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# A Roadmap to Improve Research and Technology Transition in Forensic Science

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## Table of Contents

# Reader's Guide to the Roadmap

The Forensic Laboratory Needs Technology Working Group (FLN-TWG), formed by the National Institute of Justice (NIJ) in partnership with the Forensic Technology Center of Excellence (FTCOE) at RTI International, created this document in support of NIJ's mission to improve knowledge and understanding of federal, state, local, and tribal forensic science service providers' (FSSPs') technology needs.

The research, development, validation, and subsequent adoption of forensic technology are critical steps to continuous improvement in the forensic community. Successful technology implementation stems from productive research and development (R&D) to address practitioner needs, testing and evaluation to improve the technology, validation of the technology, and finally, broad adoption across multiple FSSPs. However, realities of the forensic science community can often lead to siloed efforts and limit the productive partnerships that drive the creation of value-adding technologies. As a result, innovative technologies often do not make the transition from research product to implementation and end up in a "valley of death" that limits broad adoption. Despite strong forensic community motivation toward research and development, testing, and evaluation (RDT&E), many promising technologies fall short of implementation without proper resources and planning.

This roadmap is intended to accomplish the following:

- **Articulate actions for forensic community members** to improve the transition of research and technology into adoption by FSSPs.
- **Highlight research partnership opportunities** to improve alignment between researchers and FSSPs to help advance knowledge, simplify FSSP workflows, create functional products, and improve justice.
- **Improve the process** of RDT&E, validation, and adoption of technologies into the forensic community.
- **Enhance collaboration around shared goals** that solve problems while saving time and resources.
- **Improve awareness of forensic community perspectives** and emphasize a shared lexicon (see Glossary).
- **Drive understanding** of realities and opportunities for forensic community research.

**Readers do not need to read this roadmap from front to back; instead, focus on the subjects that resonate most with you and/or your community.**

**Section One: Theory**
To understand the forensic innovation ecosystem and the context of research and transition challenges, read pages 7-9.

**Section Two: Current Challenges**
To understand cross-community perspectives on limitations to research and technology transition, read pages 10-13.

**Section Three: A Path Forward**
To access actionable next steps that you as a forensic community member can take toward improving research and transition outcomes, read pages 14-25. This section starts with a summary roadmap and then leads to specific calls to action for each forensic community member.

## Considerations for Readers

- The roadmap captures consensus-based opinions about lowering key barriers to forensic research and technology transition to implementation in casework. It is **not an exhaustive summary** of next steps.
- The forensic innovation process is iterative and often non-linear, and it may require several cycles of RDT&E before adoption and implementation. **Not all research is intended to actively transition** into an operational laboratory.
- The roadmap **identifies activities for the next 5 years** (2024–2029) that may bridge the "valleys of death" limiting transition of forensic research into operational FSSPs.
- The roadmap **considers forensic innovation at a high level**, but the authors recognize that each discipline will have specific applicable technologies, priorities, processes, and considerations. Similarly, research institutions and FSSPs vary in available resources, location (rural, urban, city), and level of governing jurisdiction (state, local, federal, tribal).
- Although researchers are referenced separately from practitioners in this document, **FSSPs may have specific researcher positions within the laboratory** or individuals who take on an additional research duty.
- This roadmap acknowledges that **resources to enable prioritization of RDT&E are critical limitations for technology transition**. Laboratory leaders, parent agencies, and government/policymakers live with this challenge, and this document therefore focuses on downstream actions to improve transition with available resources.

### Roadmap Lexicon

- This document includes processes, methods, and products/services under the umbrella of "technology."
- Publicly funded organizations offering forensic services, such as forensic laboratories and medical examiner/coroner offices, will be grouped and referred to as forensic science service providers, or FSSPs, in this document. Practitioners will be used to refer to individuals within an FSSP providing these services.
- Technology vendors are considered as part of industry and will be used interchangeably. Although private forensic laboratories are FSSPs, their organization, pricing structure, and budgets may not reflect those of a publicly funded forensic laboratory. As such, private laboratories will be considered within the "industry" community.
- Student researchers will be included within the broad category of academic researchers.
- This document refers to conveners and enablers as organizations that aggregate resources, connect community members, and provide avenues for discussion and engagement.
- Before any method, technique, or technology is implemented into an FSSP, it must be validated in that FSSP. However, in this document, validation will specifically refer to the process by which a novel technology is shown to be fit for purpose prior to widespread adoption.

## Subject Matter Experts and Collaborators

We would like to thank the various forensic community practitioners, decision-makers, researchers, and educators who offered insight and helped inform the development of this roadmap.

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# Key Takeaways

The pathway toward improved research and technology transition requires cultural change, starting at the leadership level and engaging with forensic community members—especially dedicated FSSP research scientists who can create and buttress partnerships between industry, academia, and laboratories (see **Figure 1**). This document synthesizes perspectives from various forensic community members to understand key needs and opportunities to improve the transition of research into practice.

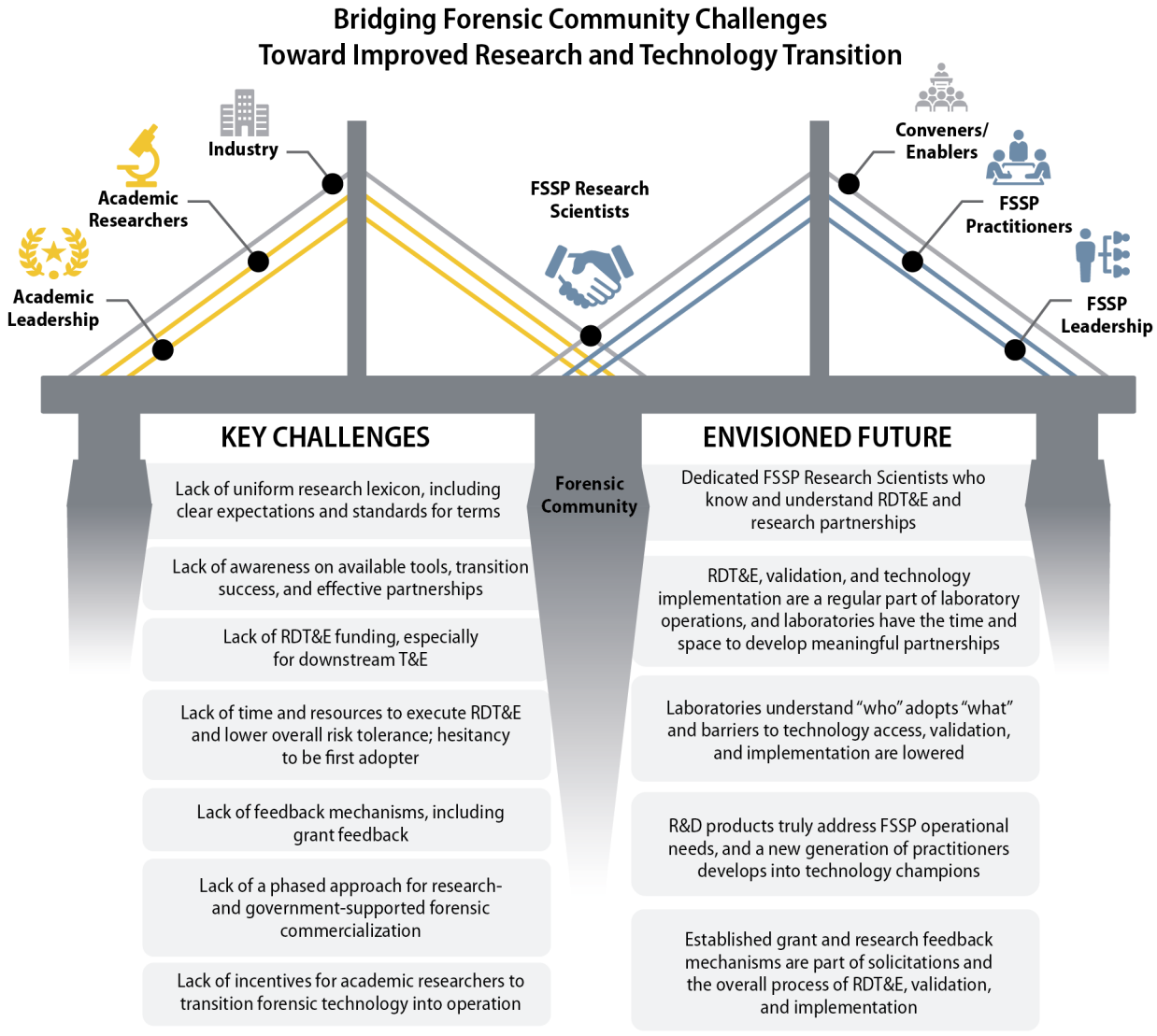


**Figure 1:** Engaging forensic community members is key to bridging current obstacles that limit research and technology transition to realize an envisioned future.

## This roadmap provides actions for forensic community members to develop and operationalize value-adding technologies.

The impact of forensic technology is realized when research successfully transitions into operation within FSSPs—where practitioners and the greater forensic community gain value using the technology in casework. Synergistic partnerships are key to improving research and technology implementation success. This entails the following critical action areas (as shown by **Figure 2**):

- **Increasing Leadership Buy-In.** Creating a culture that prioritizes RDT&E in an operational laboratory in addition to casework, which starts with advocacy for RDT&E resources from parent agencies and investors and leads to appropriate resourcing. Engagement from academic leadership bolsters research partnerships and helps build the business case for collaborative RDT&E.
- **Equipping Research Infrastructure.** Creating policies and processes to streamline research and transition activities in the laboratory and equipping laboratories with resources (e.g., space and equipment).
- **Improving Communication and Alignment.** Sharing expectations, feedback, results, and learnings across the forensic community so that RDT&E efforts align with operational needs and enable less-resourced FSSPs to also adopt technologies.
- **Facilitating Forensic Community Collaboration.** Developing partnerships that lay the groundwork for productive FSSP engagement with academia, industry, and other FSSPs. Diverse teams are crucial to testing and iterating upon technology in a realistic environment and fostering a culture of openness.

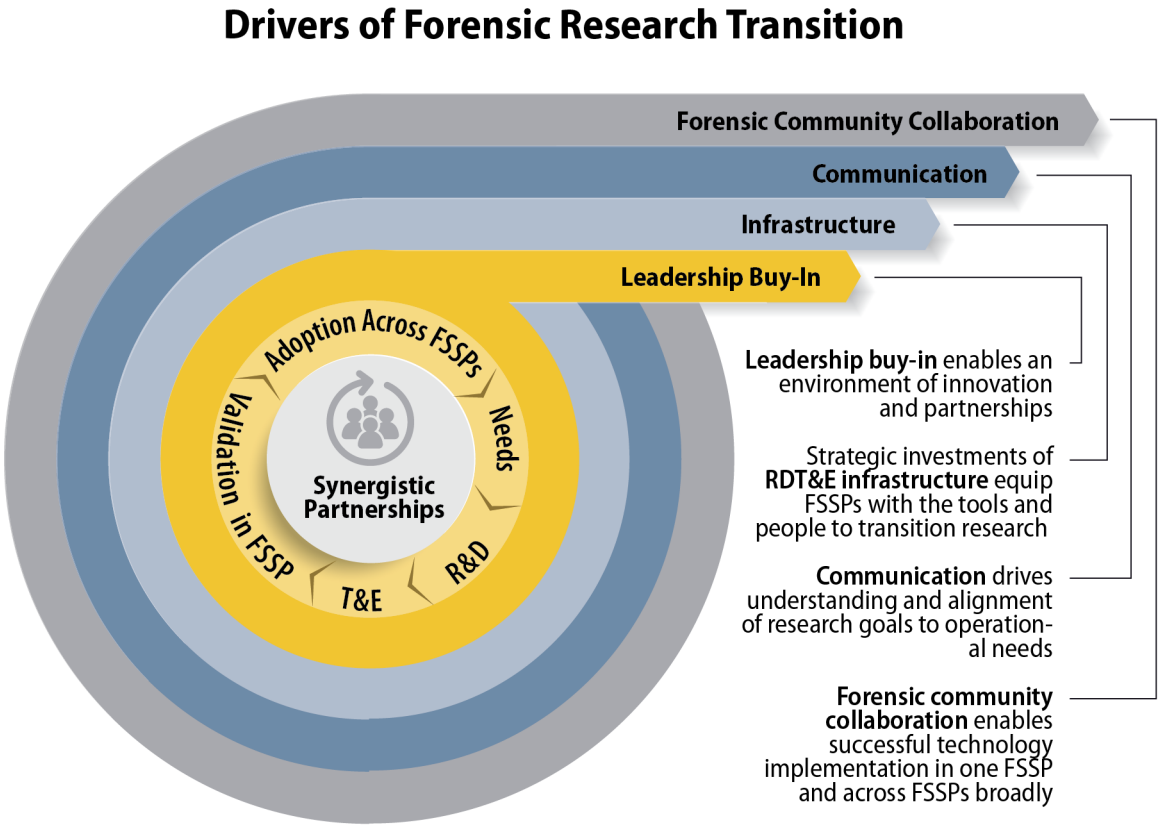


**Figure 2:** Synergistic partnerships between members of the forensic ecosystem, guided by critical action areas, drive the successful transition of research into FSSP operation.

## Improving forensic research and technology transition requires a culture of accountability, transparency, and trust, with engagement from each community member.

Each member of the forensic community brings a unique set of roles and responsibilities in transitioning technology; therefore, each member has unique action items for improving transition processes and outcomes:

While casework always remains top priority, improving transition of research starts with a mindset change of **FSSP Leadership** within and beyond laboratories to raise the priority of RDT&E and develop research infrastructure. Technology must be properly developed and validated before operational use, and FSSP Leadership should create and hire dedicated roles specifically for research and research partnerships.

**FSSP Research Scientists** should foster research and collaborative partnerships with academia, industry, and other laboratories. FSSP Research Scientists should have training in project management, research processes, and partnership agreements.

**FSSP Laboratory Practitioners** should engage with FSSP Research Scientists to share day-to-day pain points and communicate with different groups (e.g., academia, industry, and other laboratories) in alignment with appropriate rules and regulations.

**Leaders of Academic Institutions** are encouraged to foster collaborative partnerships with FSSPs. Forensic research activities should be bolstered through the provision of existing tools (e.g., tenure, sabbaticals). Academic institutions should advocate and reward technology transition by developing or supporting offices of research innovation and transition and enhancing collaboration between industry, government, FSSPs, and academia.

**Academic Research Scientists** should continuously explore ways to foster partnerships with FSSPs and industry to supplement and support transitional goals. They should actively support integration of student researchers into FSSPs.

**Industry-Based Technology Developers** should consider innovative strategies that support technology transition to FSSPs (e.g., loaning for pilot study, leasing, and other business models) and the development of value-adding solutions at the early stages of research.

**Conveners/Enablers** should serve as connectors and communication platforms for practitioners, researchers, and industry developers.

**The Forensic Community** needs to collectively drive technology adoption and transition across FSSPs. The community should enhance, increase, and enable effective partnerships—and share knowledge (e.g., successes, failures, validation resources such as validation sets, protocols, or other tools to determine fit for purpose). Public and private investors of the forensic community need to recognize the benefits of novel research and technology development for forensic science applications. To capture and disseminate best practices, the community should establish a baseline of transition metrics and periodically revisit to assess, diagnose, and overcome transition roadblocks.

# Context

## Technology adoption is critical to advancing forensic science and to enabling just outcomes in the criminal justice system.

Development and subsequent adoption of technology—whether a technique, product, or process—plays a key role in addressing forensic community needs. Implementing new tools, processes, and methods into FSSPs can advance methods and continuously improve investigations or resolve hypotheses. RDT&E of forensic technology is therefore a critical activity to address the community's evolving demands.

Technology adoption has true human impact—whether incremental or transformative. Day-to-day benefits of technology such as lower cost per test, improved sensitivity, or faster turnaround times help the forensic community deliver important investigative information and interpretations of analytical findings while addressing large caseloads and backlogs. Value-adding technologies implemented in an FSSP can reduce strain on staff; enhance capacity; provide increased objective data to drive toward just outcomes; and contribute to improved welfare, quality of life, civil right protections, and safer communities.

## Forensic technology impact is realized when research is successfully transitioned to operation within FSSPs.

The transition of science and technology refers to a broad range of activities that share the goal of shifting science and technology to higher levels of RDT&E to accelerate the introduction of new technologies into operational capabilities.[1] Transition does not represent a single event but a set of actions that lead end users to learn about, pilot, revise or build toward a product or service design, develop, continue to validate, and ultimately adopt and use the solution or improvement in casework. These critical steps include the following:

- **Understanding Needs.** Leveraging FSSP experiences and pain points to develop research questions that address operational requirements.
- **Research and Development.** Using an iterative process to generate knowledge; create, enhance, or improve a method or process; or develop a product or service that addresses a key operational need.
- **Testing and Evaluation.** Determining and improving performance characteristics of tools, technologies, and methods.
- **Validation in FSSP.** Documenting and determining whether a tool or method is fit for purpose at an individual FSSP or a group of collaborating FSSPs.[2]
- **Adoption Across FSSPs.** Enabling successful implementation of technology into numerous organizations with experiential and knowledge sharing across the forensic science community.

The steps of research transition are often presented and discussed as linear, when in reality, there is significant iteration and complicated interaction at specific steps in the process (e.g., multiple rounds of R&D, varied testing and evaluation for specific uses). A signal of successful technology adoption in the forensic community often includes acceptance in court, which drives broader adoption. Technology adoption results in improvements and ultimately leads to a new understanding of needs, which initiates the next round of technology development.

1. USC 10 2359: https://www.govinfo.gov/content/pkg/USCODE-2011-title10/pdf/USCODE-2011-title10-subtitleA-partIV-chap139-sec2359.pdf
2. Wickenheiser, R., & Farrell, L. (2020). Collaborative versus traditional method validation approach: Discussion and business case. *Forensic Science International: Synergy, 2*, 230-237. https://doi.org/10.1016/j.fsisyn.2020.08.003

## Research can be transitioned in several ways, but this roadmap focuses on transition into FSSP operations.

Several transition pathways exist, including commercialization into a market-ready product or service, implementation of methods into FSSPs, or information awareness through knowledge sharing. Not all research is intended to actively transition into an operational laboratory; basic research, for example, plays an important role in building a foundational knowledge base so that others may "stand on the shoulders of giants." **This roadmap recognizes the diversity of research and transition outcomes but focuses on research products (e.g., techniques, tools, processes) meant for transition into practice.**

## Many forensic research products fail to cross the "valley of death" into operational use, but synergistic partnerships can help bridge these gaps.

Resource investments and activity by government, laboratories, and industry across the steps of research transition (e.g., money, manpower, and time) drive successful implementation and adoption. Without this activity and alignment, forensic research products intended for end users are not transitioned into operational laboratories. As a result, many high-potential technologies fall into "valleys of death" where mature innovations never reach implementation—the first as the research product is validated and adopted into one or multiple collaborating FSSPs and the second as it is broadly adopted through the FSSP community, as shown in **Figure 3**. These valleys of death are driven by misalignments of research efforts to operational needs; risk appetites for investing in low-maturity technology; limited communication across the forensic community; and lack of practitioner resources for testing, evaluation, and validation. Synergistic partnerships between forensic community members provide an opportunity to bridge these limitations; for example, research connections to practitioners who are willing to provide feedback can help improve alignment of technology to community needs.

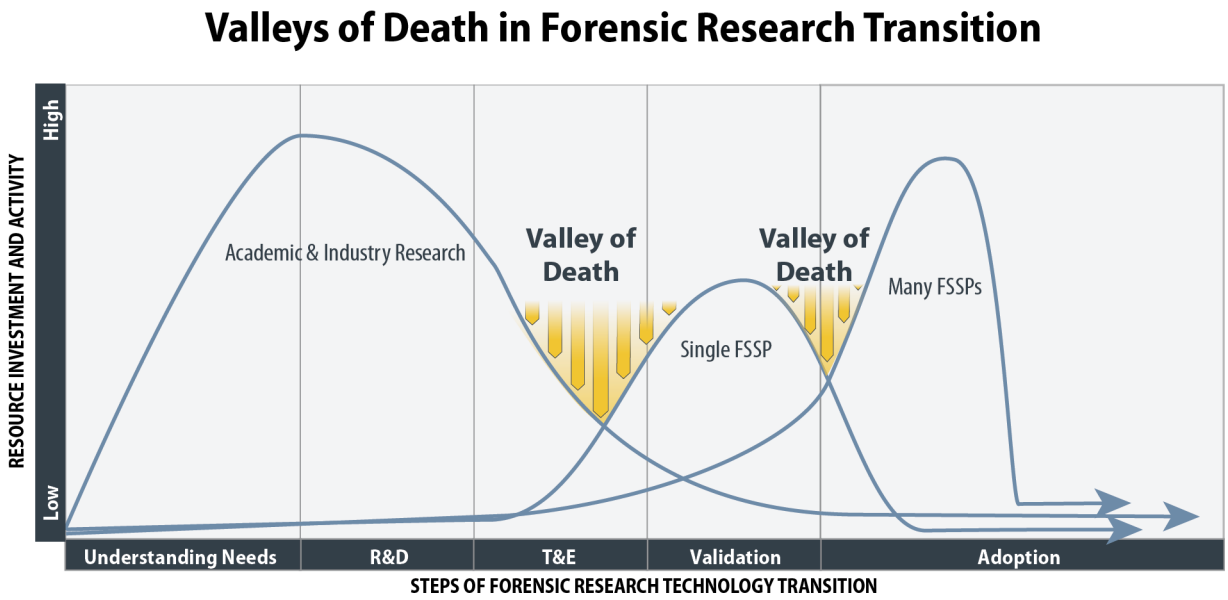


**Figure 3:** Without resource investment and activity through testing, evaluation, and validation, forensic research products often fail to transition in operational laboratories and to broader community adoption.

## Forensic community members play a collective role in improving research and technology transition.

Overcoming barriers to research transition and driving technology adoption is a shared community goal. Although forensic innovation is led primarily by researchers, it requires connections with key community members who bring varied perspectives and strengths. Forming a multi-stakeholder group that "models the economic…dynamics of the complex relationships… between actors of entities whose functional goal is to enable technology development and innovation" is commonly described as an "innovation ecosystem."[3] Successful innovation ecosystems have resources and members where individual efforts are encouraged and ideally coordinated at the community level, and the overall health of the ecosystem is demonstrated by the adoption of technology supporting changing forensic needs. For forensics, the community includes the following:

**FSSP Leadership** oversees FSSP operations, directing personnel and resources to efforts that keep the laboratory running efficiently and effectively.

**FSSP Research Scientists** foster and manage RDT&E partnerships between the FSSP and academia, industry, and other FSSPs (with respect to appropriate rules and regulations). Resourced by FSSP leadership, these research scientists have space, independent instruments, and time to develop synergistic partnerships that may lead to research transition in the operational laboratory.

**FSSP Laboratory Practitioners** serve as the end users of new methods and tools. Research products must have a significant business case for implementation; they must lead to significant improvements with a return greater than investments.

**Academic Leadership** educates the forensic community, fosters forensic research efforts, and creates a strong workforce pipeline.

**Academic Research Scientists** conduct inquiry for the purposes of (a) developing novel relevant materials, methods, or technology; (b) discovery; or (c) establishing facts. While academic researchers conduct both foundational and applied research, this roadmap focuses on the researchers who develop implementable research products within a research laboratory that advance forensic science.

**Industry-Based Technology Developers** commercialize products and services for forensic practitioners. Industry includes key development partners or transition advocates for researchers, and established companies that have successfully lowered the barrier to reaching practitioners.

**Conveners/Enablers** bring together the ecosystem and drive for impact. A diverse group of professional organizations, conveners and enablers foster discussion and collaboration and disseminate relevant resources for those considering technology implementation. Professional organizations that convene conferences, drive discussions, and provide training are essential for the forensic science community. They may include governmental agencies who support technology and training assistance, or a diverse set of community members with common goals (i.e., the National Technology Validation and Implementation Collaborative and the FTCOE). Enablers may include early adopters.

3. Jackson, D. (2011). *What is an innovation ecosystem?* National Science Foundation. https://www.researchgate.net/publication/266414637_What_is_an_Innovation_Ecosystem

# Current Realities Limiting Research and Technology Transition

Although the forensic community generally aligns on the steps of forensic technology transition, there is no clear playbook on how to execute this process (see **Figure 4**). Realities in the current forensic ecosystem make the process of transition inefficient, as motivations vary between community members and communication channels are limited. Focus groups and expert interviews of forensic community members organized by the FLN-TWG and FTCOE noted the following barriers to successful technology transition:

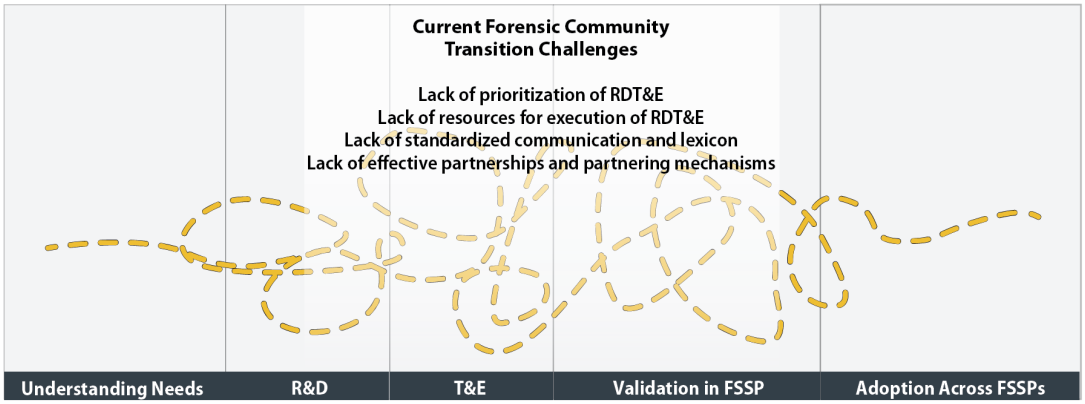


**Figure 4:** The process of developing and implementing technology is iterative and the steps of transition are often convoluted.

## FSSP leadership often struggle to adequately prioritize and resource RDT&E in an operational laboratory.

Successful technology implementation occurs when an FSSP follows a structured process, including documenting needs and validating new technology. Ideally, FSSP leadership should empower FSSP research scientists and other technical staff to create this structured process of assessing and managing technology implementation, starting from understanding needs through validation and adoption. However, FSSP leadership, faced with challenges such as resource limitations, insufficient staffing levels, and high caseloads, often finds it difficult to make time for scientific research, including acquisition and allocation of talent and funds.[4] To ensure the field is continuously improving, leadership should advocate for RDT&E dollars from parent agencies or other FSSP funders and work to articulate and demonstrate the value added by research investments.

Considering capacity limitations, leadership must weigh the value of RDT&E of emerging tools and methods, some of which may have already been proven in other areas, against existing methods. Forensic science leadership may have limited experience in defining return on investment and limited time to do so with existing resources, both of which limit the ability for leaders to advocate for new technology to be transitioned into operations. Informed by the perspectives of examiners, who bring varied perspectives on investment needs and perceived value of technology, unit leaders and laboratory directors must align on process and metrics to vet new technology (e.g., considering operational efficiencies, societal impacts) and enable the best use of RDT&E resources.

Lack of defined research priorities or plans to address these operational needs causes many of these technology implementation ideas to fail. Clear planning by FSSP leadership—and reliable, unbiased information sources about emerging technologies—is key to executing RDT&E and realizing improved justice and business values of new technologies.

**Resource limitations hinder the ability to conduct RDT&E in an operational laboratory. Hiring FSSP research scientists can help foster partnerships that can build capacity for research:**

> ***"Time required for grant management is one barrier I face. My Agency Grant Unit does not have the knowledge to handle the complexities of scientific research grants."***
>
> —Forensic Laboratory Director

4. Becker, W. S., Dale, W. M., & Pavur Jr., E. J. (2010). Forensic science in transition: Critical leadership challenges. *Forensic Science Policy & Management: An International Journal, 1:4*, 214-223. https://doi.org/0.1080/19409044.2010.508507

## Resource limitations impact the forensic community's ability to develop, evaluate, and implement new tech.

Resources lower the barrier to collaboration and implementation of new technologies; resources can be internal to an organization—for example, time and money dedicated to implementation—or offered by the greater forensic innovation ecosystem.

**FSSPs simply lack resources to execute RDT&E.** FSSPs operate on tight budgets, and addressing current casework is their priority. FSSP leadership (and their parent agencies) direct most of their limited dollars to casework applications. Resources for developing or validating potentially transformative technologies are scarce, and FSSPs may be limited to maintaining and updating current technologies, which offer only minor incremental benefits. Novel technologies naturally have a longer road to implementation and higher barriers to scale with leadership buy-in, risk management, and court acceptance. Budget and time constraints limit the ability for FSSPs to develop technology or provide feedback, especially when the technology is at a low readiness level. Seeking out, evaluating, and implementing novel technologies requires significant time investments as well as investment in equipment and consumables costs. Meanwhile, few extrinsic motivations such as career advancement or compensation are tied to successful technology transition in the laboratory. Often, "champions" who pilot and evaluate technology see inherent laboratory and societal benefits to testing and evaluating emerging technologies.

Student internships can aid research activities in forensic laboratories, but the high up-front investment to the FSSP, including extensive background checks and training, limits the ability of the interns to provide immediate value, which is an even bigger issue if they are working for a short time (e.g., the summer or a semester). Although internships require significant up-front training and vetting by the FSSP, these opportunities can be effective partnership vehicles that may lead to further collaboration and access to resources (e.g., journal articles, grant funding) while strengthening the forensic workforce pipeline. Placements such as graduate research fellowships and other projects may represent opportunities for longer-term partnerships with a higher return on investment.

**While focusing on quick wins is valuable, resourcing transformative RDT&E can lead to true impact.**

> ***"[In an FSSP], the project list is always larger than the capacity of the R&D team. Immediate priorities tend to be incremental - WIN10 upgrades, version upgrades, etc."***
>
> —Company Executive, Forensic Technology Service Provider

**Forensic R&D funding solicitations are highly competitive.** Community members noted that solicitations for forensic funding are competitive; the application pool is wide, and few agencies fund areas directly pertaining to forensic applications (i.e., NIJ, National Science Foundation, Department of Defense). Most funding opportunities focus on basic and applied research and development, not testing and evaluation of research products, and lack a phased approach that incentivizes further maturity of the research products. Without access to resources, researchers simply cannot create or transition technologies with potential value to forensic applications. Researchers who secure resources without forensic science research objectives are often encouraged to develop the technology for larger markets. Limited R&D funding leads to a dependence on industry to internally innovate and develop the future of forensic technology. Although these companies may have easier access to practitioners, they may be limited to innovation within a small set of parameters (e.g., incremental improvements on existing technologies) and unable to take on higher-risk projects. FSSP leadership and research scientists should consider that private companies executing R&D initiatives may have different goals than academic organizations executing R&D using federal funding.

**The academic community prioritizes publications over forensic science collaborations.** Researchers in academic environments often need to demonstrate they have developed a viable, independent, and self-sustained research laboratory, which means they are expected to acquire external funding and communicate their findings in high-impact publications. With fewer funding opportunities in the forensic testing and evaluation stage, researchers may be less motivated to transition the research tools, prototypes, or findings into practice and are more likely to pursue other basic and applied research funding. Researchers may shy away from high-risk research opportunities, and research efforts may be duplicative rather than pushing the edge of research.[5]

5. Rahal, R-M., Fiedler, S., Adetula, A., Berntsson, R. P.-A., Dirnagl, U., Feld, G. B., Fiebach, C. J., Jimi, S. A., Horner, A. J., Lonsdorf, T. B., Schönbrodt, F., Silan, M. A. A., Wenzler, M., & Azevedo, F. (2023). Quality research needs good working conditions. *Natural Human Behavior, 7*, 164–167. https://doi.org/10.1038/s41562-022-01508-2

**University technology transfer offices support forensic technology transition but on a limited scale.** Technology transfer offices facilitate and incentivize research outcomes beyond publications and are often driven by significant federal investments in life science.[6] Typical technology transition processes include codifying and managing intellectual property (e.g., patents) and transferring these technologies to the public or private sector (e.g., commercialization pathways, including licensing or new venture development). Although some forensic research has been transitioned to FSSPs using university technology transfer offices and traditional commercialization pathways, much of these products (e.g., new techniques, methods, databases) are transitioned to the community via knowledge sharing. Technology adoption through knowledge sharing is difficult to track and assess because it may be incorporated into FSSP protocols without the researcher's knowledge. There are several metrics and pathways to understand potential successes, but there are no sweeping efforts to identify and quantify impact.

**Practitioners cannot easily access information about emerging technology.** Practitioners rely on informal peer networks to understand who is adopting what and so they may not always connect to early adopters. Important technology information from academic researchers or companies may not be available because of confidentiality and business sensitivity concerns (i.e., intellectual property). This impacts their ability to justify the return on investment of emerging technologies to non-scientist personnel, laboratory leadership, investors, and other community members. Researchers primarily share knowledge through academic channels with publications and presentations, but they often find that practitioners cannot access their work because of publication pay walls and lack of networking opportunities to connect with FSSPs organically. As a result, research may be siloed and inaccessible to the intended end user. Practitioners can do their own research to find proof of the value of new technologies, but this can be a time-intensive process because there is no one-stop shop for all the information they need (e.g., supporting statistics, case studies, journal articles). There is an awareness issue for some resources and an access issue for others (e.g., journal paywalls, regular conference attendance).

## Communication challenges lead to misalignments in research priorities and operational needs.

When practitioners, researchers, and the rest of the forensic community lack clear feedback loops, especially at the front end of research, research efforts may not align with operational needs. Lack of information sharing often leads to redundant efforts to develop technology, evaluate, or validate.

**Researchers lack appropriate feedback to develop, evaluate, or validate technology.** Input from practitioners helps academic researchers validate the value propositions of the technology and iterate along technology development. Feedback from grant funding organizations helps identify gaps in both successful and unsuccessful proposals. In many circumstances, researchers cannot get meaningful and standardized feedback. Researchers need actionable and honest feedback early in idea conception to better align technology development with user needs. Practitioners often lack the time to devote to providing this input and may prefer to be involved later with more mature technologies.

**No common lexicon exists to communicate forensic technology transition.** Different community members in the innovation ecosystem have noted different interpretations of the same terms. They may disagree on maturity of a technology because no common Technology Readiness Level scale exists for forensic technology. When building a case for value of a technology, researchers may not use language that resonates with decision-makers, and potential return on investment may not be communicated clearly.

**Making time and space for practitioner partnerships is key to developing technology appropriate for the FSSP.**

> ***"To get the new technology in the lab, [FSSPs'] cooperation and time dedication with researchers is critically important."***
>
> —Academic Researcher

6. Fleischut, P. M., & Haas, S. (2005). University technology transfer offices: A status report. *Biotechnology Healthcare, 2*(2), 48-53.

**Validation is critical to assessing and implementing forensic technology, but the process can be ill-defined and confusing for FSSPs that have not gone through this process with new technology.** Validation is a process critical to understanding whether a new forensic technology is fit for purpose in an FSSP. However, an FSSP may struggle to effectively conduct a validation study. Although some disciplines have developed best practices related to validation, there is no known standard defining what a robust validation of forensic technology looks like. Developmental validation performed by vendors serve a different purpose than internal validation or performance checks by an FSSP, and many vendors do not provide direct support for FSSPs to internally vet the tool. Anecdotal evidence from focus group participants emphasized that working definitions of "validation" differed widely, and expectations for this process may differ. Even with a clear validation plan, practitioners may not have access to statistical support or may not be able to access past validation resources from other laboratories or technology developers.

## Collaborative partnerships, although a mystery to many, are critical to success.

Community members in the forensic innovation ecosystem bring different motivations, constraints, and perspectives to the table. Collaboration across these community members is critical to lower the barrier to adoption, but partnerships can be difficult. Researchers and practitioners have different perspectives of when and how to collaborate and what success looks like.

**Forensic community members need support but often cannot connect with the right partners.** Practitioners are open to research collaborations, especially for applied, operationalized research. However, they may not have the training or tools to execute or facilitate research projects without partner support. Academic researchers may lack situational awareness of practitioner processes and realities, which limits their ability to understand user needs. Neither practitioners nor researchers may possess the innovation and entrepreneurship skillsets to transition a technology toward mass adoption. Although many researchers and practitioners attend the same conferences, they may not connect in ways that advance technology adoption or partnerships. Practitioners often see more value in connecting to vendors and commercial leaders, where the technology is more mature with a lower bar to implementation and skip opportunities to learn about early-stage research. Furthermore, practitioners scouting out new technologies are often not decision-makers; as a result, researchers often do not have opportunities to make meaningful connections that may lead to collaboration.

**Partners must overcome barriers like data sharing challenges, lack of incentives to innovate, and lack of clear expectations.** Although researchers rely heavily on practitioner buy-in and engagement, many FSSPs do not incentivize participation in R&D. Practitioners can dedicate only limited time toward collaboration and need to overcome several red-tape hurdles for sharing data that can help test and develop technologies. Sharing adjudicated case samples, for example, is often difficult and researchers may not be able to access samples representing real-world scenarios. Access to research datasets (e.g., validated datasets from FSSPs) is not readily available or centrally located leading to missed RDT&E opportunities. Moreover, upkeep and maintenance of these datasets are not supported beyond original funding. Informal agreements and lack of clear expectations may lead to frustrations and confusion over who deserves authorship of future peer-reviewed papers.

# The Path to Improving Research and Technology Transition

Synergistic partnerships within the forensic community can improve momentum and value-added outcomes of the RDT&E process. This process is iterative but cyclical and anchored in several key action areas. An envisioned future for synergistic partnerships within the forensic innovation ecosystem looks like the following:

- **A mindset shift among FSSPs and academia to prioritize and normalize technology transition and collaborative partnerships.** Articulating processes, guardrails, and priorities can help create a culture where new technologies are incorporated into everyday practice and where practitioners and researchers have space and time to dedicate toward RDT&E, validation, and adoption.
- **Adequate community-wide research infrastructure to facilitate RDT&E, validation, and adoption processes.** Resourcing partnership-specific positions and facilitating researcher access to technology, among other steps, can lower barriers to testing, validation, and implementation and provide space and time to develop meaningful partnerships.
- **Improved communication avenues that drive alignment of operational needs and research.** Robust feedback cycles and platforms for researchers, practitioners, and industry to share learnings and needs enables the forensic community to be responsive and agile. Enhanced awareness of concurrent efforts allows researchers to help define and build on the "edge" of research.
- **Capacity to effectively partner with a diverse forensic team.** Cross-community engagement is a force multiplier for transition success, but teams need resources to speak the same language and share consistent expectations of roles and responsibilities in partnerships. Researchers and practitioners can quickly understand needs and effectively "match up." Partnerships are sustained and have consistent expectations. FSSP buy-in for academic partnership is easy to obtain, because there is a clear business case and effective risk mitigation tactics in place.

Developing synergistic partnerships that drive technology transition into operation in one FSSP—and ultimately broadly across FSSPs—will require sustained stakeholder engagement, resources, persistence, and time. **Figure 5** represents broad opportunities to move the needle, starting from a mindset shift to strategic investments. The next section speaks to how each community member would function to enable synergistic partnerships to improve research and technology transition in forensic science.

## Roadmap to Improve Research and Technology Transition in Forensic Science

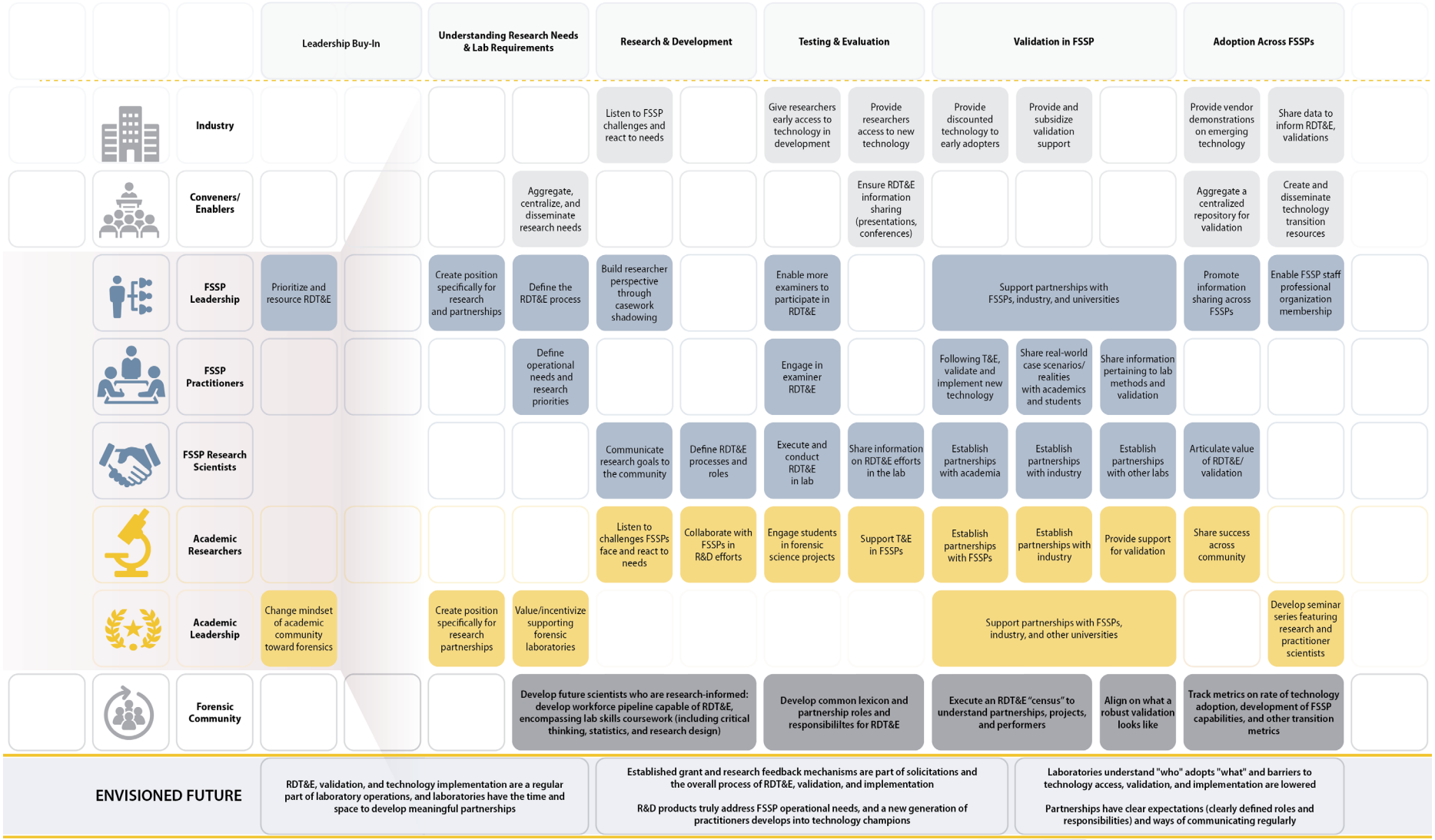


**Figure 5:** The forensic community can engage in several improvement opportunities that may enable technology adoption not only in one FSSP but adoption across many FSSPs. While engaging with government, parent agencies, and other groups for RDT&E resources is a critical upstream action, it is not represented in the roadmap.

## Improving research transition starts with changing the mindset of laboratory leadership to prioritize and resource RDT&E.

Leadership must make RDT&E a priority to advance forensic capabilities at their laboratory. While the needs of each forensic discipline vary in resources needed for validation and research, leadership should **advocate for and allocate dedicated resources to enable RDT&E success**, including research staff (including interns or fellows), equipment, and laboratory space. Leadership should **create defined roles for research scientists** to empower them to drive RDT&E within the laboratory (and thus enable leadership to focus on current laboratory operations). FSSP leadership should **establish, maintain, and communicate 5-year strategic plans** that codify and explain their RDT&E and technology advancement strategy. The plans should align internal FSSP resources while also providing visibility to other partners within the forensic community that may be able to support or collaborate.

Leadership should **leverage the FSSP's collective technical capital**—and share knowledge with collaborating FSSPs—to identify and communicate research goals, providing clear needs to academia and industry. Open conversations about implications of technology implementation on existing policies and procedures can help the organization reach informed decisions on whether to pursue RDT&E opportunities.

FSSP leadership should hire dedicated **research scientists** who are skilled in assessment of technology needs, research design, research conduct/execution, publications, project management, and collaborative partnerships. FSSP leadership should empower research scientists to establish all research and partnership related processes at the laboratory. FSSPs with research scientists have a dedicated resource to enable successful RDT&E, change management efforts, technology adoption, and partnership formation.

Hiring research scientists in roles that are specifically dedicated to research and research partnerships, in a part- or full-time capacity, can help ensure FSSPs have the best tools and technologies to support casework.

FSSP leadership, advocating to parent agencies, should revisit agency policies and grant mechanisms to advocate for leasing models or loaners as methods of technology acquisition. They should strive to provide knowledge of relevant forensic evidence samples or even adjudicated samples to ensure research is based on case-relevant evidence. **Investing in practitioner and research scientist attendance, training, or membership** in professional organizations or working groups—with the expectation that research scientists directly connect with researchers and develop partnerships—can help improve communication between organizations. Leadership should send relevant technical personnel to appropriate conferences where researchers are presenting and be willing to attend joint sessions with academics.

**Communicating successes and failures**, including results of validation studies, fosters an environment of open and honest feedback that improves research efforts and future solicitations—and helps educate academic leadership about the impact of forensic R&D.

***Laboratory leadership, how are you creating a path toward technology-enabled continuous improvement in the laboratory?***

## FSSP research scientists should foster research and collaborative partnerships with academia, industry, and other laboratories.

FSSP leadership task FSSP research scientists with advancing forensic science research to support laboratory operations. Research scientists should **have specialized experience, knowledge, and training** in both forensic science and research, which makes them exceptionally well-positioned to form partnerships to meet the strategic RDT&E goals of the laboratory. Research scientists should **collaborate with practitioners** to better understand their challenges that could be addressed by RDT&E, while also maintaining visibility of current and ongoing research at universities and other operational laboratories. This visibility enables collaboration among laboratories that have shared research goals and avoids unnecessary duplication of research which can waste laboratory time and effort.

Research scientists should **maintain a close working relationship** with other research scientists (including federal partners), project managers, program/portfolio managers, academic researchers, and industry innovation partners, in addition to the FSSP practitioners they support. Maintaining this network helps understand each organization's research priorities and their research capabilities (which includes specialized knowledge, skills, or equipment). Research scientists should **function as partnership managers** as well, with their specialized knowledge of government partnership agreements, legal authorities, data sharing agreements, and knowledge of research processes.

Research scientists are responsible for technology scouting, technology validation and implementation, and procurement to keep their laboratory ahead of the innovation curve, freeing up more time for analyst training and policy development for new methods/technologies. Research scientists should **attend forensic and research conferences** to maintain visibility of new tools/technologies. Additionally, they should **routinely visit universities** to observe their research efforts but also to foster internship opportunities at the laboratory.

FSSP research scientists should **communicate technical information** to both technical and non-technical audiences; this skill is critical for mentoring student interns and informing them about forensic disciplines and research. Research scientists should **invest time in developing the next generation of forensic scientists** who will leave the internship with greater knowledge of research skills and the importance of research.

***Research scientists, how might you serve as a connector and facilitator of RDT&E partnerships that drive technology implementation into operational laboratories?***

## FSSP practitioners should prioritize research feedback and collaboration with research scientists.

To support FSSP RDT&E investments, practitioners should **actively participate in efforts to define** FSSP operational gaps and research needs, including the performance parameters of specific needs. Practitioners should **understand the value of providing direct and specific feedback** to FSSP research scientists and quality assurance managers, especially at the front end of research. Representation in opportunities such as technical working groups, professional organizations, or one-off activities such as hackathons or design sprint challenges can help communicate operational needs to the forensic community as a whole and ultimately influence current and future R&D efforts.

With leadership buy-in and in accordance with FSSP policies and procedures, research scientists should **lead RDT&E and validation efforts with strong engagement from forensic practitioners** while also leveraging academia or industry support as needed. Bringing researchers and technology developers into the laboratory can help them better understand operational realities and consider alignment of needs and research. These partners can assist in many ways, from grant-writing support at the front end to technical support through the implementation process. Engagement in platforms such as the American Society of Crime Laboratory Directors' (ASCLD's) Laboratory and Educators Alliance Program (LEAP) and other mechanisms to search a nd connect to potential partners is key.

As the end user of the emerging technology, practitioners can provide a critical perspective through the RDT&E and validation process. **Participating in efforts to share results and communicate outstanding research needs** to other laboratories, researchers, and conveners can help additional laboratories consider and plan technology implementation. For example, sharing validation studies in ASCLD's Validation Repository can help other FSSPs as they build and execute a validation methodology.

The Air Force and Space Force, for example, organized a BRAVO Hackathon to address specific challenges identified by the Department of Defense. The opportunity provided a development environment and operational data to develop solutions, and the Air Force has chosen some of these technologies for additional development. Similar events could provide time and space for researchers to engage with forensic practitioners, access relevant data, and develop partnerships.

ASCLD's Forensic Research Committee (FRC) created the Laboratories and Educators Alliance Program (LEAP) to connect academic researchers with forensic practitioners. The FRC Collaboration Hub provides a directory of practitioners willing to partner and researchers looking for support or collaboration. LEAP also provides a Research Partnership Consideration list to define expectations up-front, and a Validation and Evaluation Repository. ASCLD also organizes monthly "Lightning Talks," which highlight emerging technologies for an FSSP leadership audience.

The NIJ also manages a list of forensic laboratories that have expressed interest in connecting to forensic researchers, and researchers interested in partnerships.

***Practitioners, how might you be an advocate for new technologies that can help your laboratory and drive continuous improvement?***

## Leaders of academic institutions need to shift their mindset toward incentivizing forensic collaboration and influencing a new generation of forensic leaders.

To motivate researchers to pursue technology transition of forensic R&D, institutional leadership needs **to build career pathways that recognize and reward researchers** who achieve this outcome. These avenues may include developing or supporting offices of research innovation and transition; staffing to support these activities; and delivering programming to enhance collaboration between industry, government, and academia. For FSSPs, universities are an access point to valuable technical capital and equipment to facilitate RDT&E and validations (as shown in **Figure 6**). Often, FSSPs need academic institutions to be the primary organization for a grant because they do not have the capacity to accept the added role and responsibilities. Academic researchers and forensic education staff should **advocate for partnership opportunities with FSSPs** by demonstrating the societal benefits of forensic technology implementation investments and working with university leadership to build resources for these relationships (e.g., equipment, co-located facilities, graduate student time).

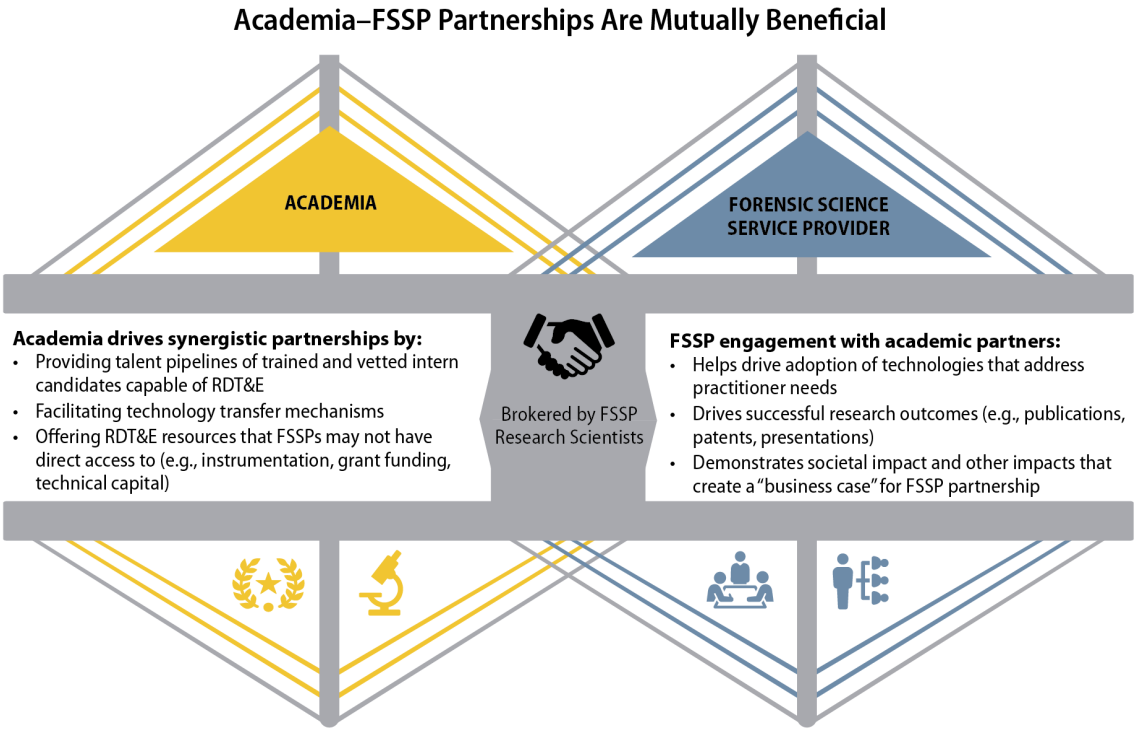


**Figure 6:** Partnerships between academia and FSSPs create a mutually beneficial cycle of feedback and resource access.

Institutions with forensic programs should **hire educators with actual forensic science experience** who recognize the value of FSSP engagement and champion the development of partnerships. Building these relationships can also help inform students of the opportunities and realities of a forensic science career pathway. These organizations serve as key talent pipelines that shape the next generation of forensic scientists. Institutions should **train and vet students (especially graduate students) with specific laboratory and research skills**, so that they may be able to train up quickly in operational laboratories, understand RDT&E and validation processes, and "speak the language" of practitioners. Leadership should **consider reviewing and developing their forensic education programs** to be more robust, leveraging resources such as the Forensic Science Education Programs Accreditation Commission (FEPAC) standards as a baseline.[7] Forming partnerships with FSSPs is a requirement of FEPAC programs and student research projects, but sustained partnership is critical.

***Academic leadership, how might you support researchers and students looking to make an impact in the forensic science community?***

7. Forensic Science Education Programs Accreditation Commission. (2012). *Accreditation standards*. https://www.aafs.org/sites/default/files/media/documents/2022%200212%20FEPAC%20Standards.pdf

## Academic researchers should be persistent in creating partnerships and support FSSPs through the transition process.

Researchers should **be persistent in reaching out for direct feedback** and support from practitioners, starting at the front end of their research. Through this outreach, researchers should **stay user-centered** (i.e., focusing on practitioners' workflows and challenges). Researchers should remain informed of needs assessments and other resources that summarize forensic community pain points and **participate in working groups and professional organizations** that could connect them to practitioner technology champions. **Leveraging databases** such as the ASCLD Collaboration Hub and LEAP, NIJ's partner lists, and RTI International's FTCOE resources can help point to collaborative relationship leads. Researchers should be aware of ongoing forensic research efforts to avoid redundant efforts that increase competition for finite resources.

The University of Central Oklahoma (UCO) partnered with the Oklahoma State Bureau of Investigation (OSBI) to **co-locate the OSBI's new laboratory and UCO's Forensic Science Institute in 2008**. The proximity has allowed the OSBI to provide hands-on education and training opportunities for students, and in return gain access to a potential analyst pipeline, continuing education, and advanced equipment.

With the support of university leadership, academic researchers should **engage in ongoing partnerships with FSSPs**. Researchers should **directly support RDT&E efforts** in the practitioner laboratory, making sure to set clear expectations on roles and any publication authorship. Researchers should **leverage university equipment, student support, and other resources** to enhance the technical capacity of the FSSP, being sure to use a commonly accessible set of tools when possible. Actively participating in the technology validation process, including sharing all relevant testing and evaluation data, helps inform future research efforts on what criteria and level of reproducibility is required for long-term adoption in practice. Researchers may consider **publishing in research journals that promote the sharing of data** in supplemental form. FSSPs gain a better understanding of how to implement technologies when researchers can be used as a resource. Researchers may be able to **leverage academic colleagues** to provide statistical support and other technical assistance to help validate emerging technologies.

As their research products mature, researchers should consider **engaging with their university's technology transfer resources** to understand transition opportunities and strategies and to consider multiple ways to engage with university–industry knowledge transfer, including contract research and consulting relationships. Academic institutional support is critical to enabling successful technology transition. However, communicating research outcomes to the forensic community is critical to informing practitioners and driving broader technology adoption. Because publications are highly impactful methods of disseminating research, researchers should consider **publishing in open-access journals** (building in resources for this at the proposal phase when it is not already a requirement of the solicitation) or disseminating resources in a variety of accessible avenues such as presentations, posters, webinars, and community forums (e.g., hackathons).

***Researchers, how might you drive sustained engagement with FSSPs to support technology transition into operation?***

## Industry technology developers should provide support to FSSPs to lower the barrier to technology access.

Technology developers, like academic researchers, should **listen and respond to the needs** of practitioners using high-level needs assessments and direct practitioner feedback. Industry should **support researchers in pre-competitive ways** to foster partnerships. For example, Industry–University Cooperative Research Centers serve as a funding mechanism to support researchers and help them understand feasibility and viability considerations. The Center for Advanced Research in Forensic Science (CARFS), an NIJ–NSF partnership, leverages feedback from industry partners.

Researchers and FSSPs often lack access to advanced instrumentation to assist in RDT&E. **Providing researchers early access to technology** in development can provide beneficial real-world use in an RDT&E setting and can provide researchers and their FSSP partners the right technology for testing and evaluation purposes. For example, lowering the barrier to early adopters through **discounted technology**, leasing models, or loaner instruments allows the FSSP to "test drive" the instrument without obligatory commitment and cost. This supports a feedback loop to the technology developers of "practical use" settings that will allow them to refine the technology early on and ensure a better experience for other FSSPs.

Adopting technology in FSSPs may require a significant amount of technical labor that the laboratory cannot complete independently; they often rely on technical support from vendors. Industry should **provide direct testing and evaluation support**, including appropriate vendor data, and offer support services to assist laboratories in validations and internal training (potentially including the validation process as a necessary part of technology onboarding). In addition to providing resources like validation sample sets, vendors could assemble collaborative teams of FSSPs implementing the same technology to create "communities of practice" that can share knowledge and perform joint validations. Engaging with FSSPs in industry evaluation and sharing findings in the form of technical or application notes can help discerning FSSPs make informed decisions on emerging technology. To keep the community apprised of new technology, vendors should **host demo days** and other demonstrations on new and emerging technology to provide opportunities for hands-on testing. Developers should **promote sharing of validation protocols** (through avenues such as the ASCLD Validation Repository) and other research products, such as vendor technology notes.

**The NSF-Funded CARFS program fosters direct input and partnerships with industry and forensic researchers.**

The Center for Advanced Research in Forensic Science (CARFS) is an NSF-funded Industry–University Research Partnership program run out of Florida International University. The program brings in a diverse set of partners—including operational federal laboratories and small to medium forensic science companies—with the goal of fostering collaboration and effective research to solve forensic community needs. CARFS provides industry an opportunity to share research needs and fund competitive research proposals. Industry partners engage with researchers throughout this process to help refine proposals. Membership offers these partners access to the center's research portfolio, access to research talent, and royalty-free non-exclusive licensing of resulting intellectual property.

***Industry technology developers, how might you lower barriers to technology that may be transformative to FSSP RDT&E processes?***

## Conveners and enablers should serve as connectors and communication platforms for practitioners, researchers, and industry.

FSSPs that have successfully implemented technology and researchers who have successfully transitioned technology represent a significant wealth of knowledge for the forensic community, offering key insights and resources such as interlaboratory and validation studies. Many professional organizations and conveners have done the work of aggregating information, and others developed resources to help the community better understand and implement emerging technologies. Conveners and enablers should **continue to aggregate resources** such as validations and evaluation studies and to **disseminate resources**, including emerging technology news, ongoing RDT&E efforts, success stories, methods and procedures, purchase contracts, training manuals, court transcripts, and scientific publications. **Creating a mechanism (e.g., database or online repository) to track all forensic research efforts**, including those that did not prove fruitful or did not transition, to guide future efforts would help avoid duplication of work in the absence of journal publications on the work.

**Examples of Conveners and Enablers:**

The **FTCOE** provides resources that inform the forensic community about emerging technologies. Webinars, podcasts, and reports such as landscape studies can help identify who has piloted or implemented new technology. These no-cost resources provide a platform for both researchers and practitioners to share learnings.

The **Center for Statistics and Applications in Forensic Science** provides learning opportunities for researchers and practitioners to apply statistical analysis to the application of forensic evidence—a key challenge noted by many community members—and opportunities to collaborate.

Florida International University has developed a **library of forensic resources**, including open-access journals, full-length books, and training references that could help practitioners stay aware of emerging technologies.

Research Days or visiting scientist events that focus on emerging technology successes that can help connect researchers and practitioners at early stages and promote good feedback and partnerships. Centralized tracking of who is evaluating and implementing what technologies can encourage forward planning and collaboration.

Enablers such as professional organizations should **create time and space for practitioners, industry, researchers, and funders to engage** and share perspectives and RDT&E progress. This could include opportunities such as pitch days, facilitated networking events, or demo days. Many instances of successful collaboration have included partners who were in close geographic proximity; enablers should start smaller with regional, regular collaboration efforts or consider virtual networking opportunities. **Regional partnerships** are another way to provide training for FSSP staff and help them stay apprised of new technology advances. Conveners and enablers **create opportunities to aggregate interdisciplinary perspectives** that help specify requirements for research needs, such as practitioner advisory boards. In addition to creating "collision" opportunities for researchers and practitioners, conveners should be actively connecting forensic community members.

***Conveners and enablers, how might you support connections and awareness building to foster effective partnerships?***

## The forensic community as a whole needs to collectively drive a future of technology champions, effective partnerships, and tracking metrics.

The forensic community has a shared responsibility to develop future scientists who are research-informed. To build a workforce of future technology champions, FSSPs and academic institutions should **provide educational opportunities that build essential skills** for RDT&E and validation in a laboratory. Coursework could include critical thinking, statistics, and research design. Programs could also focus on currently less developed laboratory skills, including analytical balance use, serial dilutions, unit conversions, report writing, and communicating results. These programs should emphasize the value of scouting emerging technology, equip students with skills to vet technology appropriately, and frame technology implementation as a necessary investment. Students should be able to critically analyze and filter out potentially biased information and methods that may not be reliable. In the short term, this front-end investment could reduce the time and resource burden of training up students for internship placements in FSSPs. In the long run, this could help foster a culture of research-informed operations.

**A common lexicon** to define technology readiness and resources would help researchers and practitioners align on roles and responsibilities (a standard TRL scale could be a place to start; see **Figure 7**). Likewise, community members should **help define what a robust validation process looks like** to help practitioners from all forensic disciplines. Consolidating these resources into a short and simple discipline-wide document and disseminating these resources across different enablers and conveners would improve visibility and uptake of these resources.

Developing a common language would build on existing efforts by the National Technology Validation and Implementation Collaborative (NTVIC) to improve technology implementation. The NTVIC was created in 2022 to develop forensic community resources facilitating technology implementation into FSSPs and forensic medical service providers. Comprising FSSP leaders, academic researchers, and technology providers, the NTVIC recently released its first document discussing policies and procedures for forensic investigative genetic genealogy.

**Establishing and tracking technology transition metrics** can help the forensic community further understand gaps, opportunities, and returns on investment. Although current efforts capture knowledge from researchers, expanded efforts to track a diverse set of transition-related factors (e.g., number of researcher–practitioner partners made) and reach a broader audience may paint a more accurate picture of transition outcomes over time. Developing and assessing metrics can help provide insight along the way on whether the community is trending toward improved transition and can help provide a clear business case for FSSP investment in RDT&E. This may look like a more expansive census that involves a diverse set of forensic community members (i.e., beyond practitioners in publicly funded crime laboratories) or may expand existing efforts (e.g., the Bureau of Justice Statistics Census for Publicly Funded Crime Laboratories).

| Readiness Level | Description |
|---|---|
| 1 | Basic (scientific) principles have been observed and reported |
| 2 | Technology concept and application have been formulated |
| 3 | Critical experimental function or proof of concept has been demonstrated |
| 4 | Experimental technology or system has been tested and validated in the laboratory |
| 5 | Actual technology has been demonstrated in a relevant environment |
| 6 | Actual technology has been tested and validated in an operational environment (forensic laboratory or field) |
| 7 | Actual system has been proven through successful mission operations (forensic laboratory or field) |

**Figure 7:** Example of a simplified FTCOE "Technology Readiness Scale" to help assess technology readiness.

Examples of potential metrics to assess transition success may include the following:

- Number of FSSPs with clearly defined research priorities
- Number of FSSPs with written RDT&E Strategic Plan
- Time from proposing RDT&E idea to execution (which may lead to implementation or abandonment)
- Number of established research partnerships
- Work hours devoted to RDT&E
- Number of FSSPs willing to engage with researchers (e.g., partnerships with local universities, increased engagement with the ASCLD LEAP site, participation in NIJ's list of forensic laboratories)
- Level of laboratory engagement with resources such as ASCLD's Validation Repository
- Number of available evaluations, validation studies, and other accessible resources such as sample and datasets, procedures, training manuals, or court transcripts
- Number of practitioner partners disclosed on grantee submissions
- Number of "success stories" of matchmaking between researchers and practitioners
- Number of publications that include multi-institutional authors and acknowledgments
- Number of presentations and patents that lead to publications
- Number of "co-locations," placements, and internship opportunities (e.g., number of senior level undergraduate or graduate student researchers gaining internship or full-time employment in forensic laboratories)
- Increase in the number of startups, commercializable opportunities, and IP
- Number of researchers engaging with technology transfer offices or programs
- Number of vendors offering validation and implementation support
- Dissemination metrics (publications, patents, adopters/speed of adoption)

***Forensic community, how might we collectively improve transition of research into operation?***

# Conclusion: FLN-TWG's Call to Action

Bridging the "valley of death" of forensic research transition starts with a mindset shift and requires investing resources, improving communication, and sustaining stakeholder engagement. A primary goal of the NIJ's FLN-TWG, which sought key perspectives and insights for this roadmap, is to ensure that research and implementation of forensic technology is relevant and responsive to forensic laboratory operational needs. As a team of researchers and practitioners, FLN-TWG recommends creating resources to help forensic community members identify their progress toward improving transition, thorough assessments to derive and track metrics related to forensic technology transition, and tools to improve community communication and collaboration.

Sweeping cultural changes to forensic technology adoption will not happen overnight or, realistically, over the next few years. However, each community member can take small steps toward fostering collaborative partnerships and creating opportunities for RDT&E, ultimately lowering the barrier to technology that improves just outcomes.

# Glossary

For clarity and accuracy, the following definitions are essentially unchanged from their citations. Where there might be differences, they reflect adjustments for clarity and conciseness.

**Research and Development:** Creative and systematic work undertaken to increase the stock of knowledge—including knowledge of humankind, culture, and society—and to devise new applications of available knowledge.[8] There are three different types of R&D:

1. Basic research. Experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view.
2. Applied research. Original investigation undertaken to acquire new knowledge. It is, however, directed primarily toward a specific, practical aim or objective.
3. Experimental development. Systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improving existing products or processes.[9]

**Development:** The acquisition of test data and determination of conditions and limitations of a new methodology; this generally occurs while the conditions and parameters are being worked out prior to the establishment of a defined assay, procedure, or product. Internal validation studies typically follow developmental validation studies.[10]

**Forensic Science Service Providers (FSSPs):** A person or entity that recognizes, collects, analyzes, or interprets physical evidence and issues test or examination results; provides laboratory reports; or offers interpretations, conclusions, or opinions through testimony with respect to the analysis of such evidence.[11]

**Forensic Practitioner:** Individuals within FSSPs who collect, identify, classify, and analyze physical evidence related to criminal investigations, and perform tests on weapons or substances, such as fiber, hair, and tissue to determine significance to investigation. They may testify as expert witnesses on evidence or crime laboratory techniques and serve as specialists in area of expertise, such as ballistics, fingerprinting, handwriting, or biochemistry.[12]

**Innovation:** "A new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)."[13]

**Technology Transition:** A process in which a technology moves from research and development stages (e.g., prototype) into operation by the relevant end user community (e.g., operational laboratory).[14]

**Technology Readiness Level (TRL):** A type of measurement system used to assess the maturity level of a particular technology. Each technology project is evaluated against the parameters for each technology level and is then assigned a TRL rating based on the projects progress. There are nine TRLs. TRL 1 is the lowest and TRL 9 is the highest.[15]

**Testing:** The determination, by technical means, of properties, performance or elements of materials, products, services, systems, or environments, which may involve application of established scientific principles and procedures. Testing typically applies to materials, products, or processes.[16]

**Validation:** Documenting and determining whether a tool or method is fit for purpose at an individual FSSP or a group of collaborating FSSPs.[17]

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RTI International (RTI) and its academic and community based-consortium of partnerships, including its Forensic Science Education Programs Accreditation Commission partners, work to meet all tasks and objectives put forward under NIJ's Forensic Technology Center of Excellence (FTCOE). These efforts include determining technology needs; developing technology program plans to address those needs; developing solutions; demonstrating, testing, evaluating, and adopting potential solutions into practice; developing and updating technology guidelines; and building capacity and conducting outreach. The FTCOE is led by RTI, a global research institute dedicated to improving the human condition by turning knowledge into practice. The FTCOE builds on RTI's expertise in forensic science, innovation, technology application, economics, data analytics, statistics, program evaluation, public health, and information science.

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