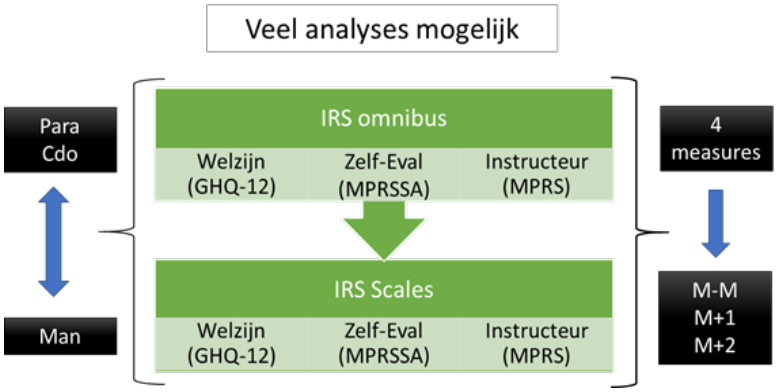
## Outcome / Analyses

An analysis plan was drawn up with the EDA working group. This plan describes the analyses to be carried out by all organisations. The analyses include:

1. Check of the IRS psychometric quality
2. Calculation of composite variables
3. Distributions and interrelationships between composite variables:
    a. Score distributions and differences between (sub)groups
    b. Correlations between composite variables
4. Predictive validity analyses:
    a. Basic (e.g. correlations)
    b. Advanced (e.g. regression, SEM, etc.)
5. Analyses of IRS change over time

The analyses in points 1, 2 and 3 show that the instrument works at the construction level. In order to remain concise, these results are not discussed in detail. In other words, only points 4 and 5 are discussed here.

Many longitudinal analyses can be carried out. There are two groups, namely Vrijw ParaCdo and Man. There are four measurements per group. There are twelve predictors (scales of the IRS) and five measurements (IRS.0, IRS.1, IRS.2, IRS.3, IRS.4). The basic predictive validity analyses (4.a.) (correlation study) were performed in two phases. First, an omnibus test was performed based on the aggregated score of all scales. This score can be seen as a measure of resilience and contains all the variance of all scales. Subsequently, the analysis was repeated at scale level.




In summary, the correlation study found the following at omnibus level for both groups (Man and ParaCdo) together.

| | IRS.0 | IRS.1 | IRS.1 | IRS.3 | IRS.4 |
|---|---|---|---|---|---|
| | | | | | |
| GHQ.1 | -,017 | -,427** | | | |
| GHQ.2 | ,015 | -,159** | -,350** | | |
| MPRSSA.2 | ,107 | ,215** | ,399** | | |
| MPRS.2 | -,068 | ,152** | ,189** | | |
| GHQ.3 | -,028 | -,028 | -,220** | -,361** | |
| MPRSSA.3 | ,048 | ,250** | ,232** | ,394** | |
| MPRS.3 | -,006 | -,058 | -,029 | ,132* | |
| GHQ.4 | -,155 | -,225** | -,237** | -,242** | -,418** |
| MPRSSA.4 | ,231 | ,319** | ,452** | ,480** | ,546** |
| MPRS.4 | ,097 | -,076 | -,014 | ,126 | ,069 |

** p-value < .01

## Conclusions:

There are four findings.

1. The data from the selection (IRS.0) does not show a significant correlation with the criterion data.

2. There is evidence for simultaneous validity of the IRS. This means that the predictors of a measurement correlate with the criteria of the same measurement. This is to a good (and even to a large) extent the case for the self-descriptive criteria (GHQ and MPRSSA). For example, there is a strong correlation between the IRS in measurements 1, 2, 3 and 4 and their corresponding GHQ and MPRSSA (e.g. IRS.1 and GHQ.1 : r = -0.427).

3. There is also evidence for predictive validity. The predictors correlate with criteria from a subsequent measurement. Again, this applies, in the main, to the self-descriptive criteria. For example, the IRS from measurement 1 correlates with the MPRSSA from measurements 2, 3 and 4. The same applies to IRS 2 and 3.

4. With the evaluation by the instructors, officers and NCO's some limited but significant links are found. The IRS from measurement 1 correlates to a limited extent with the MPRS from measurement 2. Furthermore, for measurements 2 and 3, the IRS and MPRS correlate to a limited extent.

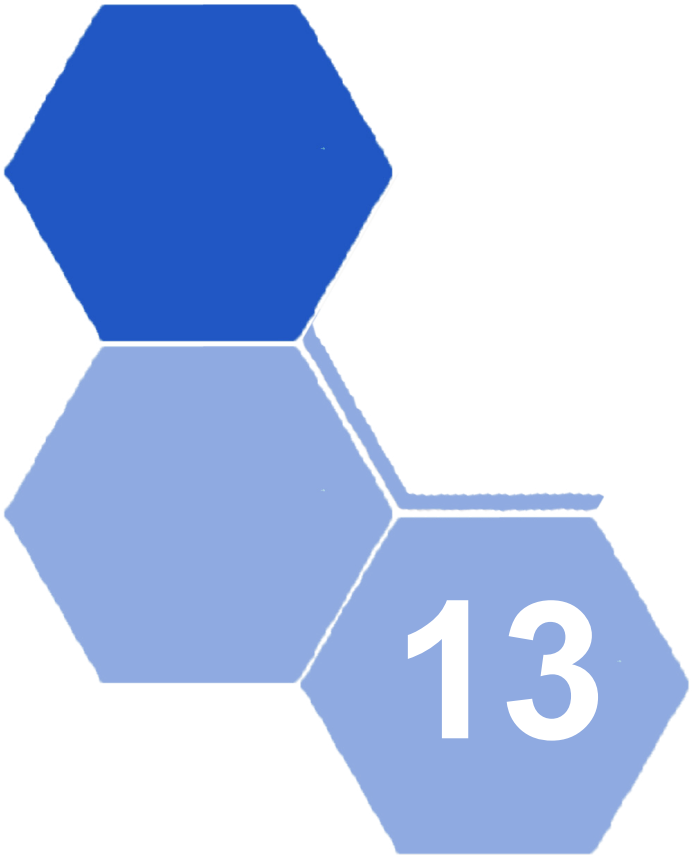
These findings can be elaborated in more detail at scale level.

1. Selection: no consistent links are found between the scales and the criterion data.

2. Simultaneous validity: consistent links are found for the scales Emotional Stability, Optimism, Self-efficacy and three scales of Coping Flexibility (Analysis and Planning, Growing and Positive Reinterpretation).

3. Predictive validity: consistent links are found between the scales Optimism, Self-efficacy and three scales of Coping Flexibility (Analysis and Planning, Growing and Positive Reinterpretation), on the one hand, and the well-being and self-assessment of performance in a later measurement, on the other hand.

4. Evaluation framework: Only a few difficult to interpret links are found with these data.




# HFM 15-01 Best practices for CBRN incidents and battlefield medical support

Director: Air force Maj Filip VAN UTTERBEECK

Researchers: Dr. Ruben DE ROUCK

Dr. Selma KOGHEE

# HFM 15-01 Best practices for CBRN incidents and battlefield medical support

## Background

There are many challenging questions concerning the management of CBRN incidents (with massive numbers of casualties) and concerning medical battlefield management. Many choices have to be made, but the medical community lacks best practice guidance. The present study will try to answer some of these questions and come up with sound evidence underpinning best practice guidelines to cope with the current shortfalls and gaps.

In contrast to real world exercises, computer simulations of medical response enable the consecutive execution of a particular scenario with changes to the occurrences and timing of particular medical interventions or modifications to the utilisation of human and material resources. This enables the evaluation of (medical) operational interventions in multiple plausible disaster or battlefield situations and the development of a resource-efficient medical response without the costs and time constraints associated with full-scale exercises.

## Objectives

The aim of this project is to simulate the pre-hospital organisation of the medical response in disaster scenarios and to use the results to provide best-practice recommendations. Here, we will specifically study a chemical incident. In order to do so, we will develop a simulator, define a scenario, and find the most realistic input.

Various CBRN and medical battlefield scenarios will be implemented in the SIMEDIS simulator, a stochastic discrete event simulation model in the Arena environment.

The simulator consists of three interacting components: the medical response model, the victim creation model and the victim pathway model.

The medical response model represents the environment (areas of interest, time), the available human and material resources, a rule-set of medical/

operational decisions and the localisation of the victims as they are evacuated from one area to another. For a typical disaster scenario, the three areas of interest are the disaster site, the forward medical post and the healthcare facilities of destination.

The victim creation model generates all the disaster victims needed in the simulation and maps these victims to victim profiles corresponding to the scenario. Each victim profile consists of general victim data, a set of possible clinical conditions (specifying primary survey, triage and diagnostic test data and injury severity scores) and a set of potential transitions in between.
The victim pathway model represents the clinical evolution of each victim in the disaster scenario and manages the transition of one clinical condition to another. These are triggered either by elapsed time or by medical treatment interventions (according to procedures, available equipment and supplies as well as skill levels of the on-site medical care providers).

## Outcome/Results

The outcomes of the study are evidence-based recommendations and rules of best practice for CBRN incidents and medical battlefield management, as well as evidence based recommendations for teaching, training and research in medical disaster management.

Once a scenario has been implemented in the simulator and all victim profiles have been defined, the experimental design for the simulation experiment is fixed. If computationally feasible, a full factorial design is selected, and several replications are run for every design. Typical runtimes for a complete experiment range from a couple of days up to several weeks.

Afterwards, a detailed statistical analysis of the collected output performance measures is executed. This procedure includes ANOVA (and, if required, MANOVA) hypothesis testing and the development of multiple linear regression models for the output performance measures.

Finally, the results of the statistical analysis are presented to the medical experts for detailed investigation and analysis (which may result in a new batch of experiments with additional design points and/or output performance measures).

Main achievements

- Recreation of the SIMEDIS simulator in Julia and using SimJulia, testing, running the Zaventem scenario from the WTOD RCDM/09 project, and analysis of the results:

    * Making an improved version that is more adaptable and faster.
    * Verification of the SimJulia version using the results of the WTOD RCDM/09 project
    * Verification of the new features in the context of the Zaventem scenario by medical experts
    * Expanding the functionality of the SIMEDIS simulator, including

- Extra options for policies, transport, and triage algorithms

- Stochastic variation of all time intervals

- Distinction between interventions that can be applied in a driving ambulance and interventions (e.g. fixation) that should be applied beforehand

- Triage errors

- Explicitly simulating T3 victims

    * Conversion of victim information from Excel sheets to SQLite database.
    * Publication of the first results in the proceedings of the 2018 Winter Simulation Conference. For this particular scenario where there is sufficient treatment capacity in the hospitals, we found that on average most victims survive when triage, preliminary triage, and a quick distribution of the victims to the hospitals are combined.

- CBRN scenario:

    * Formulating the new scenario
    * Creating the outline for the victim profiles for the new scenario
    * Setting up the framework for the new pedestrian simulator used for the victim creation


# HFM 17-05 Performance enhancement during flight training: a way to reduce attrition and increase the operationality of flight crews?

Director: Pr. Dr. Med Maj Nathalie PATTYN

Researcher: Mrs. Emily DESSY

## HFM 17-05 Performance enhancement during flight training: a way to reduce attrition and increase the operationality of flight crews?

### Background

For decades, anyone who has been pushing human aptitude to the limits of what the body and mind can provide has been offered specific training and support programmes, in order to guarantee the constant quality of this performance. The Special Forces Group is a small military unit consisting of specially selected, hyper-trained soldiers. Operators must have exceptional physical and mental resistance and must be able to operate at the highest level in extremely difficult situations, in terms of environment, workload and danger as well as uncertainty. Unlike a top athlete or a musician, the performance of an operator must therefore excel in multiple areas and must be at its optimum level throughout the year, as much in physical as in mental, intellectual and emotional terms. Due to this permanent requirement towards its operators, the unit has implemented a human performance management programme in collaboration with a multidisciplinary team of experts. Our research project aims at optimising cognitive performance of our operators. We developed a personalised monitoring and training in cognitive skills, including basic training on the functioning of the human brain as a reasoning, information analysis and decision-making tool, as well as an analysis of each person's strengths and weaknesses, to enable personalised follow-up. Moreover, we integrate psychological skills and individual cognitive training at a team level. This programme is modelled on those provided by space agencies during the training of astronauts and is adapted to the specific challenges of the operator function and the composition of the teams.

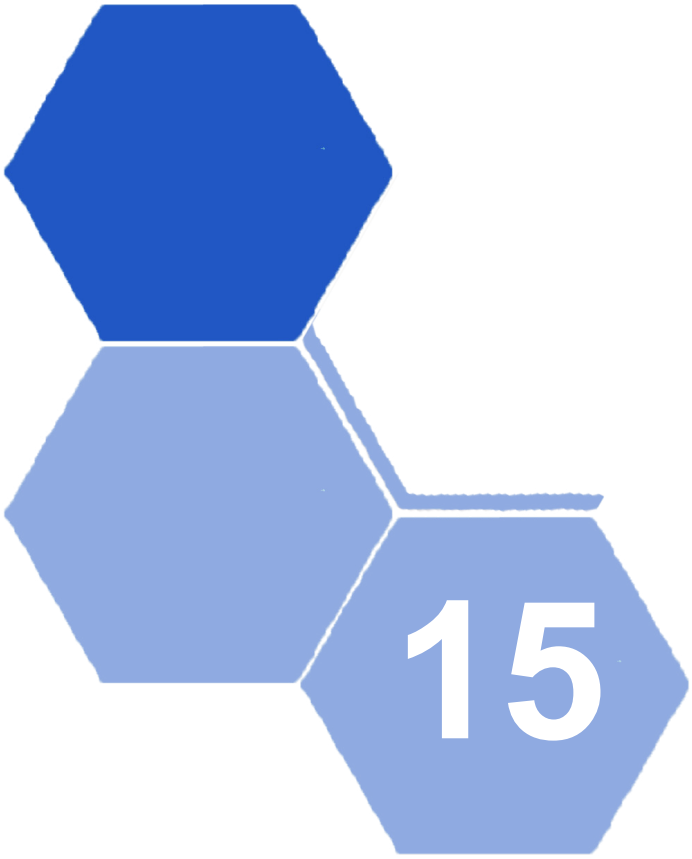
Moreover, the SF operators perform in high-risk, high-value special operations and are therefore subjected to a meticulous selection process. The selection process aims to ensure that the graduated operators are always prepared for the challenging circumstances and missions that they will encounter (Schmitz, n.d.). Therefore, the Qualification course (Q-course) of the selection process is one of the toughest courses in the country and only a select few make the cut. Despite the physical and psychological evaluation during the pre-selection phase, most of the candidate-operators withdraw during the orientation phase of the Q-course, which is a physically and individually most demanding phase.

## Objectives

As the candidate-operators should be able to handle the required levels of physical and psychological fitness to accomplish the missions during the Q-course, the question arises as to why so many candidate operators still withdraw during the Q-course. Evidence suggests that cognitive performance could be an additional contributing factor to success in the Q-course. Therefore, we assessed in our study whether the intelligence factors could be predictors for success in the Q-course.

## Outcome/Preliminary results

Over the course of two years, we evaluated 60 candidate-operators before the beginning of the Q course by using the Wechsler Adult Intelligence Scale – Fourth Edition. The results show that participants who successfully finished the Q-course (i.e., succeeding candidates) achieved significantly higher scores than those who dropped out of the Q-course (i.e., dropouts) on the total IQ-score and on all cognitive domains. Several intelligence factors were found to be significantly positively associated with successful completion of the Q-course.
Not only did this study show that intelligence is a predictor for success, it also enriches the knowledge about which specific cognitive abilities contribute to the predictive value of general intelligence in the SFG selection course. The executive functions and the more basic cognitive skills underlying them seem especially important. A possible explanation is that participants with high initial cognitive levels can still perform adequately whilst facing the stressors of the Q-course. In contrast, dropouts experienced more psychological distress before starting the Q-course, which could have lowered their initial cognitive levels. The addition of psychological stressors during the Q-course, could lead them to drop out of the programme as their cognitive levels would drop even further. This study led to important findings that could help optimise the current SFG selection process that faces problematic attrition rate. These findings suggest that implementing a cognitive evaluation during the pre-selection of the SFG selection process could improve this process and lower the problematic attrition rate as well as its financial and logistic consequences.




# HFM 18-03 Belgian Defence and (Ethnic) Diversity: The Good, the Bad and the Ugly?

Director: Prof. Dr. Delphine RESTEIGNE

Researcher: Dr. Mathias DE ROECK

## HFM 18-03 Belgian Defence and (Ethnic) Diversity: The Good, the Bad and the Ugly?

### Background

Diversity, i.e. the condition of being or becoming increasingly diverse along various parameters (e.g. race, gender, language, religion), progressively finds its way to the Belgian Defence. Internally, more and more people from different social backgrounds enter the organisation. Externally, the organisation partakes in ever more multinational missions within culturally complex environments. The question underlying this research project is threefold: first, how to understand diversity within a military context? Second, what is diversity and how to explain Belgian Defence personnel's attitudes towards diversity? And third, how do these attitudes change over time and space? Based on theory-driven research as well as focus interviews and survey questionnaires, this research project aims to better understand how diversity – and ethnic diversity in particular – creates opportunities and risks for the Belgian Defence.

The research project also seeks to lay bare and explain existing perceptions of, and evolving attitudes towards diversity, including potential radicalisation and extremism, within the Belgian Defence. The research project takes place within a larger NATO framework, i.e. HFM RTG 301 on Military Diversity, and intends to reach out to other Belgian partners. The project is relevant for the Belgian Defence because it seeks to develop knowledge and policy recommendations on and to unravel key empirical dynamics regarding growing diversity at Belgian Defence.

### Objectives

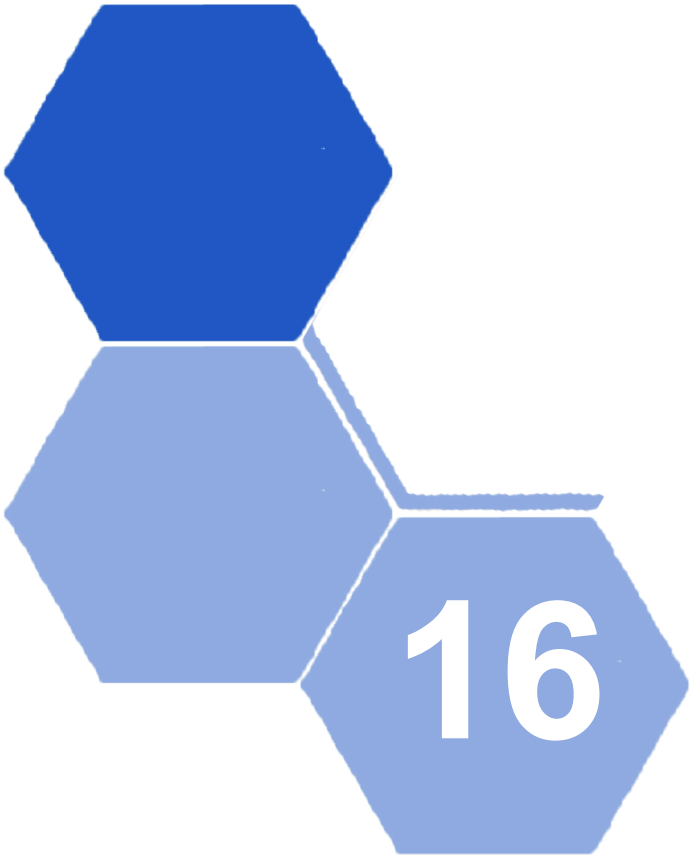
This research project contains several innovative elements. First, even though the topic of diversity already formed the subject of extensive research at the Belgian Defence, thus far only few studies offered a more holistic account on the matter. The question, for instance, as to what are the potential strengths and weaknesses of diversity for the Belgian Defence has up to now never been thoroughly addressed nor investigated. Such a question, however, is of key importance, given that it is not entirely clear what diversity implies for the overall functioning of the organisation. What is also novel about the project is an inter-

est in empirical trends, i.e. how attitudes towards diversity change over time and space, as well as attention to what explains these trends and the potential risk of radicalisation.

Finally, the research project also makes use of multiple methods (focus groups, questionnaires) and state-of-the-art measurement scales and statistical techniques to investigate and explain (radical) attitudes towards diversity. As for previous studies, the project also seeks to develop specific policy advice on managing diversity.

## Outcome/results

As there are no “major relevant findings and results since the beginning of the project” yet, this question is considered as too early in the research process. The publishable one-pager will be available as from next year.




# HFM 18-04 Design of Effective Performance Measurement Systems for Defence and Security Organisations


Director: Dr. Ir. Lt Col IMM Geert LETENS

Researcher: Air Force Capt Joaquim SOARES

## HFM 18-04 Design of Effective Performance Measurement Systems for Defence and Security Organisations

### Background

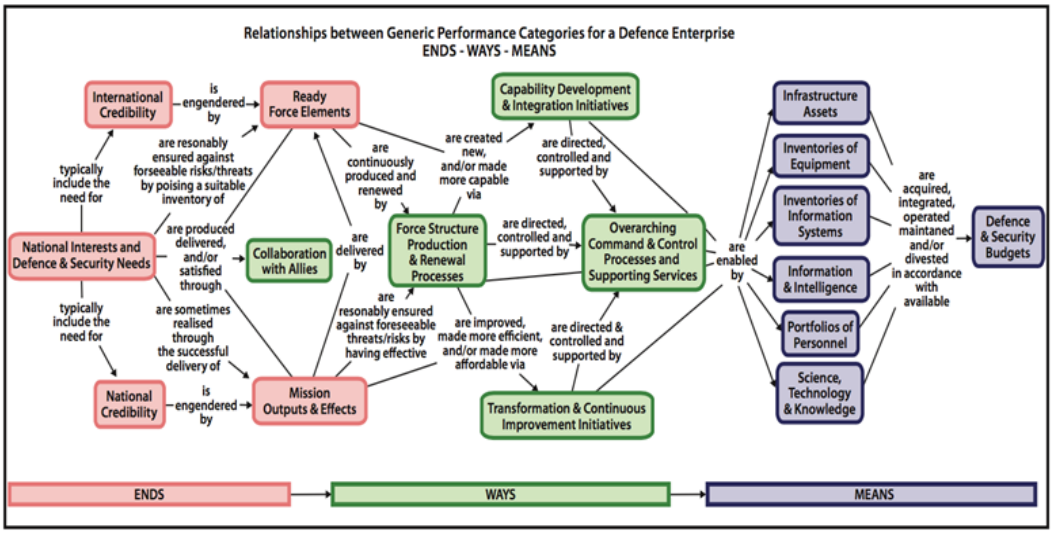
The need to “do more with less” as well as an increased demand for accountability has led military leaders to strengthen the performance of their organisations. Many armed forces have therefore introduced performance measurement (PM) systems to support their decision-making processes. Unfortunately, many national armed forces (including the Belgian Armed Forces) have experienced significant problems with the design of their PM systems. Part of this relates to the specific context of defence and security. Defence and security organisations face several specific challenges such as the conflicting expectations of multiple interdependent stakeholders, the need to perform simultaneously in a variety of environments and the combined character of defence and security initiatives. As a result, the evaluation of performance in defence and security organisations centres on a critical question: how to demonstrate performance towards this diverse and complex environment and its increasingly demanding stakeholders? Therefore, this work’s main research objective is to reflect on various ways to understand and address this question related to PM system in defence and security organisations from a multiple stakeholder perspective. The main clients of this research are the Office of the CHOD responsible for the implementation of Internal Control Systems, the Governance and Policy Support (GPS) office, Commanding Officers (CO) at various levels of the organisation and local ICS coordinators. External clients include NATO’s Science & Technology Organization Studies and Analysis Panel and participating Belgian public sector organisations such as the federal and local police through collaboration with the University of Antwerp.

### Objectives

This work’s main research objective is to reflect on various ways to understand and address the question related to PM system in defence and security organisations from a multiple stakeholder perspective. The research is using different methodologies depending on the work package of the study: Systematic Literature Reviews, qualitative methodologies (including inductive thematic analysis) and quantitative analysis methods (such as cluster and regression analysis).

## Outcome/Preliminary results

One of the initial deliverables of this research was the creation of a generic strategic PM framework for defence organisations depicted below. This framework serves as a decision tool for strategic defence decision makers, as an assessment tool for evaluating current strategic-level PM initiatives or as a guiding instrument for countries that want to implement a PM system within their own defence organisation.




Additionally, it provides a visual representation of the causal link between strategic themes, which supports the communication of defence strategy to the various stakeholders. By providing a holistic overview of strategic information for defence organisations, both internal and external stakeholder buy-in is enhanced. A by-product of the framework is a long list of categories, subcategories, strategic objectives and metrics derived from documents shared by the SAS096's 12 participating countries.

In a subsequent phase, this strategic framework was applied to the different levels (strategic, operational and tactical) and components (Air Force, Navy, Army, Medical Component) of the Belgian Defence (thereby also answering a specific NATO follow-on request). This generated interesting insights for both the organisation as a whole and its different parts including COMOPSNAV, COMOPSAIR, COMOPSLAND and COMOPSMED and the underlying participating units. The insights were also compared across other organisations

active within the security field, namely the federal and local police forces. In doing so, robust insights applicable in a wider security context were generated. Currently we are attempting to confront the insights even wider across the security sector through a new collaboration in a new NATO workgroup on comprehensive defence.

Besides having a strong NATO, RMA and KHID anchor, this study is aligned with and contributes to the implementation and deployment of the ICS (Internal Control System) methodology across the whole defence structure, as mandated by the Belgian federal Government and the Chief of Defence (CHOD). The study also provides support to academic teaching within the RMA due to the dual nature of research-teaching in higher education and the teaching positions of the project director and the researcher. Therefore, in addition to sharing the results directly with the partners and stakeholders, insights are shared within the Belgian Defence through RMA courses.


# HFM 18-05 Monitoring and Modelling Physical Function and Performance in Military Rehabilitation

Directors: PT. PhD Lt Col D. VAN TIGGELEN
Dr. Ir. Air Force Maj Robby HAELTERMAN
Researcher: Dr. Ir. Sofia SCATAGLINI

# HFM 18-05 Monitoring and Modelling Physical Function and Performance in Military Rehabilitation

## Background

Evaluating the human function and performance and identifying critical factors is a challenge due to the high number of variables and their strong interdependence. The use of 3D motion analysis with high-speed motion capture is the gold standard in kinematics but is highly inconvenient for the clinical setting.

The use of wearable technology was assessed within a previous project in collaboration with the Dept. of Ballistics (RMA) and should now be applied in rehabilitation. There is a huge interest in the physical rehabilitation of the military patient suffering from musculoskeletal injuries. The actual physical assessment of the patient with cervical, back or lower limb impairments is already of high quality but lacks functional high impact and speed movement analysis. This technology together with new healthcare algorithms and subsequent rehabilitation protocols would permit more efficient and effective rehabilitation. The smart technology could also monitor specific movement patterns, for more efficient primary prevention. The long-term concept is to provide a common wearable biomedical sensor system that enables the Belgian Defence to improve military performance while safeguarding the health and security of its personnel during training and operations.

## Objectives

The purpose of this project is to apply the developed technology into a clinical setting and to apply mathematical algorithms in order to develop rehabilitation protocols. The originality of this project stands in the combination of two disciplines (rehabilitation & mathematics) which are extremely different but where complementarity will be the lever to a new approach of the complexity of rehabilitation sciences.

## Outcome/results

Stance to swing ratio was calculated in eighteen healthy male adults (mean age 26.33±4.40 years, body mass 74.66±5.62 kg) wearing a smart shirt based on

body-worn accelerometer. Spatiotemporal parameters such as gait cycle and phases, cadence, step length and speed were calculated using the vertical acceleration and anthropometric data of the subjects that wore the smart shirt. Average walking speed was 1.3738 m/s with a mean percentage of stance as 60.298 and of swing 39.702. These results are in accordance with the literature (Perry, 1992; Auvinet et al.2002; Azmi et al.2012; Huijben et al.2018).

As a conclusion, we can say that this preliminary study permits us to verify the use of smart clothing based on trunk accelerometer as an innovative way of monitoring gait analysis in an ecological approach in different environments. Our results demonstrated that the inverted pendulum model and walking speed are affected by anthropometric characteristics with $p<0.001$, where the ratio between the gait cycle and the stance reveals to be nearby an approximation of the golden ratio ($\varphi=1.61$). As a result, smart clothing based on body-worn accelerometer revealed to be an innovative and useful way to monitoring gait analysis and, in particular, ideal gait approximation in a non-intrusive way and ecological approach in different environments.


# HFM 19-02 Post-Deployment Reintegration: Describing, Understanding and Predicting Deployment-Related Psychosocial Risks

| | |
|---|---|
| Director: | Dr. Maj Salvatore LO BUE |
| Researcher: | (none) |

# HFM 19-02 Post-Deployment Reintegration: Describing, Understanding and Predicting Deployment-Related Psychosocial Risks

## Background

Military personnel health and motivation are key strategical concerns of Defence (see Policy Handbook Defence, CHOD, 2015). However, the specific dangers related to operations and the operational work-environments threaten those key aspects. Developing specific indicators to analyse systematically those risks and their impact on health and motivation is thus paramount. Post-deployment reintegration is a domain that attracted few research and practice interest until now.

## Objectives

The present project aims at examining post-deployment reintegration among Belgian military members. We propose a three-step approach. First, we will conduct a qualitative study to describe the experience and the perception of Belgian military members coming back from a deployment. Second, we will conduct a quantitative study aiming at understanding the reintegration psychological construct and at developing an ad-hoc measure instrument. Third, we will conduct a second quantitative study aiming at predicting health and motivation in function of reintegration. This project will enable the development of specific indicators related to the risks associated with the post-deployment period.

## Outcome/Preliminary results

Since the project only recently started, the question is too early even for any preliminary results.


# HFM 19-06 Making Blood Available Far Forward: Walking Blood Bank

Director: Air Force Capt Julie DEGUELDRE

## HFM 19-06 Making blood available far forward: walking blood bank

### Background

In austere environments, operational military medical support shows ingenuity in saving the lifes of wounded individuals. Haemorrhage is still a major cause of death in civilian and military trauma population. Survival rate in the haemorrhaging patient depends of early initiation of balanced resuscitation (i.e., adequacy of haemorrhage control and resuscitation between the point of injury and arrival at an adequate medical care facility). The application or rather the transposition of the principles of Damage Control Resuscitation (DCR) in its advanced or Remote (RDCR) version turns out to be the most effective strategy to improve the specific care to war wounded in pre-hospital austere environments.

The concept RDCR, supported and considered by NATO as the standard of care for war wounds, aims to prevent or treat the lethal triad combining control of bleeding, protection against hypothermia, resuscitation with low volumes and aggressive treatment of coagulopathy. However, even if a blood transfusion can often make the difference between life and death, compensating for large volume losses in austere environments, where immediate evacuation is not possible, remains an important logistical challenge. Therefore, to address transfusion limitations due to blood components availability in exceptional operational circumstances, walking blood banks (WBB) may be used in operational settings.

A WBB is a pool of pre-screened donors who are available “on call” to donate whole blood for a specific emergency. These volunteers are part of the detachment deployed in the field. They expressed their willingness to enter the list of potential donors prior to departure and they have lifestyle briefing and serological follow-up before and after each deployment.

### Objectives

This research aims at developing an adapted and inter-operable protocol for a Belgian walking blood bank. Our study will provide deployed medical personnel with simple, clear decision-making criteria adapted to their situation and the blood products availability to ensure the best transfusion care to the patient as

well as the best protection for the donors. Moreover, our staff will be trained, informed and able to react quickly and adequately in stressful and extreme situations.

The procedure to achieve our objectives:

a. Compare the concepts of walking blood bank as well as the implementation procedures based on a literature study.

b. Analyse the donor performances to ensure donor safety.

c. Study the haemostatics characteristics of the whole blood compared to the component therapy

d. Develop the Belgian concept of the walking blood bank:
   - Define the target groups (adapted to level of ambition and resources)
   - Define exceptional operational circumstances and responsibilities
   - Establish a list of necessary materials, suited to Belgian requirements
   - Establish rules for selecting potential donors
   - Establish the essential documentary support for safety and traceability
   - Organise a training adapted to the target users
   - Establish and follow a voluntary and reliable target-screening plan

## Outcomes

We investigated in both laboratory and field settings the impact of a regular 450-ml blood donation on donor performances. Both studies were double-blinded to minimise the psychological impact of the donation on the performances. The results indicate no performance decrements after the blood donation, neither the vigilance nor the physical capacities were impacted (see figure 1). Furthermore, these studies enable us to gain a better understanding of the target audience, the blood group tests and the material for the blood collection. The rapid detection tests for transfusion-transmitted infection are currently being studied in order to choose the most appropriate one. People regularly involved in the operation will be able to guide our choice during the drafting of the protocol itself.

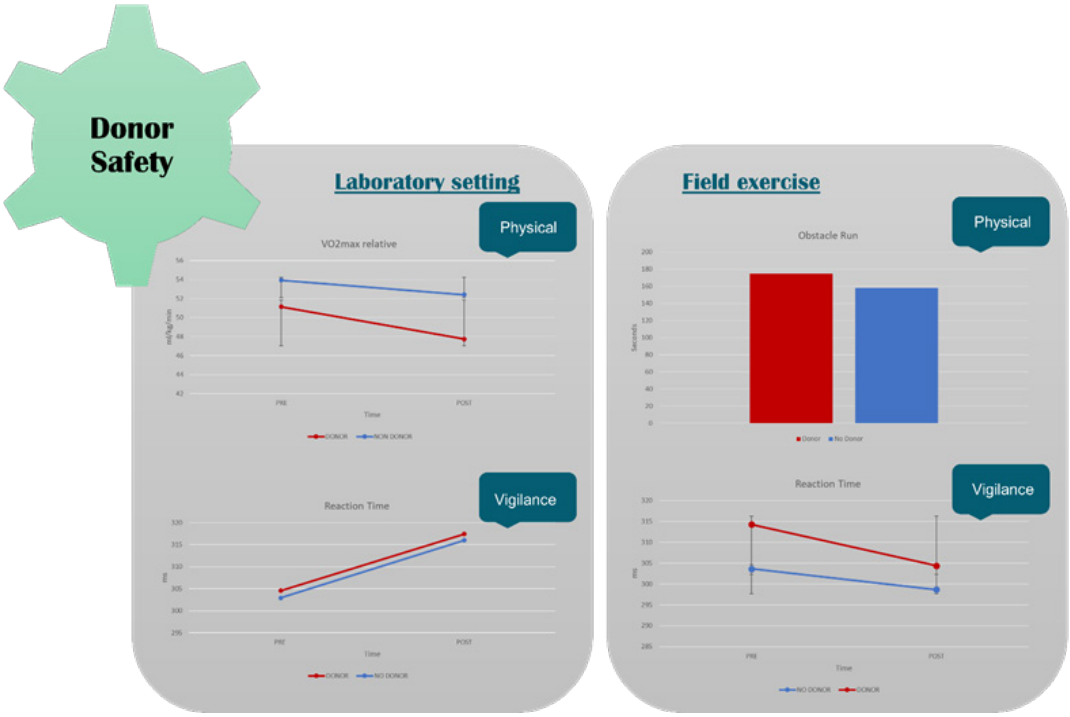


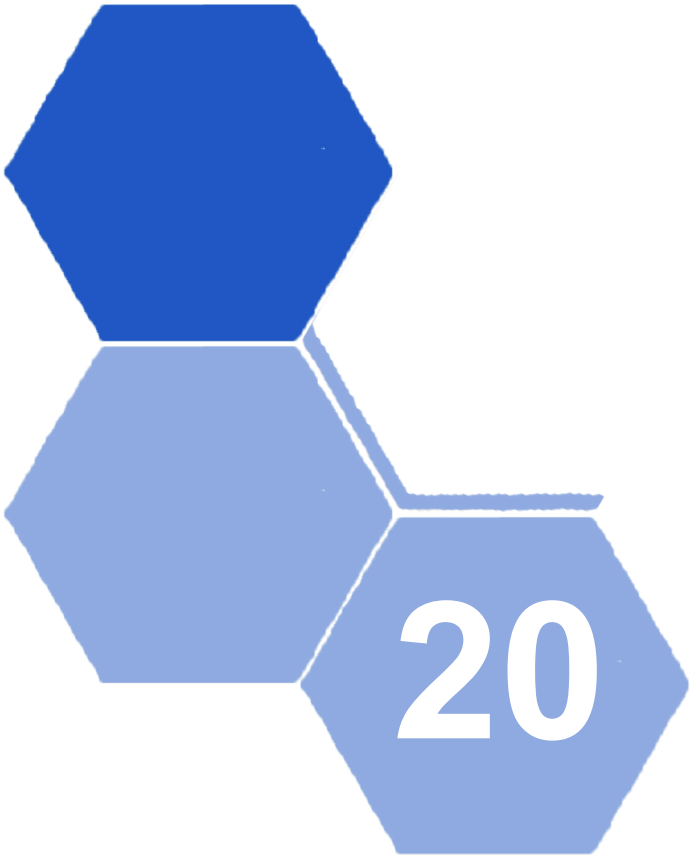

Figure 1: impact of the 450ml blood donation on the performances of the Special operation personnel. On the left side in laboratory standard setting and on the right side in field exercise.

We are currently analysing the literature on the WBB concept. It enables us to increase our knowledge and clarify the Belgian concept. Moreover, we were able to compare the procedures used by our NATO partners (e.g., France or Norway). The NATO Blood panel is also looking at establishing some common standards, which will prove to be an obvious basis for work. Finally, we have also contacted the Medical Competence Centre to consider an integrated training schedule for the medical staff concerned, which can be implemented in the training plan as early as 2021.

## Preliminary conclusion

Concerning the donor safety, the preliminary results indicate that a 450-ml blood donation has no effect on physical and cognitive performances. We are still investigating this question to adapt our recommendations to the target population and their missions. Moreover, the foundations and collaborations

necessary for the realisation of this ongoing project are well established. The practical organisation must be part of an existing training process in order to lay the foundations for regular education and training involving the training actors and the target audience.




# HFM 19-07 Fight as you train or train as you fight? Developing and integrating “deviation education” as an aviation safety tool

Director: Pr. Dr. Med Maj Nathalie PATTYN

Researcher: Air Force Maj Frédéric DETAILLE

## HFM 19-07 Fight as you train or train as you fight? Developing and integrating “deviation education” as an aviation safety tool

### Background

From investigation reports, deviations from Standard Operating Procedures (SOPs) can be considered as recurring causes for accidents, or incidents.
Deviations are negatively connoted. However, it is suggested that creative problem solving in acute situations may require both adapting the existing decisional algorithms to the reality of complex systems and, hence, deviating from the “tried and tested”. Nevertheless, a theoretical framework MAKING BLOOD that enables the delineation of decision-making processes and their applications, including the relationships between the different forms of logic that operate when we confront an unexpected risk, has yet to be developed. It may also be possible to develop effective ways for educating personnel about how to effectively apply reasoning in processes to deal with risks. Understanding reasoning is as important for preventing potentially harmful actions as it is for explaining successes.

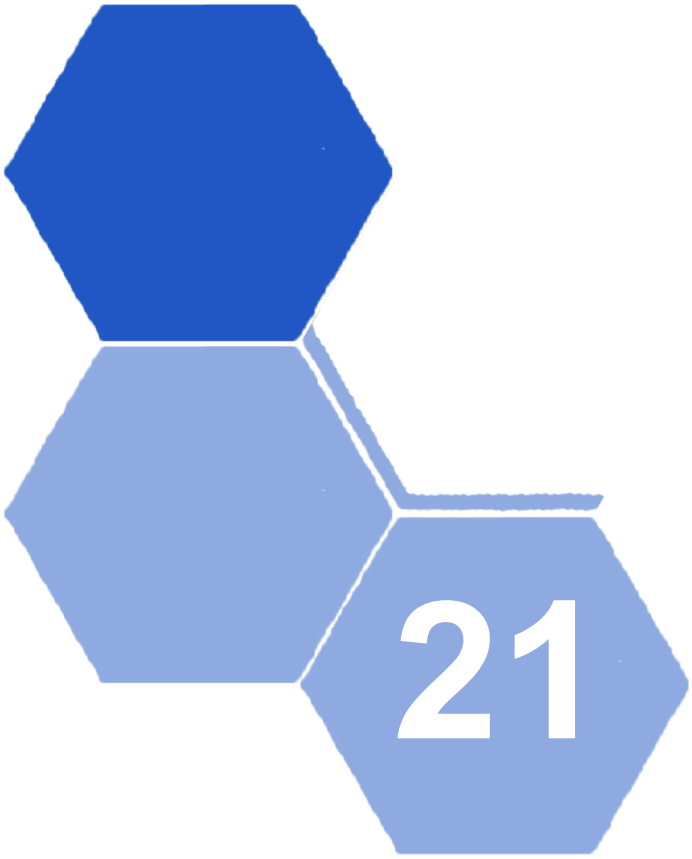
### Objectives

The present project consists in developing and integrating “deviation education” in existing training, to assist critical operators in the aviation system in times where situation may require deviations, hereby improving resilience and organisational performance.

### Outcome/Preliminary results

A critical analysis of former incidents/accidents will be the initial framework of the considered research and will aim at identifying successful deviations leading to reducing the event outcome. This will be integral part of WP2 of the current project. From the retrospective analysis of former deviations, a prospective study will be performed on identified attributes of successful deviations, considering temporal aspects. Furthermore, the deviation success will be evaluated at the individual, team, and organisational level when feasible.
So far, it is not possible to draw any conclusion on possible deviation efficiency

based on the analysed existing academic literature. Further research and hypothesis testing is required, based on further data analysis available at ASD. Depending on the ASD data quality, a further extension to other fields might be required. Provisional contact has been made with healthcare sector to share data. The sharing of data might require additional ethical committee considerations. However, the data are already anonymised and sharing is considered as valuable for both parties.




# HFM 19-08 OPTIMED. Counteracting military medical skills fade

Director: Pr. Dr. Med Maj Nathalie PATTYN

Researcher: M.Psych., PhD Martine VAN PUYVELDE

## HFM 19-08 OPTIMED. Counteracting military medical skills fade

### Background

In military deployment, medical professionals face complex operational situations that are not encountered in civilian health care practice. Even if Defence invests massively in time and money for the training of military personnel in order to ensure medical proficiency and successful care of patients in this specific context, these previously trained skills may have decayed through disuse. Although past research efforts have provided a greater understanding of the mechanisms underlying skills acquisition and decay, there are still no detailed models of skills decay, and more importantly mitigation strategies in military medical tasks.

### Objectives

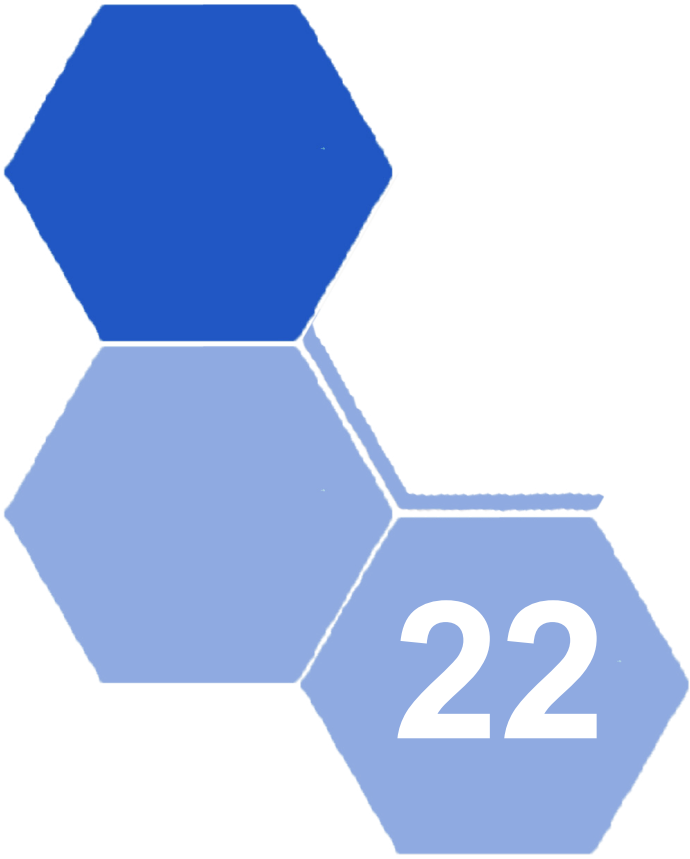
The current project addresses the need for further research in emergency military medical care, specifically understanding and quantifying medical skills decay. There is a first descriptive part to investigate and qualify skills decay. Furthermore, in a second part, the development of a set of methodologies for training interventions to counteract that skills decay will be investigated, including combinations of existing training technologies (simulation, augmented reality, virtual reality). Lastly, the implementation of this countermeasure will be tested. The successful completion of the project would enable to minimise training time, maximise efficacy and reduce medical errors during and after deployments.

### Outcome/Preliminary results

The literature review showed that a wide range of definitions and terminology has been interchangeably used to determine the loss of skills or the attempt to retain them. According to Arthur and Day (2013a, 2013b), an interchangeable use between retention and decay can be justified in that way that more decay is similar to less retention and vice versa.

Moreover, terms of “knowledge”, “skills” or the more umbrella-term “competence”

are alternately used, depending on the type and focus of the research (Arthur, Benett, Stanush & McNelly, 1998). Arthur et al. (1998) defined skill decay as “the loss or decay of trained or acquired skills (or knowledge) after periods of non-use” (p. 58), hence stressing the importance of a time-factor which is important with regard to the development of training methods. However, due to the emphasis on training procedures, the term “competence retention” has been increasingly used (Cahillane et al., 2013; Kent et al., 2015). Hence for the current project, we want to define medical competence retention as the level of competence as it changes over time in relation to the original level to which it was trained, taking into account the change of environment between civil and military contexts. The literature also showed the importance of individual factors that are influencing the retention curve. Moreover, there is an important lack of neurobiological and psychophysiological perspective and study approach, which will be an additive factor in the current project. That is, situational and collateral stress and the role of subcortical automatisation processes within competence retention. Although past research efforts have provided a greater understanding of the mechanisms underlying skills acquisition and decay, there are still no detailed models of skills decay, and more importantly mitigation strategies in military medical tasks (Perez et al., 2013) and certainly not from a neurobiological and/or psychophysiological conceptualising perspective.




# HFM 19-09 Performance optimisation in continuous operations: how to support self-management of performance in the SFG?


Director: Pr. Dr. Med Maj Nathalie PATTYN

Researcher: MSc, PhD Jeroen VAN CUTSEM

# HFM 19-09 Performance optimisation in continuous operations: how to support self-management of performance in the SFG?

## Background

The Special Operations Forces (SOF) represent the most demanding of all military specialities. People from the SOF embody a high-reliability versatile task force and are expected to meet a wide set of mental and physical demands to function during “continuous operations”, defined by a sustained performance on task for up to 72 hours. Therefore, SOF soldiers are the product of a severe selection and extended training, considering every physical and mental condition needed to succeed.

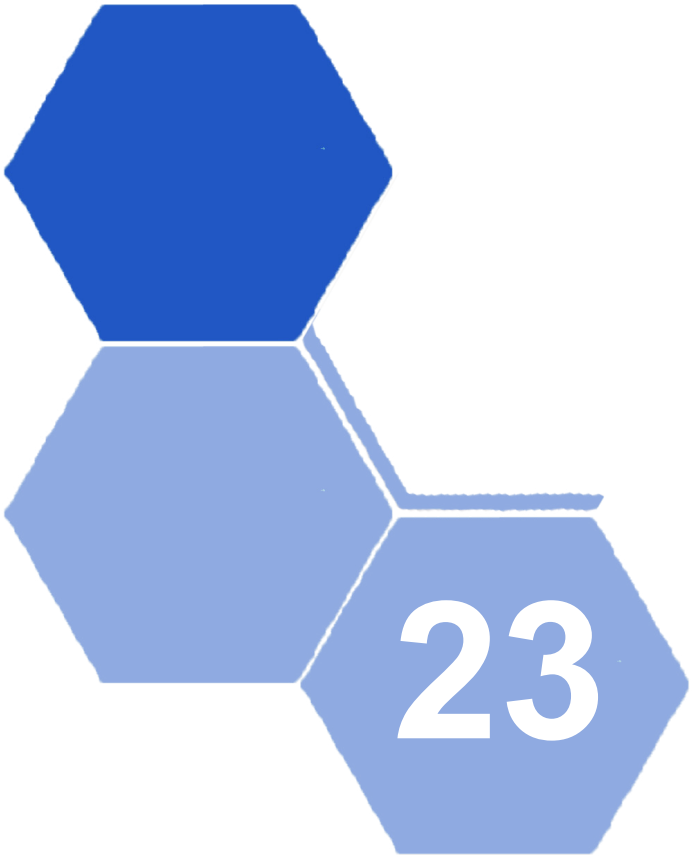
## Objectives

The project aims to identify a relevant set of crucial psychophysiological markers – in line with the concept of “Duurzame Inzetbaarheid” (sustainable employment) (DID, supported by the Medical Component and ACOS Well Being), that may serve as a base for psychophysiological self-management in BE SFG (Special Forces Group) soldiers.

From literature tackling the issues of attrition within SOF, we know that, worldwide, the attempts to decrease attrition rates mainly target program- and context-related factors, missing the main core aspect of human performance which is the building of self-management. In the last decade, this concept has evolved from solely behavioural to psychophysiological, relying on genetic-, health-, and operational-related markers. Several environments, both military and civilian, make use of predictive performance models that enable operators to schedule critical tasks to avoid performance decrement. In the current project, we aim to identify, in partnership with the BE SFG, the crucial markers that can be applied to refine a predictive model, to validate them at an individual level in order to prepare a decision-making support management tool to be used by every operator.

## Outcome/Preliminary results

For the current project, we want to define medical competence retention as the level of competence as it changes over time in relation to the original level to which it was trained, taking into account the change of environment between civil and military contexts. The literature also showed the importance of individual factors that are influencing the retention curve. Moreover, there is an important lack of neurobiological and psychophysiological perspective and study approach, which will be an additive factor in the current project. That is, situational and collateral stress and the role of subcortical automatisation processes within competence retention. Although past research efforts have provided a greater understanding of the mechanisms underlying skills acquisition and decay, there are still no detailed models of skills decay, and more importantly mitigation strategies in military medical tasks (Perez et al., 2013) and certainly not from a neurobiological and/or psychophysiological conceptualising perspective. The current project addresses this need for further research in emergency military medical care, specifically understanding and quantifying medical skills decay. There is a first descriptive part to investigate and qualify skills decay. Furthermore, in a second part, the development of a set of methodologies for training interventions to counteract that skills decay will be investigated, including combinations of existing training technologies (simulation, augmented reality, virtual reality). Lastly, the implementation of this countermeasure will be tested. The successful completion of the project would enable to minimise training time, maximise efficacy and reduce medical errors during and after deployments.




# HFM 19-10 Organisational Resilience

Directors: Lt Col Sylvie AERENS
Dr. Maj Salvatore LO BUE
Researcher: PhD Pablo ALONSO PEÑA

# HFM 19-10 Organisational Resilience

## Background

For several years now, psychopathologies have been transposed from the individual to groups or even structured groups such as organisations. Indeed, we find for example the notions of organisational crisis (Turner, 1976), or organisational stress (Bloom, 2006). Recently, the notion of organisational trauma was also introduced (Alonso Peña & al. 2017). While management methods exist for the first two, this is not the case for the latter. A model has been developed, but the theorisation of a key and antagonistic concept to this pathology, i.e. organisational resilience, is still lacking.

## Objectives

The aim of this project is to investigate more precisely the concept of organisational resilience and its mechanisms, to propose a definition of it and to imagine with precision the ways of implementing resilience mechanisms in an organisation. This approach will make it possible to plan future actions aimed at reducing the impact suffered by Defence and other organisations in a traumatic situation, and then to precisely define preventive mechanisms that promote a proactive rather than reactive organisation.

## Outcome/Preliminary results

A review of the literature has highlighted the importance of inter-relational aspects for the implementation of organisational resilience. By relying on the process proposed by Duchek (2019), it is possible to envisage several stages in the dynamics of organisational resilience (cf. Figure 1).

This process of resilience is divided into three phases: anticipation, coping, and adaptation. The first phase, anticipation, involves seeing change or critical situations coming, in order to be ready and respond positively as soon as possible. Weick & Sutcliffe (2011) explain that anticipation consists of envisaging problematic events and acting actively to interrupt the creation of unwanted situations. This anticipation phase should also make it possible to reduce future

negative consequences (Madni & Jackson, 2009) and avoid repercussions (Wildavsky, 1991). Prevention is characterised by three capacities: 1° noting internal and external changes; 2° targeting risk events; 3° being ready to deal with unexpected situations (Duchek, 2019).

The second phase, coping, is the reaction to undesirable situations. Its function is to prevent damage through proper management. To this end, it is essential to welcome the new situation, but also to prepare for it proactively. Several modes are proposed, including the description of crisis management processes and the implementation of feasible solutions (Duchek, 2019).

Finally, the third phase, adaptation, comes after coping strategies have been put in place. Here it is a question of adaptive capacities aimed at securing sustainable ways of functioning. According to Madni & Jackson (2009), adaptation enables the organisation to emerge from a crisis stronger than before. Duchek (2019) concludes that this phase is an offensive response.


This dynamics fits well within the framework of the study carried out within the Belgian Defence. Indeed, the qualitative analysis of interviews conducted with moral counsellors, prevention counsellors and FR/NL trusted persons demonstrated the essential links to be developed within the Defence to implement a coping strategy and to be able to develop the essential resources to anticipate future events and thus the implementation of an adaptation.

We note that the main demands (see Table 1) focus on three axes: organisational culture, organisational identity, and structure. The means of achieving this are, for their part, above all related to investment in future generations by proposing, as a priority, to enhance training, recognition and communication/information.

The modes of implementation are numerous and enable a diversified approach in order to improve resilience capacities within the institution and to integrate anticipation of future crises.

| | A : Structure | B : Identité | C : Culture | Total |
|---|---|---|---|---|
| 1 : Evaluation | 5 | 1 | 3 | 9 |
| 8 : Processus d'adaptation | 8 | 8 | 10 | 26 |
| 5 : Gestion de carrière | 25 | 13 | 13 | 51 |
| 2 : Ressources | 24 | 13 | 15 | 52 |
| 3 : Soutien - Accompagnement | 21 | 13 | 22 | 56 |
| 4 : Formation | 32 | 14 | 21 | 67 |
| 6 : Reconnaissance | 27 | 14 | 29 | 70 |
| 7 : Communication - Information | 35 | 21 | 32 | 88 |


# MB 14 CFD modelling of CBRN type attacks (release of small particles) in confined spaces

Directors: Prof. W. BOSSCHAERTS
Maj Benoît MARINUS
Researcher: Mrs. Laurine FAUGIER

# MB 14 CFD modelling of CBRN type attacks (release of small particles) in confined spaces

## Background

The ventilation of underground stations is often based upon natural techniques assisted by mechanical ventilation. In the case of Sainte-Catherine metro station in Brussels, the ventilation is only realised by the piston effect occurring at train arrivals and departures. The proposed research aims to model and predict the ventilation and dispersion of an airborne contaminant into the underground station, and to validate the CFD results.

## Objectives

Although previous works already have dealt with transport of contaminants and source modelling, they focused mainly on large rooms or buildings and do not take into account the peculiarities of underground stations and the influence of piston effect. One- or two-dimensional assumptions are sometimes taken to characterise the piston wind while reducing computational resources. On the experimental side, a 2009 thesis was dedicated to particle characterisation and source discrimination and identification, based on a field measurement campaign in a Parisian station. The creation of a numerical model faced difficulties due to high uncertainties of the measured input data and the complexity of the station architecture. In China in 2019, speed measurements on piston wind were done on several real platforms to observe the effect of a train braking and starting after passing through tunnels of different lengths.

Hence, this research intent to combine these different aspects to get an accurate display of the piston effect induced air movement in an underground station over time, and to use the results to compute the dispersion of a contaminant into it. From the literature review, the CFD model of this specific indoor environment, with the experimental validation, and with the introduction of a contaminant into it, appears to be quite an original work. The modelling of how a contaminant will spread and how the incoming of trains will affect it could enable to obtain quantitative results and to predict the consequence assessment regarding toxicity.

## Preliminary results

The scenario of contaminant dispersion in Brussels' Ste-Catherine underground station was prepared in collaboration with the STIB (Société des Transports Intercommunaux de Bruxelles) and UZ Brussel teaching hospital to fit the existing infrastructure, the real train behaviour and emergency procedures.

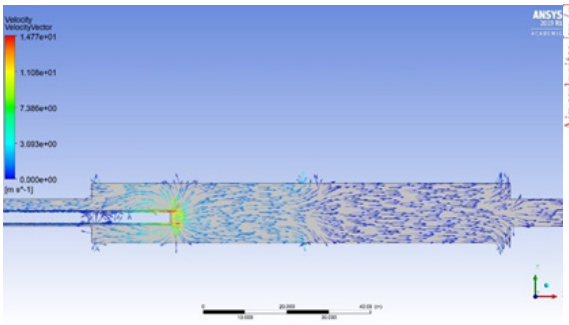


Fig. 1 – Measured air velocity on the platform

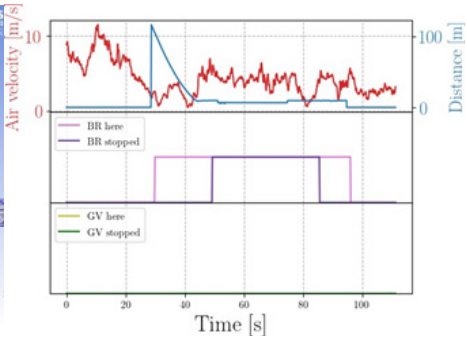



Fig. 2 – Simulated velocity vector field for one moving train

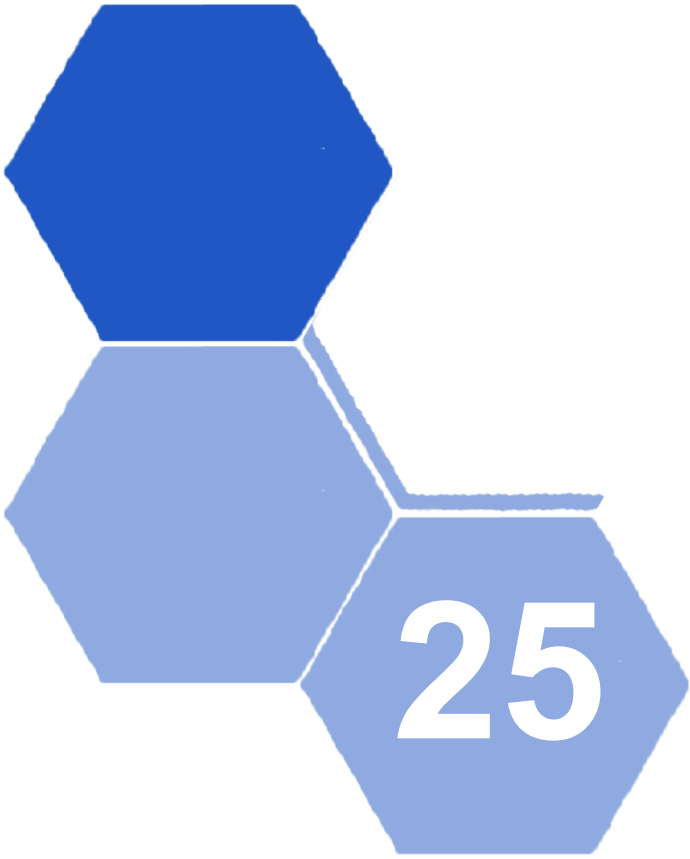
Based on the plans of the real station, a simple station and train geometry was defined, including interfaces with the exterior and a small part of the tunnel. The scenario was then implemented and simulated, first in 2D and without any contaminant source, in order to observe the internal flow field of the station (see the result for one of the time steps of the dynamic simulation in Figure 2). More efficient meshing techniques and influence of input parameters and boundary conditions are still to be considered. From the 3D simulation, we want to analyse if the vertical component is of notable influence on the air direction and velocity, or if it can be neglected, hence reducing the computational complexity.

A one-day measurement campaign was performed with a hot wire, in seven locations on the platform, synchronised with a LIDAR laser measuring the underground carriage position. One example of acquired data is shown in Figure 1, on which we can see the dependence between a passing metro and the air velocity at the middle of the platform, although further data treatment is still required to see if a pattern can be defined on an non-dimensional time scale. Air velocity at a particular point will be compared with the one from the CFD simulation to validate the latter. Apart from the validation of the numerical results, our aim there is to try to discriminate between the different factors influencing the aeraulics of the station : the piston effect from the metros arriving, stopping

and leaving the station, people's presence on the platform, the exterior wind and other weather conditions, or the air carried through the tunnel network.

In the literature, it was found that one small-scale model of an underground tunnel was built at scale 1/20 to measure the pressure and air velocity when the underground runs at different speeds into the tunnel. However, scale models of an underground station still seem to be uncommon. Here, building a small-scale model of the trains and the platforms will enable to perform PIV and obtain the whole flow field at a fixed height. The flow field would be directly comparable to the one given by the simulation, such as in Figure 2.

An application of the validated study, for further research or preliminary studies, could be to use it as a conception and decision tool before an attack: to design the spaces with regard to detection systems, and to identify the most threatened and safest zones, and to provide operational guidelines to decision-makers in order to contain the incident.




# RCDM 11 Organisational trauma

Director: Prof. Jan LEYSEN

Researcher: Mr. Pablo ALONSO PENA

# RCDM 11 Organisational trauma

## Background

An organisational trauma (OT) is defined as an “organisation’s ‘over’-adaptation to the rupture of its protective emotional membrane, caused by a potentially traumatising event and involving the appearance of emotional and organisational disturbances.” In chaotic economic and political times, ever more organisations are confronted to such potentially traumatic events. Hence, the probability grows that an organisation will develop this organisational pathology. Because of its role, its missions and the difficult context, the Belgian Defence too it at risk of being impacted by organisational trauma.

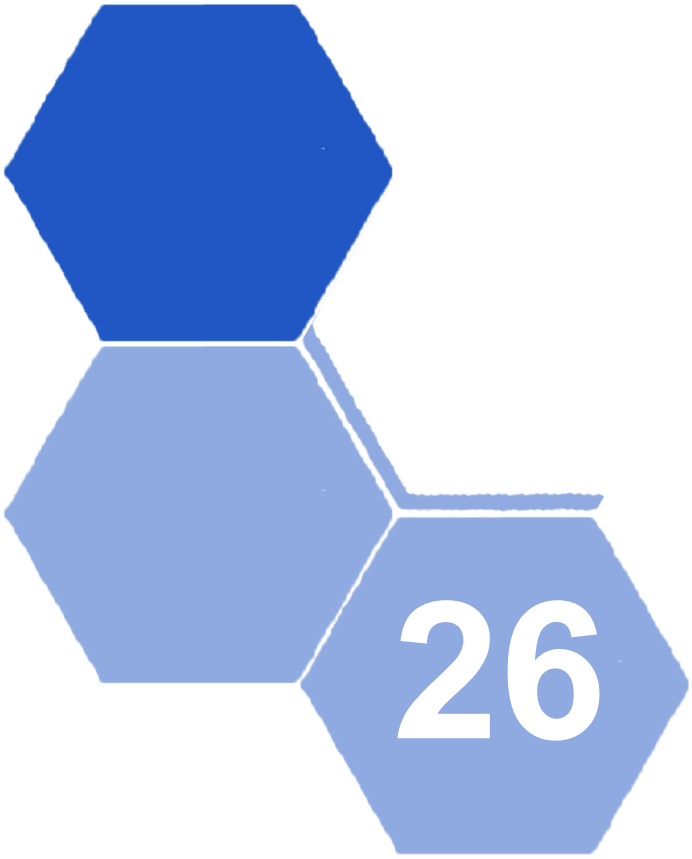
## Objectives

In order to evaluate to what extent the Belgian Defence is affected by an organisational trauma, this research has focused on two points. First, conceptualising the symptomatology of the pathology and its underlying process. Secondly, operationalising this in order to measure the impact on the organisation.

## Outcomes

The research resulted in the design of a diagnostic tool (OUDITO) validated and applied to the Belgian Defence. The questionnaire has enabled to highlight the impact of organisational trauma and the stage of traumatisation on the Defence organisation. OUDITO is composed of 48 items measuring 6 symptomatic dimensions, corresponding to the successive stages of an organisational trauma: Internal communication and cohesion, Relationship with the organisation, Organisational functioning, Emotional reaction, Employee wellbeing, and Leadership.


**Legend:**
- **R** : Identity consistent with the Albert and Whetten 1985 definition corresponding to the reality of individuals close to the "ground"
- **I** : Identity defended by the parties involved that reflects the organisation's ideal
- **R' & I'** : Identities that have undergone minor changes during the traumatising process
- **R'' & I''** : Identities that have undergone major changes during the traumatising process




# MSP16-01 An expert simulation system for MCM operations using unmanned systems

Directors: Air Force Maj Filip VAN UTTERBEECK
Lt Col IMM. Ben LAUWENS
Researcher: Ir. Damien DESMIDT

# MSP16-01 An expert simulation system for MCM operations using unmanned systems

## Background

The current NATO mine countermeasures (MCM) planning and evaluation (P&E) methods and tools are not fully adapted for modern MCM systems based on autonomous unmanned systems (including underwater vehicles equipped with side-looking or synthetic aperture sonars) which cooperate to perform the detection, classification, identification and neutralisation of the mines.

Existing MCM planning and evaluation algorithms and software have been designed for traditional MCM assets. Current MCM doctrine is centered on the use of the software tools MCM EXPERT and DARE, containing assumptions that make their use valid only for traditional systems. The objective is threefold:

1. the development of a simulator that enables the evaluation of a planned MCM operation for a given scenario;

2. the integration of a simulation optimisation module which will enable us to automatically deduce “best practices” for a wide range of scenarios;

3. the creation of an expert system module which will propose efficient planning settings in near real-time and which is able to adapt the planning to cope with unexpected changes in the scenario.

This tool will also enable Belgium to define the optimal suite of unmanned vehicles and MCM sensors to be acquired in the future MCM capacity.

## Objectives

The expert simulation system will be developed in three phases.

In the first phase a simulator for P&E of MCM operations will be developed. This will enable the evaluation of a proposed planning without incurring the cost of a real-life exercise.

The simulation model of a specific MCM scenario will be based on 5 input modules:

- the threat,
- the environment,
- the mission,
- the resources, and
- the planning.

The threat input specifies the mines (their type, actuation mechanism, position, etc.). Part of this information (e.g. intelligence on the type of mines used) may be available for the planning process, but most of it will be considered unknown. The environment input defines the zone of operations in 3D, including info such as the bottom type, clutter density, bathymetry and sea currents.

The mission input defines the operational objective (e.g. level of confidence that all mines have been detected) and operational constraints (e.g. time limits).
The resource input defines the quantity and the capabilities of all available resources [sensor suite characteristics (e.g. range, probability of detection and classification), navigation, propulsion, power, magnetic-acoustic signatures].

Finally, the planning input module computes the deployment strategy of the available resources (what, when, where and how).

The simulator itself is a stochastic computer simulation model combining discrete-event and continuous-time process modules that will be developed in SimJulia.

The simulation logs will be analysed by an evaluation output module that will calculate an array of outcome performance measures such as, e.g.:

- the level of clearance,
- the risk to the first transitor and
- the “CAS assessment” (the expected number of casualties in an established number of transits).

In a second phase, a simulation optimisation module will be added to the system. The exact optimisation algorithm to be used will have to be determined during WP4. Various classic heuristics such as e.g. scatter search, tabu search or memetic algorithms have been successfully implemented for complex

simulation optimisation problems, but alternatives such as hybrid algorithms, hyper-heuristics or swarm intelligence merit consideration.

The application of the optimisation module will enable us to deduce “best practices” [i.e. near-optimal settings of the planning parameters for a given scenario (threat, environment, mission and resources)].

Large-scale experimentation (based on experimental design to deal efficiently with the large dimensionality of the parameter space) will lead to the construction of a “knowledge-base” of best practices for a wide variety of scenarios.

In the third and final phase, an expert system module will be added.

This module will use artificial intelligence techniques to exploit the available knowledge base and combine this with the optimisation module in order to suggest near-optimal planning parameters for new MCM-scenarios as rapidly as possible.

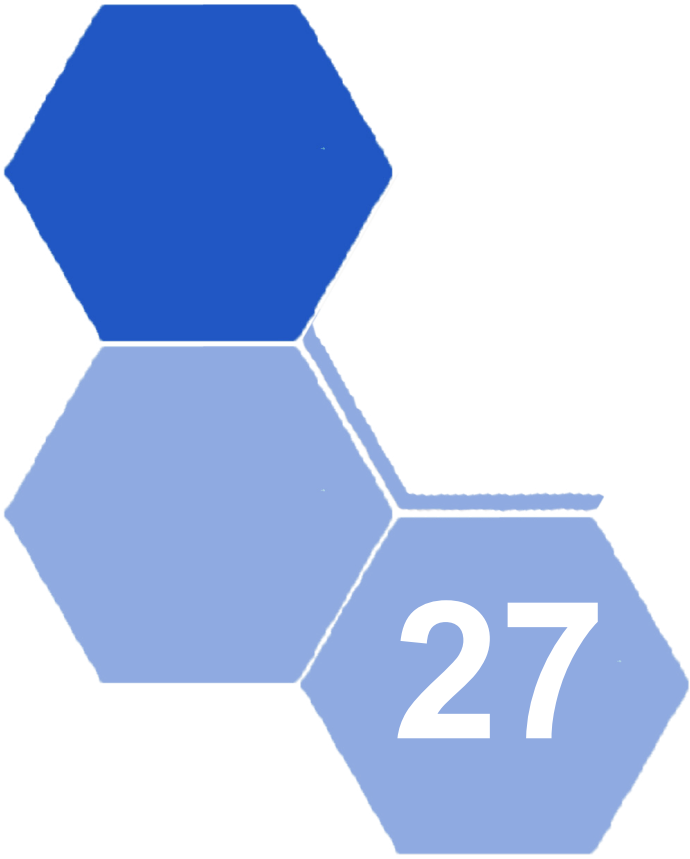
Moreover, the module will be able to re-optimise the planning if changes to threat, environment, mission or resources occur (e.g. an unexpected threat is identified, a mission constraint is modified or an unmanned system is lost).

## Expected outcome

The proposed expert system for P&E of MCM operations will integrate the use of both multiple autonomous unmanned systems and modern sensor suites, which is not the case in the currently used software.

Moreover, the simulation optimisation module will enable the automated optimisation of the deployment strategy and the deduction of “best practices”.

Finally, an innovative expert system will be coupled with the optimisation module to enable near real-time automated planning and the adaptability to cope with unplanned scenario changes.




# MSP16-06 Multiphase flow modelling for CBRN applications

Director: Maj Bart JANSSENS

Researcher: Mr. Yoshiyuki NISHIO

# MSP16-06 Multiphase flow modelling for CBRN applications

## Background

Two improvements will be made to the existing modelling capabilities: first, the effect of dispersion in atmospheric conditions and in the presence of complex terrain will be investigated. This will require work on the modelling of the atmospheric flow itself and on the accuracy of the particle and gas dispersion models. Secondly, a model for protective clothing will be developed, in order to predict the protection factor in the presence of a non-homogenous flow laden with toxic particles and/or gases.

Objectives

The purpose of the current study is to apply the numerical model from a previous study in support of existing CBRN research in Defence.
After consulting with DLD (Defence laboratories) and taking into account a question from the Defence staff (Dept Risk & Environment) two interesting applications were identified:

1. Simulation of protective clothing tests: DLD performs tests regarding the protection factor provided by different types of CBRN-protective clothing. Simulating a flow around a test subject and modelling the behaviour of the clothing would enable a numerical estimation of the protection factors. Existing data from DLD could be used to validate the model.

2. The dispersion of toxic particles and gases, especially over complex terrain, is an important parameter when determining the risks associated with the storage of dangerous goods, such as the toxic ammunitions stored at the DOVO site in Poelkapelle. Further improvement of existing models helps in determining accurate bounds of the concentration. Based on this, appropriate emergency plans and countermeasures can be established. This can save lives by making sure the necessary measures are in place, but it can also save costs by not exaggerating safety perimeters.

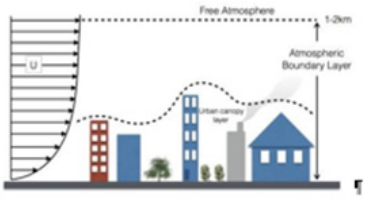
In conclusion, we will focus on two main goals in this project: the development of a protective clothing model and the validation and improvement of the dispersion model in the case of a release in complex terrain.

## Preliminary results

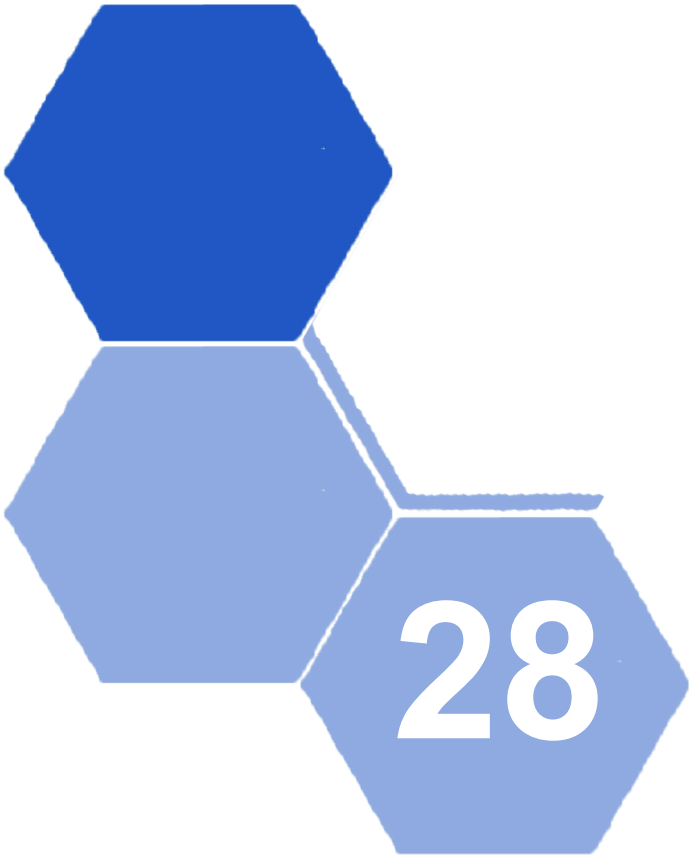
The first idea is to avoid the traditional filtered equations, source of difficulties (e.g. in-homogeneous non-commutative filters necessary for wall bounded flows), by use of the variational projections.
The second idea is to confine the “modelling” to the fine-scale equations so that the numerical consistency in the coarse-scale equations is retained, facilitating the numerical method’s convergence.
In the traditional approach, the convergence rate is limited, due to the “artificial” viscosity effects in the fully resolved scales (e. g. Smagorinsky-type models), introducing the turbulent dissipation and, de facto, inducing a consistency error.
In order to confirm the interest of the study, we tried to implement a finite element/volume code for an unstructured mesh and compressible flow that was successfully applied to complex test cases, avoiding the use of eddy viscosities while enabling to capture all scales consistently and therefore demonstrating the competitiveness with traditional LES methods.

To conclude, since the variational multiscale methods are usually considered as the more general formulation of the classical stabilised methods (e. g. Streamline-Upwind/Petrov-Galerkin – SUPG) that is currently implemented in our code, we have great expectations that the current implementation of this method in this work will produce results not altered by numerical oscillations and, therefore, generating the expected ABL.

*Figure·1:·Dispersion·in·the·air,·after·an·explosion,· Houston·2019·(source:·internet)*




*Figure·2:·Urban·ABL·sketch·(source:·[2])*




# MSP16-07 Low Noise Design of Single Open Rotors

| | |
|---|---|
| Director: | Maj Benoît MARINUS |
| Researcher: | Own personnel |

## MSP16-07 Low Noise Design of Single Open Rotors

### Background

Remotely Piloted Aircraft (RPA) are the subject of extensive studies due to their increasing use in various applications. This trend has renewed the interest in developing propellers, studying the mechanisms of noise which they generate and proposing treatments to reduce it. The silent flight of owls has attracted the attention of researchers for years. Studies on the owls' feathers have shown that they are equipped with leading edge and trailing edge serrations which are responsible along with other features for the noise generation mechanism. Serrations have proven to be an efficient way of reducing trailing edge noise for airfoils in translation and large wind turbines. Hence, we investigate their use for mini-RPA propellers where the advance ratio (which compares the translational velocity of the propeller to its rotational velocity) is quite different from the existing applications.

Noise is currently the main reason behind detection of such RPAs (Remotely Piloted Aircrafts). In the low and very-low speed ranges, broadband noise is dominant since most noise sources result from the interaction between the blade and upstream turbulence or between the blade and the turbulent boundary layer on it. Due to the complexity of the coupled flow/noise mechanisms at play, this is a fundamental study relying on time-resolved Computational Fluid Dynamics.

### Objectives

This disruptive study aims at proposing advanced shapes for propellers to be used on those mini-RPAs.
To achieve the goal of proposing disruptive shapes offering a technological advantage with direct operational implications, a selected set of shapes has been submitted to detailed flow field and noise analysis. For this purpose, a novel time-domain formulation for the computation of broadband noise has been derived from the existing theoretical background. This analytical formulation has been validated against lattice Boltzmann time-dependent flow simulations, which are computationally extremely demanding but resolves the finest details of the flow around and in the immediate vicinity of the blade.
Building on previous expertise and inspiring from biology, specific leading- and

trailing-edge serrations have been investigated for their potential broadband noise reduction while maintaining high efficiency. The computationally cheap analytical formulation is now available for optimisations.

## Outcome

The Very Large Eddy Simulations (VLES) were performed by leveraging the inherently transient capabilities of the PowerFLOW solver [1] based on the three-dimensional 19 discrete particle velocities (D3Q19) lattice Boltzmann model (referred to as LBM in this paper). The Boltzmann equation governs the dynamics of particle distribution-functions representing the probability to find a number of particles having a velocity in a given interval in an elementary volume during an infinitesimal time interval. The model constructs a simplified form of the mesoscopic dynamics that includes sufficient physics so that the desired macroscopic behaviour is recovered. Macroscopic flow quantities such as density and momentum are calculated by discrete integration of the distribution functions. According to turbulence theory, the unresolved universal scales in the dissipative and inertial ranges are modelled by introducing a local effective relaxation time in the collision operator governing the Boltzmann equation. This can be compared to the concept of eddy viscosity in a Navier-Stokes solver. The sub-grid scale turbulence dynamics is represented by two additional equations that complete the LBM.

*Trailing-Edge Noise Formulation*

Trailing-edge noise is generated by the interaction and acoustic response of the turbulent structures conveyed over the sharp trailing edge. Lyu et al. [2] generalised Amiet's [3] model for the prediction of noise generated by the interaction of a turbulent boundary layer with a straight trailing edge to serrated trailing edges. This model was further extended to account for rotation by applying a Doppler frequency shift and averaging over all possible angular locations of the blade segments. The far field noise Power Spectral Density (PSD) for a rotor with B independe nt blades is calculated from the far-field PSD of an airfoil $S_{pp}^{\Psi}(\bar{x}, \omega_e)$ calculated in its local reference (Fig. 1) frame by

$$S_{pp}(\overline{R_0}, \omega) = \frac{B}{2\pi} \int_0^{2\pi} \left( \frac{\omega_e(\Psi)}{\omega} \right)^2 S_{pp}^{\Psi}(\bar{x}, \omega_e) d\Psi$$

where $\omega_e$ is the emitted frequency at position Ψ, and ω is the observed frequency at the observer's location. The main inputs to $S_{pp}^{\Psi}(\bar{x}, \omega_e)$ are the serrations geometry and the wavenumber spectral density of the surface pressure fluctuations beneath the turbulent boundary layer on the airfoil surface.

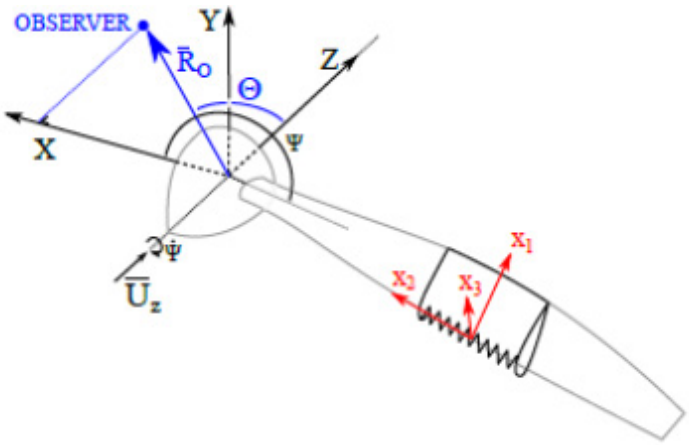



Figure 1. Coordinate system used in the rotating blade model.

*Leading-Edge Noise Formulation*

Leading-edge noise is generated as freestream turbulence interacts with the leading edge. Lyu et al. [4] derived an expression for the PSD on an airfoil with leading-edge serrations that involves the serration geometry and the PSD of the vertical velocity fluctuations assuming the von Karman model for the upstream isotropic turbulence. It is extended to rotating blades using the same formulation as for trailing-edge noise.

## Validation & Results

*Trailing-Edge Noise Formulation*

Validation of the formulation is done for airfoils (Fig. 2) for which vast amount of literature is available [5]. Next, the formulation is compared to lattice Boltzmann time-dependent flow simulations which are computationally extremely demanding but resolves the finest details of the flow around and in the immediate vicinity of the blade [6-7]. Finally, the computationally cheap model was employed in the search of optimal geometries (Fig. 3).

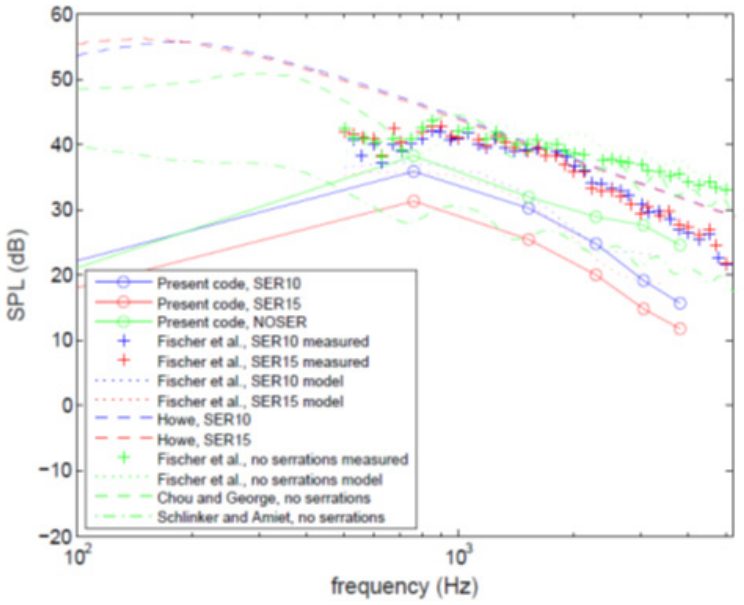



Figure 2. Far field spectra calculated with the present model for the baseline and two serration geometries of an airfoil. Comparison with other analytical models and measurements. [5]

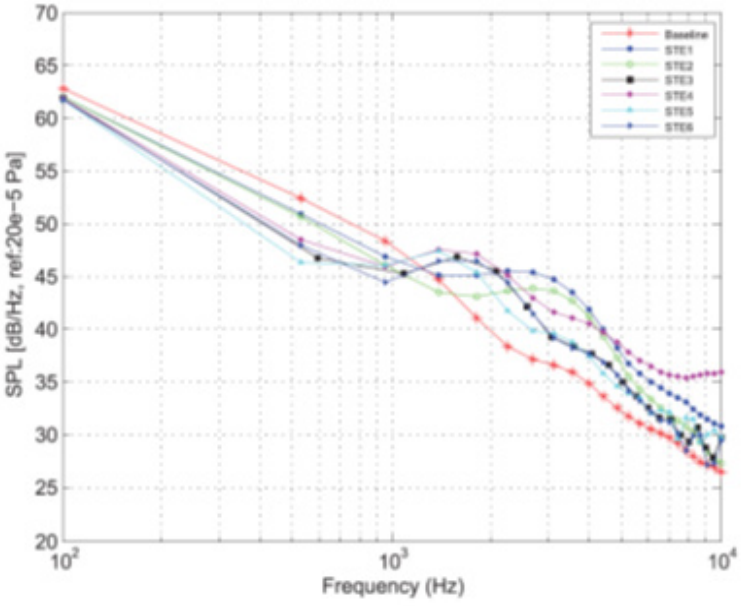



Figure 3. Results comparison between the predicted noise spectra of the serrated trailing edge blades and the baseline blade [7].

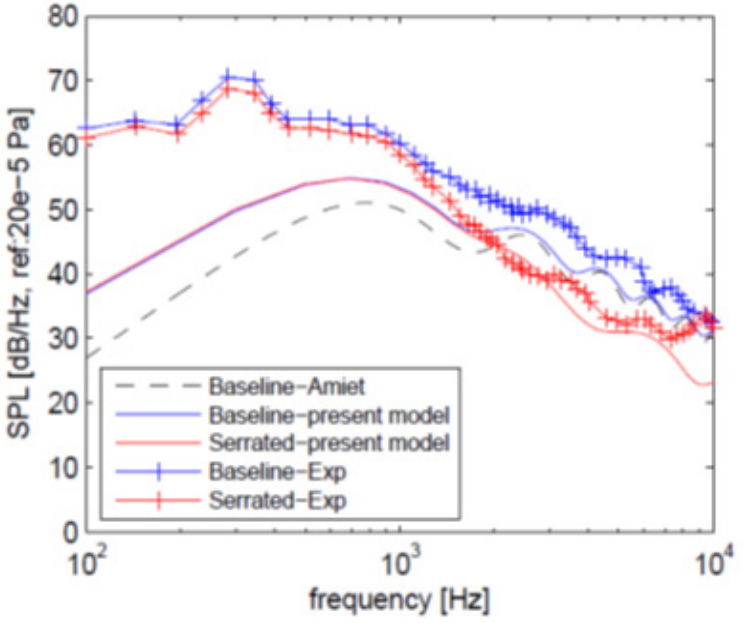



Figure 4. Comparison of the results obtained with the present model with experimental data for baseline and serrated at plates. [5]

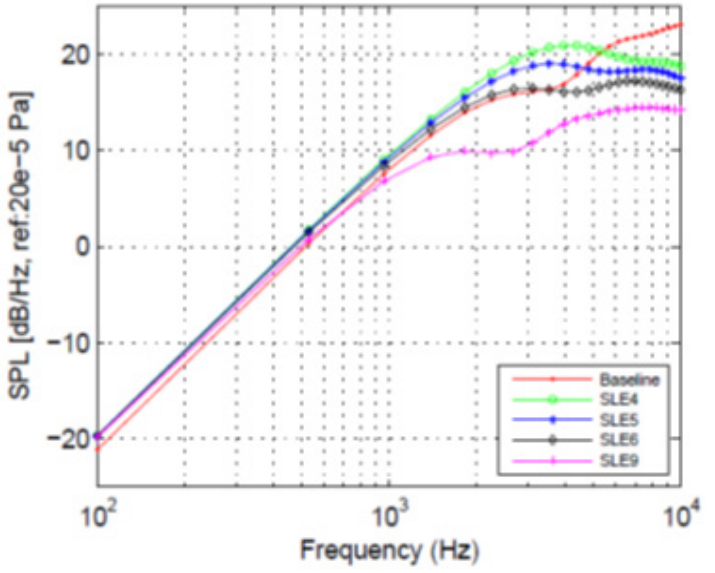



Figure 5. Results comparison between the predicted noise spectra of the serrated leading-edge blades and the baseline blade [8, 9].

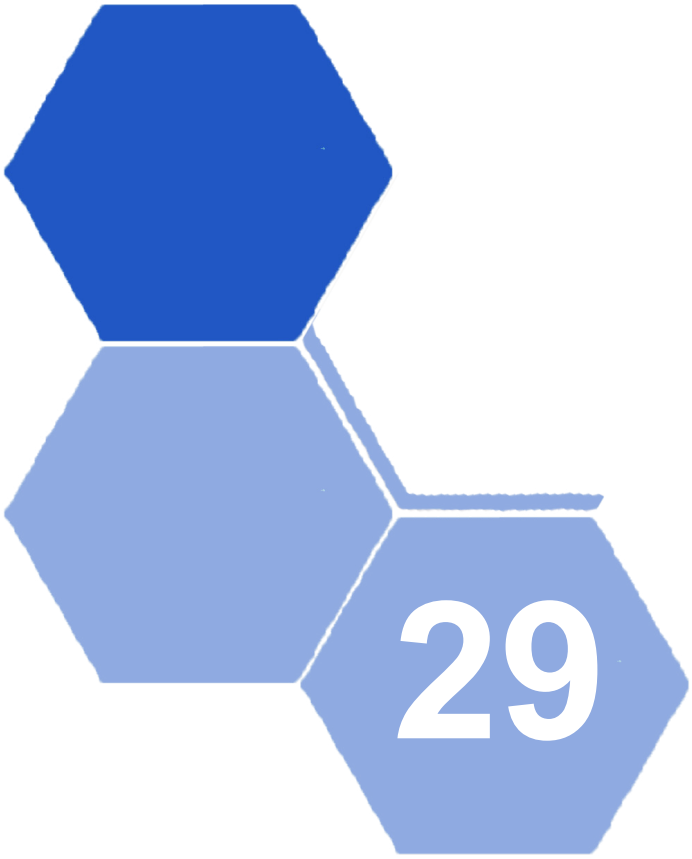
Validation of the formulation is also done for airfoils (Fig. 4) although data is scarcer since turbulent interaction noise is in general one order of magnitude lower than trailing-edge noise [5]. Then, the computationally cheap model was employed in the search of optimal geometries (Fig. 5).

## Conclusions

The results show that the frequency-domain analytical model for predicting noise from serrated trailing or leading-edge is able to predict the noise from straight and serrated propellers with sufficient accuracy for optimisation purposes.

The results of the parametric study conducted with sawtooth trailing-edge serrated blades show that the use of serrations reduces the noise emitted by the propellers at low to mid frequencies but induces a noise increase at high frequencies. The sharpest serrations were found to achieve the better performance in terms of reducing noise. This result is identical to what was found for non-rotating airfoils by several authors though it is here extended to the case of rotating airfoils hence with the occurrence of cross-flow and spanwise varying flow conditions.

The results of the parametric study conducted with sawtooth leading-edge serrated blades show that the use of serrations reduces the noise emitted by the propellers at high frequencies. The noise reduction increases with increased serration amplitude, while the variation of serration wavelength show no significant effect on the noise reduction. Moreover, the leading-edge noise reduction is sensitive to flow conditions: it was found to be an increasing function of both increasing advance ratio and turbulence intensity. The turbulence length scale is found to be an important factor that determines the noise reduction from serrated leading edges.




# MSP17-01 Novel adsorbents for an improved CBRN protection: a hoax or not?

Directors: Prof. Michel LEFEBVRE (previously Col IMM. Peter LODEWYCKX)

Researcher: Mrs. Leticia FERNANDEZ VELASCO

# MSP17-01 Novel adsorbents for an improved CBRN protection: a hoax or not?

## Background

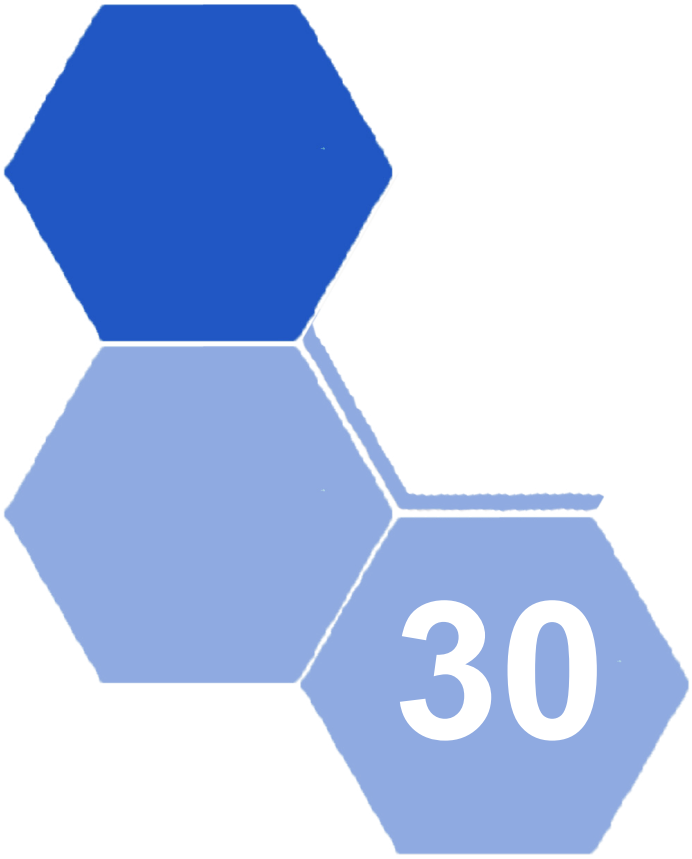

Over the past few years the traditional adsorbents used in filter media, activated carbon and, to a lesser extent, zeolites have been joined by new adsorbents such as MOFs, COFs, graphite oxide as well as metal and mixed metal oxides. Either all these materials have recently been developed, or adsorption is seen as a novel use for them. In literature, despite the fact they are significantly more expensive than the traditional adsorbents such as impregnated activated carbons, they are presented as superior to traditional adsorbents – even when their performances are only based on theoretical considerations.. Thus, the aim of this project is to study their performance in realistic conditions (respiratory filters, presence of humidity, etc.) and to evaluate the feasibility of their implementation from an economic, technical and efficiency perspective.

## Objectives

The study started with an extensive literature search in order to establish a complete list of novel adsorbents and their known strengths and weaknesses. Then the adsorbents that seem promising have been completely characterised and are being thoroughly tested against chemical warfare agents (e.g. HCN) and toxic industrial chemicals (NH3, SO2, for example). These results have been compared to those obtained from the latest generation of impregnated activated carbons. This will lead to clear and concise recommendations to the Belgian Defence regarding the viability of each class of novel adsorbents to replace activated carbon in CBRN filters and protective garments.

## Preliminary results

The results obtained so far indicate that the use of these novel adsorbents alone is far from being technically feasible due to their powder nature and the loss of their properties when they are agglomerated into bigger particle size. Moreover, only some of the novel adsorbents (e.g. UiO-66, ZIF-8) showed stability to humidity as demonstrated by consecutive water sorption cycles. Then, the efforts were directed to their use in combination with activated carbons in different arrangements: physical mixtures, alternate layers and composites. The first option led to a slight enhancement of the performance of the filter when compared with that of commercial impregnated activated carbons used in this application. However, the maximum extent of this improvement (15% longer breakthrough time) does not fully justify the use of the novel adsorbent in both economic and practical terms. The use of alternate layers of both types of adsorbents led to various operational problems linked with an inadequate flow pattern and drop pressure through the filter. On the other hand, it seems that an intimate coupling between the carbon and the novel adsorbent is most wanted. Thus, our current research efforts are focused on the in-situ growth of the MOF or the metal oxide inside the porous network of the nanoporous carbon.




# MSP17-03 Experimental evaluation of kinetic energy non-lethal weapons

Director: Maj Alexandre PAPY

Researcher: Mr. Cyril ROBBE

# MSP17-03 Experimental evaluation of kinetic energy non-lethal weapons

## Background

Evaluating kinetic energy non-lethal weapons (KENLW) was the key objective of the previous two studies. Very good results were achieved, illustrated by already two available NATO standards. These documents are largely inspired by the work performed during these two studies.

## Objectives:

The proposed research project is the continuation of this evaluation, leading to standardisation. First of all, the thoracic impact and the head impact evaluation will be improved – in order to reach a NATO standard –, as well as the skin penetration standard. Then, the evaluation of the abdominal impacts and the limbs impacts will be studies, possibly leading to new NATO standard documents as well. Finally, the study will propose scientific methods to evaluate the effectiveness of KENLW in terms of induced effects.
During all these evaluation processes, the current Go/No Go approach will be replaced by a more graduate injury scale, enabling deciders to adapt the material, the rules of engagement and the risk of injury to the mission. Finally, all the evaluation methods will possibly be extended to contiguous applications such as the behind armour blunt trauma (BABT), or close range techniques (CRT) and baton impacts.

## Outcomes:

Two major breakthrough are presented in the following lines.
Firstly, 2019 gave the opportunity to organise the 10th European Symposium on Non-Lethal Weapons at the Royal Military Academy. This event, as the only international conference on the subject, gathered experts from all around the world, speaking and sharing about various subjects concerning non-lethal weapons, including their use in a law enforcement or military environment, their evaluation or their development. The Royal Military Academy published an astonishing number of 11 papers in the proceedings of this conference,

including 7 written by the director and the researcher of the study MSP17/03. Five of these papers were further published in the international scientific journal entitled “Human Factor and Mechanical Engineering For Defense and Safety” (HMDS), three of which were written by the director and the researcher of the study MSP17/03. The 10th European Symposium on Non-Lethal Weapons was the opportunity to place the work performed in the RMA and the department of weapon systems and ballistics (ABAL) under the spotlight, boosting its networking, and promoting collaborations between the RMA and other institutions.

Figure 1: Some key attendants of the symposium

Secondly, another breakthrough for the study during 2019 was the design of a new methodology in order to assess the abdominal impact of kinetic energy non-lethal projectiles (KENLP). This methodology is based on the use of the “blunt trauma torso rig”, a biomechanical surrogate that was developed for evaluating the behind armour blunt trauma occurring during the impact of a small calibre projectile impacting a target wearing a ballistic protection, without provoking perforation of the protection. The set-up was adapted and the post-processing of the results was modified in order to enable evaluating the abdominal KENLP impacts. The biofidelity of the process was assessed using open literature data, consisting of post-mortem human subjects (PMHS) and pigs undergoing a blunt impact produced by rigid non-lethal projectiles. These first results are the first breakthrough in the development of a dedicated methodology for assessing KENLW impacts. The objective is to obtain mature results in order to standardise the methodology.

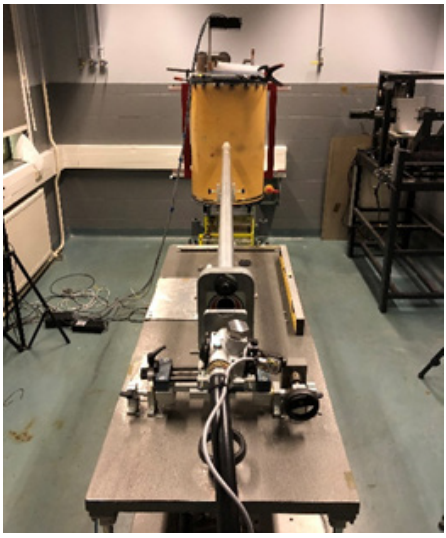
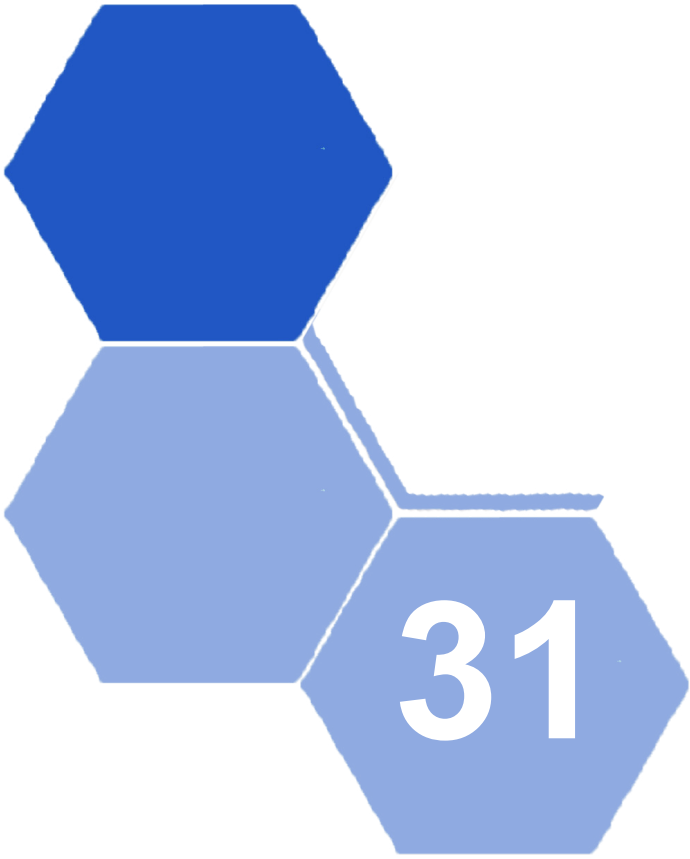


Figure 2: The modified set-up for assessing KENLW abdominal impacts




# MSP17-07 SIMNUMDEF

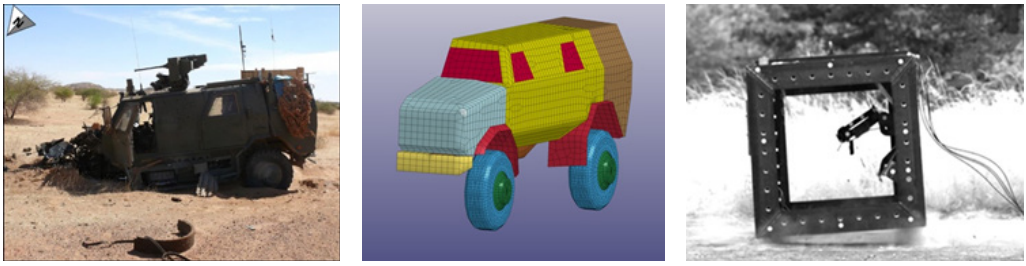
Director: Lt Col IMM Frederik COGHE

Researcher: Mr. George KECHAGIADAKIS

# MSP17-07 SIMNUMDEF

## Background

The main threats for armoured vehicles deployed in conflict zones are currently antivehicle mines and the improvised exploding devices (IEDs). For this reason, the current generation of armoured combat vehicles (Dingo, Piranha, Pandur, Lynx) used by the Belgian Armed Forces all have an integrated blast protection that is evaluated when purchasing the vehicles. Nevertheless, it is often not clear what effect small and medium vehicle modifications, due to operational and/or logistic requirements, have on that initial level of blast protection.



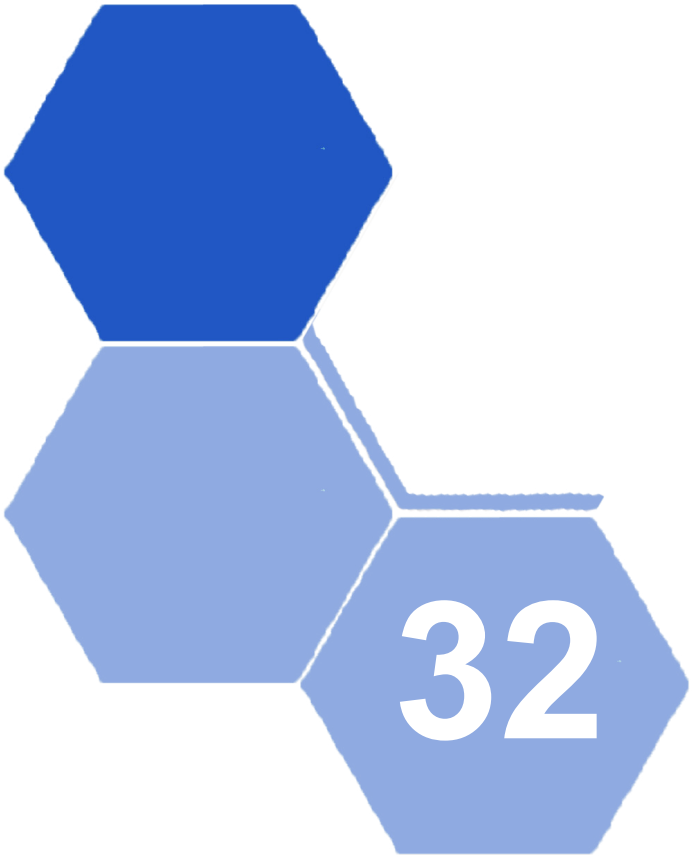
*The main threat for armoured vehicles are currently the IEDs, as illustrated in (a) by a Dingo vehicle destroyed during operations in Mali. The effect of an IED can be simulated and quantified using a numerical model of the vehicle (b) after which the effect can be experimentally reproduced using a drop cage to test vehicle sub-assemblies (c).*

## Objectives

The main objective of the SIMNUMDEF project was hence to develop a new methodology that would permit the Belgian Armed Forces to reliably estimate the blast resistance of its armoured vehicles after small and medium vehicle modifications without assistance of the original equipment manufacturer (OEM) nor the need for full-scale destructive vehicle testing.

## Outcome

The SIMNUMDEF project developed for the aforementioned objective a dual-track approach based on a combined numerical-experimental evaluation. By developing simple numerical models of the different armoured vehicles used by the Belgian Armed Forces, the effect of mine and IED incidents on the vehicle deformations and accelerations can be estimated. These effects can then be reproduced using a purpose-build test set-up. The latter consists of a drop cage in which representative vehicle subassemblies (e.g. the modified vehicle components or modified structural parts) can be mounted and subjected to a drop test. By modifying the drop height, the orientation of the drop cage and the impacted surface (e.g. steel plate, concrete slab, sand,etc.), the dynamic loading can be varied according to the simulated IED event.




# MSP18-01 Characterisation of the effects of temperature and ageing on fibre-based materials for ballistic applications

Directors: Prof. Luc RABET
Lt Col IMM Frederik COGHE
Researcher: Dr. Ir. Lionel GILSON

# MSP18-01 Characterisation of the effects of temperature and ageing on fibre-based materials for ballistic applications

## Background

The weight of a ballistic protection is one of the critical parameters affecting the portability for the user. With the development of high-performance fibres, new generations of woven or fibre-based composite materials have replaced the old protections made of heavier materials. However, this new generation of armour materials is more sensitive to temperature variations and ageing. This is especially the case with the current operations in warm foreign countries. Temperature variations and the effect of time affect the static and dynamic mechanical response of the materials, especially in the case of synthetic fibres. It is therefore of vital importance to know whether such ballistic protections keep their capabilities when the field conditions change and when they are used for a long period. While the process of ageing and the influence of temperature are well known as such, there is only little information concerning the influence of these effects on the static and dynamic response of armour materials. Hence, this project aims at proposing new methodologies for studying the influence of temperature and ageing processes on the dynamic mechanical response of composite materials, in order to get a better knowledge about the material response of the different constituents of ballistic protections.

### Objectives

The immediate profit of this study will be the performance assessment and optimisation of personal armours used in the field for mitigating ballistic threats. Therefore the aims of this study are to:

- Deliver an extended knowledge base on the effect of temperature and ageing on the performance of soft body armour.Develop a standardised methodology to test the performance of body armour in extreme field conditions and their evolution with time. This would reduce costs to evaluate the body armour performance.

- Increase the efficiency of future body armour designs and lower the costs associated with the evaluation, the acquisition and the replacement of body armour.

- Evaluate the currently in use conventional methods to assess the risk associated to extreme field conditions and ageing (by evaluating the V50 and σ50) by comparison with advanced FE models and experience.

- Extend the range of applications for the Bullet Simulating Projectiles

## Preliminary results

According to the literature [1-6], the elastic modulus and the yield strength of polymers exhibit strong sensitivities to the temperature and the strain rates while it is less the case with the plastic flow.

Among the activities in 2019, the acquirement of adapted samples for performing tests implying ageing and study of the influence of temperature on the performance of ballistic protections was performed. A set of 210 bullet-proof vests (model 95T – Fig. 1(a)) was acquired from DGMR to perform experiments on its main component: Kevlar® 29 fabrics. This material is interesting as tests can be conducted directly on the fabric layers, but also on yarns and filaments constituting the textile layers. Also, as we have a quasi-unlimited quantity of samples, statistical analysis can be also performed.

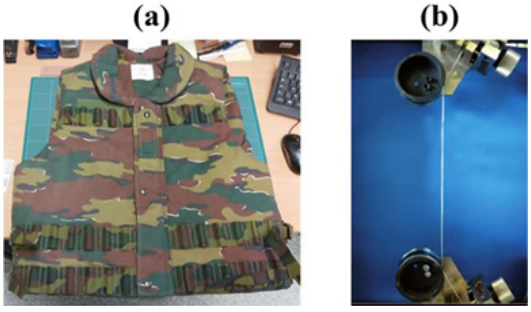
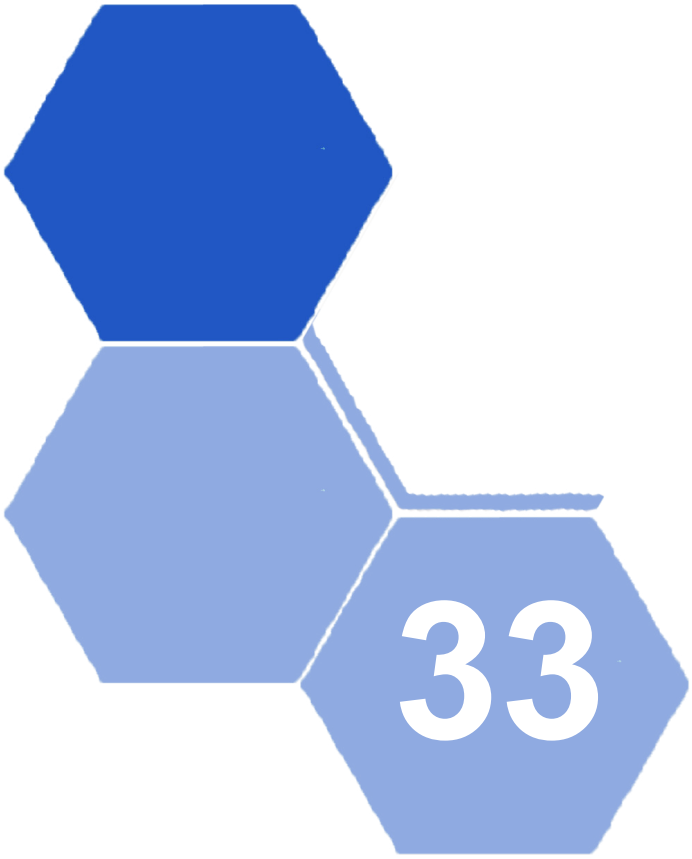



Figure 1. (a) One of the acquired vest containing Kevlar® fabric and (b) fixation system enabling to perform tensile tests on yarns by reducing slip.

Collaboration with the DLD (Peutie) is now established for conducting tests on Kevlar® fabric samples. The results of these analyses will give information about the global behaviour of the fabric as a function of temperature and ageing.

Moreover, as fixing Kevlar® yarns or filaments in a tensile test device constitutes a critical limitation for performing tensile tests (too low frictional coefficient of para-aramid based yarns), the acquisition of specific grip systems (Fig. 1(b) – yarn fixing system) is discussed for being adapted to an available tensile test device associated to an oven.

Also a set of vests will be aged in a climate room before being ballistically impacted to assess the influence of the thermal ageing on their ballistic performance. Based on statistics, it should provide knowledge on how weather and temperature can influence the performance of Kevlar®-based ballistic protections.




# MSP18-02 Study of low-cost lightweight ceramic sacrificial claddings for the protection of vehicles against IED threats


| | |
|---|---|
| Director: | Dr. Ir. Maj David LECOMPTE |
| Researchers: | Ir. Bachir BELKASSEM |
| | Ir. Bruno REYMEN |

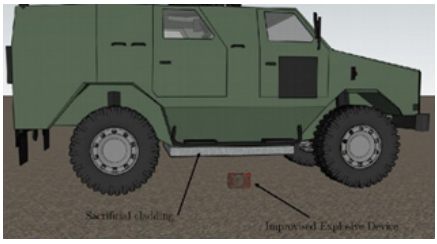
# MSP18-02 Study of low-cost lightweight ceramic sacrificial claddings for the protection of vehicles against IED threats

## Background

Improvised explosive devices (IEDs) have been responsible for the majority of Coalition lethal casualties in Iraq and Afghanistan. As IED threat increases – both in size and sophistication –, (lighter) vehicles are gradually given more protective armour in response. As a result, ground forces have to balance the need for heavy armour against the need to be light and flexible, with the ability to go off-road. Mobility is a form of protection in itself, and with heavier armour, mobility is sacrificed for greater protection.

## Objectives

The objective here is to protect armoured vehicle crews from under-belly mine and IED blast effects, by limiting the deformation of armour plates and reducing the resulting global acceleration, while retaining the tactical mobility of the vehicle. This can be achieved by improving both the structural concept of the blast mitigation system and the nature of the material used. This project studies low cost lightweight sacrificial claddings (SC) composed of a ceramic foam core positioned between two lightweight ceramic composite skins (front and rear plate).




Ceramic foams are a promising material for blast reduction given their low density, their fire resistant properties and the fact that the material, when exposed to a close range detonation, absorbs a part of the blast energy by compaction and disintegration. In the event of an explosion near or under the vehicle, it ensures

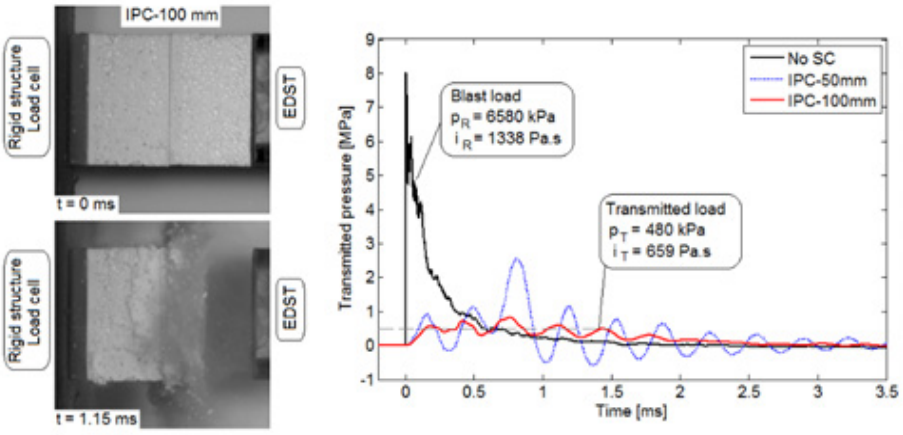
the reduction of the transmitted pressure to the vehicle thanks to the dynamic mean crush load of the foam core. The proposed concept combines the use of a novel material with an interesting closed cell structure, obtained thanks to the nature of the foam itself. The properties of the core, i.e. density and thickness, should be selected in order to enable the complete deceleration of the front plate before the entire crushing of the core. Hence, a design of the ceramic SC could be devised to be very effective in mitigating the energy of a blast load on vehicles, by considerably reducing the pressure and possibly the impulse transmitted to the vehicle.

## Outcomes

In the following, the mitigating potential of the proposed ceramic SC is demonstrated by studying the resulting load on the structure, the global acceleration of the structure and the resulting deformation of the structure, without and with the proposed protective SC.

1. **Transmitted load to a fixed rigid structure**

The SC is mounted onto a steel plate and fixed to a rigid structure through a load cell, enabling the measurement of the transmitted load. The uniform blast load is generated using an Explosive Driven Shock Tube (EDST).

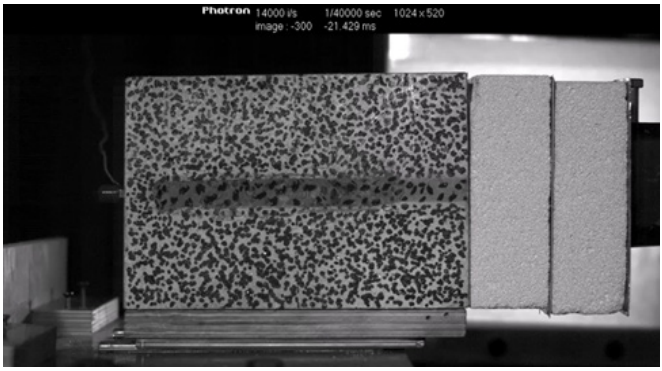


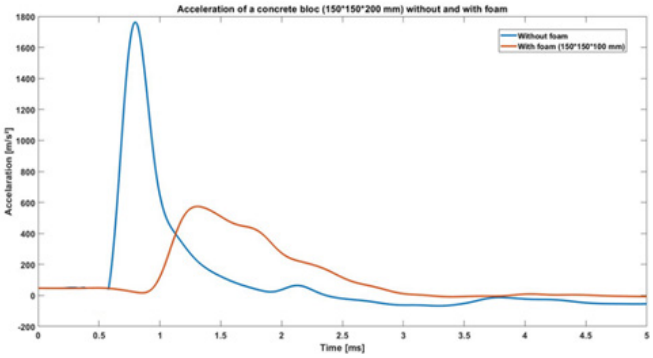

The graph shows on the one hand the blast load on a rigid structure, without protection, and on the other hand the transmitted load to the structure in the case where the proposed protection is applied. Two different thicknesses are

considered: 50 and 100 mm. The results of the 100 mm thickness specimen indicate a significant reduction in the transmitted pressure and impulse to the structure to be protected. The reduction in transmitted impulse is explained by the pulverisation of the foam material, which results in the ejection of a part of the foam mass in the transverse direction. The large peak, at 0.8 ms, for the 50 mm protection corresponds to the impact of the front plate with the structure, because the thickness of the protection is not sufficient to completely decelerate the plate.

## 2. Global acceleration of a mobile rigid structure

The impulsive blast load associated with an under-belly explosion often leads to the projection or the rollover of the targeted vehicle, resulting in severe injuries for its occupants due to the associated G-forces (accelerations). In the previous section, it is shown that the proposed SC, using a ceramic crushable foam core, is able to transform the hazardous blast loading into a much safer transmitted load to the structure.



This section shows the effect of this change in loading type on the global acceleration of a mobile rigid structure.

The uniform blast load generated using an EDST and presented in the previous section is now applied on a concrete block. The block has a mass of 11.5 kg and sits on a platform and a pair of linear rail guides, giving the block one degree of freedom with very limited hinder. The displacement and acceleration of the block are recorded using high-speed full-field measurements and an accelerometer, respectively.

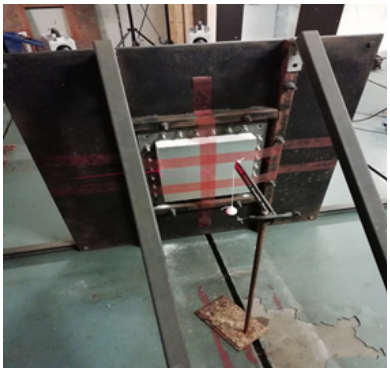
The graph shows the resulting acceleration of the concrete block without and with the proposed ceramic SC. The results show a significant reduction of 67% of the peak global acceleration, when using the protective SC with a thickness of 100 mm.

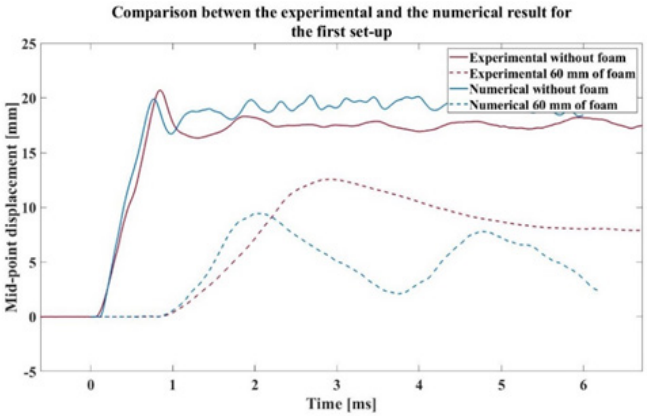
## 3. Response of a fixed deformable structure

3D high-speed full-field measurements and finite element simulations are used to determine the efficiency of the ceramic foam to protect a fixed deformable structure against a near-field explosion.

The mitigating potential of the foam is evaluated by comparing the deformations of a blast loaded aluminium (EN AW-1050A H24) plate without and with the foam protection. The plate is fully clamped in a fixed rigid frame. The square specimens of 400 mm by 400 mm and a thickness of 2 mm are clamped to the steel frame using bolts leaving a free area of 300 mm by 300 mm. The blast loading is generated using a charge of 19.8 g of C4 (25 g TNT equivalent) at 250 mm, measured between the detonation point and the blast face of the clamped aluminium plate. This distance remains unchanged when the protective SC, with a core thickness of 60 mm and a front plate thickness of 2 mm, is added. Thus, in the latter case, the charge is located at 188 mm from the front plate of the SC. The reflected pressure and impulse for the unprotected case are estimated to be 7.9 MPa and 200 Pa.s, using ConWep. For the protected case, the reflected pressure and impulse on the front plate of the SC are estimated to be 16.8 MPa and 300 Pa.s.

The graph presents the displacement of the centre of the plate and shows that the presence of the foam decreases the maximum deflection of the plate by 38%, even if the reflected pressure and the impulse on the protected structure have increased by 112% and by 48% respectively. The delay in the onset of the response of the aluminium plate is due to the time necessary to compress/crush the foam core.

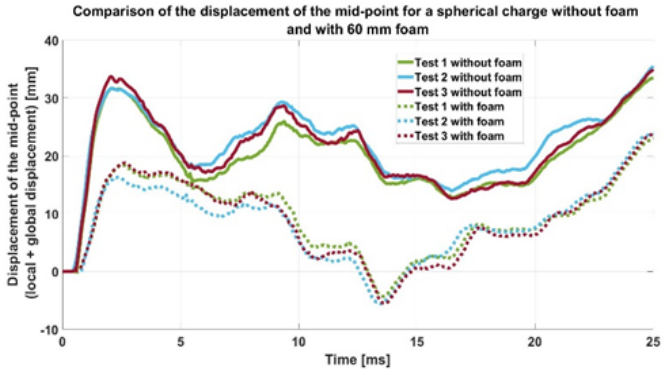





## 4. Response of a mobile deformable structure

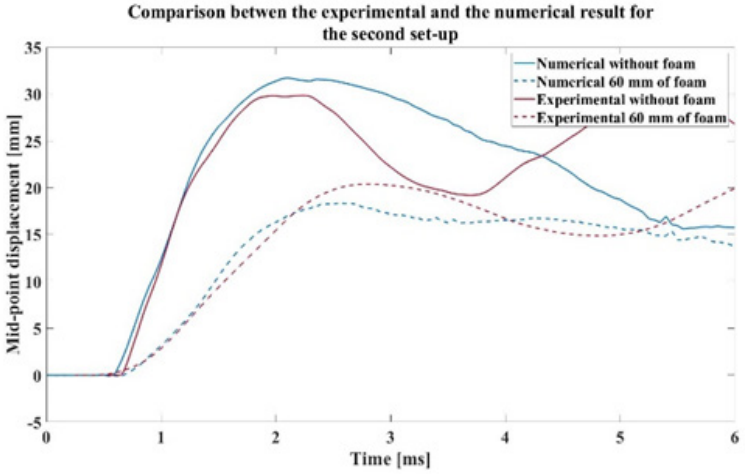
3D high-speed full-field measurements and finite element simulations are used to determine the efficiency of the foam to protect a mobile deformable structure against a near-field explosion.

The mitigating potential of the foam is evaluated by comparing the deformations of a blast loaded aluminium (EN AW-1050A H24) plate without and with the protective SC. The plate is fully clamped in a rigid steel box, with a mass of 26.8 kg and the following dimensions: 81 cm in length, 31 cm in width and 15 cm in height. The box is suspended in a fixed rigid steel frame, using rubber bands. This enables the box to move freely. The rigid steel box and the aluminium plate represent a small-scale vehicle and its armoured belly plate respectively. The blast loading, representing a scaled under-belly explosion, is generated using a charge of 19.8 g of C4 (25 g TNT equivalent) at 250 mm, measured between the detonation point and the blast face of the clamped aluminium plate. This distance remains unchanged when the protective SC, with a core thickness of 60 mm and a front plate thickness of 2 mm, is added. Thus, in the latter case, the charge is located at 188 mm from the front plate of the SC. The reflected pressure and impulse for the unprotected case are estimated to be 7.9 MPa and 200 Pa.s, using ConWep. For the protected case, the reflected pressure and impulse on the front plate of the SC are estimated to be 16.8 MPa and 300 Pa.s.

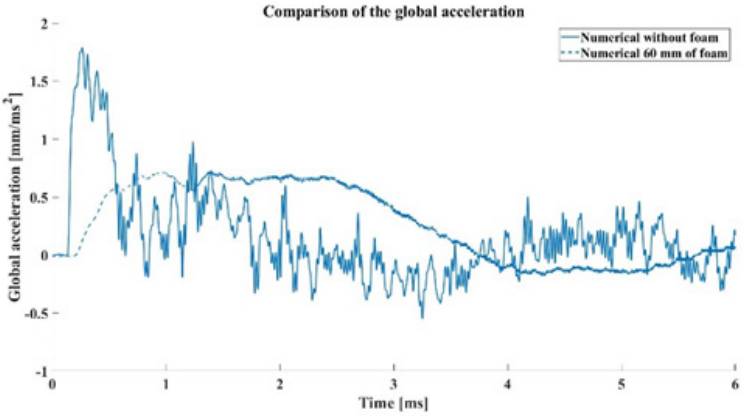



The graph presents the displacement of the centre of the plate for two sets of experiments, i.e. without and with the ceramic SC. The presence of the foam decreases the maximum deflection of the aluminium plate by 29%, even if the reflected pressure and the impulse have increased by 112% and by 48%, respectively.

A Finite Element Model (FEM) of the experimental set-up is devised and used to calculate the response of the aluminium plate for the two cases considered. The results are shown in the graph and show a relatively good correspondence with the experimental results.




The model is also used to calculate the global acceleration of the rigid steel box holding the aluminium plate and representing a vehicle. A reduction of 60% in peak global acceleration is found.




## 5. Conclusion

The mitigating potential of the proposed ceramic SC is shown in terms of the transmitted load to the structure to be protected, the global acceleration of the structure and the out-of-plane deformation of a thin aluminium plate. For the latter parameter, two different set-ups are used in which the deformation of a thin aluminium plate is measured, without and with the protective SC. The first set-up offers fixed boundary conditions for the fully clamped plate and the second provides the plate with mobile boundary conditions. The maximum deflection of the centre of the aluminium plate is reduced by 38% and 29%, respectively for the first and the second set-up. In the second set-up, the global acceleration is reduced by 60%.


# MSP18-03 Development of Thorax/ abdomen and Head Finite Element Models (THFEM) for the risk assessment of blunt impacts on the human body

Director: Maj Alexandre PAPY

Researcher: Mr. Nsiampa NDOMPETELO

# MSP18-03 Development of Thorax/abdomen and Head Finite Element Models (THFEM) for the risk assessment of blunt impacts on the human body

## Background

Military forces are confronted with an increasing threat of small calibre rounds and fragments (HE projectile, IEDs, etc.) in current operational theatres. This has led to the development of adapted body armour solutions, but these solutions when impacted may lead to blunt injuries (behind armour blunt trauma – BABT) that can be severe, even fatal. Apart from the conventional missions, military forces are more and more called to intervene in homeland or abroad in policing missions in which the kinetic energy non-lethal weapon (KENLW) solutions are widely used to avoid severe injuries to the targeted people. In both cases, there is a need to make an injury risk assessment in order to prevent or avoid severe or life-threatening injuries. For this purpose, physical surrogates and numerical surrogates (numerical models) have been developed.

## Objectives

The research project aims to build an anatomically based versatile numerical prediction tool namely the anthropometric human torso and head finite element models (THFEM) for blunt injury resulting from impacts of ballistic projectiles at high velocities on protected or unprotected human head and torso (thorax + abdomen).

## Outcome

The methodology for the creation of 3D anthropometric head finite element model (FEM) is given in Figure 3. It consists of building a realistic geometry of the different head organs from medical images (CT scan). Each organ geometry is then meshed. The way each organ will interact with the surrounding organs has to be taken into account. A material model describing the way each organ react under solicitations is then assigned to the organs of the head and contacts are defined between organs. Finally, the validation process is performed. After integrating all the organs, the head FEM with the different organs that have

been modelled is given in Figure 4. The ongoing work is the validation of the head model using different tests of validation found in the literature.

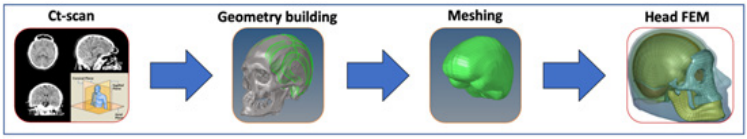



Figure 3: Methodology for the creation of the head FEM

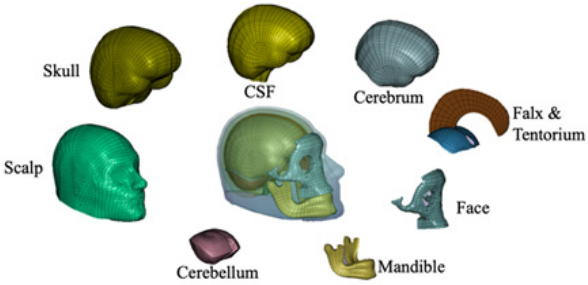



Figure 4: Head FEM model with the different modelled organs of the head

For the thorax/abdomen, the same methodology given in Figure 3 is used.

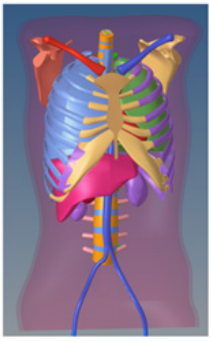
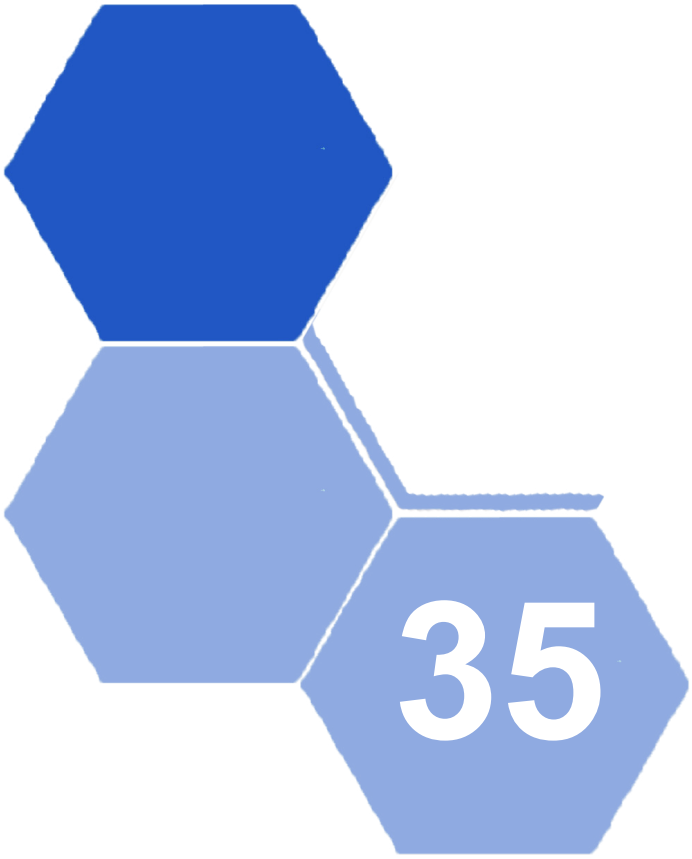


Figure 3: Partial Thorax

The ongoing step is the generation of the corresponding geometry




# MSP18-05 A new framework to evaluate the ballistic resistance of combat vehicles

Director: Dr. Ir. Col Johan GALLANT

Researcher: Ir. André CHARBOTIER

# MSP18-05 A new framework to evaluate the ballistic resistance of combat vehicles

## Background

The Department of Weapon Systems and Ballistics (ABAL) has been working since 2001 in the field of evaluation of weapon system effectiveness and survivability. The reliability of these analyses depends heavily on the used models for the different phenomena and interactions that take place.

## Objectives

This project aims at developing a toolbox with analytical models for terminal ballistics. These models describe the behaviour of a projectile and a target material after impact based on the initial impact conditions. They will not only predict the risk of perforation but also behind armour effects in order to assess the associated risk for personnel and equipment behind it. This toolbox will enable Defence to independently assess the effects of armour layout modifications of its assets on their vulnerability and also deliver a unique support during the procurement phase.

Over the past decades, the laboratory of ABAL and CC R&A CEM built up a tremendous experience in the field of impact testing. In a first phase, these results will be digitised and create a unique database, ready for extrapolation and meta-analysis. This will enable a whole new parametric insight across different datasets and on a scale that was previously unattainable. Hence, new empirical models for terminal ballistics will be established.

In a second phase, these models will be complemented by a digital library of analytical models. This library will cover a broad spectrum of projectile and target shapes and materials. Models from both open and classified sources will be implemented and supplemented with in-house developed models. The accent of these models will shift from the classical perforation-is-kill paradigm to accurate descriptions of the projectile and target material after impact to estimate residual risks.

The toolbox will be applicable to analyse the outcome of one-to-one engagement scenarios as well as in a larger framework to evaluate the vulnerability of various systems and infrastructures deployed by Defence.

## Preliminary results

In the field of survivability and lethality studies, the heavy emphasis on modelling and simulation is obvious. The destructive nature of live-fire tests combined with the high cost of both the platforms and weapons involved makes it nearly impossible to conduct these full-scale tests. The current development of vulnerability assessment simulation tools tends to be focused on the integration of many smaller tools into a major simulation toolkit, as can be seen on Fig. 1. The reliability of the global analysis depends heavily on the use of elaborate, validated sub modules. A digital library, with penetration and damage models is a critical component in this survivability and lethality calculation chain.

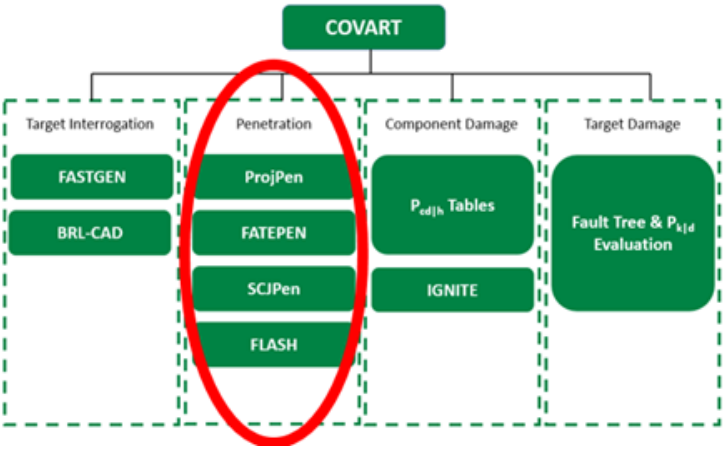



Fig. 1: Vulnerability assessment code and composing modules (DSIAC 2017)

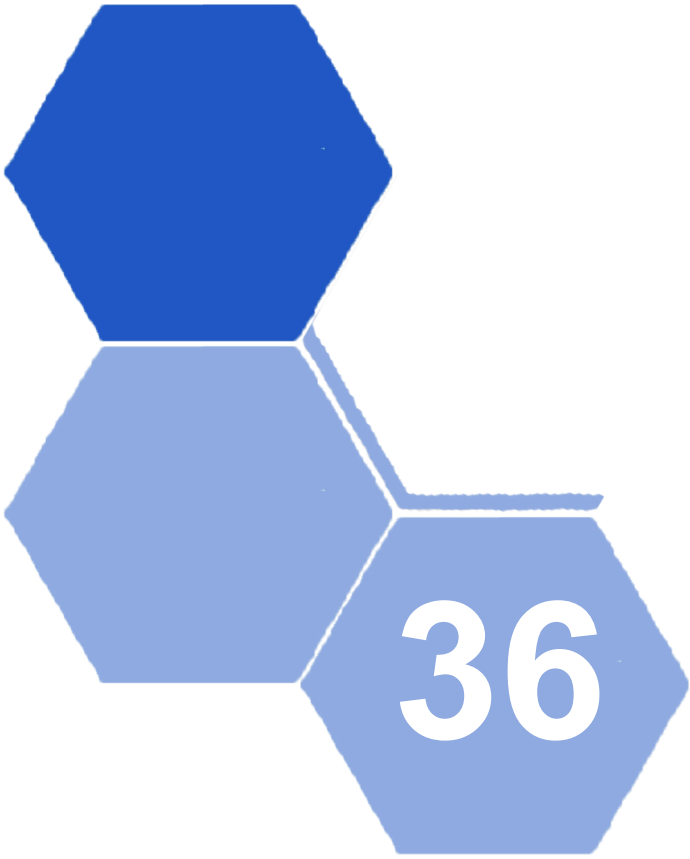
Although several countries have large research organisations working in this field, access to information in the open literature is limited. This is due to the security classifications of both the protective performance and the effectiveness of the weapon systems against designated targets. Many countries have developed an in-house assessment methodology to model the vulnerability of their assets but the use and knowhow of these tools is limited to the national government agencies and their contractors.

New threats, like piracy and improvised explosive devices (IEDs), have incited solutions such as add-on armour and belly plates. Lower intensity conflicts with asymmetric threats can sometimes favour the deployment of lighter vehicles. These can need quick protective solutions in case of a degeneration of the local safety situation. With a toolbox that incorporates not only penetration

models but also residual behind armour effects, it becomes possible for Defence to accurately estimate the effects of layout modifications of its assets on their vulnerability, but also on the secondary effects on crew and equipment. Validated, accurate models for terminal ballistics are a cornerstone in modern vulnerability codes as the reliability of the system analysis depends heavily on the accuracy of the ballistic resistance predictions.

This toolbox is useful in different phases of the life cycle of a system: from the feasibility study, over the definition of the specifications, to the modification to counter new threats. Possible applications include: ballistic protection optimisation of the current armoured vehicles, and vulnerability assessment of the new Belgian frigates against a number of threats. Such analysis is mandatory because of the price and strategic importance of the latter, as well as the will to reduce risk for personnel and equipment and to avoid expensive, unnecessary upgrades.

Finally, if the Belgian Defence wants to assess the risk on casualties against nonstandard threats that were not specifically foreseen in a testing standard they currently do not dispose of any means to do so. The new framework will enable assessing such nonstandard risks.




# MSP18-06 Development of a system-of-systems model for rapid prototyping of kinetic weapon systems


| | |
|---|---|
| Directors: | Dr. Ir. Col Johan GALLANT |
| | Dr. Maj IMM Ben LAUWENS |
| Researcher: | Ms. Irene NDINDABAHIZI, Ir. |

## MSP18-06 Development of a system-of-systems model for rapid prototyping of kinetic weapon systems

## Background

Various models of interior, exterior and terminal ballistics are frequently used at the Department of Weapon Systems and Ballistics. However, all models are used separately since a single model, integrating these different models, is not yet available. The reason is the multitude of parameters in each model and the very different integration methods, making it difficult to combine these models in a system-of-systems model. The advantage such a model could give is that the design process of a weapon and its ammunitions would be shortened and that a countermeasure to a new threat could be developed much quicker.

### Objectives

The first step of the project is to develop an integrated environment for the computation of the complete ballistic cycle, including error budget computations based on stochastic simulation. An important part of this step is the definition of an appropriate method for the analysis of the error propagation.
In the second phase, the model will be validated by comparing its results with well-known weapon systems, such as the AW Accuracy sniper weapon and the 105 mm howitzer, of which the error budget is available.
The last part is to use the model for the development of new defence weapons, such as an anti-UAV and anti-swarming weapon.

### Outcome

Modern warfare is a constant arms race of measures and countermeasures. With weapon system developing cycles taking years and large budgets, it is not uncommon for military technology to become obsolete by the time it is deployed, as western defence forces have experienced in Iraq and Afghanistan. To address this dilemma, the department of weapon systems and ballistics (ABAL) in collaboration with the department of mathematics (MWMW) proposes to build an integrated environment based on the theory of systems. It aims at replacing the classical monolithic weapon systems simulation with a more flexible approach, enabling the exploration of new capabilities faster and at a reduced

cost. This is achieved by means of an open architecture using interchangeable modules that are rapidly upgradeable, and is based on the idea of replacing only a part of the system rather than the whole. The modules are based on well-known ballistic models, whereas the architecture must be developed. Such an integrated simulation environment is not possible in conventional software environment, hence the motivation for this research activity.

The system-of-systems model will give Defence the possibility to answer, more rapidly and with more detailed knowledge, questions such as:

- How must an existing non-lethal weapon be adapted to make it effective against low slow small unmanned aerial systems (LSS UAS) in an urban environment, while reducing the risk of collateral damage to a minimum (falling projectiles may not be harmful for people in the street)?

- What are the optimal fire rate, muzzle velocity and projectile geometry for a close-in weapon system (CIWS) that defends a ship against incoming targets, such as swarms of drones and supersonic anti-ship missiles?

- Which are the maximal fabrication tolerances for a sniper rifle ammunition such as the requested hit probability is attained?

Such a model is useful in all phases of the life cycle of a weapon system: from the feasibility study, over the definition of the specifications, to the modification of existing weapon systems to counter new threats. It will provide an analysis of every aspect of the weapon system, whereas the actual methods give only a partial solution: an optimisation in the field of interior ballistics, or exterior ballistics, or terminal ballistics. The project is limited to the analysis of kinetic weapons.

Figure 1 shows the layout of the toolbox enabling the rapid analysis of a weapon system. The input of the toolbox is an analysis request. The nature of the request will determine the output: an optimal configuration in the case of the study of a new weapon system, or an error budget when analysing any weapon system (existing – if the system is to be modified – or in development).

The ballistic models will be adapted for discrete event simulation. In contrast with time-continuous simulation – the standard simulation method –, discrete event simulation reduces significantly the runtime of a simulation. This is important since the error budget evaluation will be done using time-consuming

non-deterministic simulations, such as Monte Carlo. In order to link the different models, interfaces between the interior and exterior ballistics models as well as the exterior and terminal ballistics models must be defined.

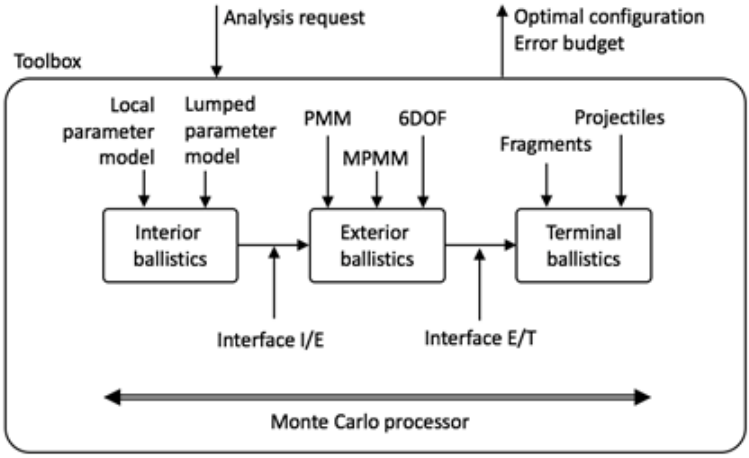
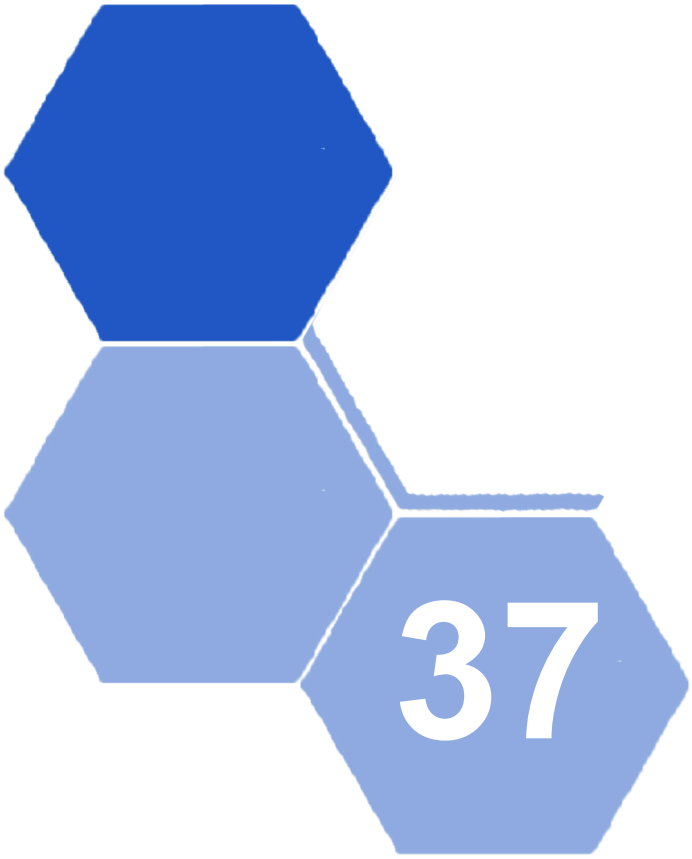



Fig. 1. The toolbox with its ballistic modules, interfaces, Monte Carlo processor and I/O




# MSP18-09 Commissioning and exploitation of an ICRH system for the stellarator W7-X


| | |
|---|---|
| Director: | Prof. Michael VAN SCHOOR |
| Researchers: | Dr. Jozef ONGENA |
| | Dr. Fabrice LOUCHE |

# MSP18-09 Commissioning and exploitation of an ICRH[1] system for the stellarator W7-X (Max-Planck-Institut für Plasmaphysik, Teilinstitut Greifswald, Germany)

## Background

Wendelstein 7-X (W7-X) is the largest and most advanced stellarator[2] in the world. It is an optimised stellarator built to demonstrate the viability of this type of device as a future fusion power reactor. W7-X started operations in the beginning of 2016. In the previous study, the Laboratory for Plasma Physics of the Royal Military Academy (LPP-ERM/KMS) developed and constructed in collaboration with the colleagues of IEK-4/Plasmaphysik of the Forschungszentrum in Jülich, Germany, an ICRH antenna system for heating and generation of fast particles in W7-X, essential for the experimental programme of this device. It is now time to earn the fruits of the investments of the previous years, by taking into operation this antenna. This is essential for LPP/ERM-KMS as it will enable: (i) to provide practical experience to the young generation of researchers, (ii) to consolidate the existing experience and (iii) to be able to test experimentally the recently developed theoretical ideas in the lab.

## Objectives

The overarching aims of this study can also be summarised as follows:

- Exploitation of the ICRH antenna system conceived and built in the previous study
- Extend the existing knowledge, acquired on tokamaks, to stellarators
- Consolidate the position of LPP/ERM-KMS in the worldwide research on controlled fusion.

[1] ICRH: Ion Cyclotron Resonance Heating is a method to heat plasmas to relevant fusion temperatures which uses electromagnetic waves tuned at the resonance frequency of the ions so that absorption of the energy is efficient.

[2] A stellarator is an alternative magnetic confinement device, with a more complex magnetic field than the tokamak. Whereas the tokamak is by design a pulsed device, the stellarator allows steady state operation. Modern stellarators are optimised to improve confinement.

## Outcome

In this project, we are preparing an ICRH system for W7-X. The main aim of the system is to provide a sufficiently large population of fast ions with the right energy to study the confinement of fast ions in W7-X, a crucial test to check the viability of this type of optimised stellarator in view of a future fusion reactor. Two radio frequency generators (2MW, 10s, 25-38MHz), the 96m long transmission lines, a matching and tuning system, a complex 3D shaped antenna and an up-to-date control and data acquisition system (Siemens PCS7) form the core of this system.

Figure 2 shows the actual status of the antenna system where all major components are indicated.

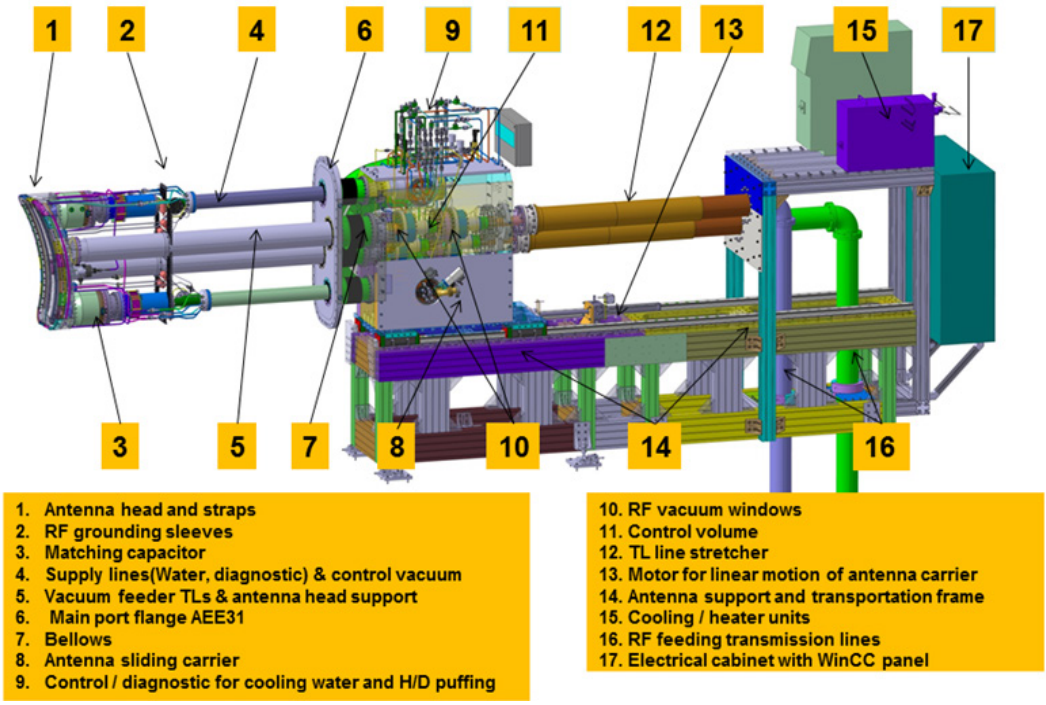



Figure 2 : Overview of the ICRH antenna system.

## The Main Work Covered in This Report Focuses On

### 1. DEVELOPMENT AND PREPARATION OF AN ICRH SYSTEM FOR W7-X

Our team has undertaken the following tasks for the ICRH W7-X system in 2019:

- Refurbishment of the RF generators and matching system;
- Mounting of the full test system with the mock-up antenna (see Figure 3);
- Testing of the full system to check electromagnetic properties, vacuum properties, high voltage standoff, etc.
- Project management

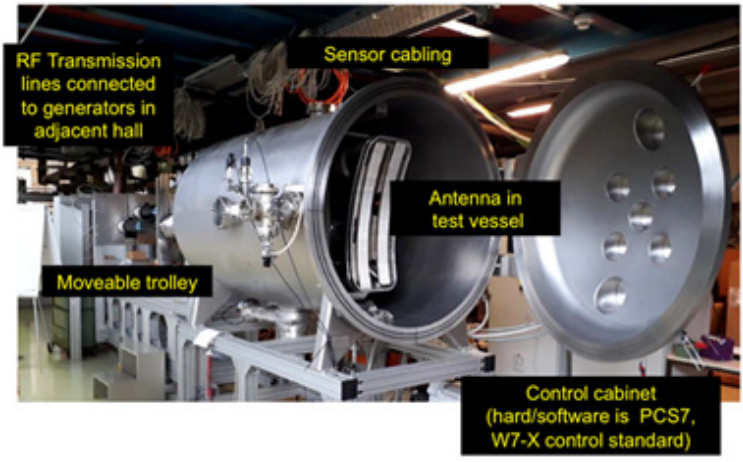



Figure 3: Fully mounted test stand in Jülich before closing the vacuum vessel for the tests

Presently, all activities are on time for first ICRH test operation in the next experimental campaign OP2.0.

### 2. NUMERICAL STUDIES OF ANTENNA PERFORMANCE

In preparation for the ICRH antenna commissioning work planned in OP 2.0, existing estimates of the coupled ICRH power on W7-X are being updated due

to further developments resulting in changes on the W7-X ICRH system and the antenna itself. The computations mentioned above were performed for H minority ICRH scheme (5% H in a D or 4He plasma) with the ICRF antenna coupling code TOPICA, using the reference electron density profile and a flat antenna model as input. Recently, a fully 3D antenna model based on CAD drawings has been developed, enabling more realistic electromagnetic calculations. Additionally, a reassessment of the antenna radial displacement capability has shown that the minimum distance between the antenna frame and the LCMS for the standard configuration of W7-X has increased by 1.7 cm. Finally, the current planning of the ICRH commissioning in OP 2.0 relies on operating the system in hydrogen plasmas without a resonant damping mechanism; both antenna straps will be fed by a single RF generator through a T junction. Extensions to H-D, full D, or equivalent H-4He or full 4He plasmas, are under discussion and planned for later campaigns. This also implies that testing of the H-(3He)-D 3 ion heating scheme can only take place in the future.

When comparing the results for the flat and curved antenna models, the transmission and matching network is not taken into account. However, because tuning capacitors are connected to two of the four ports of the antenna (these capacitors cancel the strap inductance and therefore lower the voltage standing wave ratio VSWR on the feeding lines), the coupled RF power depends on the capacitor settings as well as their voltage and current limits. This comparison is illustrated in Figure 5, which shows the maximum coupled RF power as a function of capacitor settings, for the flat and 3-D antenna models, left and right, respectively. These computations were made for an H + 5% 4He plasma, f = 38 MHz and dipole antenna phasing. It is found that the curved antenna model yields somewhat less coupled power for a given pair of capacitor settings. Results for 25 MHz, monopole antenna phasing and a pure hydrogen plasma are similar.

As stated, ICRH power coupling depends strongly on the electron density profile directly in front of the antenna. Since it is not known a priori to which extent the reference density profile is realistic, it was proposed as a first step to shift the reference profile radially to get an approximate estimate of the sensitivity of the coupled RF power on the relative position of the fast wave cut-off layer with respect to the antenna straps. Two limiting cases were considered: i) edge density $n_e$=*1.16 1017 m*$^3$ (reference profile) and ii) $n_e$=*5.05 1017 m*$^3$ (higher coupling). Calculations were done at f = 25, 37.5 and 38 MHz, monopole and dipole phasings and two plasma compositions, namely pure hydrogen and H + 5% 4He to simulate the effect of impurities. Only the 3D antenna model was

used. The full transmission and matching network was included in order to evaluate the voltage and current distribution everywhere and ensure that the corresponding limits are not exceeded on any component. As the main figure of merit, the commonly used loading resistance $R_L = 2\ (Z0)^2\ PL/(Vmax)^2$ is computed, where $P_L$ is the net power flowing along the line with characteristic impedance $Z_0$, and maximum voltage on the line $V_{max}$. Here RL is the average of the two feeding lines. Note that in this case it depends not only on the plasma loading but also on the capacitor settings, with the latter usually chosen to position a voltage antinode at the T-junction.

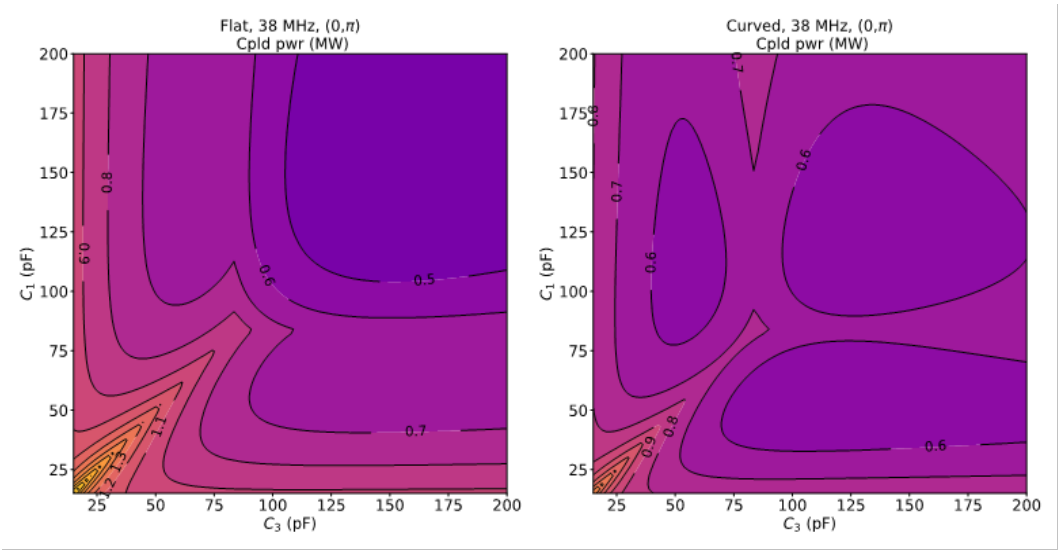
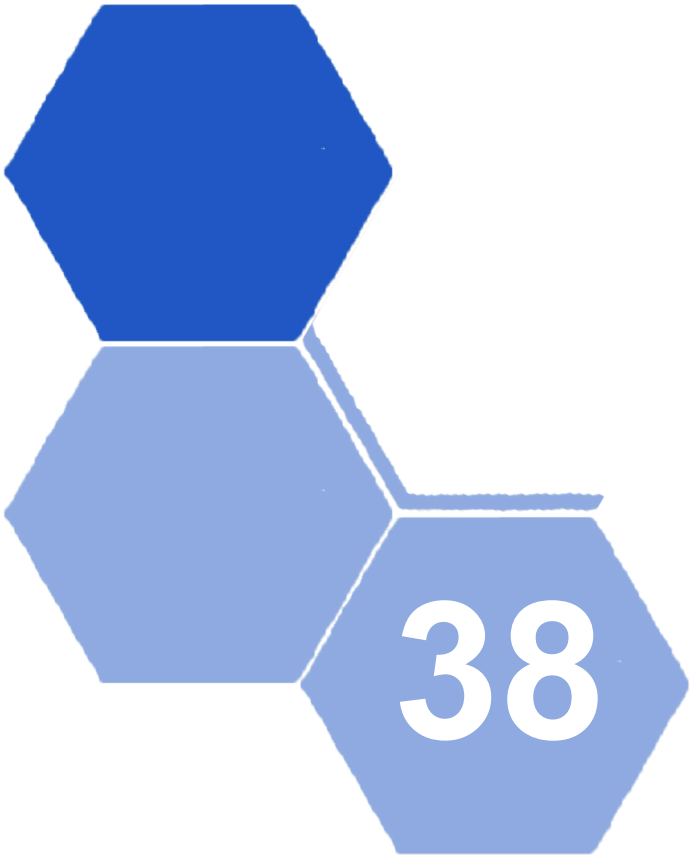



Figure 5: Maximum coupled power as function of the two capacitor settings (indicated with C1 and C3), 38 MHz and dipole, i.e. (0, π) strap phasing. Flat model in the left figure, 3-D model in the right figure.

## Future planning

Calculations for the full system geometry – including two RF generators and a decoupler (to eliminate the mutual coupling between the closely placed straps of the antenna) – updated density profiles and an antenna model including a portion of the W7-X first wall (which mimics much better the real boundary conditions as in W7-X) are planned for 2020.




# MSP19-04 Homemade explosives: phlegmatisation, detection and post-blast analysis of TATP and HMTD

Directors: Prof. Michel LEFEBVRE
Maj Bart SIMOENS
Researcher: Mrs. Laurence JEUNIAU

# MSP19-04 Homemade explosives: phlegmatisation, detection and post-blast analysis of TATP and HMTD

## Background

Due to the terrorist attacks in Brussels, different needs have arisen for the BEL EOD, for the Laboratory of Energetic Materials and Blast Engineering (LEMBE) at the RMA and for the Canine Unit of the Belgian Police. These needs concern the phlegmatisation of TATP and HMTD, their post-blast analysis and the preventive detection of TATP and HMTD.

The study of the phlegmatisation of TATP and HMTD has begun during study EM01 and will continue during this study. More specifically, the effect of water and soap on the sensitivity of the explosives will be investigated.

The detection of explosives by dogs will be mostly investigated and different factors will be studied such as the influence of the synthesis and purification methods on the dog response, the stability of the explosive used for the dog detection, etc.

## Objectives

Two aspects of the post-blast analysis will be investigated: the collect of samples and their analysis.
New homemade explosives will be studied if necessary, as it is the case of Urea Hydrogen Peroxide (UHP) for which an investigation (based on information from FBI) as been asked by the Counter Terrorism Unit D2 of the European Commission.

## Outcome

The main achievements up to now are:

- Development of a quantitative method for the detection of TATP.
- Quantification of the TATP present on gauze and on filter papers used for the training of dogs by the Canine Unit of the Belgian Police.

- Investigation of the influence of different synthesis parameters on the sublimation of TATP and HMTD

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- Establishment of a procedure to perform a post-blast analysis of TATP.


# MSP19-08 Tailored High Altitude Propeller - THAP


| | |
|---|---|
| Director: | Dr. Ir. Major Benoît MARINUS |
| Researchers: | Ir. Nikolaos MOUROUSIAS |
| | Ir. Ahmed MALIM |

# MSP19-08 Tailored High Altitude Propeller - THAP

## Background

## Objectives

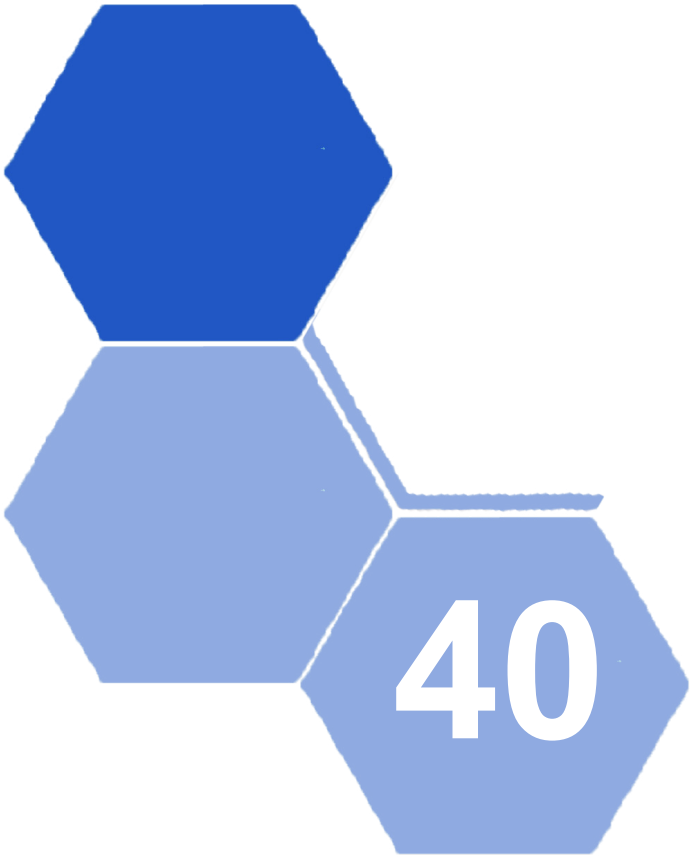
The project focuses on a propeller for a HAPS UAS. The objective is to design, develop, optimise, manufacture and test a stratospheric propeller that can operate at different altitudes with optimised performances. However, this objective is accompanied by many challenges that must be overcome. The low air density and temperature at high altitudes make the flow around the propeller adopt a special regime (low Reynolds and high Mach number). In addition, the power absorption of the propeller is expected to be considerably lower.

Two propeller designs would be considered; the first will be a stratospheric UAV demonstrator operating at 16 km altitude at 45 m/s with an aerodynamic and aero elastic investigation in close linkage with the industrial partners (Stratos Solutions = SONACA & STEMME). After the design and the manufacturing of the propeller, it will be certified the venture Stratos Solutions. The second design will be a stratospheric permanent UAV final product that should be able to operate mainly at 16-20 km as cruise altitude with optimal performances and keep good performances in the take-off stage and the climb through dense atmosphere, as well as to ensure the structural integrity.

To reach the purpose, multidisciplinary optimisation will be conducted to optimise aerodynamic and aero elastic performances in parallel with mechanical design by using classical and advanced manufacturing techniques (3D printing: FDM, SLA, etc.) that will define more appropriate constraints for the optimisation process.

## Outcome

The project started in October 2019.
Since the start of the project, an article on “Exploratory Optimisations of Propeller Blades for a High-Altitude Pseudo-Satellite” from Benoît G. Marinus, Nikolaos Mourousias and Ahmed Malim, was submitted to the AIAA 2020 Aviation Conference.




# LabMCT Evaluation of saliva sampling procedures for SARS-CoV-2 diagnostics

LabMCT (Queen Astrid Military Hospital)

Microbiology research personnel

Picture on page 176

# LabMCT Evaluation of saliva sampling procedures for SARS-CoV-2 diagnostics

## Background

Massive RT-qPCR based testing for the presence of SARS-CoV-2 RNA is a key element in the strategy to control the current COVID-19 pandemic. At present, collecting samples from the upper respiratory tract is recommended for diagnostic testing by the World Health Organization and (American and European) Centres for Disease Control and Prevention, with nasopharyngeal swabs being considered the standard collection procedure. While extremely sensitive, this sampling method is not patient-friendly and requires a healthcare professional with personal protective equipment to collect. Before the outbreak of SARS-CoV-2, several studies have reported on the utility of saliva for testing respiratory viruses. The non-invasive nature of the specimen collection in a simple container, enabling home sampling, and the absence of swab and transport tube requirement (both plagued by global supply shortages), make saliva a very attractive biomaterial. While several recent studies have documented the potential utility of saliva for diagnostic testing of SARS-CoV-2, these studies suffer from one or more limitations, i.e. non-paired study design, small cohorts, testing in biased populations such as previously confirmed positive cases and/or hospitalised patients.

## Objectives

We set out to prospectively evaluate the utility of saliva for diagnostic testing of SARS-CoV-2 using a large population of more than 2,500 individuals, including pauci-symptomatic and a-symptomatic participants, in triage centres in Belgium with matched nasopharyngeal and saliva collection at the same moment. We evaluated 2 types of saliva collection devices and all samples were analysed by 2 independent laboratories (Fig. 1).

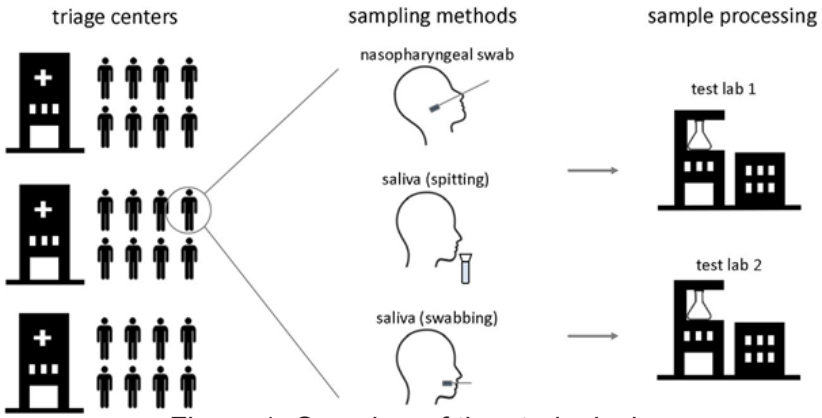


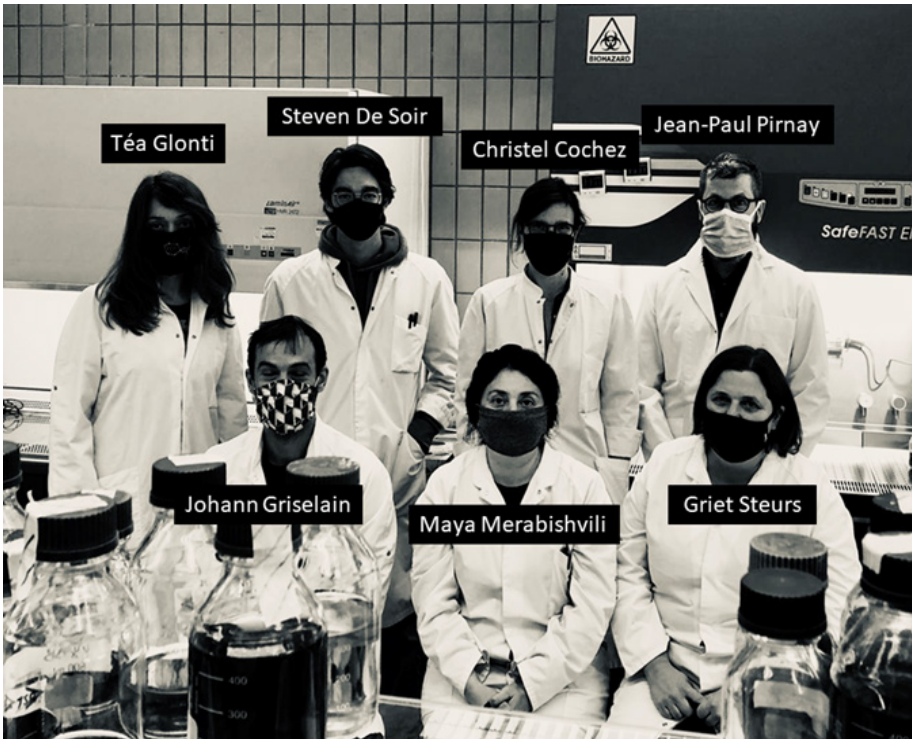
Figure 1. Overview of the study design.

Outcome or preliminary results

We observed an overall poor sensitivity in saliva for SARS-CoV-2 detection (30.8% and 22.4% for spitting and swabbing, respectively). However, when focusing on individuals with medium to high viral load, sensitivity increased substantially (97.0% and 76.7% for spitting and swabbing, respectively), irrespective of symptomatic status. Our results suggest that saliva cannot readily replace nasopharyngeal sampling for SARS-CoV-2 diagnostics but may enable identification of cases with medium to high viral loads.

A preprint was recently published:

Pieter Mestdagh, Michel Gillard, Marc Arbyn, Jean-Paul Pirnay et al. Evaluation of saliva sampling procedures for SARS-CoV-2 diagnostics reveals differential sensitivity and association with viral load. medRxiv 2020.10.06.20207902. doi: https://doi.org/10.1101/2020.10.06.20207902
Weblink: https://www.medrxiv.org/content/10.1101/2020.10.06.20207902v1



LabMCT (Queen Astrid military hospital) – Microbiology research personnel

41

# LabMCT Inteliphages: a powerful therapy to fight antimicrobial resistance

LabMCT (Queen Astrid Military Hospital)

Microbiology research personnel

Picture on page 176

# LabMCT Inteliphages: a powerful therapy to fight antimicrobial resistance

## Background

Today, antibiotic resistance affects all countries regardless of their level of development and causes about 700,000 deaths worldwide (WHO 2014 report). According to a study performed by RAND Organisation (an international not-for-profit research organisation that helps to improve policy and decision-making), by 2050 some 10 million deaths related to antibiotic-resistant infections may occur mainly in Asia (4.7 millions) and in Africa (4.1 millions). The study predicts an annual average of 390,000 deaths in Europe and 320,000 deaths in the United States (European Commission, 2016). However, the established pharmaceutical industry is reluctant to develop either new classes of antibiotics or bacteriophage therapy because of limitations in intellectual property protection and in fitting bacteriophages into traditional models for drug development. However, bacteriophage (Phage) therapy is currently considered by many global experts to be the most promising and sustainable way to fight resistant bacteria, especially in the favourable regulatory context now available in Belgium.

## Objectives

The aim of the project is to develop dried and encapsulated phages, which can be taken orally in order to treat bacterial infections that are either resistant to antibiotics or for which antibiotics are not indicated for other reasons. The development of dried and encapsulated phages targets 3 pathogenic bacteria (K. pneumoniae, S. aureus and P. aeruginosa), which are often multidrug-resistant and confer a high risk for hospitalised patients. The development of dried phages will significantly improve their stability (e.g. in the gastrointestinal tract) and will enable an adequate storage (longer shelf-life, storage at room temperature, etc.) and dosage. Orally administered phages face important challenges, mainly related to the hostile conditions found in the gastrointestinal tract. These include temperature, salinity, proteinase activity and primarily pH, which is exceptionally low in certain compartments. Phage survival under these conditions can be jeopardised and undermine treatment.

## Outcome or preliminary results

Four bacteriophages, belonging to different families [Luz19 (Podoviridae), 25 and 14/1 (Myoviridae), and JWX (Siphoviridae)], were produced at high titres and purified for spray-drying experiments. Ten spray-drying series involving the above-mentioned phages were performed and the resulting phage activity/stability of 160 dried phage samples were determined using a conventional phage titration technique (Figure 1). Spray-dry formulations/conditions resulting in an acceptable activity/stability of the dried product were identified.

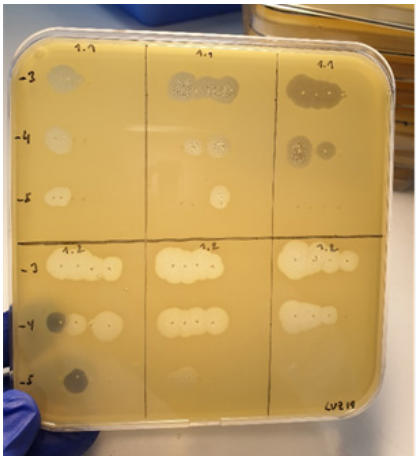


Figure 1. Phage titration. Phage lysis plaques (transparent) on a bacterial lawn (opaque).

Sponsor: Walloon Region (BIOWIN Appel 25)

42

# LabMCT Pastor: Phage Antibiotic Synergy for the Treatment of biofilm-related infections on ORthopaedic implants

LabMCT (Queen Astrid Military Hospital)

Microbiology research personnel

Picture on page 176

# LabMCT Pastor: Phage Antibiotic Synergy for the Treatment of biofilm-related infections on ORthopaedic implants

## Background

Biofilm-related antibiotic-resistant bacterial infections of implantable medical devices, and more precisely orthopaedic implants, are posing a severe threat to human life as current treatment [consisting of salvage debridement, antibiotics and implant retention (DAIR)] often fails to eradicate bacteria present in these biofilms. Replacing these infected implants by new ones is a risky and costly intervention and represents a high burden to the patient's quality of life. Bacteriophages are a promising alternative or addition to antibiotics. Recent evidence suggests that bacteriophages are active against dormant, antibiotic-resistant bacterial colonies present in biofilms, but could also be used to degrade biofilm matrix components such as polysaccharides, eDNA, etc. As such, they could increase antibiotic potency against biofilm-resident bacteria.

## Objectives

Current biofilm models only incorporate one bacterial species, while the more complex infections involve multiple species. We therefore plan to develop a novel multi-species biofilm model consisting of Gram-positive bacteria (*Staphylococcus aureus or epidermidis*), Gram-negative bacteria (*Pseudomonas aeruginosa*) and a fungus (*Candida albicans*) that will grow on titanium coupons (metal used in orthopaedic prostheses). In parallel, we will isolate and characterise phages from the environment, active against these bacterial species. We will determine the host range of the isolated phages while identifying depolymerases produced by these phages as well as other lytic enzymes able to destroy the biofilm structure. Subsequently, we will assemble a bacteriophage cocktail, which will be used in combination with antibiotics (at different concentrations) on our multi-species biofilm model. This will enable us to determine the optimal (synergistic) combinations/concentrations of phages and antibiotics needed for an efficient eradication of biofilms. Finally, we will perform a proof-of-concept study in an animal model of peri-prosthetic joint infection in mice aiming to confirm our hypothesis.

## Outcome or preliminary results

A multispecies (*S. aureus, P. aeruginosa and C. albicans*) biofilm model (Fig. 1) was developed. Several *P. aeruginosa and S. aureus* phages were isolated from samples from 8 hospitals (waste water), 4 lakes and a waste water treatment facility.

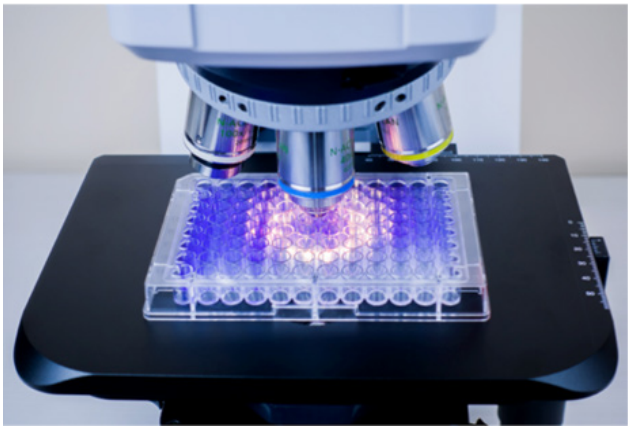


Figure 1. Microscopic evaluation of a biofilm model in the wells of a microtitre plate.

Sponsor: Brussels Region (Innoviris)

43

# LabMCT Phage therapy case studies

LabMCT (Queen Astrid Military Hospital)
Microbiology research personnel

Picture on page 176

# LabMCT Phage therapy case studies

## Background

In 2007, the Queen Astrid Military Hospital (QAMH) in Brussels was the first Belgian hospital to reinitiate a focus on phage therapy, and this under the umbrella of article §37 (unproven interventions in clinical practice) of the Declaration of Helsinki, which was developed by the World Medical Association. Since then, patients have been occasionally treated by phage therapy at the QAMH. Today, Belgium has implemented a pragmatic phage therapy framework that centres on the magisterial preparation (compounding pharmacies in the US) of tailor-made phage medicines, which paved the way for a broader and more structured application of phages in Belgium. Since 2017, a spectacular increase in phage therapy requests to the QAMH has been observed. All these requests were re-directed to a centralised e-mail address (pt@mil.be).

## Objectives

A dedicated patient care workflow in phage therapy was created to ensure an accurate and systematic monitoring of phage therapy requests, treatments and follow-up. The mission of LabMCT is to develop and supply phage preparations fit for use in clinical applications.

## Outcome or preliminary results

Phage preparations developed and produced by LabMCT have been used in dozens of clinical applications in the QAMH, 6 university hospitals in Belgium, and hospitals in France, Germany, Austria, Scotland and Latvia. Shipments of phages to Switzerland and Austria are being prepared at the time of writing. Several cases have been published in the scientific literature; many other papers are in preparation. Some of our phage products have been used in “high profile” cases, such as a 13-month-old liver transplant patient (Fig. 1).


Figure 1. Report of a “high profile” phage therapy case in the media.

Sponsor: Belgian Defence


# LabMCT Phages 4 persistent Staph. aureus carriage

LabMCT (Queen Astrid Military Hospital)

Microbiology research personnel

Picture on page 176

# LabMCT Phage therapy case studies

## Background

Antimicrobial resistance is a growing problem worldwide that poses a significant threat to human health. “Superbugs”, i.e. bacteria resistant to virtually all commercially available antibiotics, have emerged and there are currently few new antibiotics in the development pipeline. On a theoretical level, phage therapy could be a promising therapeutic alternative to standard antibiotic therapy.

## Objectives

The main objective of this study will be to determine whether local phage therapy is able to reduce or eradicate the bacterial load of Staphylococcus aureus chronic nasal carriage (Fig. 1) in otherwise healthy volunteers and in haemodialysis patients. The secondary objectives will be to determine other clinical, microbiological, epidemiological and immunological effects of phage therapy.

Figure 1. Detection of S. aureus nasal carriage.

This is a prospective clinical research project, divided into 2 parts, to be carried out at Erasme hospital (ULB), in collaboration with the Queen Astrid Military Hospital and the LHUB-ULB:

- Part I: Prospective, double blinded, randomised clinical trial of phage cocktails versus placebo to decolonise persistent S. aureus carriers in otherwise healthy volunteers;

- Part II: Prospective, double blinded, randomised clinical trial of phage cocktails versus placebo to decolonise persistent S. aureus carriers in haemodialysis patients.

## Outcome or preliminary results

No patients have been included yet.

Sponsor: Walloon Region (FRS-FNRS)

45

# LabMCT Improving the phage selection protocol for the treatment of CF patients with MDR lung infections

LabMCT (Queen Astrid Military Hospital)

Microbiology research personnel

Picture on page 176

# LabMCT Phage therapy case studies

## Background

The lungs of cystic fibrosis (CF) patients are often infected with bacteria that are resistant to all commonly used antibiotics. In these cases, it is worth trying to clear the antibiotic-resistant bacteria with bacteriophages, viruses that specifically attack certain bacteria but are harmless to humans. At this moment, the best working phages are selected in the lab, against bacterial strains isolated from the patient's coughed up mucus. Bacteria present in a culture on a petri dish in the lab are, however, in a quite different condition that bacteria in the patient's lungs, where they are surrounded by a mucosal biofilm (Fig. 1), a kind of protective wall built around the bacteria. Inside the biofilm, bacteria go into a kind of hibernation, which makes them very difficult to detect and eliminate.

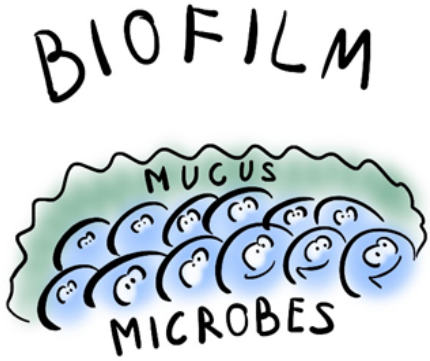



Figure 1. Cartoon depiction of bacteria hibernating in a biofilm.

## Objectives

A consortium of researchers from the Ghent University and the Queen Astrid Military Hospital will try to improve the method for phage selection by taking into account the realistic condition of bacterial pathogens in the lung environment. Do the phages do their job in the lungs as well as in the lab? Can they detect and infect the "hibernating" bacteria in the biofilm? For this purpose, phage activity is evaluated directly in the mucus of CF patients. These mucus samples

are obtained during intensive physical therapy, so that they can be sampled from deep within the lungs, where the biofilm is still present.

## Outcome or preliminary results

No patients have been included yet.

Sponsor: Belgian CF Association and Fund Alphonse and Jean Forton (managed by the King Baudouin Foundation).

46

# TRIVALENT


Director: Prof. Cind DU BOIS

Researcher: Dr. Marion VANSAN

# TRIVALENT

## Background

TRIVALENT is an EU-funded project (H2020 – agreement no. 740934) aiming to better understand the root causes of the phenomenon of violent radicalisation in Europe in order to develop appropriate countermeasures, ranging from early detection methodologies to techniques of counternarrative. The project contributes to a holistic view on violent radicalisation, based on model assessment of radical behaviour coupled with a three-layer strategy:

- Predict to prevent
- Communicate to prevent
- Good policing & community engagement to prevent

The project ran from 1/5/2017 to 30/4/2020 and involved 21 partners from different European Member States. The RMA was represented as a partner by DEML (Dept. of Economics, Management & Leadership) by Prof. Cind Du Bois and Dr. Marion Vansan.

## Objectives

1. Developing a multidimensional model to better understand the root causes and related specific characteristics of violent radicalisation and to define different categories of radicalised individuals as well as to provide a set of early detection indicators;

2. A critical assessment of the strengths and weaknesses of different types of policies for countering radicalisation by testing them in the context of national and local experiences through a comparative analysis, with emphasis on best practices, aiming at the definition of a set of policy recommendations targeting different types of radicalised individuals;

3. Developing analytical tools to assess specific online contents and communication codes used by extremist groups, aiming at contributing to the creation of media communication strategies directed to spread, both online and offline, an alternative narrative and counternarrative;

4. An increase in the efficiency of information exchange and more effective means of cooperation, coordination and communication between LEAs, local authorities/communities and civil society actors;

5. Elaborating suitable means and countermeasures to prevent youth radicalisation in the families and at schools, as well as to develop measures to contrast the spreading of extremism among those detained;

6. Updating existing methodologies and improving competencies, skills and characteristics of the practitioners involved in preventing, detecting or countering violent extremism.

## Project Results

1. Multi-dimensional model aimed to better understand the factors and steps leading to violent radicalisation, as well as to identify different typologies of radicalised individuals;

2. IT techniques for identifying violent/non-violent radical social media accounts, using content, network, and behaviour analysis methods;

3. IT tools to track radicalisation stages and alert of radicalisation turning points;

4. alternative narrative techniques, identifying appropriate channels and media to spread them, and related methods to assess their effectiveness;

5. new skills and competencies of LEAs through pilot training courses (train-the-trainers);

6. IT tool to foster communication/cooperation between LEAs and civil society;

7. Policy recommendations basically focused on preventing measures and cooperative efforts involving all the relevant actors.


# SOLOMON
# Strategy-Oriented anaLysis Of the Market fOrces in EU defeNce

Director: Dr. Ir. Geert DE CUBBER

Researcher: Dr. Daniela DOROFTEI

# SOLOMON

## Strategy-Oriented anaLysis Of the Market fOrces in EU defeNce

## Background

Technology non-dependence is an essential parameter of the strategic autonomy and freedom of action of the EU Member States. Uninterrupted supply from trusted sources of key materials, including raw materials, components and technologies for critical armament systems is fundamental for the reliable use of military capabilities when and where needed. Trusted supply without limitations from non-EU countries regarding the use or export is also essential for the competitiveness of the EU defence industry, enabling competing in global markets with technological solutions that do not have to respect third parties conditions.

To gain an overview about the technology dependence challenge, a stocktaking of ITAR and other non-EU sourced components used in Europe's armament systems would be the first step to tackle this issue. A methodology consulting Member States and defence industry would need to assess the sourcing risk and criticality in order to identify and prioritise components and materials desirable to be available in Europe in the future. For selected technologies, roadmaps and business models can be produced to provide proposals for research topics for a follow up of defence research programme.

## Objectives

SOLOMON will investigate the value chain of European Defence Systems, to put in evidence the "disruptive capabilities", in their operational dimensions. Specifically, SOLOMON has as objectives:

1. To development a taxonomy for mapping the value system of the EU defence industry;

2. To study the value chain of naval, land, aerial, space and cyber armament systems;

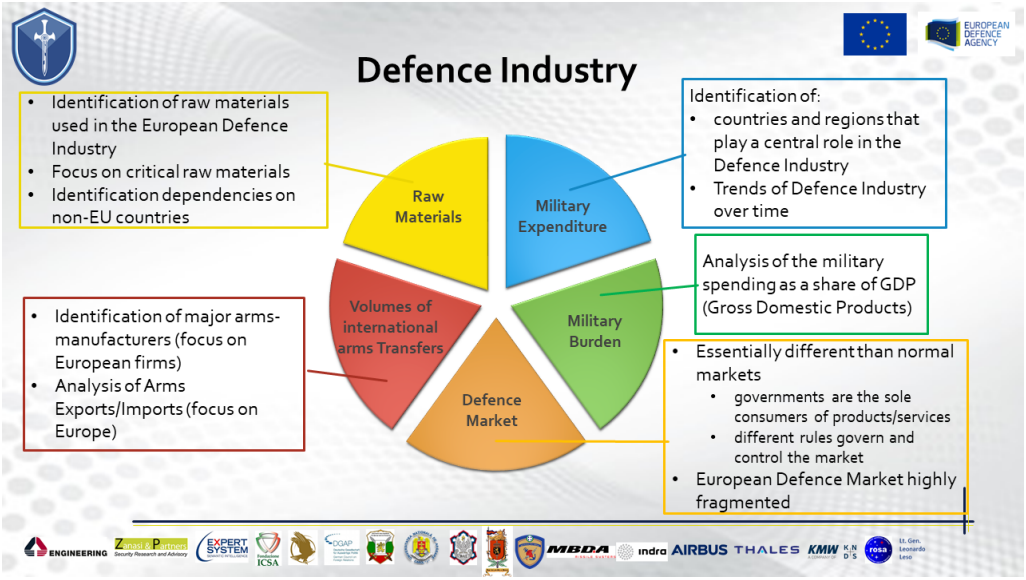
3. To identify relevant themes for the future European Defence Research Programme;

4. To develop a data analytics system to analyse critical defence technological dependencies;

5. To open new market opportunities in the defence sector for European SMEs;

6. To identify all the dependencies in the EU defence industry value system;

7. To develop a methodology to assess the supply risk of EU defence industry.




## Outcome & Results

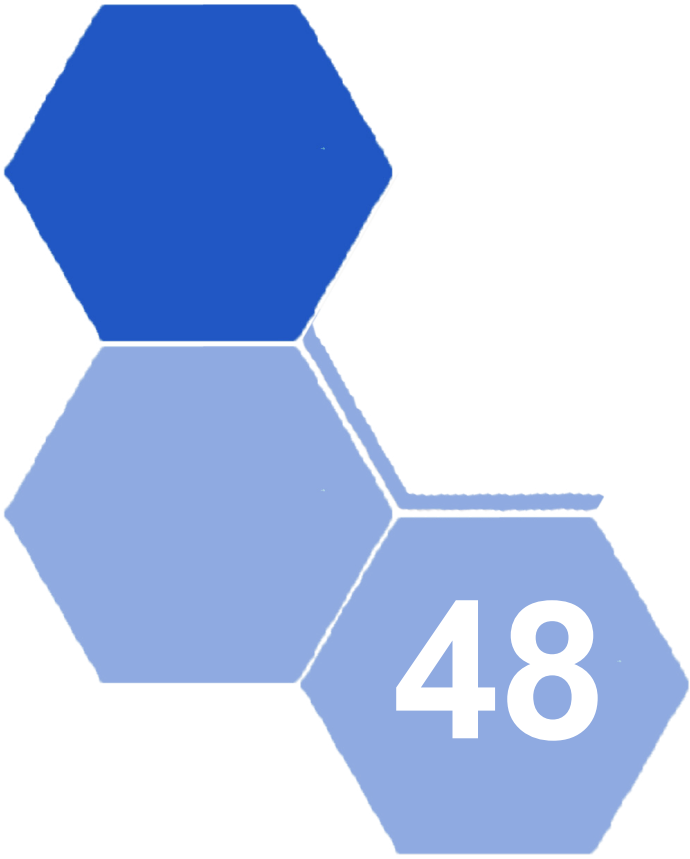
1. Mapping of ITAR and other non-EU sourced components and materials in the systems developed by the EU industry and to be used by the EU armed forces;

2. Identification of critical technology building blocks and components for future systems and disruptive capabilities for which European technology non-dependence will be crucial;

3. Development of a methodology to assess the supply risk of technologies and components and their criticality for armed forces and the defence industry;

4. Preparation of technology roadmaps, including cost substantiated predictions, and suggestion of business models for selected technologies, taking into account supply risk and criticality.

More information: http://www.solomon-padr.eu/




# SSAVE
# Shared Situational Awareness for Vessels


Director: Air Force Maj Robby HAELTERMAN

Researchers: Dr. Ir. Geert DE CUBBER

Mr. Rihab LAHOULI

# SSAVE
## Shared Situational Awareness for Vessels

## Background

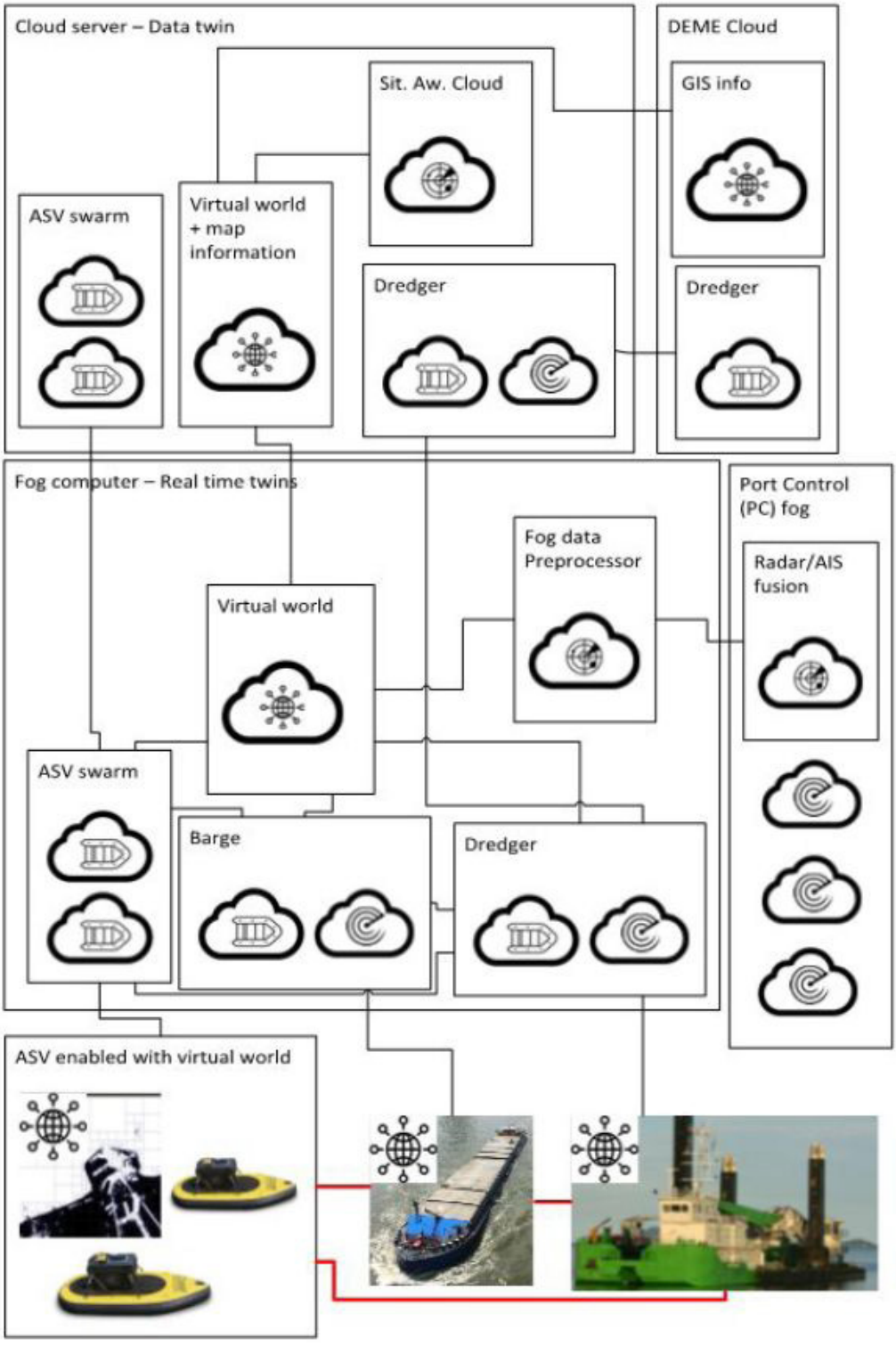
Ships are becoming more and more connected. With the evolution towards remotely controlled and autonomous vessels in mind, reliable data and communication is essential. Interconnectivity and interoperability between assets in maritime and inland waterway environments, however, is a challenge as current solutions are already restricted by the boundaries of available technology. The data intensity of point clouds often poses problems in robotics and, certainly for maritime operations, network saturation becomes a blocking factor for the deployment of autonomous systems. Optimal use of bandwidth and data routes would resolve part of the existing limitations. Data transfer intensity reduction, qualitative information generation, data sharing and real-time accessibility are therefore key requirements of the SSAVE project.

## Objectives

The goal is to improve data quality, interconnectivity and interoperability between assets in the maritime and inland waterway environment. This will be achieved by enabling secure and verified direct and indirect communication between assets. The exchanged data information will be extended with additional sensor information to efficiently represent and communicate shared situational awareness. This sensor data extension, representation and communication is a crucial step towards efficient and flexible interoperability. Concrete objectives of the project are:

- Defining methods and technologies for secure and verified connectivity and data sharing between field assets from different manufacturers and owners through standard open interfaces;

- Defining low-cost IP-like technologies, enabling the deployment of meshed ad-hoc edge networks;


Cloud server – Data twin
Sit. Aw. Cloud
ASV swarm
Virtual world + map information
Dredger
DEME Cloud
GIS info
Dredger
Fog computer – Real time twins
Fog data Preprocessor
Virtual world
ASV swarm
Barge
Dredger
Port Control (PC) fog
Radar/AIS fusion
ASV enabled with virtual world

- Working towards a standard sensor data exchange format characterised by data reduction and enrichment between field assets from different manufacturers and owners;efining software architectures to optimally fuse sensor information, with a focus on real-time sharing of situational awareness;

- Enriching point cloud-based vessel localisation through motion models;

- Standardisation of inter-asset communication, towards a next-generation AIS system.

## Outcome & Results

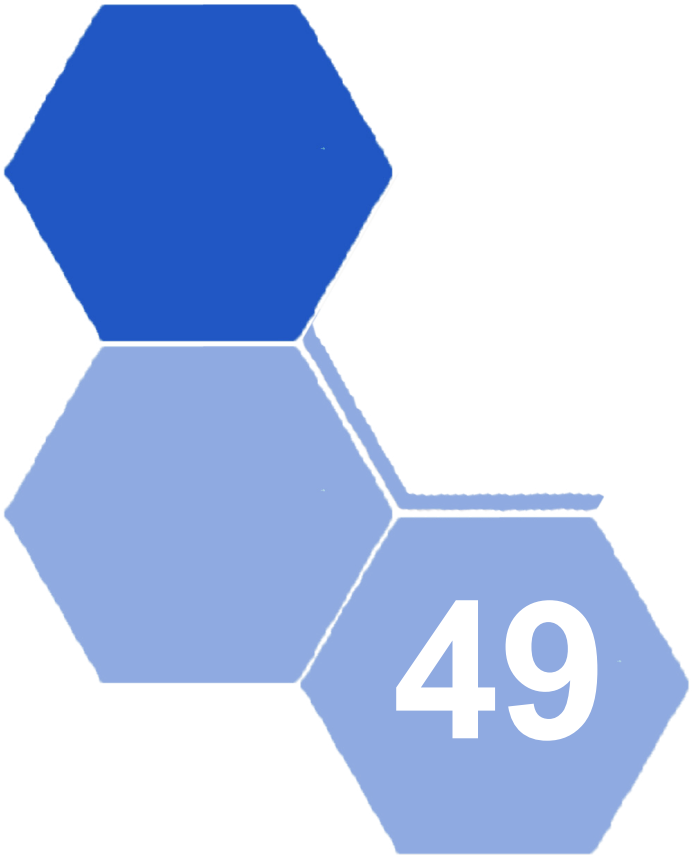
The main leaps in knowledge will be the enabling of shared situational awareness through the design of a novel digital twin architecture and a distributed platform for situational awareness using distributed sensor fusion. The main innovations are:

1. The addition of a meta-data layer to the sensor data that provides information on the data reliability, quality and timeliness. This will enable vessels to perform more robust sensor fusion in a distributed context;

2. A robust data fusion methodology that can handle transmission delays, packet dropouts, and other communication disturbances from heterogeneous and asynchronous data sources;

3. The embedding of situational awareness in the data-sharing platform to determine which data is relevant for other vessels.

More information: http://mecatron.rma.ac.be/index.php/projects/ssave/




# Laboratory for Plasma Physics of the Royal Military Academy


| | |
|---|---|
| Director: | Prof. Michael VAN SCHOOR |
| Researchers: | Dr. Jozef ONGENA |
| | Dr. Fabrice LOUCHE |

## Laboratory for Plasma Physics of the Royal Military Academy (LPP-RMA/ERM/KMS)

On 9 October 2014, fusion research bodies from European Union Member States and Switzerland signed an agreement to cement European collaboration on fusion research. EUROfusion, the European Consortium for the Development of Fusion Energy, was born. EUROfusion supports and funds fusion research activities on behalf of the European Commission's Euratom programme.

EUROfusion's mission is to pave the way for fusion power reactors. To do so, the consortium funds the research of its 30 members based on the "European Roadmap to the Realisation of Fusion Energy" as a joint programme within Euratom Horizon 2020.

Its objective is a to build a world in which fusion power plants feed the grid with CO2-free fusion power and complement other sources of energy production.

Along with EUROfusion, the European fusion efforts are channelled to ITER through Fusion for Energy. While EUROfusion organises the European fusion research, Fusion for Energy oversees the industrial contributions to ITER. Apart from this, EUROfusion is also one of the eight members of the EUROforum, which brings together the resources, facilities and expertise of its member organisations to support European science in reaching its full potential.

The European Fusion Roadmap outlines the research and development required to provide the basis for an electricity-generating fusion power plant.

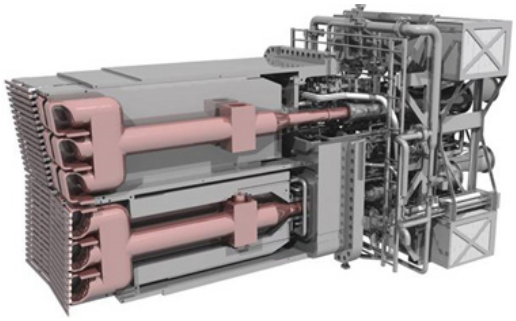
In the short to medium term, the key research infrastructure is the ITER project, a worldwide endeavour, which will demonstrate the scientific and technological feasibility of fusion on Earth. ITER will generate ten times more fusion power than the power injected to sustain the fusion process. While the design of a demonstration fusion power plant DEMO is already ongoing, high-performance operation of ITER will give important input to fine-tune the DEMO design. DEMO will demonstrate that the first contribution of electricity production to the grid could be done through fusion.

The fusion fuel is abundant. Tritium can be produced from lithium, a metal ubiquitous in the Earth's crust and in seawater. There is also enough deuterium dissolved in natural water to fuel fusion power plants for tens of thousands of years without risk of shortages or monopoly of supply. The fusion power plant is

inherently safe: less than a gramme of fuel makes up the plasma, which rapidly extinguishes itself in case of any malfunction. Deuterium-tritium reactions release neutrons that will activate wall materials. The resulting radioactive by-products are short-lived and decay in a period of about 100 years, to a level comparable to that of the waste from coal power plants. The benefits of fusion power as a carbon-free, sustainable energy source to complement renewables are persuasive arguments in favour of fusion.

Belgium is a member of the EUROfusion Consortium. The Convention of Association on the implementation of the Belgian fusion activities, supervised by the FPS Economy, SMEs, Self-Employed and Energy combines the efforts of 2 federal laboratories (LPP-ERM/KMS and SCK-CEN) and 4 universities in fusion research.

LPP-ERM/KMS signalled it's strong commitment to ITER. In April 2007, the ITER Working Group on Heating and Current Drive (WGHCD) recommended that the reference design for ICRH on ITER should be based on the LPP-ERM/KMS proposal. LPP's effort in the framework of ITER over the last years aimed, in close collaboration with UKAEA, ORNL (US) and ITER IO, at further verifying ITER's functional requirements and at WGHCD's implementing additional recommendations.



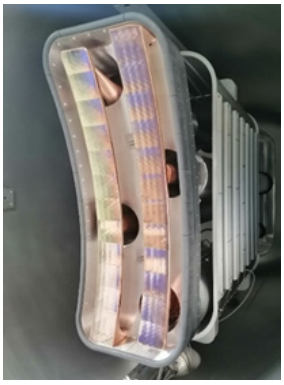
The ITER ICRF antenna consists of a close-packed array of 24 straps arranged in a 6 poloidal by 4 toroidal arrays. Three poloidally adjacent straps (a "triplet" of straps) are fed in parallel through a 4-port junction from one single 20Ω feeding line. Load tolerance is achieved by feeding two poloidal triplets through either a 3dB hybrid coupler or a conjugate-T scheme. The array has to radiate 20MW of RF power over a frequency range of 40MHz to 55MHz and different toroidal phasing. The figure above shows a cut of the front part of the antenna. The whole antenna is recessed from the first wall of the tokamak. The high power density of the compact antenna, the large antenna-plasma distance and the

mutual coupling between the 24 straps make the design of the ITER antenna system a challenging task.

Currently LPP-ERM/KMS is developing an Ion Cyclotron Resonance Heating antenna for the stellarator W7-X. The main aim of the ICRH system for W7-X is generating fast ions (with energies of ~ 60-80 keV) in order to demonstrate that a stellarator is able to confine this kind of fast particles. In addition, the antenna also provides a heating and current drive tool for short periods, complementing the steady-state Electron Cyclotron Resonance Heating system. The system can also serve as an Ion Cyclotron Wall Conditioning (ICWC) system.

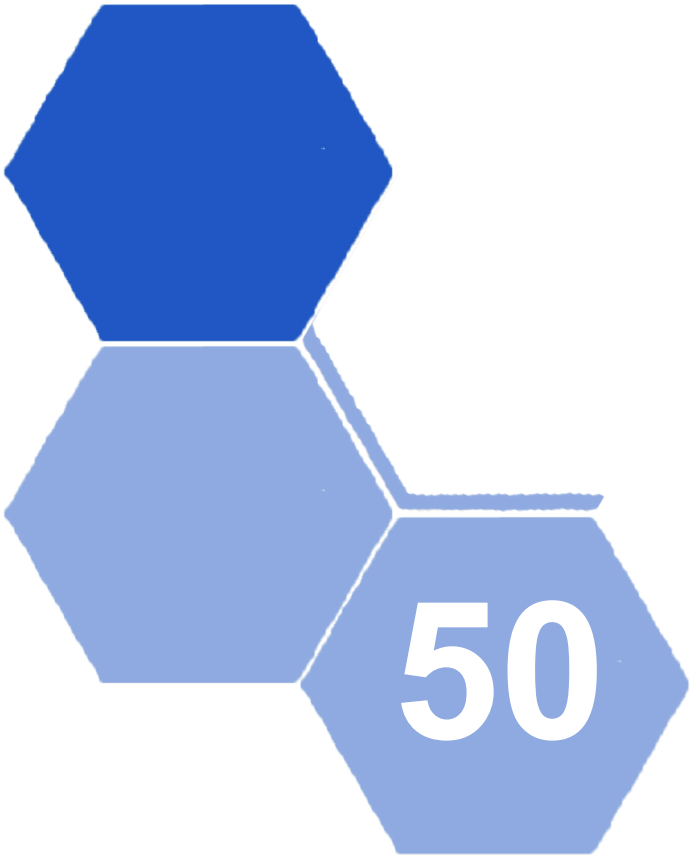
One of the main aims of the W7-X device is demonstrating the reactor potential of stellarators. It is therefore crucial to show that an optimised stellarator configuration can provide sufficient confinement of fast alphas.

The picture below shows the W7-x antenna, which has been tested on a test stand in 2019 and which will be installed on the stellarator in 2020-2021.



References

www.euro-fusion.org
www.fusion.rma.ac.be




# NEXT GENERATION POWDER PROJECT (NGP)

Director: Prof. Michel LEFEBVRE

Researchers: Dr. Geoffrey VIDICK

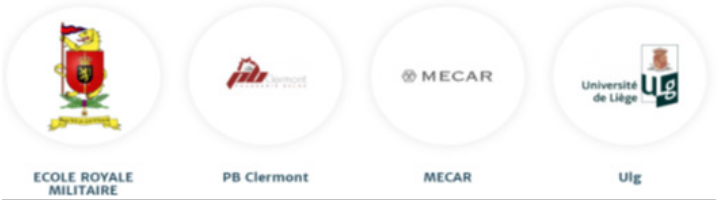
Mrs. Nathalie WILMET

# NEXT GENERATION POWDER PROJECT (NGP)

## Background

The NGP project is a research project within the framework of the “Plan Marshall 4.0” financed by the Walloon Region. This project brings together industrial partners: MECAR and PB Clermont, as well as laboratories of ULiège and the Laboratory for Energetic Materials and Blast Engineering (LEMBE) of RMA to carry out research that will develop greener and more efficient gunpowders.

*Partners*




## Goals

This research focuses on the development of a new spherical propellant powder with a greater granulometry and higher energy content, aiming to be used in medium calibres and mortars, while maintaining the specificity and advantages of spherical powders. The working principle of this new propellant is to enable a better control of combustion while generating more pressure and therefore extra thrust for the ammunition when fired.

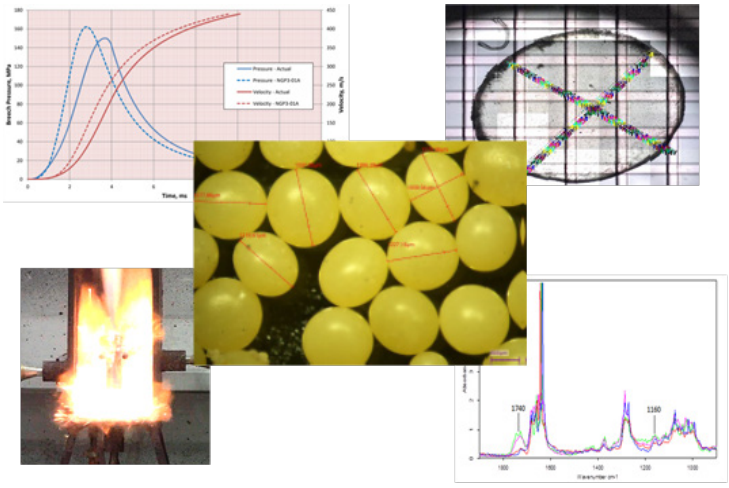
## Current achievements

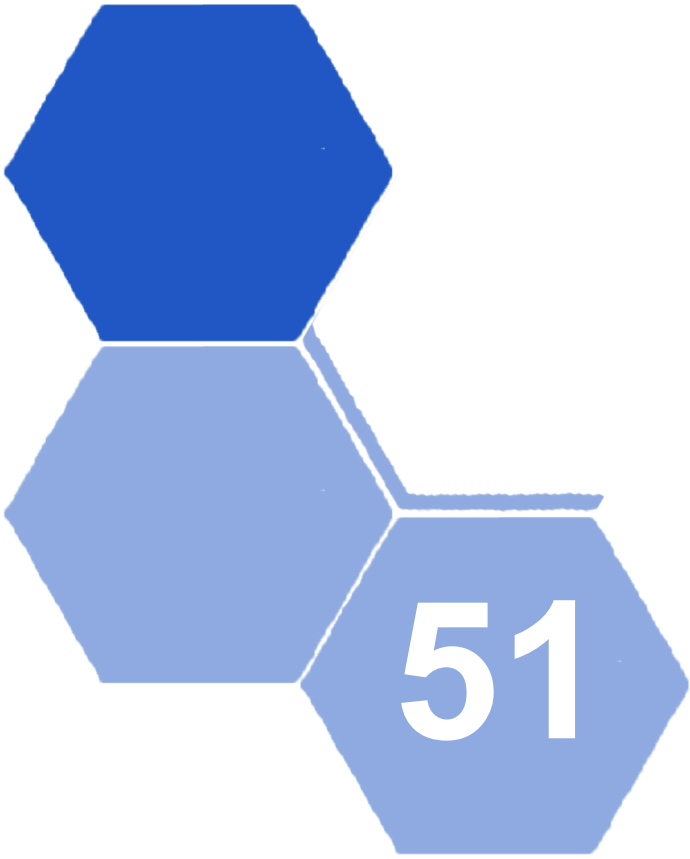
Today, at the midterm of the project, the LEMBE has demonstrated the “proof of concept” of the project. It has developed a programme for optimisation of the formulation parameters based on thermodynamic calculations and performed sensitivity and explosiveness determination tests, enabling project partners to support their risk analyses. LEMBE has also developed a synthesis platform of a new high explosive and it has characterised both physico-chemical and reactive aspects of the explosives alone or incorporated in the formulations.

A series of formulations has been studied in closed vessel. The experimental results obtained are consistent with the thermodynamic calculations carried out.

## Outlook

Internal ballistics studies should definitively validate the work carried out. Firing tests are considered for one of the applications. A semi-empirical approach is ongoing to enable achieving the other goals.






# Belgian soldiers executed by firing squads in 1914-1918 – Procedural regularity before Belgian courts-martial

Director: Prof. Stanislas HORVAT

# Belgian soldiers executed by firing squads in 1914-1918 – Procedural regularity before Belgian courts-martial

## Background

During the Great War, eleven Belgian soldiers (some corporals) were shot after being condemned to death by courts-martial. Since then myths and reality about the functioning of Belgian field courts-martial during the war regularly emerge. In 2013, in prospect of the commemoration of the Great War, MPs and relatives of executed soldiers requested the rehabilitation of those soldiers and solemn apologies to these by the Belgian government. They alleged that breaches of the regular procedure had led to the judgments and that the soldiers had been shot “as a warning to others”. The government asked a scientific committee of historians to provide an expert opinion. Following this, the Royal Military Academy provided the abovementioned scientific committee with a detailed expert report.

## Objectives

The research by the Royal Military Academy aimed at analysing the legal and historic circumstances of the offenses committed by the said soldiers, as well as the regularity of the procedural conduct by the military and judicial authorities and the legal basis of the sentences.

Outcome

The research resulted in a detailed and comprehensive report, showing the discrepancy between long-lasting myths (i.e. the alleged breaches of procedure, the alleged innocence of the shot soldiers, the alleged shootings “as a warning”) and reality. If occasional errors occurred during some procedures as a result of lacking detailed war legislation or earlier jurisprudence, in only two cases was the underlying cause of the prosecution disputable – even if legally correct –, in two other cases it is not excluded nor proven that some of the offences resulted from emotional distress. But there was neither a “policy” of groundless convicting and condemning soldiers nor a “will” of shooting personnel “as a warning”. Strict prosecution and severe judgments were the result of severe wartime regulation.

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# SCIENTIFIC RESEARCH
## IN THE BELGIAN DEFENCE FORCES
## Report 2019

Royal Higher Institute for Defence
Department Scientific and Technological Research of Defence

Responsible editor: Director-general Filip BORREMANS (MSc Eng), Air Force Colonel GS

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