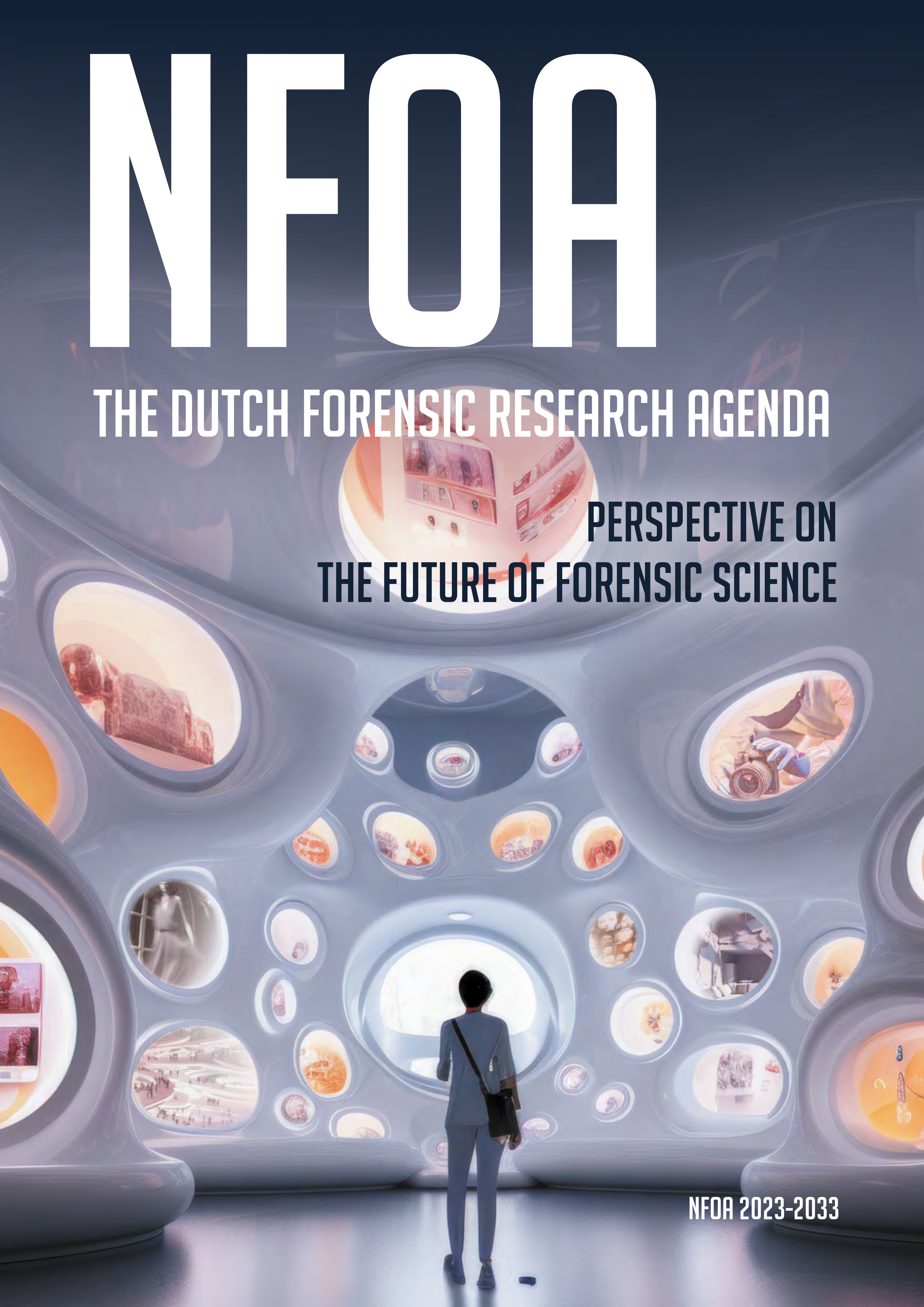
NFOA

THE DUTCH FORENSIC RESEARCH AGENDA

PERSPECTIVE ON THE FUTURE OF FORENSIC SCIENCE



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BACKGROUND

A just and safe society in which citizens have faith in the judicial system – this is the goal to which forensic science seeks to contribute. Forensic science covers the broad deployment of scientific knowledge and technology to uncover the truth in criminal investigations. Investigating physical evidence found at a crime scene ('the silent witnesses') yields vital information on the events that have occurred and those involved. Forensic reconstruction assists police investigation and allows the police, the Public Prosecution Office, and courts to consider hypotheses and suggested scenarios in a better-informed manner. Sometimes, the forensic investigation of a single microtrace results in a breakthrough and allows investigators to identify a perpetrator or victim many years after the crime. The value of forensic expertise gains its full significance in court. This is where forensic evidence assists the judges in making the crucial final decision concerning a suspect's guilt or innocence. The information on which the court bases these vital decisions must be of impeccable quality in order to prevent or at least minimize miscarriages of justice.

Due to its important role in the criminal justice system, the field of forensic science is highly dynamic and demands continuous investment in explorative, fundamental, and applied scientific research. This ensures that the most recent scientific insights and state-of-the-art technologies are available to unravel the truth and that forensic methods remain reliable and relevant.

A CHANGING WORLD

The continuous development of new scientific knowledge and technology impacts our society and the criminal justice system twofold. New knowledge and technology can be abused, thus leading to new forms of crime. This demands new forensic methods that can help with the investigation and unravelling of criminal acts. New forms of crime can lead to changes in occurrence of relevant physical and digital (trace) evidence. Some evidence materials (such as paper documents) are becoming less and less common at the crime scene, whilst new traces emerge providing promising opportunities if the right investigative methods are developed (digital evidence in particular). This 'justice & society pull' means that forensic science must continuously develop to remain valuable, relevant, and future-proof.

NEW OPPORTUNITIES

At the same time, scientific breakthroughs and technological innovations continue to provide new opportunities for the forensic investigation itself. Forensic experts attend scientific conferences and collaborate closely with academia and commercial companies to explore the forensic potential of new scientific and technological developments. This enables the creation of promising new methods and techniques and their implementation in forensic practice. This ensures that criminal investigations remain state-of-the-art. This 'science & technology push', however, is more than just monitoring, discovering, selecting, and introducing new science and technology in the domain of forensic science.

Criminalistics is an independent science domain in which scientists engage in fundamental research and develop new knowledge. Of specific forensic relevance is the interpretation of the findings in a scientifically correct manner within a framework of given hypotheses and scenarios. Not only does this involve establishing the evidential strength of a new method, but it also requires a sensible implementation within the criminal justice system. The results must comply with several scientific and legal requirements to warrant admissibility and all stakeholders must be able to understand the findings and the expert interpretation. These stakeholders include law enforcement officials, judicial and legal professionals, suspects, victims and their family members, and journalists that report on the criminal case. The intended contribution to a safe and just society can only be realized if the soundness and reliability of a new forensic investigation method can be demonstrated to a broad audience.

The scientific and technological opportunities and rapidly changing society require a forensic scientific innovation programme that boldly embraces and addresses new options and challenges. A programme that also stimulates collaboration between academia, innovative companies, and forensic practice. However, the reality is often that forensic science resources in academia are limited and that experts at forensic institutes have little time for innovation due to the relentless, everyday pressure of case work.

With the Netherlands Forensic Research Agenda (Nederlandse Forensische OnderzoeksAgenda, NFOA) the Co van Ledden Hulsebosch Center, Netherlands Center for Forensic Science and Medicine (CLHC) and the Netherlands Forensic Institute (NFI) have joined forces to break this pattern. Following a careful and extensive consultation within forensic practice and based on the contributions made by numerous scientists, forensic investigators, and professionals in the Dutch criminal justice system, the forensic network in the Netherlands proudly presents an inspiring research agenda for the next decade with five interdisciplinary themes. Given the right financial resources, this agenda will enable the start of a valuable research programme for the development of forensic methods for tomorrow and the foreseeable future!

THEMES

The Dutch Forensic Research Agenda (abbreviated to NFOA in Dutch) introduces five interdisciplinary themes that will determine the course for forensic scientific research in the Netherlands for the coming decade. These themes have been formulated following extensive discussions with academics, forensic experts, and police and legal professionals in the Dutch criminal justice system. They connect new technological possibilities and recent scientific insights to the needs of criminal investigations, with the goal of creating new forensic capabilities that can make a difference in criminal investigations and legal proceedings.

Theme 1

Finding, securing, and following the trace

Essential for investigating crimes is the accurate finding, securing, and tracking of even the smallest forensic trace. Supported by advanced technology and science, investigations at the crime scene can extract maximum relevant information from minimal trace material. This starts with discovering crucial physical and digital evidence, followed by the careful processing and examination of the evidence material.

Theme 2

The ultimate forensic reconstruction

Forensic research revolves around the precise reconstruction of potential criminal human activities. This requires an interdisciplinary research approach, interpretation of evidence at activity level, and a thorough statistical analysis. Experts must be able to explain the forensic reconstruction comprehensibly without compromising scientific values.

Theme 3

Everyone, everywhere, everything, always

In criminal investigations, the immediate availability of forensic information can be of crucial importance. Technological developments enable the use of forensic methods outside the laboratory, provided that the quality is guaranteed for both the criminal investigation and subsequent prosecution.

Theme 4

AI and data science in forensic practice

The combination of artificial intelligence (AI) and the availability of large-scale data offers significant opportunities in the forensic field. A transparent approach is essential to harness the full forensic potential of the data science revolution. AI methods must be fully transparent and explainable to legal professionals and society.

Theme 5

Doing more with forensic information

Large-scale forensic case work provides valuable information regarding crime and the effectiveness of criminal investigations. By focusing on overarching case connections and general trends, forensic data can become a source of information to understand and combat crime and to optimize (forensic) research methods within the entire criminal justice system.

THEME 1

FINDING, RECOVERING, AND FOLLOWING THE TRACE

FINDING, IDENTIFYING, ACCESSING, RECORDING, RECOVERING, AND PRESENTING TRACE EVIDENCE

A forensic investigation starts with finding, recognising, and recovering evidence. Cognitive processes play an important part in searching for and recognising physical evidence at the site of an incident (crime scene) and in evaluating and using (quick) analytical results in the police investigation process. It is important, in the criminal investigation, to devote attention to the effects of exchanging tactical, technical, and digital information in order to be able to make optimum use of information and minimize the risk of bias. Only in this way will the results of the forensic evidence analysis contribute to the best possible representation of the truth.

After analysis at the crime scene, trace evidence is stored, analysed, and often stored once again for a longer period of time. It is vital in the course of the investigation that trace evidence remains in the same condition as it was found, or at least that it is known how it has changed over time, for instance due to analytical or ageing processes. Another important aspect is that experts must record the context and coherence of trace evidence in a simple and unambiguous manner so that it can be easily reproduced at a later stage.

Challenges relating to finding, recording, and analysing physical traces secured at a crime scene also apply to digital trace evidence obtained from (mobile) devices, data carriers, networks, the cloud, or the internet. The nature of the challenges and possible solutions may, however, be fundamentally different. There is an additional challenge where it concerns digital evidence, namely accessibility. There are rapid developments in encryption methods on the one hand, and hardware and software to circumvent data security on the other. These developments can be used to commit and facilitate crimes as well as to solve them. For this challenge in particular, it is interesting to keep track of developments in the field of quantum computing which is claimed to provide unprecedented decryption capability.

Forensic investigators need new and specific procedures, equipment, and software to improve the effectiveness and reliability with which evidence is detected, sampled, and recovered at crime scenes. To safeguard the feasibility, practical usefulness, and acceptance of such innovations, they must be developed from the perspective of the user, such that they are:

- Portable, sensitive, fast, cost-effective, simple, infallible, and preferably suitable for contactless measurement (to avoid contaminating or damaging evidence);
- Able to localize, detect, classify, quantify, and date evidence (ideally with all of these features in a single device);
- Comprehensible and accessible for the various partners in the criminal justice system;
- Securely sampling traces in a way that allows for counter-expertise in the future.

Sometimes a forensic investigation of a single, minute trace can turn a criminal investigation in the right direction

RELIABLE CSI: UNDERSTANDING AND PREVENTING PERI- AND POST-DETECTION CHANGES IN TRACE EVIDENCE

Avoiding contamination and alteration of trace evidence, both during and after traces are found or detected, is an important consideration when developing effective sampling methods. This is vital if one is to ensure a safe, reliable, uniform, and high-quality crime scene investigation. Preventing alteration of evidence in the course of detection, sampling, recovery, analysis, transport, and storage (i.e. a reliable chain of custody) requires comprehensive insight into the 'dynamics of trace evidence'. To this end, equipment, and methods must be developed that allow one to map the properties of forensic evidence both macroscopically and microscopically. This reduces the impact of the investigation on the condition of trace evidence. Such equipment and methods must be fast, user-friendly, and cost-effective. The investigators must be able to minimize the risk (probability of occurrence x consequences) of contamination.

The principles of a reliable chain of custody apply to both digital and physical evidence. Authenticity, encryption, and quality assurance are important challenges when considering digital evidence. The relative ease with which digital traces can be manipulated and reproduced (copied) and the onset of new powerful techniques like generative Artificial Intelligence (AI), is enabling malicious parties to produce and manipulate digital material, for instance by producing so-called 'deepfake' videos and images. This requires a completely new forensic toolbox to analyse and authenticate digital evidence.

Important developments in forensic trace analysis include:

- Equipment and methods that detect, record, recover, and analyse physical and digital evidence, and register and present (visualize) the results in the context of the crime scene and forensic reconstruction;
- Equipment and methods for fast, robust, and secure sampling of physical and digital evidence whilst preserving integrity;
- Transport and storage materials that maintain and preserve evidence integrity;
- Technologies for fast 3D scans of evidence on both microscopic and macroscopic scale;
- Tools to record the movements, actions, choices, and motivations of crime-scene investigators;
- New forensic decryption methods that continue to ensure access to digital evidence;
- New forensic methods for analysing the authenticity of (digital) evidence;
- Technologies and (visualisation) methods to enable unbiased analysis and display of physical and digital evidence, including their context and interrelationships, and presentation of such information in an understandable manner in court;
- A 'virtual colleague' for real-time (decision-making) support for crime scene investigators.

THEME 2

THE ULTIMATE FORENSIC RECONSTRUCTION

***What happened? And who did it?* These two questions constitute the basis for reconstructing events at the site of an incident. Without reconstruction, no case!**
Experts can conduct ever more sensitive measurements on ever smaller traces using state-of-the-art methods while including a proper statistical analysis of findings. Increasingly, this leads to questions about how or when the trace ended up in the place where it was found. At the same time, there are ever more possibilities to reconstruct crimes and accidents, particularly thanks to the combination of digital and physical trace evidence. It is important to visualize reconstructions in a scientifically correct and comprehensible manner.

The forensic process occurs primarily at three physical locations: the incident site (the crime scene), the laboratory, and the court – each with their own important questions and answers.

INCIDENT SITE

This is where the evidence was created due to actions and interactions between people, animals, plants, or objects. Later, investigators search for (and may or may not find) the physical evidence, recovering, and selecting the individual traces for further analysis. Human behaviour plays an important part in this process, so developing knowledge and methods to support investigators in making decisions is vital. Which traces may be caused by criminal behaviour? And which traces are caused by everyday actions? Which injuries are clearly inflicted? And which injuries are more likely to have been caused by an accident? What level of force must be exerted on a skull such that it breaks? How can a forensic investigator use knowledge about human behaviour and the traces they leave to arrive at a good investigative strategy for a given incident? What information is vital in this context?

→ The suspect in a criminal investigation into an alleged homicide is found to be an acquaintance of the victim. The suspect spent time at the victim's home on a regular basis. What activities would a visitor undertake at a friend's house? And where can you find these traces? What about acts of violence? Do these actions result in the same trace evidence at the same location in the house? And how do the traces of the suspect in the victim's house (such as fingerprints or DNA) relate to the incident?

A lot of relevant scientific knowledge has already been collected on this subject, but gathering knowledge is one thing, using it effectively is something else entirely. The lack of feedback loops throughout the process is characteristic for the entire criminal justice system, from recovering evidence at the crime scene to the outcome of a trial and its impact on the evidence that was recovered. As a result, the ability to learn throughout the criminal justice system is less than optimal. For instance, there is no systematic deliberation between the police, laboratory, and legal counsel on choices made and their impact in a specific case. How do we ensure continuous assessment and improvement? The projects within this theme aim to develop a robust learning system with a measurable impact.

In the case of cybercrime, the criminal actions primarily occur in cyberspace. The term 'cyberspace' is used to describe a network with connected equipment, such as computers and other devices, and these constitute the incident site. Reconstructing such an incident is a different process in many ways. Particularly because the incident is often still in progress, leading to the creation of new traces while old traces disappear as the investigation is conducted. Research must yield new methods to establish the location in cyberspace, to reconstruct what happened, and to identify the perpetrators and the victims.

THE LABORATORY

A forensic reconstruction of a crime or accident aims to validate or invalidate scenarios or specific parts thereof. This may lead to questions at the level of individual trace evidence, such as ***'What is the composition of the trace material?', 'How was the trace created?'*** en ***'How old is the trace?'*** Questions may also arise with respect to the position of persons with regard to each other or objects. Forensic experts play a vital part in finding explanations for the presence or absence of traces or in weighing up the trace evidence under several alternative scenarios.

→ Bloodstains were found on the clothing of the suspect of a violent incident. Rapid DNA analysis establishes, within a few hours, that it is the victim's blood. What do the bloodstain patterns tell us about the relative positions of the suspect and victim? Do the spatter and contact stains match the suspect's statement that he tried to resuscitate the victim, or better match acts of violence?

Forensic experts will establish the probability of the investigation results given several potential scenarios. This requires a deep understanding of the 'behaviour' of traces: *How are stains transferred? How and at what level of violence are damage and injuries caused? What traces relate to what kind of human action? And what happens to these physical or digital traces in the time between the incident and the moment when the forensic analysis takes place?* Forensic experts interpret the data using state-of-the-art probability models and provide data visualization for the relevant scenarios. In this way, they offer the court insight into what the vital forensic evidence in a specific case could mean for the reconstruction.

For biological evidence, the investigation covers not only the identity of a donor, but also cell typing (bodily fluids or organs) and non-human biological materials. The options for identifying those involved continue to expand, even when traces contain biological material from multiple donors or identical twins. Coupling of findings remains challenging, for instance: *Which person contributed which cell type to a biological trace? Or: Can a soil sample be linked to the crime scene?*

Everything is possible, but not everything is probable, how can the forensic expert best explain this?

Time is another important aspect in reconstructions. Biological traces potentially can reveal when the traces were left at a crime scene. As such, the linking of findings and the dating of traces can yield vital information in the reconstruction of the events that occurred at the crime scene.

Mathematical/computer models are vital in finding explanations for observations and for probability calculations. For instance, analysing the probability that specific injuries could occur in a victim. *Was the victim abused or did she simply fall?* The same holds for the investigation of traffic accidents. At what speeds does the vehicle sustain the greatest damage? Outcomes of simulations must be fully transparent, handle uncertainties in a scientific manner, and take human factors into account.

The great variety of trace types and of scenarios that can be of importance in criminal investigations means that knowledge about the behaviour of evidence and the associated models must be shared nationally and internationally.

A few areas of interest for forensic scientific research are listed below.

→ Reliable models of the occurrence of physical evidence with a broad, robust applicability and a high degree of user-friendliness (also for lay users), developed in co-creation by developers and users;

→ Platforms/frameworks for continued development, use, and integration of models;

→ Process and functional validation of existing and new models and tools.

COURT

Simulations and animations of e.g. traffic accidents, bullet trajectories, and acts of violence, constitute powerful means to clarify how well forensic observations match relevant scenarios. Such reconstructions also entail the risk that they mislead the judge or other users (such as detectives, defence counsel, or the public prosecutor's office). Due to their visual nature, animations may be considered true while every visualisation merely represents an interpretation of observations by forensic experts and other stakeholders.

When interpreting the forensic observations, the experts might in the future use a graphic representation of the probability model.

Such graphic models offer insight into the relevant routes of transfer of traces through different actions and the associated probabilities. *Could such visual models help the experts and court judges to better understand the evidential value of the encountered traces?*

Developing methods for supporting forensic visualisations that are unbiased, transparent, and represent the evidential value, is vital. Researching effective methods for transferring information between forensic scientists and legal professionals, for example by introducing new forms of forensic reporting and visualisations, aids this process.

→ The clothes of a victim are examined for the presence of traces after a sexual offence. The suspect's DNA is found in the groin area of the victim's panties. The suspect states that no sexual acts occurred but that he had legitimate social interaction with the victim. They had dinner together and watched a movie at home on the sofa. In both scenarios, there is a large number of activities that could transfer DNA between the persons involved and their surroundings.

What do the traces tell us about the activities that occurred, ultimately this is what it is all about in court

THEME 3

EVERYONE, EVERYWHERE, EVERYTHING, ALWAYS

The effectiveness and impact of forensic information are significantly improved when it is accessible in the right place, at the right time, in the right manner, and to the right individuals. Recent advancements in data science, artificial intelligence (AI), and mobile technology have made it possible to conduct robust forensic investigations beyond traditional laboratory settings. Understanding how individuals adapt to new technology in their work processes (human factors) and the introduction of secure, collaborative data platforms with advanced user interfaces enable trustworthy forensic analyses, even by non-experts. Delivering and sharing valuable information from the very start of an investigation, however, requires that ethical and legal frameworks are in place to make the results admissible as reliable evidence in court later in the process.

Fast methods that can be deployed directly at the site of the incident focus on a various types of forensic evidence. This includes chemical trace evidence, such as the identification of drugs or explosives, and biological and biometric evidence for the identification of bodily materials and for establishing the donor's identity. Additionally, there is a growing significance of digital evidence in modern society for reconstructing potential crimes. To handle such evidence effectively, forensic experts must initially detect, visualize, document, and preserve it. Here, too, modern mobile technology can play an important role.

Regardless of the type of evidence or investigation, several crucial prerequisites must be met for a successful integration into forensic practice:

- The deployment of (advanced) technology outside the laboratory necessitates simple methods and uniform processes that investigators intuitively apply correctly. This must be taken into account at the outset of any development. Any misuse is the responsibility of the developer to rectify, requiring a 'return to the drawing board';

- Quality and reliability are key values where it concerns forensic evidence. Central to this is the Chain of Custody, being able to demonstrate ownership at any given time, and the Chain of Evidence, being able to demonstrate the integrity of the evidence in the course of the investigation and analysis. While forensic laboratories are typically established to adhere to stringent quality standards, ensuring the same level of assurance during on-site investigations is more challenging. The goal is to integrate quality control proactively into technologies, methods, and procedures to prevent potential issues;

- The extensive use of rapid on-site methods, coupled with centralized data storage, can also provide new criminological insights with regard to modi operandi or criminal networks and organisational networks. The huge volume of data can be leveraged to improve forensic methods and offer suggestions for detecting, recording, and sampling evidence. Here, too, for such new opportunities, the use of AI shows significant promise.

The dramatically increased computing power of mobile devices now allows for preliminary data processing on-site, with the original 'raw data' always preserved for subsequent data processing and further assessment at a central location. Mobile AI-powered algorithms have seen notable advancements in both speed and versatility. This pre-processing approach enables forensic investigators to streamline initial data transfer, facilitating quicker analyses, and avoiding significant delays. As a result, on-site investigations receive optimal support. In this way, forensic information becomes a natural component in the ongoing investigation, with security and data integrity guaranteed by block chain-based technology, for example.

Education is essential for successful innovation at the crime scene

It's just NEVER fast and easy enough

The deployment of mobile and data technology in the forensic domain will lead to revolutionary innovations in forensic practice:

- Fingerprint identification at the crime scene facilitated by the integration of advanced cameras and communication technology in smartphones. Successful innovation projects by the Netherlands Police show that the future will see the widespread digitization of fingerprint recovery and uploading at crime scenes. The use of hyperspectral cameras provides improved contrast functionality, potentially replacing the invasive application of dactyloscopic powders. Fingerprint evidence collected at the crime scene will be instantly and automatically compared to the HAVANK database and swiftly reviewed by experts. By utilizing fast algorithms, on-site investigators receive real-time information during the ongoing crime scene examination. This information pertains to the quality of collected or scanned fingerprints, as well as potential donors (victims, suspects, witnesses). Since a fingerprint is a biometric trait, extra attention is dedicated to data security and privacy aspects (dactyloscopy).

- Very fast, robust, and large-scale chemical identification of drugs and explosives using portable spectroscopic and mass-spectrometric equipment. Various measurement setups can be linked to a central cloud infrastructure for storage and analysis of data generated on site. Users will be able to upload data and download results conveniently using mobile equipment or a smartphone. The swiftness of this process permits results to be taken into account in making critical decisions, and its robustness ensures admissibility as evidence in court. Building extensive datasets via multiple instruments connected to the same data infrastructure enhances forensic and criminological insights (forensic chemistry).

- The immediate location and quantification of DNA materials at the point of evidence collection, enhances the selection of evidence and the likelihood of obtaining a usable DNA profile. Examples include human-specific DNA staining and the use of selective biosensors for simultaneous detection and classification of bodily fluids. On-site biological analysis will be possible by using upcoming technologies such as fast DNA profiling, direct PCR, microfluidics, and lab-on-a-chip technology. Nanopore sequencing holds potential for detailed DNA analysis, opening up various forensic investigation opportunities in forensic biology, including questions about the perpetrator's identity, origin, or physical characteristics.

- Recovering digital evidence in networks and operational equipment. The ongoing development of 'live forensics' for digital evidence is essential, with a focus on efficiently recording forensic data during incidents. It is crucial to ensure that the continuity of the primary processes remains uninterrupted, or any disruptions are minimized, to make reliable forensic data available to the right people at the right time.

THEME 4

AI AND DATA SCIENCE IN FORENSIC PRACTICE

Data science is an emerging field that is permeating every facet of our society. The integration of increasingly powerful artificial intelligence models aligns with advancements in data acquisition and utilization. This evolution opens the door to many prospects in the field of forensic science.

Simultaneously, there is a growing demand for transparency, requiring experts to consistently communicate their responsible use of such technologies. Consequently, this is a profoundly interdisciplinary domain, involving not only data scientists and forensic experts but also ethicists and legal authorities, all contributing significantly to the discipline.

OPPORTUNITIES FOR INNOVATIVE METHODOLOGIES

Some expertise areas of forensic science are already integrating AI models into their processes. AI is proving valuable in automatically sifting through vast datasets from (crypto)phones to locate photographs and text messages, and experts use software to compare faces and fingerprints. These applications have become feasible due to significant investments by major commercial entities, enabling widespread adoption in forensic practice. However, there is a need for further scientific research to extend these capabilities to fields where commercial applications are less common but where speed and empirical support are equally vital. For instance, this could involve dating injuries in both living individuals and the deceased or identifying concealed graves using aerial photographs.

→ A combination of alcohol, medication, and drugs is found in the blood of a deceased person. What can we say about the cause of death? Or about the cause of specific behaviour in relation to a genetic background ('bad genes' in response to medication: pharmacogenetics) of this person? Or how leaving this person alone whilst unconscious may have contributed to his/her death? Numerous uncertainties are inherent in the intricate toxicological processes, and the available data are frequently characterized by their diversity, scarcity, or limited scope to specific cases. This gives rise to both fundamental and practical inquiries: which probabilities hold relevance, and how can one theoretically address the causal question within this context? How can this theoretical understanding be effectively translated into practical applications? In what ways can data science facilitate access to data and support well-grounded interpretations, even when dealing with relatively limited and heterogeneous datasets?

Data science encompasses a broader spectrum than just AI; it includes a range of innovative methods that can enhance the efficiency and robustness of forensic science. Research into historical success rates can contribute to the identification of relevant evidence and the making of optimal decisions. Fundamental inquiries, such as *'How can we enhance the measurement of evidentiary value and make it more universally applicable?'* or *'What insights can we gain regarding the causal relationship between two events?'* are relevant across various forensic fields. These questions necessitate ongoing advancements in (forensic) statistics and probability calculations.

Finally, fresh perspectives are essential when dealing with criminal cases in which statistical evidence or information is the primary component. Consider scenarios concerning a recurring involvement of a person in a series of incidents, whether they be medical, fire-related, or traffic accidents. It is imperative to ascertain whether this is merely chance or if there exists a causal relationship as well.

RESPONSIBLE METHOD DEVELOPMENT IN PRACTICE

For the development and validation of novel methods or models, open, easily accessible academic datasets are often used. However, the sensitive nature of forensic investigation presents formidable challenges. Not all investigative operations or the data they yield can be openly shared.

OPPORTUNITIES FOR INNOVATIVE METHODOLOGIES

Black-box AI models hold the potential to enhance forensic investigation in terms of speed and efficiency. However, their usage is not without associated risks. The effectiveness of AI systems is intricately tied to how these models are applied, the resulting outcomes, and the level of trust people place in them. It is imperative to conduct research on defining the meaningful role of experts in AI application and identifying the optimal synergy between human expertise and machine capabilities. This necessitates a comprehensive understanding of the advantages and disadvantages of expert judgments and AI in the context of forensic investigation. Moreover, it is essential to convey this in a transparent manner to legal experts, policymakers, and society. Research must also focus on methods to ensure the highest demonstrable validity and reliability without introducing bias, both in expert opinions and AI-generated results.

→ For instance, it becomes imperative to evaluate not only the impact of an AI model but, more importantly, how it is practically implemented. How can centralized and remote data processing enable us to train and assess models without the need to use or share sensitive data? When sharing datasets is unavoidable, how can we accomplish this in an ethical and legally compliant manner, adhering to regulations like the General Data Protection Regulation (GDPR) and the AI Act, while avoiding undue complexity in the innovation process?

→ Consider, for instance, a scenario where the police wish to collaborate with another party to develop an AI method for identifying death threats in chat messages. Is it both desirable and legally viable to provide this external party with extensive samples of chat messages from criminal cases? How can the algorithm effectively learn from this specific data without the data leaving the secure police environment?

→ Consider a scenario where a legal expert has produced a report comparing a suspect's images with surveillance camera footage using AI. The defence counsel argues that this algorithm is unexplainable and, therefore, unreliable, potentially violating the fair trial principle as they cannot mount a defence against a black-box system. In such a case, the judge must make a decision. What scientific knowledge and insights can be utilized to assist in reaching an informed judgment?

AI holds significant promise, but how do we do this responsibly and maintain trust?

THEME 5

DOING MORE WITH FORENSIC INFORMATION

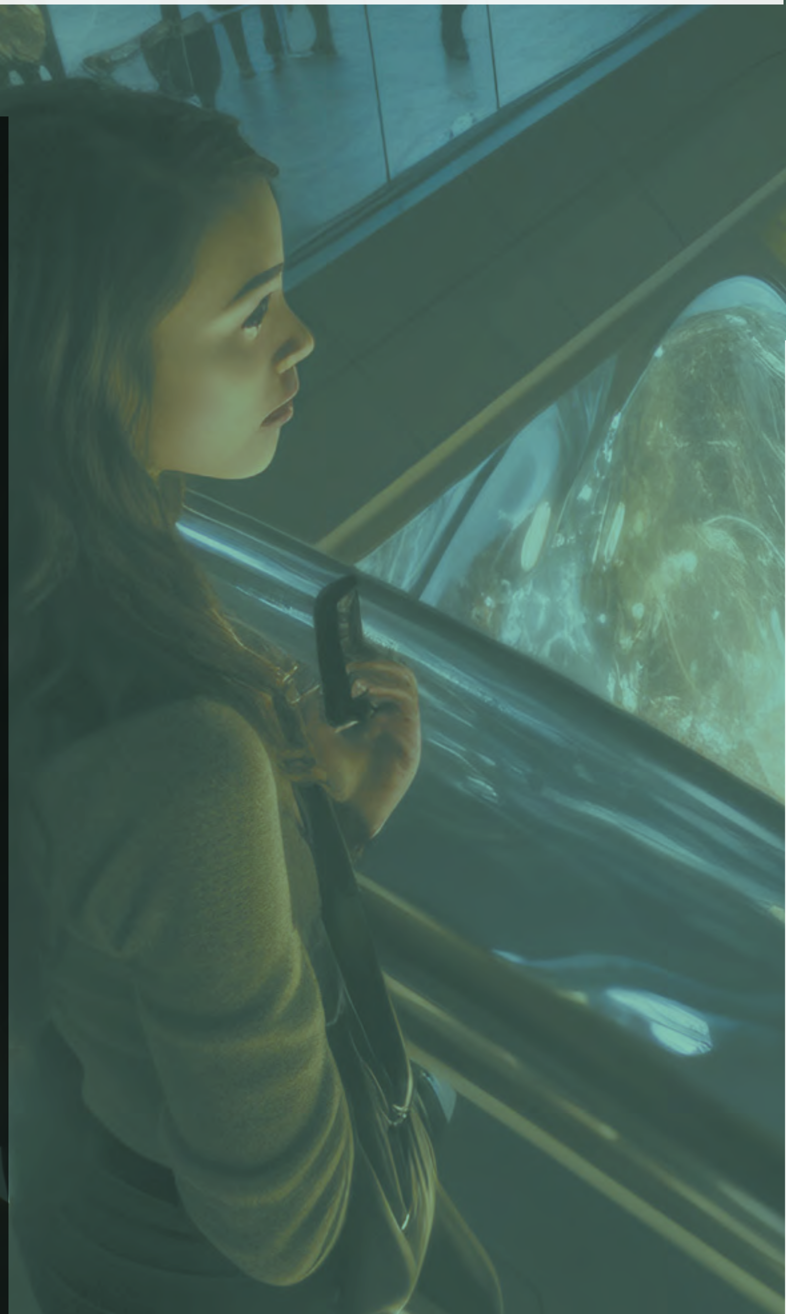
Forensic information from criminal investigations provides unique insights into both criminality in society and the effectiveness of the associated investigation. Thus far, this potential goldmine has barely been exploited due to a focus on individual case investigation ('the n=1 doctrine'). Cross-case analysis of forensic data offers insights into new forms of criminality, such as cybercrime, starting points for combating crime, and opportunities to optimize processes throughout the criminal justice system, from prevention to prosecution.

OPPORTUNITIES

Forensic institutes can analyse the goldmine of data and information they generate through case investigations at the meta-level to optimize both their own processes and processes in the criminal justice system. New **data science** functionalities play an important part in creating unique overviews and insights without requiring an excessive amount of effort from the relevant investigators and scientists. In this way, the primary process contributes to a continuous cycle of optimisation and improvement, and it is possible to support every individual forensic investigation with data from all previous similar investigations. This strengthens, corroborates, and demonstrates the expertise and experience of the forensic experts.

Chemical profiling, also called chemical fingerprinting, is used by forensic investigators to determine whether two or more materials could have a shared origin. This application can be compared to matching DNA profiles or fingerprints. However, the presence of contaminants can also be interpreted chemically. Forensic experts can determine what raw materials were used to synthesize a material and under what conditions. In this way, umbrella analysis of large-scale case flows can yield unprecedented insights into criminal modi operandi. New developments focus on deployment of AI and data science, better statistical justification, building reference databases, profiling new, forensically relevant materials, and chemical identification and determination of any contaminants that are present.

→ An algorithm automatically monitors the results of gunshot residue analyses for trends and patterns. This analysis shows that samples from two police regions are found to contain significantly more gunshot residue particles in the forensic microscopic examination. When asked, police specialists in these areas are found to use a slightly different method to recover gunshot residue based on a joint improvement project executed in the past. Further examination of the method reveals a logical explanation for the better results, and the method is introduced nationwide as the new standard. This national innovation increases the chances of actually sampling and detecting gunshot residue particles that are present.



→ A new AI system for automatically screening large-scale drugs analysis with the NFiDENT system monitors the case flow for divergent profiles. Shortly after it goes live, an unknown contaminant is detected in several analysed amphetamine samples. Detailed research by the experts leads to a new pre-precursor for amphetamine synthesis. After receiving this information, a tactical investigation team discovers a large-scale international supply route for this material. Covert investigation eventually leads to a big illegal production facility. The facility is shut down, those involved are arrested, and a new policy Is introduced to prevent the pre-precursor being imported.

Every forensic investigation substantiated by the collective knowledge from all preceding investigations

Developments in **genetics** are proceeding quickly, offering excellent opportunities in forensic science. A method like massively parallel sequencing (MPS), for example, enables us to reveal many more details of human and non-human DNA or RNA in minimal forensic biological trace evidence. Especially since such methodology is becoming ever more accessible and cost-effective. The forensic possibilities of such large-scale and detailed genetic analyses play an important complementary role compared to the traditional STR (short tandem repeat) DNA profile. This makes it possible to distinguish identical twins or relatives in the paternal line. Moreover, forensic science is succeeding more and more in mapping distant relatives. Combined with criminological, genealogical, and tactical investigation, unsolved crimes have been solved in a spectacular manner in several countries, such as Sweden and America. It is also possible to extract knowledge about biogeographic origin or physical characteristics of an unknown donor in addition to personal identification information. Investigators can study epigenetic variation to obtain valuable information about a donor's age or lifestyle. These aspects are important for the police investigation, but additional information with regard to the interpretation of biological evidence can also be obtained by identifying the biological tissue type in trace evidence and even linking the tissue type to a person. In this way, forensic biology can not only answer the ***who question*** but also make a contribution to the scenario-driven investigation at the activity level *(what, how, when, where?)*.

→ Human remains are found in a clandestine grave and present a mystery. A large-scale comparison of the forensic DNA profile against several national and international databases does not yield a match. There have been no missing person reports that investigators can link to the discovery. The most recent technologies yield more genetic details that can provide an indication about the age and appearance of the victim and their genetic background. In combination with a comprehensive genetic analysis, the trail leads to an Eastern European country. By collaborating with local authorities, the investigators manage to link the investigation in the Netherlands to a young woman who has gone missing in that country. Regular DNA analysis then confirms the victim's identity.

Take a step back and see the bigger picture

Forensic methods can also be developed and deployed specifically for purposes other than the 'traditional' analysis of physical evidence found at the crime scene. So-called **markers** and **tracers** are materials created specifically by forensic experts that can be used in the tactical investigation to map the suspects' activities and demonstrate involvement in criminal acts. A wider application of forensic knowledge and expertise is possible in close collaboration with the (digital) criminal investigation unit, but also with other scientific domains, such as psychology, economics, and social sciences (including criminology). And vice versa insights from these domains can help deploy forensic knowledge and expertise more effectively.

CHALLENGES

The wider deployment of forensic methods often demands a multidisciplinary approach that is data driven. Here, a big challenge is that this requires a combination of data that is available selectively and within different domains. Extracting and linking such data from systems run by several partners in the criminal justice system is usually not an easy process, not just technically but also legally and ethically.

As discussed in the previous theme, applying the academic open data standards is more complex in the judicial system, even though it is especially the data from forensic practice that is necessary to demonstrate added value and optimize methods as well as ensuring quality assurance. In this context, quality assurance also has a legal component that guarantees that innovations can be applied in criminal law. The implementation of new forensic investigation methods with the aid of data science also requires **transparency** and **understandability**.

Sharing forensic information from cyber incidents is very important, but it is also a huge challenge due to the required public/private collaboration. The collaboration between forensic professionals, investigators, and the authorities can and must be improved in the future. Today, knowledge about cyber incidents is shared with stakeholders through the National Cyber Security Centre (NCSC). They collect and share information to prevent, detect, and combat cyber incidents. Sharing information and methods for digital forensic investigation is primarily of a practical nature and incident driven. The High-Tech Crime Team and the police's regional cybercrime teams are the first point of contact for private security service providers in the case of incidents. Even so, it is important to strengthen the scientific knowledge in the field of cyber forensics among judiciary experts, too.

THE NFOA PROCESS

How exactly did the Dutch Forensic Research Agenda come into being and who contributed to its development?
In the first phase, an online survey was submitted to 227 scientists, forensic experts, and professionals in the Dutch criminal justice system. The survey was completed by 106 respondents in the summer of 2020. We obtained valuable insights into the development of fields of expertise, expected new scientific and technological methods in forensic investigation, and expected social and criminological trends and their impact on criminal modi operandi and forensic evidence patterns. Early 2021, we reported on the results of the survey and shared them with all of the participants. The company FutureConsult coordinated the execution and reporting of the survey on behalf of the NFI and CLHC. Based on the results, the second phase was initiated in 2021 with the organisation of theme-based workshops in partnership with the Lorentz Center. The aim of the workshops was to explore a domain-specific, interdisciplinary or more socially focused theme from the survey in greater detail with a relatively small group of scientific and professional stakeholders in the criminal justice system. The COVID-19 epidemic forced us to postpone the workshops for more than a year. Eventually, eleven on-site workshops were held at the Lorentz Center on Leiden University's campus in October and November 2022. In each of these workshops, some 20-25 participants established valuable directions for research and forensic scientific insights. Each workshop was moderated by a team of 2 to 3 persons: a workshop leader, a workshop co-lead, and a workshop coordinator. The Lorentz Center provided support in preparing the workshops, sometimes deploying specific work methods (Open Space Technology). Individual contributions by the participants and the outcomes of the workshops were shared without restrictions. All teams created a report detailing the outcomes between November 2022 and January 2023. In this way, the Lorentz Center workshops constituted the basis for the NFOA Dutch Forensic Research Agenda as it stands today.

A group of writers consisting of representatives of the workshop teams created the agenda between February and August 2023. The themes were written by smaller sub-teams. As such, all of the members of the writing team are also the authors of this agenda. After internal alignment and approval, the draft version was shared with all workshop participants who were allowed to respond and reflect. The agenda's AI-based graphic design is created by Matterhorn Amsterdam. The website associated with this publication will feature the outcomes of the Lorentz workshops that constitute the basis for the NFOA. The research agenda was originally written in Dutch, this English version is based on the translation by the Taalcentrum VU. Martin White assisted the NFOA writing team in further improving the accuracy and readability of the English text.

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The NFOA was created as an initiative of the Co van Ledden Hulsebosch Center (Arian van Asten, Maurice Aalders) and the Netherlands Forensic Institute (Annemieke de Vries).

This agenda was made possible by contributions from many scientists, experts, and professionals in the criminal justice system, initially with over 100 completed surveys from the forensic field. The results of this survey, reported by FutureConsult, constituted the basis for the eleven workshops that were organized in collaboration with the Lorentz Center. The workshops were moderated by Didier Meuwly, Erwin Mattijssen (Biometrics and Pattern Recognition), Zeno Geradts, Harm van Beek, Meike Kombrink (Digital Forensic Investigation), Titia Sijen (Forensic Biology), Maurice Aalders, Arjo Loeve, Leah Wilk (Forensic Physics), Arian van Asten, Jaap van der Weerd, Mirjam de Bruin-Hoegee (Forensic Chemistry), Maurice Aalders, Arian van Asten, Annemieke van Dam, Ruben Kranenburg (Mobile Technology), Christianne de Poot, Madeleine de Gruijter, Rosanne de Roo (Intelligence & Human Factors), Bas Kokshoorn, Charles Berger, Rosanne de Roo (Activity Level), Hans Henseler, Christian van der Woude (Cyberforensics), Mattijs Koeberg, Hannah Tops, and Meike Kombrink (Subversive Crime).

The results of the workshops in turn constituted the basis for the definitive agenda before you. The text of the agenda was compiled by the 'NFOA writing team' with representatives from all the workshops: Maurice Aalders, Arian van Asten, Harm van Beek, Katharina Draxel, Zeno Geradts, Hans Henseler, Mattijs Koeberg, Bas Kokshoorn, Arjo Loeve, Erwin Mattijssen, Didier Meuwly, Christianne de Poot, Titia Sijen, Marjan Sjerps, and Rolf Ypma.

The readability and accessibility of the agenda were further improved by the recommendations of Meike Willebrands of the Netherlands Forensic Institute and Martin White. The NFOA leaflet (digital and physical) and associated website were designed by Umali Pattirua and Bob van den Berg at Matterhorn.

THE DUTCH FORENSIC RESEARCH AGENDA

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