TECHNICAL ANNEX

1. S&T EXCELLENCE

1.1. Challenge

1.1.1. Description of the Challenge (Main Aim)

The main objective of this Action, entitled *'MULTi-modal imaging of FOREnsic SciEnce Evidence (MULTI-FORESEE)- tools for Forensic Science'*, is to promote innovative, multi-informative, operationally deployable and commercially exploitable imaging solutions to analyse forensic evidence. This includes but is not limited to fingermarks, hair, paint, biological fluids, soil, fibers, documents, digital evidence and living individuals. Imaging technologies will include physical, optical, mass spectrometric, spectroscopic, chemical imaging, digital forensic and advanced visualisation techniques (eg. computer vision, augmented reality). The use of imaging technologies enables multiple information to be captured in one analysis, from a single specimen/evidence; information are more easily conveyed and understood allowing a more rapid exploitation. The 'enhanced' value of the forensic evidence is conducive to more informed investigations and judicial decisions, thereby contributing to both savings to the public purse and to speedier and stronger Criminal Justice Systems (CJS). This fact is related to the digital nature of the evidence that could be shared, guaranteed and preserved over time. Moreover, lack of "knowledge sharing" and of standardised terminologies, ontologies, protocols and training has prevented these technologies from being exploited at their full potential by the End Users. End Users already employ imaging techniques for the analysis of security features and evidence tampering (e.g. questioned documents, footwear marks, ink dating, vehicle paint layer analysis, face recognition etc.). However, it is their view that *"the technological improvement of the present imaging systems and the development of innovative and multi-modal systems will significantly contribute to a more effective response in a shorter space of time".* However, to date, a lack of communication between three key players Academia, Industry and End Users has negatively impacted on the transition from laboratory to operational deployment. This Action will therefore use the unique COST networking and capacity-building capabilities to achieve the following overall aims: **a)** connect excellence throughout Europe (and worldwide) amongst Academia, Industry End Users to synergistically engage in facilitating knowledge exchange and advance imaging technology; **b)** create a European scientific and technological legacy by training and providing networking opportunities for Early Career Investigators (ECI); **c)** increase the impact of multi-modal imaging technologies research on policy makers, regulatory bodies, CJS, Crime Scene Investigators (CSI), crime laboratories and on the private sector, through establishing and disseminating standardised terminologies, ontologies, protocols; **d)** apply the Integrated Digital Forensic Process Model IDFPM for data acquired by multi-modal imaging, to generate exchangeable standard data formats (e.g. JSON); **e)** enhance knowledge sharing with the implementation of the Dynamic Knowledge Management System as framework for End-Users. COST funding is crucial to achieve the above aims by supporting activities such as meetings, conferences, training schools, round-robin studies and Short Term Scientific Missions (STSM). These activities will contribute to conquer the aforementioned challenges and will provide a legacy to Europe to advance knowledge and lead to the deployment of innovative and implementable imaging forensic science.

1.1.2. Relevance and timeliness

The advancement in forensics that the COST Action will bring about lies primarily in the opportunities to effectively innovate and more rapidly impact upon the recovery, quality, quantity and the communication of forensic information through multi-modal imaging technology by: **1.**

Broadening the intelligence that can be gathered from forensic evidence (including digital) using state-of-the-art imaging and multi modal imaging technologies, provided by Academia and Industry. Examples of intelligence include amongst other (a) *identification and comparison* of individuals or objects (e.g. fingermarks, footwear marks, bodily fluids, faces, vein map, registration plates, erased numbers on firearms), (b) *age estimation* of trace evidence (e.g. biological stains, fingermarks, inks), (c) *typing and classification* (i.e. discrimination of fibres, paint and biological fluids), (d) *human categorisation* (e.g. sex, age, ethnicity, diet, lifestyle), (e) *forgery* (documents), (f) *detection and/or quantification of substances of forensic interest* (e.g. drugs, warfare agents, bodily fluids, poisons) in trace evidence, (g) *geographical mapping/provenance* (e.g. hair, soil, fingermarks, bodily fluids) and (h) *localisation* (e.g. bodies in movement, objects). Intelligence from these types of evidence will be recovered through a combination of digital forensic, chemical, mass spectrometric, physical, optical and spectroscopic imaging technologies, integrated with ICT solutions. **2.** Ensuring that the imaging methodologies fulfill the requirements for evidence collection, examination and admissibility in European Courts of Law. **3.** Building capabilities for multi-modal imaging platforms enabling complementary information to be obtained from forensic evidence (including digital) and to be easily but comprehensively accessible, sharable and conveyed. **4.** Developing multi-modal imaging devices to promote their use directly at the crime scene (e.g. improved portability, reduced costs, acquisition time, connectivity); some portable multi-modal biometric identification devices are already available on the market (eg. MSite from Human Recognition). Specialist Investigation Vehicles have on-board labs, for example the “Schengen-buses” performing basic functions of multimodal imaging using thermal cameras with laser range meters for tracking and identifying migrants; in 2014, The Hungarian National Police initiated the design of handheld and/or portable Raman-spectroscopes for such crime scene inspection vehicles (SciAps SWIR, IDRaman mini 2.0, Progeny X2); though these systems still need systematic/concerted evaluation, the use of handheld Raman Imaging systems was reported to be widespread used around the world already in 2001. In the mass spectrometry field, Prosolia Inc. (US) is pushing the boundaries in the miniaturisation of portable DESI spectrometers. Therefore, there is strong evidence that portability is an achievable goal and it is entirely realistic that this Action can contribute to its achievement. *The Action fits the COST statement of mission; it is relevant and topical* since technologies such as Mass Spectrometry Imaging (e.g. MALDI, SIMS, MeV SIMS microPIXE, microRBS, microERDA and DESI), spectroscopic imaging (e.g. hyperspectral, Raman, Infrared and thermal imaging and X-Ray imaging), and chemical imaging (e.g. fluorescent tags, elemental imaging SEM-EDX, XRF) have proven their ability to provide robust forensic intelligence, rapidly and, often, with minimal invasiveness. However, large amount of data render any technology/multi-modal platform ineffective and/or very expensive, due to manual processing and data sharing difficulties; the digitalized data formats of hard evidence are also developing the same gap between availability and processing ability. These issues can be addressed with digital forensics. Emerging Deep Learning technologies based on neural networks have been exceptionally successful in overcoming traditional limitations of computer vision approaches but their applications in forensics are still very limited. The IDFPM approach will be pursued as it will allow effective data processing and integration requiring less resources (same platform for both types of evidence) providing better chances for finding correlations patterns amongst the different data/pieces of evidences. During the Action, the scientific dialogue will be flexible in structure remaining open throughout its lifetime and allowing new members to join. Thus, realignment of strategic objectives may occur as the Action progresses. *This Action is timely*; a lack of effective interfacing between different sectors of science and technology is still a barrier to translational science and particularly in forensic science, which also suffers from lack of dedicated funding. For this reason, innovation in this field has been slow with imaging techniques not yet utilised at their full potential. Academia has developed cutting edge instruments/methodologies operating at exquisite sensitivity providing intelligence at a molecular level. However, lines of communication with the relevant End Users have not sufficiently evolved to warrant proof of concept technologies/kits/methodologies societal and/or economic impact. Industry, in contrast,

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has a much more "realistic R&D approach" as only commercially viable products would be developed; though, the lack of sophisticated facilities and involvement of academics with the appropriate expertise has slowed progress down. Also, only partially met needs/requirement of End Users have negatively impacted on the development and uptake of products. Therefore this COST Action will directly benefit the expansion/robustness of the industry commercial portfolio. Finally, although End Users have knowledge of desirables, they often do not have access to/awareness of the state-of-the-art imaging technological developments, due to insufficient interaction with the Industry and Academia. "Fingerprinting" is exemplary in this respect as this process has remained unchanged for over 100 years; in the UK, only recent interactions between Academia and the Home Office/Police and between Industry and Academia has promoted exploitable research for gathering additional intelligence from fingermarks and for visualising them on challenging specimens respectively.

1.2. Specific Objectives

1.2.1. Research Coordination Objectives

The main goal of this COST Action is to build synergies between relevant cutting edge research within currently employed imaging technologies and those under development for operational and commercial exploitation. This will enable the Action to address issues of global forensic relevance and scientific importance by fulfilling the following objectives: ***1.*** *Characterizing the imaging technologies applied to different types of trace evidence* in terms of sensitivity, robustness, versatility and compatibility. This objective will be achieved and measured through appropriate round-robin studies. This will: **a)** inform on the state-of-the-art capabilities; **b)** establish the amount and reliability of information extractable from a single type of evidence and **c)** provide indications on the combination of compatible techniques for multi-modal imaging. This objective is timely because its fulfilment establishes the starting point, the direction and the rationale for further technological developments. It is anticipated that Standard Operating Procedures guidelines will also be developed for sharing worldwide; ***2.*** *Identify the needs for further instrumental and software development.* This objective will be achieved through workshops and round-robin studies which will highlight the desirables for enhancing the value and communication of the information as well as allowing operational deployment. This objective is measured through reports documenting issues, desirables and proposed solutions. ***3.*** *Disseminate and integrate complementary imaging techniques/expertise applied to different types of forensic evidence*. Within this objective, the network will share knowledge and expertise to maximize outputs from internal funding by improving the coordination of isolated parallel efforts. Beneficiaries will be: **a)** academics, as they will receive feedback on suitability of research developments, desirables and legal and operational requirements, thus further driving innovation and pathways to impact; **b)** End Users (Law Enforcement Agencies (LEAs), police forces, crime scene units and crime laboratories, prosecutors, magistrates and policy makers) as they will be informed on the analytical requirements for the recovery and preservation of evidence as well as on the latest exploitable technological opportunities and **c)** Industry (manufacturers, software engineering, service providers) as they will strengthen and expand their commercial portfolio thanks to a collaborative dialogue with both Academia and End Users. This objective will be achieved through both COST Action facilitated networking activities and dissemination as outlined in section 2.2.2. This is timely and relevant to the nature of the Action as it addresses the current lack of interfacing between the three key players, which, as a group, will be the driving force towards operational exploitation of multi-modal imaging technologies for forensic evidence. The objective will be measured by the level of engagement of the three key players as well as through scientific publications, primers and on key relevant topics demonstrating joint efforts.

1.2.2. Capacity-building Objectives

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In order to empower the fight against crime making the transition "from the laboratory to the field", the following objectives must be fulfilled: ***1.*** *Train scientists in the basic practical aspects of crime scene and crime lab investigations as well as into the basic legal requirements for the admission of the evidence in European Courts.* This will ensure the understanding of the operational and investigative protocols and will in turn steer Academia and Industry into conceptualising and developing feasible and exploitable imaging/multi-modal imaging methodologies. This will be a novel opportunity since Academia and Industry's general lack of awareness of legal and procedural constraints may prevent evidence to be admitted in court. These aspects will be considered at national and EU levels to establish and share best practice. The fulfilment of this objective can be monitored through the delivery of the appropriate activities (workshops and training schools) and can be measured by the reporting of the modifications to practice, as a result of this training, in workshops/conferences/papers/web resources. ***2.*** *Train CSI in methodologies for the collection and storage of evidence, within the constraints and flexibility allowed by their protocols, enabling imaging technologies to be applied*. This will provide researchers with representative test samples to improve and adapt imaging methodologies whilst suitably preserving the evidence and the chain of custody. Through COST networking with End Users and training opportunities, Academia and Industry will be involved in pseudo-operational trials to develop technologies in the field, through integration with under/post graduate training programmes. The fulfilment of this objective is clearly both novel and timely as crime scene samples are rarely delivered to specialised analytical centres or they are delivered in less than a suitable condition for the imaging analysis to occur at their full capabilities. The fulfilment of this objective can be monitored through the delivery of the appropriate activities (workshops and training schools) and impact can be measured by the number of pseudo-operational trials taking place as a result of this training. ***3.*** *Improve the conversion rate of laboratory settings technologies into operationally deployed technologies by engaging in a "practical" dialogue with the relevant Industry*. The fulfilment of this objective will provide industry with insights into state-of-the-art knowledge, needs and requirements for operational imaging technologies thus developing their portfolio, strengthening excellence and increase market competitiveness. This will contribute to incentivising prototyping for operational use. The fulfilment of this objective will drive R&D in a much more focussed, robust and successful fashion, thus effectively assisting in scientific investigations and boosting Europe's economy and leadership role in technological innovation, ultimately having societal impact. The fulfilment of this objective can be monitored through the delivery of the appropriate activities (workshops) and achievement can be measured by the number of prototypes and internal industrial R&D projects established as a result of this engagement.

1.3. Progress beyond the state-of-the-art and Innovation Potential

1.3.1. Description of the state-of-the-art

Emerging imaging technologies applied to forensic evidence are characterised by various degrees of quality/quantity/transferability/sharing of information, spatial resolution, reliability, ease of interpretability, sensitivity, invasiveness/destructiveness, portability, robustness and compatibility. There is scope to push current technology specifications and for integrating multiple imaging technologies through collaborations with relevant academic expertise and the appropriate industrial partners whose incentive will be more efficient and novel products for their portfolio. Crucially, there is an underlying lack of standardisation in the analytical protocols for the acquisition, processing and reporting of imaging data. Software packages integrated with statistical analysis for processing the imaging data are missing or not specific to the type of evidence investigated. This naturally leads to incomparable data between centres using diverse methodologies and hinders the development of integrated multi-modal imaging platforms. Quantitative imaging for trace evidence is still in its infancy with few published reports. The determination of the age of the evidence has a huge forensic value to establish the temporal location of a suspect but despite decades of effort, there is no currently adopted methodology for this purpose; though hyperspectral

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imaging has proven so far to be the most informative and accurate technology for the determination of the age of bloodstains , further work is required to enable operational deployment and portability.

1.3.2. Progress beyond the state-of-the-art

This COST Action will promote the establishment of a controlled vocabulary and ontologies for efficient and productive communication between Academia, End Users and Industry.
The application of the IDFPM will break the barrier between digitalised hard evidence (multi-modal images) and digital evidence process, giving End Users a toolset with simplified approach for future challenges. Knowledge sharing will be boosted by deployment of Dynamic Knowledge Management System, aiding in converting large datasets into "operational knowledge", as well as generating a Social Network of Knowledge. The Action will create the right networking opportunities with Industry to push the boundaries of current instrumental and software specifications applied to forensics. Improvements to spatial resolution, processing and communication of the information and, where feasible within the duration of the Action, portability, may significantly drive the technological implementation in forensic casework. This Action will offer a unique trustworthy environment to share data and protocols through dissemination, round-robin studies and STSM thus enabling a) each laboratory to experience and integrate new approaches and b) the establishment of standardised imaging methodologies across Europe that will withstand court scrutiny.

1.3.3. Innovation in tackling the challenge

Innovation lies in the development of communication and business routes to innovate, improve and operationally deploy imaging technologies. Through round-robin studies and pseudo-operational trials, new knowledge will be acquired on the full potentialities, as well as limitations, of the imaging technologies applied to forensic evidence which will be exploited to drive innovation. The link with the End Users is perhaps one of the most innovative features of this Action and it is essential to devise operational technologies/methodologies. Training of both scientists and CSI will naturally increase knowledge and understanding of technologies, processes, needs and requirements for casework, thus enabling imaging technologies to access the market, governments and society. Developments will be pursued on both Industry Imaging products (collaboration with Academia using their equipment and expertise) and Academia processes/concepts/technologies (translational collaboration with Industry) using available internal funding resources. In this light, exploitable and innovative improvements are foreseen in instrumentation, software, methodologies and End Users' operational protocols . It is anticipated that one of the most innovative and economically beneficial deliverables will be the establishment of collaborations to design IT tools to process specific imaging data acquired from specific types of evidence to improve the quality, comprehensiveness, communication and sharing of the information. New workflows will be conceptualised whereby multiple imaging technologies can be compatibly applied in a series for multi-modal imaging of forensic evidence.

1.4. Added value of networking

1.4.1. In relation to the Challenge

Translational science in this area may only be granted through a synergistic approach. Academia adds value to the network by sharing cutting edge knowledge and state-of-the-art facilities; End Users will shape and channel innovation as they are the main repository of the knowledge with respect to operational and legal requirements; Industry has the scientific expertise and the business vision to turn "an academic idea" into an actual "product". An additional value of this network will be the identification and adoption of a "common language" between different sectors

to reach a common goal with individual benefits and impact. The networking activities proposed in this Action will promote a positive cycle of experimenting, learning, refining and adoption of such a common language enabling a deep understanding and knowledge of each other's capabilities, expertise, requirements and needs. Technological developments will be boosted by bringing together distributed expertise and technologies within the relevant Working Groups (see Section 3). Additional European mobility of ECI from the different sectors and disciplines will consolidate the network and contribute to the sharing of best practice, knowledge and further drive innovation. Such concerted effort at a European level will build a tradition of interfacing and communication providing legacy for the permanent establishment of such a network. This will, in turn, help Europe to maximise benefits and impact on the economy, on the CJS and ultimately create a safer society by channelling investments and resources into the most robust, applicable and commercially exploitable imaging forensic science. Finally, such a network will help establish appropriate, interdisciplinary and multi-sectorial collaborations to build stronger future bids further promoting technological innovation by integrating sound, innovative and impactful imaging science capable of withstanding Court Scrutiny across Europe.

1.4.2. In relation to existing efforts at European and/or international level

The application of advanced imaging techniques is a field with a relative low level of activity networking in Europe and the Action is unique. The broad scope of applications presented in this Action has not been addressed to date due to the challenges presented in establishing contacts and the difficulties to convert innovation to deployment when any of the three sectors amongst Academia, End Users and Industry did not engage in the dialogue. The only three examples of commendable forensic network efforts at an European level are: a) a previous COST Action on Forensics and Biometric systems (Action IC1106), b) SPIRIT (www.spirit-ion.eu), an integrated infrastructure linking ion beam labs across Europe and c) the European Network of Forensic Science Institutes (ENFSI) devoted to "share knowledge, exchange experiences coming to mutual agreements in the field of forensic science". This COST Action resonates with the efforts of reaching out for and connecting European Excellence. The present Action seeks to capitalise on SPIRIT and Action IC1106 and complement ENFSI specifically within the development and implementation of multi-modal imaging
techniques applied to forensic evidence. This COST Action has a greater "inclusiveness" character than ENFSI due to a wider participation of both Academia and Industry and will inform the work of ENFSI. STSM are also an additional feature which is missing within the ENFSI network.

2. IMPACT

2.1. Expected Impact

2.1.1. Short-term and long-term scientific, technological, and/or socioeconomic impacts

This Action clearly impacts on Europe's safety and social welfare (societal impact), by empowering the CJS through: **a)** Improved Capabilities and Operational Effectiveness (medium to long-term impact); **b)** Increased confidence and morale of detectives (medium to long-term impact); **c)** Increased confidence of the civilians in the policing authorities (long-term impact) and **d)** a standing eco-system of knowledge for End-Users (long-term impact). The multi-informative nature of imaging/multi-modal imaging technologies (and the ease in conveying/understanding information), to retrieve intelligence from various types of forensic evidence will offer detectives additional and/or more specific investigative leads. This will contribute to a greater drive, morale and confidence in solving a case, thus impacting on operational effectiveness of the End Users whose capabilities will be enhanced by reducing time and wastage of human and financial resources. More robust forensic evidence, more confident and driven detectives and increased capabilities and operational

effectiveness will contribute to stronger and speedier course of justice, thus leading to a renewed confidence in the overall CJS; civilians' confidence in the policing authorities will also be conducive to a higher rate and promptness in reporting crimes, with civilians being more collaborative in supplying relevant information. This in turn would reduce delays to the course of justice, enable crime prevention and/or allow crime scenes to be accessed by CSI in a more timely manner thus reducing evidence tampering, destruction or degradation. The Action will also benefit Europe's scientific and technological innovation as well as economy because it will directly impact on: **a)** effective opportunities for collaboration between the three key sectors represented in the network (short-term impact); **b)** comprehensive outlook of technological potential and applications (medium-term impact) and **c)** provision of guidelines and best practice (medium-term impact). Through this Action's joint activities, knowledge sharing efforts and mobility of young talents working on projects of common interest, will further increasing opportunities for new collaborations. This will be a crucial and speedier drive for technological innovation. In turn, it will facilitate the interfacing with Industry pitching research that has been cross-validated and protocols that have been optimised. The Industry will therefore need to spend fewer resources on R&D and can channel efforts into prototyping and market launch. Commercially exploitable innovation will lead to widening the Industry sales portfolio with medium-term impact on their profits as products will have benefitted from the input of End Users who, therefore, will likely endorse the products. Exporting this portfolio outside Europe is a foreseeable outcome, especially through inviting International Partner Countries such as Australia and the US; this opportunity will additionally boost the European economy. The activities and networking opportunities offered by this Action will enable a deep exploration of the capabilities and range of application of imaging protocols/technologies (impact on academia). This comprehensive outlook will be hugely important to identify gaps in knowledge, limitations and also needed appropriate HD and SW instruments (impact on Industry) enabling adoption of the technology in the field (impact on End Users). Moreover, increased knowledge on the most effective and reliable ways to employ imaging technologies to enhance intelligence gathered from the forensic evidence, will enable the provision of guidelines and best practice. These will be European documents to be made public to the wider forensic community thus likely widening the economic impact and capabilities in Europe and worldwide and contributing to Europe's reputation of promoter of forensic technological and scientific innovation.

2.2. Measures to Maximise Impact

2.2.1. Plan for involving the most relevant stakeholders

The most relevant stakeholders in this Action are End Users and Industry. The outputs of this COST Action will greatly benefit End Users by enabling the operational and innovative use of fast, multi-informative and robust Imaging and Multi-modal Imaging Technologies for the analysis of forensic evidence. The drive fuelling their participation is the governments' long term vision to maximise resources by reducing costs while giving course to more informed and robust investigations/judicial debates. *To engage End Users, activities such as workshops and round robin studies are organised around priority challenges, identified by End Users themselves, that can be addressed by the use of imaging technologies*. These activities will evolve through the course of the Action to include pseudo-operational trials in collaboration with Academia and Industry. Annual conferences will be thematic and the active participation of LEA, forensic experts, lawyers, data protection/ethics policy makers will be constantly pursued. The application to STSM will be open to End Users: specifically to CSI, forensic investigators and crime lab scientists. STSM will enable them to be trained and to integrate their protocols and procedures facilitating the application of imaging and multi-modal imaging techniques. Industry has an obvious drive, that is, the expansion of sales portfolio. They will be involved: **a)** within the annual conferences as presenters reporting on their technological innovations; **b)** in workshops and round-robin studies to support collaborative studies and contributing to brainstorming around key themes relevant to them and **c)** in STSM as hosts of ECI upon appropriate agreements that will be put in place to protect

intellectual property. Though not the most immediate stakeholder, Academia has great interest in keeping engaged with such a network in order to progress and develop research through stronger multi-disciplinary bids, accounting for the legal and operational requirements for adoption of imaging technologies, as well as to contribute to the formation of the next generation of scientists. This will maximise the impact of their research. The Action intends to widen participation extending it to academics and researchers having expertise in the relevant technologies but who have not applied them to forensic evidence. Some members of the network have sought to expand their application fields and look forward to actively joining the forensic community. A fresh outlook from such participants will certainly benefit the network as a whole. In order to keep engaged Academic participants of the Action and to involve new participants, triggering and strengthening collaborations inter-Institution and across Europe, annual conferences will be one of the most appropriate activities. Conferences agenda will be sent to the relevant members and, using the strong European connections of members of the present network, it will be possible to reach out for additional relevant participants. A cementing activity will be the use of STSM as they will enable ECI to train and acquire/exchange knowledge on the most relevant technologies to them, contributing to their professional development and career through short collaborative projects across Europe. This will no doubt boost joint bids, generating a virtuous circle self-fuelling subconsortia created during the COST networking activities. This Action also intends to capitalise on a previously successful training schools on biometrics (Action IC1106) by revising the content to make it relevant to this present Action in its entirety.

2.2.2. Dissemination and/or Exploitation Plan

Dissemination of knowledge will be undertaken via different routes (and according to the different stages of the COST Action) such as: **a)** conferences, workshops, round-robin studies, training; **b)** publications including guidelines and best practice manuals; **c)** Public and Media engagement. This will enable outreach of different target audiences as well as diversifying the involvement of expertise. As an example, in the case of Industry, different IT solution and communication companies may contribute through the development of acquisition/processing software, integrated platforms with statistical modelling, data reduction and transmission, dedicated servers for data sharing, management and storage at different levels of a scale ranging from proof of concept to prototype. Different manufactures may contribute through the development of sensors, heavy equipment, portable devices, instrument parts and forensic and legal services. Improvements in these areas will boost sensitivity, throughput, robustness, quality of information, education/training opportunities and generally contribute to technological translation for operational deployment. Route a) will enable knowledge sharing and dissemination on both state-of-the-art imaging technologies/application and progress as a result of the Action's activities. Knowledge exploitation is foreseeable through uptake by Industry and the opportunity for new collaborations for the development of either existing/emerging technologies/processes for the analysis of forensic evidence. Training of CSI and academics will both boost knowledge transfer and contribute to knowledge exploitation through pseudo-operational trials and Industry specific project collaborations (which will depend on available internal funding). Through route b) publications are intended as scientific peer reviewed papers (likely to originate primarily from STSM and from round-robin studies), applications notes (collaboration with Industry), progress reports (Working Group activities) and guidelines/best practice documents. This route will enable dissemination of the Action's outputs on a much larger scale thus contributing to (i) up-to-date knowledge of imaging systems, integration and application for multi-informative analysis of forensic evidence, (ii) encourage participation of other Countries, (iii) significantly contribute to PhD level and ECI professional development and (iv) promote best practice to rapidly implement these technologies/processes in Forensic Providers laboratories. Route (c) acknowledges the importance of public dissemination. There is media and public attention on the topic covered by this Action and this has no doubt helped with the public perception that the policing of the countries

involved is forward thinking and keen on scientific innovation to enhance people's safety. This circumstance helps warranting this Action's societal impact through a virtuous circle of trust in the Country's LEA and CJS contributing to more prompt reporting of crime. Impact of dissemination (measure of success) will be assessed by monitoring the growth of the network, website hits and member subscriptions as a result of each type of dissemination event, scientific collaboration being established, collaborative bids submitted and, at the end of this Action, through the crime reporting statistics in each European Bureau. Knowledge generated IP rights is a foreseeable outcome (see Section 3.1.4); within the constraints of the principles set out in "Rules for Participation in and Implementation of COST Activities", the interested parties will communicate to the Management Committee, MC, (through the Working Group (WG) Leaders) the intention for a collaborative project. The MC will facilitate/monitor the drafting and signing of Non Disclosure Agreements and, where necessary, specific agreements detailing the terms, rights and the entitlement of each party involved in the collaborative project.

2.3. Potential for Innovation versus Risk Level

2.3.1. Potential for scientific, technological and/or socioeconomic innovation breakthroughs

This Action aims to exploit COST framework and support to maximise innovation and breakthroughs within the challenge described. Classically, research is carried out predicting impact on End Users. In this Action, End Users will play a key role and provide their input at the developmental stage, through their active participation into the activities planned, taking a leading role when appropriate (e.g. in training, workshops and pseudo-operational trials). This inclusion/engagement strategy alleviates the risk of not achieving socioeconomic impact due to unmet CJS needs and requirements; it will also impact directly on their operational protocols for collection, transportation, *in situ* analysis and handling of the evidence to permit the application of multi-modal imaging techniques. There is a strong emphasis placed on the active involvement of ECI from any of the sectors in the Action. This will manifest in dissemination, workshops and round robin-studies as well as through the implementation of STSM. These activities will ensure young talent mobility, professional and scientific development thus also "seeding" good practice and forefront knowledge exchange across Europe, especially important for those Countries that are less research-intensive. Genuine collaboration opportunities, strengthening research and increasing the potential for scientific and technological innovation, and potential outputs stemming from STSM will minimise the risk of data replication. The constant consideration of the importance of protecting intellectual property, through prompt signing of appropriate agreements prior to the start of the research work, will ensure a productive and trustworthy dialogue between the Academia and the Industry; this will greatly impact on new concepts/technologies, whilst minimising the risks of misuse of information thus damaging business for either of the two parties. Building an IT capability to ensure an efficient data sharing and secure handling of the data is also paramount within the Action (see Sections 1.1.1, 1.1.2, 1.3.1, 3.1.1. and 3.1.4). The role of the MC and of the WG Leaders and the mechanisms put in place to monitor activities, milestones and impact (See Sections 2.2.2 and 3.2) will ensure coherence in the: a) evolvement of the Action and its activities; b) timely delivery and milestones capitalisation; c) maximisation of impact and d) minimising a "stall" in the COST Inclusiveness Target Countries.

3. IMPLEMENTATION

3.1. Description of the Work Plan

3.1.1. Description of Working Groups

Working Group 1. - Best practice guidelines for application of imaging protocols/technologies

-OBJECTIVE 1: Identification of the state-of-the-art of technological/methodological Imaging capabilities and application range; DELIVERABLE: generation of decisional tree flowcharts indicating the most appropriate/efficient technology to adopt in context as well as multi-modal capabilities. The flowchart will be devised according to the type of evidence and information required including quantification, sensitivity, robustness, resolution and need for portability (MILESTONE 1.1). Relevant ACTIVITIES will be undertaken such as: **a)** STSM (to train talents, work on small projects pertinent to the objective and share knowledge), **b)** a technology intercomparison round-robin study, in which grading of the methodologies/protocols/technologies will be undertaken on the basis of the data generated, according to specific criteria (e.g. speed, reliability, quali/quantitative level of information) including level of preservation of the integrity of the evidence, **c)** pseudo-operational trials in order to test methodologies and technologies at relevant scenes and on relevant samples and d) a workshop to brainstorm and draw conclusions on the results of the different activities as well as to identify "desirables" for each technology/methodology in order to improve capabilities. Academia, Industry and the End Users will be TASKED with designing the round-robin study and the relevant projects enabling mobility of talents as well as being involved in the structured organisation of the workshop. The End Users will be tasked with identifying opportunities for pseudo-operational trials within the constraints of the legal and operational requirements.

-OBJECTIVE 2: Identification of End User requirements for evidence collection, treatment (recovery storage and where applicable transport conditions), examination and admission to a Court of Law; DELIVERABLE: identification of strategies enabling compatibility with imaging technologies. The End Users will be TASKED with leading an interactive dialogue informing participants on relevant legal issues, national requirements and guidelines for evidence recovery and preservation, protection of human rights and for admissibility in Court (MILESTONE 2.1). A workshop will be used as main ACTIVITY, enabling the fulfilment of Objective 2, organised in close collaboration with this Consortium Industrial expertise in law enforcement and officers training. A training school will be organised by the leading Industry, tasked with facilitating the dialogue between different sectors, to train both CSI and scientists on the aspects described above.

Working group 2. - Image processing and capabilities integration within a digital environment

-OBJECTIVE 1: Standardisation of structure and approach to knowledge generation from forensic evidence (e.g. fingermarks, paint, fibers, hair, ink, biofluids, documents, spent cartridges); DELIVERABLE: Assessment of current state of the art of the relevant imaging technologies. This will be achieved through: **a)** analysis of the capabilities and limitations of current processing imaging software and identification of desirables (MILESTONE 1.1); **b)** improved understanding of the effect of image processing on the possible introduction of artefacts and generation of guidelines for best practice (MILESTONE 1.2); this will be accomplished through a structured and efficient use of metadata for data acquisition, storage, manipulation and analysis which will be explored, particularly in relation to existing metadata standards (e.g. the INSPIRE Directive protocols). Sharing of metadata will be accomplished according to a data management plan to be agreed by the parties and that could be modelled on existing ones. The WG Leaders will host metadata on appropriate password protected file stores; **c)** conceptualisation of software capabilities for integrating mathematical algorithms, databases and statistical modelling, for the analysis of forensic evidence (MILESTONE 1.3) and **d)** development (on a scale ranging from conceptualisation to proof of concept) of centralised (multi-modal) imaging software with expanded image processing capabilities; meanwhile, data interoperability and exchangeability will still be investigated using IT tools enabling searching and indexing large amounts of image formatted data (e.g. ColumbiaImageSearch, ImageSpace, TopicSpace), building up relations between different sources of intelligence (e.g. Karma, ImageCat), finding origins or copies on the web (e.g. SourcePin) and effective visual analysis (e.g. DIG) - this will allow entering the processed results

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into one single LEA platform with application of the IDFPM on digitalised hard evidence easying the work of LEAs as they will only need one type of tool to evaluate all evidences, enhancing relation and context building possibilities as well. Knowledge gained will be managed in the Dynamic Knowledge Management System (DKM) to dynamically capture, aggregate, and correlate current and historical data in real-time and transform it into "operational knowledge". (MILESTONE 1.4). Academia and End Users will be TASKED with leading/moderating a workshop and Academia with the organisation of training school that will be used as main ACTIVITIES to deliver milestones 1.1 and 1.2. Industry will be TASKED with leading the dialogue with End Users and Academics in a workshop and, where appropriate, using STSM for the delivery of MILESTONES 1.3 and 1.4.
-OBJECTIVE 2: Standardisation of structure and approach to knowledge generation for semantic information (e.g. identification of people, faces, objects and scenarios); DELIVERABLE: improvement and/or development of centralised software IT framework (on a scale ranging from conceptualisation to proof of concept according to finances available) enabling enhanced intelligibility of the information. This will be achieved through **a)** establishment of guidelines for the detection of artefacts and verification of the integrity of the information (MILESTONE 2.1); **b)** determination of "fit for purposes approaches" amongst decision fusion frameworks (to use/compare/integrate complementary information from different analyses) and learning and pattern recognition techniques for extracting/infer semantic information (MILESTONE 2.2); **c)** identification of legal/ethical issues to feed into a structured and standardised approach for knowledge generation which can be lawfully employed. The network will closely cooperate with CEN/TC 391 on identifying and addressing terminology gaps and standardization issues. Academia and Industry will be TASKED with leading the dialogue in appropriate workshops used as main ACTIVITY for the delivery of both milestones. A training school will also be hosted by Academia with consolidated experience in this field with considerable training input from both Industry and End Users. For all the objectives outlined, knowledge advancement will be monitored through Activities such as internal and external dissemination including annual conferences.

3.1.2. GANTT Diagram

MONTH	1-3	4-7	8-11	12-15	16-19	20-23	24-28	29-32	33-36	37-40	41-44	45-48
WG1	MCm			MCm			MCm			MCm		
Objective 1												
Milestone 1.1		oCF WS	TS									
Objective 2												
Milestone 2.1				RRS	RRS, CF	WS						
				STSM	STSM	STSM						
WG2	MCm			MCm			MCm			MCm		
Objective 1												
Milestone 1.1		WS										
Milestone 1.2			RRS									
Milestone 1.3				WS	TS, CF							
Milestone 1.4						WS						
		STSM	STSM	STSM	STSM	STSM						
Objective 2												
Milestone 2.1								WS	CF			
Milestone 2.2										TS, RRS	RRS, WS	eoaCF
							STSM	STSM	STSM	STSM	STSM	

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oCF = opening conference (ALL participants); **CF** = annual conference (ALL participants); **eoaCF**= End of Action Conference (ALL participants); **MCm**= Managemeommittee meetings (also occurring at the start of each annual conference event); **RRS**= Round Robin Study; **STSMs**= Short Term Scientific Missions; **TS** = training school; **WS** = workshop.

3.1.3. PERT Chart (optional)

3.1.4. Risk and Contingency Plans

One of the obvious risks of any workplan is delays in the delivery of the milestones. To mitigate this, monitoring mechanisms will be put in place, whereby WGs will compile regular reports to submit to the MC containing: (i) a description of the progress made towards the agreed milestones; (ii) a description of any issues that might have caused deviation from the anticipated timeline and (iii) an action plan to counteract the issues by bringing the WG project tasks back on track; the Action plan will have to be ratified by the MC. A possible risk is the implementation of round-robin studies which heavily depend on alternative funding. Whilst one mitigating measure is the exploitation of STSM
, the MC and the WGs will carefully survey resources available and design attainable studies with minimal financial involvement. One of the major risks is not being able to deliver the anticipated breakthroughs when dealing with disciplines producing large datasets. The network has several participants having software development skills for data mining, artificial intelligence and signal processing. In addition, they have access to smartphone app and cloud-based processing software development skills allowing the close integration of data acquisition, processing, storage and dissemination, within customized packages and applications. The DKM will provide a platform to create multiple knowledge domains each representing an activity such as: investigation case, Joint Investigation Team file, Share of Analysis WorkFiles etc. Different types of knowledge, even in large datasets, can be shared and jointly updated, while organized into domains each containing centralized dashboard. Highly secured access to knowledge domains is granted only to invited members (role base users). Knowledge pages in each domain can be shared between multiple knowledge domains to allow a better re-usage of data and knowledge coherence between domains. The minimisation of the risk of gender imbalance within the network will be a regular item on all MC and WG agendas with updates on the current and further potential involvement of women within the Action's roles (see Section 3.2). Half of the places for the training courses and Workshops will be reserved to women until 3 weeks prior to the start of the event. To reduce the risk of disengagement by less research intensive Countries, venues will be strategically selected for the activities planned, ensuring inclusion of locations within said Countries. To counteract the risk of disengagement of non academic participants, End Users and Industry led/facilitated activities will ensure active involvement of these sectors. End Users will use the LEA networks to which they have access to raise attention on the Action and involve additional End Users thus enhancing both engagement by this Sector and Action deliverables. Finally, legal risks have also been considered. "Heads of Agreement" will be drafted including provisions for IP ownership, exploitation rights for foreground IP and access rights to relevant background IP featuring purely commercial and/or dissemination routes. The implementation model may be relatively complex and may translate into licensing to Industry, via establishment of spin out companies, could involve directly delivery of analysis services to forensics customers, or LEAs could establish their own analytical services and will be a mechanism for the members to agree on the appropriate model.

3.2. Management structures and procedures

The management and organisation of this Action will conform to “COST Action Management, Monitoring and Final Assessment” (COST 134/14) and “Rules for Participation in and Implementation of COST Activities” (COST 132/14). The Action will be managed by the Management Committee (MC); MC Members will be nominated by the COST National

Coordinators of the Participating COST Countries. The MC will make decisions on the Action's activities and WGs will report on their work, on the key aspects and scientific goals of the Action, to the MC. In its coordinating capacity, the MC will allocate resources to each WG, following yearly Action Grant Agreements and budget plans, agreeing on a plan of activities which build on the previous year's milestone(s).STSMs and annual Workshops will be key to knowledge-transfer and exploitation within the Action's network. Knowledge transfer and integration will be monitored through the submission of reports from each STSM and Workshop to each WG Leader, who will then report to the MC. All forms of evidence of knowledge exchange and integration will be monitored. For example, each WG member will be required to report to the WG Leader any dissemination that occurred as a result of the STSM and workshop including peer reviewed papers, joint grant submissions, presentations on other conference/seminar platforms. Collaborations on specific projects between the different participants of the network will also be recorded by the MC in order to monitor and measure impact. Particularly important will be the monitoring of the milestones and therefore each WG will be tasked with the preparation and submission of regular and annual progress reports to be submitted to the MC (see Section 3.1.4). An Action specific website will be created and maintained to ensure dissemination of the Action's outputs thus benefiting the wider Forensic Science Community, End User and relevant Industry. The website will be a very important resource for both the Action's participants and the public; it will include public, public password-protected and Action specific areas. The two public areas will be used for stating the mission and predicted impact of this Action, disseminating the research and outputs of the Action and to report on the Management Structure, WGs and key contacts. The members' area will be used to facilitate an effective collaboration of the Action's members and to coordinate the Action's different activities. Members' Area of the website will include all progress reports, an overall agenda detailing forthcoming Meetings, Training Schools, Workshops, STSMs and Annual Conferences. Each WG will also have a page, containing a separate agenda, a forum and a dedicated common work area where data files and documents can be shared. Within this structure, different decision making and leadership roles will be available which will be awarded to ensure age, gender and geographical balance. These roles include: MC Chair, MC Vice Chair, WG Leaders, STSM Coordinator, Action webmaster, marketing (reach out operations), organisation of workshops and training schools, round-robin and pseudo-operational trial leads.

3.3. Network as a whole

During the planning of the Action the network comprised 49 proposers from 14 COST Members Countries. Participants belong to the three key Sectors involved in the delivery of the Action namely: Higher Education and Associated Organisations (Academia, 59.9%), End Users, 22.5%, Industry 16% and Private Non-Profit without market revenues, NGO 1.6%. The proportion of participation from the different Sectors has naturally reflected the strategic philosophy of the Action that will be driven by Academia, informed by End Users and translated into exploitable concepts/technology by Industry.
Academia and associated organisations are based in UK, IT, NL, ES, PT, FR, SE, CH, BE, HU, and PL demonstrating good geographical balance; these 11 Countries together with **a)** the multiple number of proposers from the same Institutions dealing with different subject areas pertinent to the challenge described, and **b)** multiple number of proposers from different institutions make up for a total of 30 out of the 49 proposers; this demonstrates suitable Academia/Research Institutions critical mass for starting the Action and also for immediate expansion in order to keep counteracting the risk of a member of the network leaving the Action while ongoing, as each of the 30 proposers is extremely well connected in Europe; outreach has already begun and will continue for the duration of the Action. Academic expertise (some of which already supporting LEAs) is in the area of chemical and spectroscopic imaging, physical imaging, data/knowledge integration including legal and technological tools for the safe treatment of imaging data, improvement of images and visual data, face recognition and multi-modal fusion and exploitation of interoperability

of forensic-based digital evidence. This excellent expertise together with core ones in chemistry, engineering, physics, earth and related environmental sciences, biological, medical and technologies are crucial for technological innovation in imaging science. Some of the proposers have the above technological expertise applied to areas other than forensics; this is an opportunity for a fresh outlook to widen the application to forensic evidence (greater impact). In this newly constituted Network, Industry is represented by 5 COST Member Countries (DE, HU, NL, PT, UK and IT, with UK and IT having more than 1 proposer with, considering that 2 members are affiliated to both Academia and Industry, a total of 10 proposers. Core expertise lies in spectral and multi spectral imaging, thermal, laser imaging, sensors and electronics, digital and photogrammetric imaging, Imaging software engineering and Empirical Legal Studies. These areas of business mirror and complement academic expertise and will offer the support for translating new concepts and technologies in the field. The involvement of small to medium mass spectrometry and optical/spectroscopic device manufacturers will be pursued in order to complete the range of expertise needed from the industrial side and investigate portability of benchtop systems. End Users are represented in the network by LEAs, Government Ministerial departments and EU agencies and are based in UK, IT, NL, HU, PT, HL and LV demonstrating good geographical balance. Additional End Users will be sought exploiting the contacts of the End User secondary proposers to strengthen critical mass and facilitate innovation and adoption of cutting edge technology across Europe. At the start of the Action, the ENFSI digital imaging working group will be encouraged to join the Action to maximise impact and knowledge transfer. Additional experts in immunogenic imaging, from an outlook on different forensic practice/guidelines and from the specific expertise in the knowledge sharing platform which will be employed in the Action will also be encouraged to join the network; the counterparts will benefit from the dialogue with a large and diversified network of experts in imaging science as applied to forensic evidence, with new opportunity for innovation, effective collaborations and product development.

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