FORENSIC INNOVATION THROUGH DEEP TECH: A HISTORICAL AND FUTURE PERSPECTIVE

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Abstract

The intersection of forensic science and deep technologies represents a transformative frontier in both criminal investigation and scientific inquiry[1]. This paper explores the evolution of forensic methodologies across eras, highlighting how technological shifts have continually redefined investigative possibilities. From the early reliance on physical evidence and rudimentary chemical analyses to the integration of digital forensics, biometrics, and artificial intelligence, forensic science has consistently adapted to the tools available. The emergence of deep technologies—such as machine learning, blockchain, quantum computing, and advanced imaging—offers unprecedented opportunities to enhance accuracy, efficiency, and reliability in forensic practice. At the same time, these innovations raise critical questions about ethical use, data privacy, and the admissibility of technologically derived evidence in judicial

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processes[2]. By adopting a comparative lens, the study evaluates historical milestones alongside contemporary advancements, identifying patterns of innovation and disruption. It further considers the implications of deep tech for predictive policing, cybercrime investigation, and cross-border legal cooperation. Ultimately, the paper argues that forensic science, when synergized with deep technologies, can transcend traditional limitations, enabling investigators to reconstruct complex events with greater precision. However, this potential must be balanced with robust legal frameworks and interdisciplinary collaboration to ensure that technological progress aligns with principles of justice and human rights. The research thus positions forensic science not merely as a reactive discipline but as a proactive, evolving field shaped by the possibilities of deep technology across eras.

Keywords: Forensic Science, Deep Technology, Digital Forensics, Artificial Intelligence, Ethics and Legal Frameworks

INTRODUCTION

An expert is someone knowing more and more about less and less, eventually knowing everything about nothing.

Sir Bernard Spilsbury

Deep tech (Deep Technology) is a decades-old term used, at first, to describe any form of advanced technology in general. However, in the last decade, deep tech has gained a more precise and specific meaning. In 2014, Swati Chaturvedi, CEO at investing firm Propel(x), coined the definition that is widely used today[3]. Deep tech aims to develop innovative solutions and approaches to address major societal challenges, be it climate change, pollution, food and drinking water security, chronic diseases, waste recycling and management, and such other issues[4]. Deep tech involves the vast utilization of advanced solutions, including Artificial Intelligence (AI), Machine Learning (ML), Big Data, Block-Chain, Quantum Computing, Advance Materials, Biotech and Nanotech, Robotics etc. and are put to use in many fields including Forensic Science – DNA fingerprinting, Vision and speech algorithms, Language processing, analysis of big data, creation of crime scene and many other areas[5]. The significance of forensic science in criminal investigations lies in its ability to objectively analyze evidence and provide clarity in complex cases, making it an indispensable tool in modern law enforcement.[6]

The noun *forensic,* meaning "an argumentative exercise" derives from the adjective *forensic,* whose earliest meaning in English is "*belonging to, used in, or suitable to courts or to public discussion and debate."* The English word was derived from a Latin word *forensic* meaning "of the market place or form, public," which in turn comes from the Latin word *forum,* meaning *"market place, forum."*

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[6] Vinay Kumar and Yogender Singh, Forensic science in the Indian Legal framework: Challenges and opportunities in criminal investigations and trials, International Journal of Civil Law and Legal Research, p213, 2024, 4(2), 213-220

Forensic Science, is defined as *"the application of the methods of the natural and physical sciences to matters of criminal and civil law", involves use of multiple sciences, like physics, chemistry, biology, medicine, engineering etc. Thus, any science can be a forensic science because almost any science can contribute to solving a crime or evaluating a civil harm. In fact, with few exceptions, forensic sciences are no different in what they study than traditional sciences. The only difference is that forensic scientists apply the methods and techniques of established sciences to legal matters.*[7] Forensic evidence is recognized as persuasive evidence to prove guilt or innocence of a person. Forensic science is known as *"pobulic science or criminalistics"* in USA, French call it *"Criminlistique"* and German call it *"Kriminalistik".*

Forensic science and forensics are terms that are often used interchangeably, but they have distinct meanings and applications. While forensic science is a broad field encompassing various disciplines that apply scientific methods to legal matters, forensics refers to the art of debate and presentation of evidence in public forums[8]. DNA profiling, fingerprinting, forensic ballistics, magnification (comparison Microscope), NARCO analysis, computer science for crime detection in forensic science. Use of Artificial Intelligence (AI), Block-chain, Brain-mapping, Vision and Language processing are new additions.

Historical Perspective: Till a few years back persons involved in administration of justice, particularly criminal justice system were not believing in forensic science and were even hostile to scientific evidence, because since long the judicial system has been adhering to 'eye-witness testimonies'. However, when Hugo Munsterberg – father of Allied Psychology observed that moral issues in America "inexorably gravitates towards the courts," he challenged the reliability of the eye-witness and observed that his memory failed to recollect properly the event of burglary committed in his own house. His conclusion that human memory is capable of suggestions, distortions and omissions.[9] The contempt for scientific evidence started to decrease and was relied on more and more for dispensation of justice particularly criminal justice[10].

Forensic science was applied during ancient civilizations also. Advancements of Forensic science span from early fingerprinting techniques in Babylon (5000 to 3000 BC) to cutting-edge DNA analysis in the contemporary times. And its progression continues with the developments in science and technology. The Hammurabi Code by king of Babylon is the oldest medico-legal code. Chief justice and Chief Physician of the King Zoser of Egypt was the first medico-legal expert. Different techniques were developed for the preservation of the dead bodies-mummification.[11] In India prominent treatises that were regarded as authoritative sources of legal counsel included the Arthashstra of Kautilya – written between third and fourth century BC and Manu (3102) was the first lawgiver in India and his Manuscript, enumerate various techniques to help in criminal justice system prevalent at that time. Indians knew for long that the handprints, known as the, *'Tarija'* were inimitable. The use of fingerprints as signatures by illiterate people in India, introduced centuries ago, was considered by some people as ceremonial only, till it was scientifically proved that identification from fingerprints was infallible[12]. The "Eureka" legend of Archimedes (287-212 BC) can be considered an early account of the use of Forensic Science, by examining the principles of water displacement, to prove that a crown was not made of gold, as it

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7 Forensic Science- The importance of identity in theory and practice, National Center for Biotechnology Information - PubMed Central (July 08, 2026).

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[11] P.C. Dikshit, Textbook of Forensic Medicine and Toxicology, p 2, Peepee Publishers and Distributors (P) Ltd. New Delhi

[12] B.S. Nabar's Forensic Science in Criminal Investigation, 3rd Edition (referred in Forensic Science in India and the World, p 14 2008

was fraudulently claimed, by its density and buoyancy.[13]" "Use of science to solve the cause of death or crimes like murder dates back to ancient Greek and Roman civilization….Egyptian civilization, Indus civilization and Indian medicine have profoundly used various processes for acquittal …Early techniques for lie detection were based on oaths, pledges, magic, attestation, etc. making it hard to differentiate innocence and guilt…the earliest known account for lie detection comes from ancient China, which corresponds to modern polygraph techniques, as it relied on physiological changes to certain situations – technique is based on the production of saliva when a person is under stress it is believed that the flow of saliva is less"[14] Further, in the 3rd century jurists established protocols for the identification of forgeries and the methods to be used in their detection…autopsies, which attempted to determine the cause of death of the deceased, have been attested since the early 3rd millennium BC… poisons as the cause of death were compiled in the writings of the renowned physician and poet Nicander of Colophon (c 200 BC), but it wasn't until 1499 that his works were first printed….[15]

In 1880, Dr. Henry Faulds predicted the usefulness of forensic fingerprinting, after making additions to the work of Sir William James Herschel, who had been using fingerprinting in India as a way to battle signature forgery. He proposed fingerprinting as a, effective investigative tool. Dr. Faulds initially took the help of Charles Darwin, and then Galton - who popularize the first method of modern fingerprint classification a few years later. In 1984, Sir Alec Jeffreys, showed that DNA has both similarities and differences between family members, making it perhaps the most accurate form of identification ever discovered. And in 1986, Jeffreys' method was employed for the first time in a criminal case, and it continue to play role in forensic investigations since then. Who first identified DNA is often given to James Watson and Francis Crick, though they furthered Miesher's discovery with their own ground breaking research nearly 100 years later. They contributed to the understanding of DNA in terms of genetic inheritance. Gregor Mendel, (1866) suggested that characteristics are passed down from generation to generation and coined the terms, Recessive and Dominant. Albrecht Kossel, (1881), named DNA identified nuclei as a nucleic acid. He isolated five nitrogen bases adenine (A), cytosine (C), guanine (G) and thymine (T) which is replaced by uracil (U) in RNA. Walther Flenning (1882) discovered mitosis while executing systematic study of the division of chromosomes. Theodor Boveri Sutton (early 1900), gave the Boveri-Sutton chromosome theory of inheritance. Sir Archibald Edward Garrod (1902) study recessive inheritance in human beings and added to our understanding of how chromosomes carry genetic material and pass it down from one generation to the next. Erwin Chargaff (1944 to 1950) discovered that DNA is responsible for heredity and varies among species, known as Chargaff's Rules and proved that guanine and cytosine units, as well as adenine and thymine units were the same in double-stranded DNA. Barbara McClintock (1940s) discovered the mobility of genes and gave the idea of 'jumping genes'. Roslind Franklin (1951) discovered the helical form of DNA, confirmed by Watson and Crick much later. Roslind was acknowledged posthumously. Watson and Crick (1953), confirmed double helix of DNA, that twists to from the ladder like structure, when we see the picture of DNA.[16]

In the 1990s, the first DNA database was established in India, allowing law enforcement agencies to match DNA samples from crime scenes with potential suspects.[17] Fingerprint of every person is unique thus making it a significant tool to identify the person, after comparing the samples collected from crime scene with known suspects, store in the fingerprint database. Actually, in 1892, Sir Edward Richard

13 Deepak Ratan & Mohd. Husan Zaidi, Forensic Science in India and the World, p 10, Alia Law Agency, Allahabad, 2008.

14 Petretei D, Fingerprints in Ancient China–A Mini-Review p-1. (For detailed discussion, may be browsed on http://www.thefreelibrary.com/Fingerprints+in+Ancient+China-A+Mini+Review.-a0835362706, visited 22 June 2026).

15 Ibid 1.

16 Runjhun, Genesis and Development of Forensic Science in India,

17 Kaushtaub Mishra and Amit Singh, Forensic evidence in Indian courts: Analyzing the role of investigating agencies in justice delivery, International Journal of Civil Law and Legal Research, p142, 2024. (Refer for details on the subject).

Henry (1850-1931), Inspector General of the Bengal Police, employed Mr. Qazi Azizul Haque and Mr. Hem Chandra Bose in the police service, to develop the, "Henry Classification System" of fingerprints. Haque, reportedly, provided the mathematical basis for the system, while Bose complemented it by devising a telegraphic code system for fingerprints. The research of Henry-Haque-Bose revolutionized criminology (criminal investigation and identification) and the successful application of the "Henry Classification System" of fingerprinting worldwide for a century (1899-1990s). In fact, the "Henry Classification System" also played a highly influential role in the development of the current biometric systems, that is, in the formation of today's Integrated Automated Fingerprint Identification System technology.[18].

Forensic Disciplines: DNA and Fingerprint are not the only type of forensic disciplines.

Forensic science, as mentioned earlier, is an umbrella term that includes various scientific disciplines, contributing to legal investigations[19]. Main forensic disciplines include Computer Forensics-Investigating digital data for evidence. Forensic Accounting- Analyzing financial records for fraud or embezzlement. Forensic Audio-Examining sound recordings for authenticity or content. Forensic Linguistics- studying language use in legal contexts. Forensic Pathology-Determining causes of death in a legal context. Forensic Psychology-Assessing psychological aspects related to legal cases. Forensic Anthropology-Identifying human remains and interpreting trauma[20]. Criminalistics-Applying natural sciences to analyze physical evidence. Criminalistics is a subset of forensic science that integrates disciplines like biology and chemistry to scrutinize evidence such as DNA, bodily fluids, fibers, hair, soil, fingerprints, and tire tracks. Criminalists also engage in ballistics, drug analysis, crime scene photography, and reconstruction.[21] However, with the advancement in science and technology more futuristic disciplines got added, such as Advanced Fingerprint tools, Forensic engineering, Forensic biology and DNA analysis, Digital forensics, ballistic and Firearms mark analysis, Forensic anthropology and odontology, Forensic toxicology, Forensic accounting and financial investigation, Forensic pathology, Bloodstain pattern analysis, Crime scene investigation and reconstruction, Document examination and forgery detection and such other disciplines[22].

A few Important Cases: Mentioned earlier, that the mindset of the judicial system was not favorable to the forensic evidence. In fact, there was some contempt towards it. However, with the development of more accurate, transparent forensic tools, courts in India started to allow forensic evidence and legislature followed the suit by enacting regulations to allow specific forensic evidences in the court of law. Some of the leading court cases in this domain are – **The Jessica Lal Murder Case** (1999). The murder of Jessica Lal in shooting incident at a restaurant in Delhi. Investigation was compromised due to corruption and inadequate evidences. However, due to public pressure and the emergence of forensic evidence culminated in the retrial of the accused, leading to their conviction in 2006. **The Sohrabuddin Encounter Case** (2005). Allegedly a case of extrajudicial killing by police officials raised serious concerns about the integrity of the law enforcement system. Mobile phone records, ballistics analysis and post-mortem reports played a vital role in investigating the case. After the Supreme Courts intervention and the use of forensic findings let to the reopening of the case and the subsequent trial of the several police officials. The case established the crucial role of forensic evidence in criminal justice system in ensuring accountability and transparency in law enforcement practices.[23] **The Aarushi Talwar Murder Case**

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[18] THE DAILY STAR, E-paper, Wednesday, June 23, 2026

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[21] Ibid 10, p144

[22] Xavier, C.; Omar, F. Dataset: Technologies Forensic Sciences—I&P. Mendeley Data V1. Available online: https://data.mendeley.com/datasets/264nznwdm9/1

[23] Ibid 10, p 145

(2008) murder of Aarushi Talwar and domestic help Hemraj, drew significant media attention due to public out-cry. Initially investigation faced numerous challenges. However, DNA analysis and forensic odontology played crucial role in the investigations. Due to the lack of proper procedures, let to controversies over the reliability of the forensic findings. Ultimately the Talwar couple was convicted in 2013, but the case raised questions about the integrity of forensic evidence and investigative process. **The Nirbhaya Gang Rape Case** (2012) – the gang rape and murder of a 23 year woman ignited nationwide protests and calls for justice were raised. DNA profiling confirming the involvement of the accused also highlighted the importance of forensic science in such cases. **The Vyapam Scam** (2015) – it involves irregularities in admissions and recruitment examinations in Madhya Pradesh, revealing extensive corruption and malpractices. Handwriting analysis and digital forensics aided in identifying fraudulent activities and establishing connections between various actors involved. The case highlighted the potential of forensic science in tacking systematic corruption in public offices. Likewise **The Asharam Bapu** high profile case was solved through DNA testing and medical examinations.[24] The landmark **Gujrat riots Case** 2002, where DNA evidence was used to establish the identity of victims and accused, showcased the transformative impact of DNA analysis on the investigative process.

Contemporary Forensics: The evolution of forensics is not over. "With the advent of advance science and technology the tactics and working of investigating authorities has changed and in this regard the role of Forensic Scientists is most important and they may pride themselves as independent finder of truth by advancement of science. [25] Science and Technology is growing with lighting speed and affects every aspect of human lives, forensic science is no exception to this change[26]. The contemporary innovations, and to refine and make tools and innovations more advanced, effective and cheap, Forensic Sciences is one of the fastest-growing field globally. "According to the U S Bureau of Labor Statistics (BLS 2024), there will be a 14 percent increase in jobs for forensic science technicians nationally between 2023 and 2033. The BLS indicates that this growth is due to new forensic science techniques that have increased the availability and reliability of objective forensic information[27]. Courts and law enforcement agencies need to hire additional staff to use these techniques to analyze data for use in trials"[28].

Future Deep tech Forensic Science Technologies: Next Generation Sequencing: Next-Generation Sequencing (NGS) analyze DNA in greater detail. With this technology entire genomes or specific regions with high precision can be examined, even if DNA samples may be damaged, small, or old[29]. This technology has enhance the effectiveness and reliable, ability to identify suspects and victims. In the coming years NGS be able to link DNA evidence to specific locations, predicting physical characteristics, and even identifying unknown remains. It will transform the way forensic investigations are conducted.

Omics Techniques: Omics Techniques (OT) will provide more accuracy in interpreting the behavioral characteristics of species related to forensics at the genetic level.

Mass Spectrometry Techniques: This technology is highly selective and sensitive, a tool for analyzing complex biological samples. Synthetic cannabinoids, are serious challenge in drug detection due to their structural diversity and continually changing compositions. However, method can simultaneously identify and quantify 24 synthetic cannabinoids in urine.

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[24] Ibid 10, p 145

[25] Keith Chikushi, Forward to Book Forensic Science in India and the World, Alia Law Agency, Allahabad, 2008.

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[28] Ibid 10, p 144

[29] Tom, K.R.; Knorr, K.B.; Davis, C.E. Next Generation Identification system: Latent print matching algorithm and casework practices. *Forensic Sci. Int.* 2022, *332*, 111180.

Forensic Bullet Comparison Visualizer (FBCV): Forensic Bullet Comparison Visualizer (FBCV) will enhance the objectivity of bullet analysis. This innovation bridges the gap between complex data analysis and practical forensic application, improving the accuracy of bullet comparisons.

High-Speed Ballistics Photography:

You might not think of it right away as a tool for forensic scientists, but ballistics specialists often use high-speed cameras in order to understand how bullet holes, gunshot wounds, and glass shatters are created[30].

Virtually anyone, from a crime scene investigator to a firearms examiner, can operate a high-speed camera without any additional education or training. Identifying and matching bullet trajectories, impact marks, and exit wounds[31].

Integrated Ballistic Identification System (IBIS): Integrated Ballistic Identification System (IBIS) facilitates the sharing, comparison, and automated identification of significant quantities of exhibit information and images across a network of imaging sites. It will provide 3D imaging and advanced comparison algorithms[32].

Artificial Intelligence: Artificial intelligence (AI) is now utilized extensively in all forensic components of a criminal case. However, it find its place in digital forensics analyze a crime scene, compare fingerprint data, draw conclusions from photograph comparisons, and many more[33].

Next Generation Identification System: Next Generation Identification System (NGI) will provide identification of an individual more efficiently and accurately. Basically a modern biometric techniques, applied in facial recognition, fingerprint analysis, iris scans etc. Advanced system is having facility of continuously monitoring suspects in law enforcement databases and provides real-time updates on any new criminal activity, they may be involved.

Biosensors for Fingerprint: Even minute traces of bodily fluids found in fingerprints can be analyzed to identify the suspect. Data that can be detected include age, medications, gender, etc.

Immuno-chromatography: Through these tests substances in bodily fluids, such as drugs, toxin and medications can be ascertained.

3D Technology: this technology use 3D imaging to map the exact dimensions of damaged bones and then replicated the pieces using a 3D printer, to determine if pieces fit together[34].

Nanotechnology: Analyzing forensic materials at atomic or molecular level can offer insights that previously weren't accessible. Nano-sensors are being employed ascertain the presence of countermand drugs, explosive materials, and biological agents on the molecular level.

DNA Pheno- typing: With provides identifying traits of the suspect, including hair, eye, and skin color. In future, even age of the individual can also be predicted.

Forensic Palynology: Pollen, spores, seeds, grains, and such other material can be used to identify the location of an individual. The techniques to gather and compare these trace materials and use them as evidence.

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Proteomes: Proteomes are a complete set of proteins produced by an organism. These can find proteomes in blood, bones, and other biological materials and analyze them results in detection of undetectable venom or matching a degraded body fluid. Proteomes differs from DNA as they change with time, offering valuable insights into age and other environmental factors of the victim at the time of death.

Blood Pattern Analysis: Bloodstain pattern analysis (BPA) software is an emerging technology to reconstruct crime scenes by analyzing blood and bloodstains, by estimating the Area(s) of Origin (AO) of a bloodletting event[35].

Carbon Dot Powders: Fluorescent carbon dot powder applied to fingerprints, makes them fluorescent under UV light and subsequently much easier to analyze. With this new application, fingerprints will glow in different colours -red, yellow, or orange.

Geolocating using Stable Isotopes of Water: Investigators can determine the origin of the sample by isolating the isotopes in a water sample found on a suspect or victim.

Digital Vehicle Forensics: Data such as recent destinations, typical routes, personal data, and favorite locations will be possible to gather, by digital vehicle forensics.

Cloud Forensics: To protect the data integrity and maintain a custody chain, use of block-chain technology in digital forensic, is essential because it is impossible to tamper with block-chain.

Drone Forensics : Unmanned aerial vehicles (UAV) has given criminals a sophisticated tool to attack victims, smuggle drugs, and perform illegal surveillance, and many other offences and antisocial activities. Gathering and analyzing data from drones, SD cards, and cell phones will be step ahead of criminals and their use of UAVs for nefarious activities.

Social Network Forensics: Billion are on social networks, it has increase to about 4.5 Billion.
Evaluation of this huge data, by social network models, to be reproducible, explainable and testable, so that they will be acceptable to the court.

Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS): The glass samples of any size is broken down to their atomic structure, matching is done the smallest shard of glass found on crime scene, by its highly sensitive isotopic recognition ability.

Alternative Light Photography: Alternative light photography is one of the coolest tools to help see the damage even before it is visible on the skin. A camera such as the Omni-chrome uses blue light and orange filters to show bruising clearly below the skin's surface.

Digital Surveillance: The XFT is being developed to visual access to hidden files on the Xbox hard drive.

Magnetic Fingerprinting and Automated Fingerprint Identification (AFIS): With these forensic technologies, quickly and easily compare a fingerprint at a crime scene with an extensive virtual database. Incorporation of magnetic fingerprinting dust and no-touch wanding allows to get a perfect impression of fingerprints.

Software for strange financial activities: The software can now combine observations of strange digital financial transactions, customer profiling, and statistics to generate probabilities of illegal behavior patterns.

Blood Pattern Analysis Software: Bloodstain pattern analysis (BPA) Computer-based software can estimate the Area(s) of Origin (AO) of a bloodletting event, to provide crucial insights into the sequence of events at a crime scene.

Sensitive Detection Methods: It refers to the use of advanced technologies to detect minute amounts of specific substances or changes in the body. Techniques like mass spectrometry, fluorescence detection, and molecular imaging are commonly utilized for sensitive detection.

Fold-scope: Being portable and very low cost, the Fold-scope can be used in the field to make on-the-spot determinations of samples, including blood, hair, and soil.

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Video Spectral Comparator 2000: It is possible to look at a piece of paper and see obscure or hidden writing, determine the quality of paper and its origin, and "lift" indented writing. It may further be possible to complete these analyses even after a piece of paper has been so damaged by water or fire that it looks unintelligible to the naked eye.[36]

Future of Forensics: The evolution of forensics is far from finished. With advancements in every area of forensics and the amalgamation of deep tech innovations with forensic science, one genuinely feels that it will drastically change the forensic science. There will be marked accuracy, transparency and accountability as well as scientific professionalism in forensic science and its applications. Forensic inventers of advanced tools and techniques are required to look inward at their own internal biases (if any), at systemic injustices, scientific shortcomings and at the violation of human rights particularly right to privacy. Any forensic tool or application coming under scrutiny is required to be welcomed and their willingness to overcome shortcomings as well as errors ungrudgingly.

Objectives of new area forensic sciences: The main objective of Forensic science is to establish the presence or absence of a link between the crime, suspect, and the place of crime through scientific analysis of physical evidence. Forensic experts have to analyze the given evidence using multidisciplinary science through deep tech innovations /tools. They have to cooperate with all stakeholders - the investigating officer, forensic scientists, academicians and coordination with forensic laboratories, police, and advocates, Jury / Judges. Like any other discipline of science and technology, forensic science is not devoid of limitations and negative effects. However, as mentioned earlier the new innovations are / will be very accurate, transparent and cost effective and the developers of such technologies / tools to be also willing to appreciate the negative effects of the technology / innovations developed. This may happen because of the pressure of well-informed citizenry, particularly in democratic societies, where right to speech and raise genuine issues is guaranteed by the constitutions and upheld by the courts. Hence the challenges and issues relating to the implementation of future technologies and innovations will be addressed, as far as possible, at the developmental stage. Both public and private stakeholders are key to harnessing the transformative benefits of the new technologies / innovations to help accelerate our mission of "No Criminal should be spared and No Innocent should be punished".

Challenges: Undoubtedly, the invention of new and sophisticated technologies, particularly under Deep tech regime is will impact the world in all its spheres ranging from environment, health to transportation to war, energy to food security and what not. This development is bound to make the life of man on this planet and even beyond, more easy and fruitful. But as per our past experience and interaction with technological developments, the outcome is not always rosy- some consequences, do result having negative effects on the society. The benefits have always come with negative consequences, be it in the shape of Atomic Explosive Device or Climate Change, Environmental Degradation or Societal Disintegration, Digital Divide or Economic Disparity, Privacy violations or Inexorable Materialistic Greed, Human rights Violations or Undue Surveillance. For instance, we will highlight briefly surveillance technologies and right to privacy and how it can be eroded without even knowledge of the subject. Though, Surveillance technologies have become indispensable for maintaining security and preventing criminal activity in both the public and private sectors, however, the proliferation of surveillance tools- ranging from CCTV cameras to advanced data analytics and AI-powered monitoring systems –have raised important questions about the limits of monitoring and the rights of individuals. Social Media Monitoring, Big data analytics to analyze patterns in behavior, location, and preferences to predict future actions. Facial recognition Technology is used everywhere from airport security to retail environments, enabling automated identification in real-time. Mobile device tracking systems, track user movements. Surveillance capitalism, companies collect and monetize personal data for advertising purposes without user consent. High-profile cyber-attacks, exposing millions of user's personal data, leading to financial

[36] Kimmy Gustafson, Modern Forensic Science Technologies, reviewed by Jocelyn Blore, Forensics Colleges, updated April 11, 2026. (For more details refer article).

and personal harm. And the common man is confused and absolutely helpless. He is not positioned to rediscover the safe technology not undo the harmful effects of the present one. However, in spite of all such negativity, a ray of hope is there, that good times are forthcoming. Man has learnt from his past mistakes and good sense will prevail and technology will be developed and used for the good of the mankind and development of the society. In India progressive legislations such as The Digital Personal Data Protection Act, 2023 is a welcome step and significant one, to enhance privacy protections, secure citizens' data, establish data protection laws and ensure balanced privacy framework that align with the needs of digital age demands. The information Technology Act (2000) permit lawful interception with strict procedural safeguards to balance privacy with National Security.[37] However, the potential for misuse of power have intensified with the indiscriminate collection and analysis of vast amount of personal data raise apprehensions about the scope of government surveillance and the protection of individual privacy rights. Biases inherent in algorithms and machine learning models used for predictive policing or suspect identification can perpetuate systemic injustices and lead to discriminatory outcomes, particularly against marginalized communities.[38]

Suggestions: Contemporary Times are the Data Generation and Data Transfer Times. To handle an unprecedented data growth, resulting from exchange of data and information internationally, we need a cheap, reliable and transparent, robust and technologically advanced infrastructure. However, most data centers are in developed or developing countries and their expansion is primarily concentrated in upper-middle-income economies. Launching data centers in under developed countries is necessary to expand digital potential and reduce the digital divide, by ensuring a stable broadband infrastructure, development of trained and skilled manpower and employment opportunities, secure and safe business environment, a transparent regulatory mechanism, reliable, and cost effective energy, will ensure development in such countries and reduce despondency among the natives and also reduce economic and digital divide. This all development with environmental sustainability and societal rights are to be kept in consideration, for harnessing tremendous opportunities to deploy data for human good. Both public and private stakeholders are key to harnessing the transformative benefits of such initiatives to help realize our mission of a world without crime and no criminal be let off and no innocent be punished. Admissibility of forensic evidence be encouraged, after deep tech innovations are tested and meeting the criteria prescribed by rules and ordered by judiciary. Contempt of forensic sciences and scientific evidence be minimized with awareness of all stakeholder including masses, jury and judges. "Justice and Science are a meaningful subject. … In the field of law the scientific approach to anything involves observation, measurement of entities that can be quantitated, the accumulation of data's and analysis of finding as distinguished from an invective approach[39]. US Court held on admissibility of evidence, "The general legal standard for admitting evidence in US federal court requires it to be relevant, authentic, and not based on hearsay. In cases involving scientific or technical evidence like metadata, its reliability and the method used to generate it are crucial factors"40. It is now settled rule that two important aspects for the admissibility of digital evidence in the court of law: legal aspects (authentic, accurate and complete) and technical aspects (transparent, explainable and chain of evidence). Further, it must be appreciated that digital evidence is very hard to handle and preserve compared to physical evidence because of the characteristics like 1) easy to transmit and is fragile in nature 2) vulnerable to tampering and removal 3) time sensitiveness and ability to cross borders and legal jurisdictions on the fly. Thus digital evidence comes with its own unique challenges related to chain of

[37] Ibid 1, p 1-5.
[38] Kartik & Shruti Malhotra, Use of Technology in Modern Criminal Investigations, International Journal of Novel Research and Development, vol. 9, issue 4 April 2024e769, (www.ijnrd.org)
[39] Deepak Ratan & Mohd. H. Zaidi, Forensic Science in India and the World, p 17, Alia Law Agency, 2008.
[40] United States v. Schatz, 2007

custody because of complex and volatile nature.[41] While developing deep tech tools and innovations for forensic sciences, these guidelines – Legal as well as Technical are mandatory to keep in mind, so that the forensic science and forensic evidence are welcome and acceptability is not questioned. Sophisticated techniques and tools warrants technically and professionally trained personnel to perform such techniques and tools. Adequate forensic science institution be established to make good of the scarcity of the trained personnel. It should be followed by continuous skill up gradation of trained personnel to keep them abreast of the latest innovations and techniques. Another very important aspect, though usually neglected is forensic reforms. Given the evolving nature of deep tech particularly new tools and innovations in forensic sciences, there will be a continuous need for reforms that enhance forensic practices within the legal framework. Establishment of standardized protocols for forensic investigations, the creation of independent forensic review bodies, and the incorporation of newer scientific techniques into the legal framework to keep pace with advancements in forensic science,[42] are a must to keep pace with the rest of the world.

In the countries like India, resources scarcity – skilled professional manpower, latest sophisticated equipment including software, interdisciplinary research and society with absence of scientific temper- are challenge and must be taken care off. The public funding from the government may not be available as per the requirement, Public-Private-Partnership should be explored, where private organizations may create sophisticated infrastructure and use will be on paid basis. Skilled professional will be trained in the Centre of excellences established in PPP mode, with government supervision to impart the latest training in forensic and employability will be ensured in academic institutions, technical, judicial, police and other law enforcement agencies. However, a word of caution is required to avoid all and any interference with the outcome of investigations / results by the private parties. Further, our judiciary is overburdened and at times judicial process is slow, leading to delays in utilization of forensic evidence in trials resulting in delays. These delays can undermine the effectiveness of forensic evidence in establishing timelines, connections in investigations and most important casing frustration in victims, defendants and investigating personnel.[43] Traditional methods of documentation of a death scene include photography, sketches, and notes, electrostatic lifting, or casting, as well as field forms and video footage. An alternative, supplemental method of documenting transient evidence may be the three-dimensional (3D) imaging.[44] This is the power and efficacy of new innovations. And days to come it will drastically and significantly impact the forensic science for the benefit of the mankind.

Conclusion: Forensic science has a promising future as new methods, technologies, and scientific advancements create new possibilities that have not yet been imagined. For example, while the discovery and utilization of DNA has transformed current day forensic science, it will continue to do so as the detection technologies develop and our understanding of trace DNA transfer, persistence, prevalence, and recovery grows. New discoveries can create incremental evolutionary changes or revolutionary changes that will reshape the face of forensic science all together. We cannot predict the innovations and new technologies that will come to be, but we can certainly expect that they will happen.[45] And that they will create new possibilities for forensic science, probability is they may significantly change forensic science and its tools, methods and perception, because the precocious

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[41] Hamid Lone and Prof. Roohie Naaz Mir, Forensic-chain: block-chain based digital forensics chain of custody with PoC in Hyper-ledger Composer, Digital Investigation, p 44 Vol-28, March 2019. (For detailed discussion refer the article)

[42] Ibid 10, p143

[43] Ibid 18, p 144

[44] Massimiliano Esposito, Monica Salerno and others, Advances in Technologies in Crime Scene Investigation, Diagnostics 2023, 13, 3169, (Visit https://doi.org/103390/diagnostics1320169 for full article).

[45] Taleb NN, The Black Swan: the impact of the highly improbable, New York, NY: Random House is the publisher, 2007 quoted in the Editorial, A Futuristic Vision of Forensic Science, Itiel E. Dror and Ruth M. Morgan, Journal of Forensic Sciences, 2019doi:10.1111/1556-4029.14240 available online at: onlinelibrary.wiley.com

way the deep tech is developing. It is clear that with all these new and exciting possibilities, new challenges and vulnerabilities also arise. Utopian fiction highlights the potential of this kind of data-rich world to transform society and human nature, but these new technologies and capabilities also create a world that faces very serious challenges (such as disclosure,[46] and issues around ethics and privacy)[47] and there will certainly be new (as yet unknown) Challenges. The future certainly looks bright, but given that complex challenges require collaborative and holistic solutions, to achieve this kind of capability will require a truly interdisciplinary approach from across the sciences, arts, and humanities that beings these emerging capabilities together with experts from computer science, statistics, cognitive science, and other related domains.[48] Here ancient knowledge may come to the rescue of the humanity, to change the avaricious mindset of contemporary man to benevolent one. To shift his aim from cut-throat-completion to cooperation and strive for human good, with the mindset that punish the criminal and secure the innocent, and live peaceful life.

To conclude, with a meaningful story, "In the 12th BC, Greece declared was on the city of Troy. The dispute erupted than the prince of Troy abducted the queen of Sparta and declared that he wanted to make her his wife. This naturally angered the Greeks (and especially the queen of Sparta). The Greeks besieged Troy for 10 years but met with no success as Troy and very well fortified. In a last effort, the Greek army pretended to be retracting and left behind a huge wooden horse. The people of Troy saw the horse, and thinking it was some kind of a present from the Greeks, pulled the horse into their city, unaware that the hollow wooden horse had some of the best Greek soldiers sitting inside it. Under the cover of night, the soldiers snuck out and opened the gates of the city, and later, together with the rest of the army, killed the entire army of Troy."[49] Development in Forensic Science is not a Trojan horse, but the sunrise rays that further irradiate the field of forensic science and its techniques. It should not be dismissed as contemptuous due to our biased mindset. Instead, our endeavor must be to embrace the new tools and techniques and apply them for the human good. Knowing more about forensic sciences and any limitations in it is required to be removed.

[46] McCartney C., Commentary: disclosure in the criminal justice system, Forensic Legal Med 2018;24(1): 7-24

[47] House of Commons Science and Technology Committee. The work of the Biometrics Commissioner and the Forensic science regulator. Nineteenth Report of Session 2017-2019. 2019, (For full report visit http://publications.parliament.uk/pa/cm201719/cmselect/cmsctech/1970).

[48] Ibid 26, p 3

[49] Prof. R. K. Chaubey, An introduction to Cyber Crime and Cyber Law, p321, Kamal Law House, Kolkata. (The word 'Trojan Horse' is generally attributed to Daniel Edwards of NSA, he is given credit for identifying the attack).