

The author(s) shown below used Federal funds provided by the U.S. Department of Justice and prepared the following final report:

Document Title: Denver DNA Efficiency Improvement Project,
Final Technical Report

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Document No.: 240638

Date Received: December 2012

Award Number: 2009-DN-BX-K001

This report has not been published by the U.S. Department of Justice. To provide better customer service, NCJRS has made this Federally-funded grant report available electronically.

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FY 2008 Forensic DNA Unit Efficiency Improvement

Denver Police Department Crime Laboratory

Award Number: 2009-DN-BX-K001

Authors: Lindsey R. Horvat, Susan G. Berdine, and Dr. Gregory S. LaBerge

FINAL TECHNICAL REPORT

November 30, 2012

Abstract

STR DNA analysis began at the Denver Police Department Crime laboratory in 1999. Due to many individual case successes and programs, demand for DNA services soared, and between 2000 to 2011 the Denver Police Department Crime Laboratory's DNA Unit experienced a 228% increase in case submissions due to successful projects such as the 2005 – 2007 DNA Expansion Demonstration (expanding the use of DNA in solving burglaries in Denver)¹ and “Solving Cold Cases with DNA” projects² funded by the National Institute of Justice.

In October 2009, the laboratory was awarded \$138,005 in funding from the National Institute of Justice DNA Efficiency Improvement Program. The goals of Denver's project were to:

- 1) Use specialized software to create a simulated model of the workflow of the Forensic Biology/DNA Unit, and subsequently identify areas for efficiency improvements and
- 2) Draw on employee input and a teamwork approach to identify and implement additional efficiency improvements. The ultimate goals of the efficiency gains were to decrease the backlog and turnaround time of DNA cases.

Using these funds, the laboratory hired a full time project manager and purchased simulation software called Simul8®. The DNA Efficiency Improvement Project Manager built a model or process map in Simul8® with input from DNA Unit personnel. One year of casework data was entered into the model, and test simulations were performed revealing two important findings: 1) Instruments and equipment were not causing bottlenecks in the workflow, and increasing the number of instruments did not improve the case backlog, and 2) An increase in trained DNA personnel improved the backlog and turnaround times to desired levels. Moreover

¹ Grant Award #2005-DN-R-095

² Grant Awards # 2009-DN-BX-K012 and 2010-DN-BX-K004.

the simulation provided definitive data on the number of staff required to eliminate the case backlog, and meet target objective turnaround times.

The DNA Unit's efforts to use teamwork approaches to identify efficiency issues and implement solutions was the most successful part of the project, and resulted in a number of improvements, including new procedures (statistical tools, Identifiler®Plus, male DNA screening of sexual assault kits), new equipment, and collaboration with groups outside of the Crime Laboratory (retaining grant employees, consumptive testing, and Forensic Laboratory Technician positions). Most of the issues were identified by personnel within the DNA Unit, and the use of initial anonymous employee surveys was an invaluable tool for identifying problems. The early successes in resolving a few of these issues fostered buy-in within the DNA Unit, and an environment where additional suggestions were welcome, and staff were willing to accept any changes being implemented. Additionally, having a dedicated Efficiency Improvement Project Manager to document and analyze each efficiency improvement, as well as implementing and evaluating them, contributed to the success of the program. One of the DNA Unit's hypotheses was that many of the solutions would be low-cost or no-cost, which was proven true for the majority of the improvements.

Overall, these improvements yielded impressive results, and are estimated to have saved the DNA Unit one full year of analyst time, and \$307,096 in costs in the past two years. The laboratory continues to use the foundation of the project to examine practices for additional cost and time savings, as well as developing efficient workflow as demands continue to increase.

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Executive Summary

Synopsis of problem and background

As the use of forensic DNA increases in criminal justice, the Denver Police Department Crime Laboratory, like many others, struggles to handle the backlog of cases at all steps: awaiting screening, DNA analysis, interpretation, and review. The goal is to always provide results to investigators in a timely manner. After implementing STR DNA analysis in the fall of 1999, from 2000 to 2011, requests increased by 228%, due in part to successful projects such as the DNA Expansion Demonstration (expanding the use of DNA in solving burglaries in Denver)³ and “Solving Cold Cases with DNA” projects⁴ funded by the National Institute of Justice.

The DPD Crime Laboratory has a history and a culture of implementing efficiency improvements including batching cases in a 96-well plate format, streamlining review of DNA data, and conducting laboratory work in a team approach from 2006 - 2009. These combined improvements increased the completion rate of casework by an astounding 285%⁵, yet a backlog of cases remained as demand outpaced the laboratory’s capacity. Demand is continuing to increase due to increased customer awareness of DNA analysis and its sensitivity, the expansion of DNA services to more cases (e.g., property crimes), and re-opening of cold cases. These increased demands and workload are occurring during a time when funding/resources have remained static.

To find new approaches to improving DNA efficiencies, the laboratory was challenged by the fact that it had only a subjective view of its own processes, and had limited data to

³ Grant Award # 2005-DN-R-095

⁴ Grant Awards # 2009-DN-BX-K012 and 2010-DN-BX-K004

⁵ DPD Crime Laboratory BEAST data; 2001 vs. 2011

indicate what solutions will, in fact, result in improved efficiency. A more objective, evidence-based analysis was needed in order to notably improve Denver's DNA processes further.

Project Purpose and Objectives

The National Institute of Justice DNA Unit Efficiency Improvement Program sought novel and innovative approaches to improve efficiency in forensic DNA laboratories to reduce reducing backlogs and turnaround times. This appealed to the Denver Crime Laboratory, which had prior experience with basic process mapping and efficiency improvements and wanted to build upon that foundation. The laboratory also had an ongoing backlog of cases awaiting DNA analysis and opportunity for further improvements to be realized. The objectives of the DPD DNA Efficiency Project were:

- 1) Identify all bottlenecks in the process by first creating a flowchart of the DNA process, and then entering at least six months of DNA workflow data into Simul8®, a multi-dimensional simulation software tool, and
- 2) Use a teamwork approach of critical thinking, along with simulation/modeling, to implement solutions and to identify and implement additional efficiency improvements.

The ultimate goals of the efficiency gains were to reduce DNA turnaround time, increase the number of DNA samples analyzed per analyst, and to decrease the number of backlogged DNA cases.

Project Design

The funding was used to first hire an efficiency project manager who worked full time on the project for approximately one and a half years to build a dynamic simulation model of the DNA process, as well as to identify efficiency challenges, and lead implementation of selected solutions. Secondly, the project enabled purchase of Simul8® simulation software, along with on-site training by the company on how the software could be applied in a forensic laboratory setting. The project was divided into four phases as follows – 1) The project manager was selected and hired, the Simul8® software was purchased, and three efficiency issues were identified through the teamwork approach; 2) The project manager and two supervisors received 3-days of on-site training in Simul8®, baseline performance measure data was collected, a process map for forensic biology was completed, and nine additional efficiency issues were recorded; 3) A process map for DNA was completed, one year of casework data was entered into Simul8® with software validation beginning, and five efficiency issues were recognized; 4) Test runs in Simul8® yielded several key observations, validation efforts for Simul8® continued, but were not ultimately successful, an additional efficiency issue was discovered, and final data was analyzed with summary reports prepared.

The efficiency issues were identified by several means: employee feedback through anonymous surveys collected by the project manager, input from the supervisors, a customer request, and a suggestion by another forensic laboratory. Each of these efficiency issues was documented in an Efficiency Improvement Project (EIP) report compiled of five sections: Problem, Possible Solution(s), Implementation Phase, Outcomes, and Post-Evaluation. The problem statement introduced the issue, and was as detailed as possible. The possible solutions statement documented the different options brainstormed in the unit in order to improve the

issue. The implementation documented which solution was chosen and what steps were taken to implement the improvement. The outcome was an analysis of the solution as well as its impact (in terms of time savings, cost savings, or any other tangible improvement). Finally, a post-evaluation was the follow-up to the EIP. Here any adjustments to the solution or unforeseen impacts were documented.

Results

The DPD Crime Laboratory was successful in building a process map in Simul8® and entering one year of casework data. The Simul8® model was not fully validated; however the partially validated model was used to run test simulations to test varying resources, such as personnel and equipment. The test simulation yielded interesting results: namely, when instruments were added, such as additional DNA extraction robots, work still waited and the DNA backlog did not improve. None of the instruments were being utilized at full capacity, meaning the instruments were idle for significant time periods, but many areas in the simulation were “Resource Starved” waiting for an analyst to be available to complete the task. The backlog and turnaround times in the model only improved once personnel numbers were increased in the model. This finding was consistent with the laboratory’s hypothesis.

Through simulation modeling, the DPD Crime Laboratory can now definitively state the level of DNA Unit staffing that will be required in order to meet its target case turnaround time. Denver’s testing in Simul8 demonstrated that the ideal number of staff for the DNA Unit’s caseload is 14 fully trained analysts, accompanied by three lab technicians, three supervisors and one staff assistant. To obtain these results, the DNA Efficiency Improvement Project Manager ran test simulations, and in each subsequent run, added an additional qualified analyst to test the

impact. The simulation was also increased to 1,084 days instead of 365 days to understand the long term effects of the additional analysts. The simulation was run several times to determine the best outcome for staffing levels.

The simulation revealed that when the DNA Unit reaches the proposed staffing levels with all staff fully trained, it will take 26 weeks (six months) to eliminate the existing backlog. After new staff are fully trained, assuming the number of incoming cases remains constant, turnaround times will be maintained at seven days for rush cases and 45 days for all other case types.

The model runs with a virtual clock showing cases moving through the workflow and, when validated, the simulation should mimic the number of cases being completed in the real world. There were issues with the model accurately reflecting interruptions to the work process, and capturing the complexity of the entire process within the model. The model was revised numerous times, and the most accurate version differed from real world data, showing a slightly lower number of cases being completed in one year than in actuality. This version of the model was used to draw the conclusions detailed above, and the difference was accounted for.

The laboratory’s second objective was to use a teamwork approach of critical thinking to identify a total of 21 efficiency issues and implement improvements for 18 of them (the remaining 3 were not addressed during the period of the project). The 21 EIPs addressed a variety of issues and are summarized in Table 1.

Table 1 - Summary of 21 Efficiency Issues Identified in DPD DNA Unit

Issue Noted	Solution Implemented	Detail Provided in	Impact of Improvement
Analysts did not proficiency test in required methods	Streamlined ordering, tracking and assignment of tests	Results: Section A	Zero quality issues since implementation & cost savings of >\$540 since implementation

Turnover of grant-funded DNA analysts	Brokered solution with City to transition these employees to “permanent” status	Results: Section B	Tenure of grant-funded employees improved from 19 mo to 34 mo and \$337,146 savings in recruiting/training
Unnecessary analyst time spent on adjudicated cases	Weekly updates from DA’s Office; automated system to stop testing on adjudicated cases	Results: Section C	Unnecessary testing was stopped on more than 50 adjudicated cases, saving >150 hours of analyst time to date
Process for testing sex assault kits was time-consuming and lacked sensitivity	Test sex assault kits for presence of male DNA instead of biological fluids	Results: Section D	Increased number of sex assaults tested by 78% between 2010 and 2011
Amplification procedure required two amp kits, and re-analysis for inhibited samples	Validated single kit for amplification, Identifiler® Plus	Results: Section E	Savings of \$14,500 annually in reagents, 27 hours instrument time, & zero samples require re-analysis for inhibition
STR statistical calculations performed by hand were slow and error prone	Created and validated internal STR statistics workbook	Results: Section F	Saves 11 days per DNA analyst annually
No printer was available in the FBIO lab, causing interruptions to work	A printer and photo card reader were purchased for the FBIO lab	Results: Section G	Cost savings of \$6,383 in first year
Lab support duties (e.g., making reagents, instrument maintenance) performed by DNA analysts	New laboratory technician jobs created and filled	Results: Section H	Salary savings of \$12,830 and 12% increase in cases completed
Practices for requesting and receiving permission to consume evidence were slow	New procedure implemented with single point of contact and template for making request	Results: Section I	Permission to consume evidence promptly received in 8 of 9 cases since implementation
Y-STR mixture statistics calculated slowly by hand & available tools did not meet needs	New tool was internally developed and validated	Results: Section J	Reduced calculation/review time by 95% - from 3.5 hours to 10 minutes per mixture
Unnecessary analyst time spent looking for case files	Created process map, updated practices and trained all staff	Appendix D	Reduced time to find case files by estimated 75%

Differential extraction workbook format did not meet user needs	Workbook was updated	Appendix E	Saved 6.7 hours of total analyst time since implementation
Testing for biological fluids unnecessary on many FBIO cases	Updated procedure to allow analysts to omit human blood, saliva and cellular material testing	Appendix F	Saved 56 days of total analyst time and \$392 in reagent cost since implementation
Note taking during evidence exam could benefit from specialized forms	Created 5 specialized forms for note taking on certain items	Appendix G	Saved 9.8 days of total analyst time since implementation
CODIS reports contained repetitive information, and had many corrections at review stage	Created new report templates with standardized language	Appendix H	Saved 8.4 days of total analyst time since implementation
Workbook for tracking pending FBIO cases had duplicate/inaccurate information	Removed duplicate information; made case priorities consistent; trained all users	Appendix I	Reduced data entry time by 20%
DNA extraction batches were limited by manual techniques or small robots	Validated 96-sample format for DNA extraction, QIA Symphony®	Appendix J	Saved \$6,063 in reagent cost since implementation
Bottleneck around 2 GeneMapper®ID analysis computers	Determined GeneMapper® was compatible with LIMS; installed on 9 analyst computers	Appendix K	Saved 22 days of total analyst time since implementation
DNA samples are extracted by sample type rather than by case #, delaying completion of some cases	Identified during the project period – resolution will occur after the grant expiration		
Analysts spend unnecessary time waiting for evidence to be pulled	Identified during the project period – resolution will occur after the grant expiration		
Forensic Biology SOP does not include overall procedures for note taking, photography, etc.	Identified during the project period – resolution will occur after the grant expiration		

Overall, the laboratory estimates that these improvements saved one year in analyst time and \$307,096 in recruiting, training, salary/benefits, reagents and supply costs over the past two years.

Performance measure data was collected throughout the project to assess the impact on the project goals, which were to reduce the backlog, decrease turnaround times, and increase the number of DNA samples analyzed per analyst. The laboratory used data from 2009 as its baseline performance measure data – in that year the Forensic Biology/DNA Unit of the Denver Crime Laboratory completed 1707 cases; 847 requests for Forensic Biology (FBIO) and 860 for DNA. During the last year of the project period (August 1, 2011 - August 1, 2012), the units completed 810 requests; 498 in Forensic Biology and 312 in DNA. In 2009, 635 samples were analyzed per analyst for DNA compared to only 266 samples analyzed for DNA as of August 31, 2012. In 2009, the unit received 409 CODIS hits, whereas the unit received 121 as of August 2012. Overall, the turnaround time increased for all case types compared to the start of the project period. In 2009, the average turnaround time for forensic biology and DNA was 170 days as compared to 278 days in 2012. The backlog of cases also significantly increased from 2009 to 2012: 463 assignments were backlogged in 2009 versus 1,009 assignments as of August 31, 2012. Although the performance metrics were short of expectations, the reasons are understandable – the increase in backlog and turnaround time are attributed to the unit being staffed by 13 full-time employees in 2009, and had only seven at the beginning of 2012. This highlights the greatest deficiency the unit faces: a lack of trained personnel. In the summer of 2011 the DNA Unit lost four trained employees in a 3-month period, and a fifth trained analyst left the laboratory in October of 2011. These positions remained vacant, pending hiring and

training of new employees, until the middle of 2012, and the DNA Unit is only beginning to recover from these losses in late 2012.

Table 2 - Performance Measure Data from Before and After the Efficiency Improvement Project

	Samples	CODIS Hits	Completed Requests	Turnaround Time	Backlog
Before: 1/1/09 – 12/31/09	635	409	1707	170	463
After: 8/1/11 – 7/31/12	266	121	810	278	1009
Difference	-58%	-70%	-53%	64%	118%

Conclusions

The operational model in Simul8®, although only partially validated, revealed two important results that confirmed the laboratory’s hypotheses. First, equipment and instrumentation were not limiting resources, and thus, increasing capacity through additional instrumentation did not have a significant impact on backlog or turnaround time. Second, the model proved that trained personnel were the primary limiting resource for DNA Unit efficiency.

The model enabled the DNA Unit to specifically test how many additional staff would be required to both eliminate the case backlog (and in how much time), and then subsequently handle its caseload to meet the target turnaround time of 45 days for all case types (and seven days for rush cases). Initially, the DNA Unit varied the target turnaround times based on case priority, and then determined that a best practice is to complete rush cases in 7 days, and all other case types in 45 days or less.

The DNA Unit’s efforts to use teamwork to identify efficiency issues and implement solutions was the most successful part of the project, and resulted in a number of improvements, including new procedures (statistical tools, Identifiler®Plus, male DNA screening of sexual assault kits), new equipment (a printer) and collaboration with groups outside of the Crime

Laboratory (on issues related to grant employee retention, consumptive testing, and Laboratory Technician duties).

The efficiency improvements that had the greatest impact (in terms of cost and time savings) were retention of grant employees, the Male DNA Screening validation, the Identifiler®Plus validation, hiring Forensic Laboratory Technicians, and eliminating Forensic Biology testing for human blood, saliva and cellular material on many items. One of the DNA Unit's hypotheses was that many of the solutions would be low-cost or no-cost, which held true for the majority of the improvements.

Overall, these improvements yielded impressive results, and are estimated to have the saved the DNA Unit one full year of analyst time, and \$307,096 in costs over the past two years.

Implications for Policy and Practice

The simulation data is beneficial for presenting a compelling case to upper management that more resources are required, and that the impact of additional resources will be tangible and meaningful. Other forensic laboratories could implement simulation using Simul8®, or explore other simulation software options. A key to successful simulation is to build the process with less detail, ensure that it works appropriately, and then add detail as necessary. If simulation is not a viable option, a forensic laboratory can still implement any number of efficiency improvements through employee surveys, process mapping, and an environment that welcomes feedback and beneficial change.

We expect that many forensic laboratories would reach the same finding that we did: that additional personnel, rather than instruments, are the greatest need to improve case backlogs and turnaround times. However, the national trend according to a February 2011 NIJ Special Report, is to use DNA Backlog Reduction funds for equipment; Nelson notes that “federal funding

covered 10% of the budget for reagents, 85% *for instrumentation*, and 20% for training”[1]. Our laboratory has previously used grant funds to address the area of greatest need and hire additional forensic scientists, but that was one of the main efficiency problems addressed through our DNA Efficiency Improvement Project. We found that funding DNA analysts on grants was not cost-effective or efficient because the positions were not sustainable, employee tenure was short, and there were significant employee retention issues. In the Denver Crime Laboratory DNA Unit, additional staff was needed, but grant funding was not an effective way to increase DNA analyst capacity. This underscores Nelson’s next point, “The degree of reliance on federal funding reported by many laboratories suggests a critical need for state and local governments to seriously evaluate investment in their own forensic crime laboratories” [1]. In order to truly improve the efficiency of forensic DNA testing, DNA analyst capacity must be built through investment at the local and state level through new, permanent positions.

Ten of the efficiency improvements outlined in the Results section are applicable to other forensic laboratories, and this report provides guidance for similar implementation or adaptation to each laboratory’s needs. Most of the issues were identified by personnel within the DNA Unit, and the initial anonymous employee surveys were an invaluable tool for identifying problems, and are highly recommended to the other laboratories as a starting point for identifying issues in their workflow. The early successes in resolving some of these issues fostered buy-in within the DNA Unit, and an environment where additional suggestions were welcome, and staff were willing to accept the changes being implemented. Additionally, having a dedicated person who documented and analyzed each of these efficiency improvements, and then helped to implement and evaluate them, contributed to the success of this program. As a result, the scientists in the unit were able to continue to complete casework with minimal interruptions. It is unlikely that

the DNA Unit would have had the focus and resources to resolve many of these issues without this program, and a dedicated Project Manager. Funding a dedicated Efficiency Improvement Manager could be difficult for crime laboratories, yet the payoff can be in the thousands of dollars in saved time and other costs.

Implications for Further Research

The Denver Crime Laboratory is expanding this study in 2012 to the Latent Print Unit to realize efficiency improvements in that section. The main lesson learned from the simulation project is to include less detail in the model, which will be applied in this next effort. The workflow in the Latent Print Unit is less complex compared with the DNA Unit due to fewer staff, no robotic methods, and cases are worked one at a time rather than batched together. These differences, as well as efforts to include less workflow detail, are expected to result in a functional and validated model.

Like the efforts in the U.K. SWIM program, process mapping and simulation could be applied to the entire criminal justice system through a “crime scene to courtroom” approach with broader performance measures, such as the number of cases solved, and changes in reported crime rates. While the City and County of Denver does not have plans to perform this research, a similar community – wherein there is a single Police Department, Crime Laboratory, and District Attorney’s Office that already works closely together – would be an ideal test environment.

Technical Report

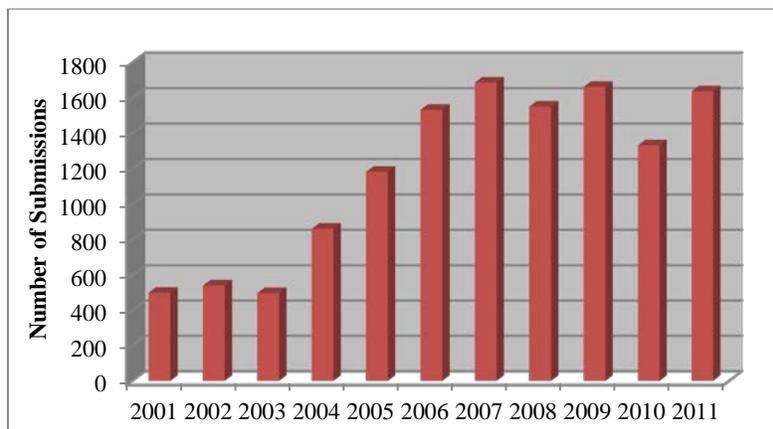
I. Introduction

Statement of the Problem

With ever shrinking budgets and increased demand, government agencies, including forensic laboratories, are examining their processes to do more with the same or fewer resources at their disposal. This is relevant in particular for DNA Units, as the demand for DNA testing—an invaluable investigative tool—exceeds the capacity of forensic laboratories across the United States [1]. With DNA laboratories already stretched thin to manage increasing caseloads, there is little margin for error, nor flexibility to implement operational changes that may yield efficiency benefits.

This is true in Denver, where the Denver Police Department (DPD) Crime Laboratory serves the 640,000 citizens of the City and County of Denver, Colorado. Between 2001 and 2011, the DPD Crime Laboratory’s DNA Unit experienced a 228% increase in caseload.

Figure 1: Denver Police Crime Laboratory - DNA Unit Caseload by Year



Although Denver’s DNA Unit strives to improve throughput and decrease turnaround time, this rapid increase in the number of cases submitted for DNA testing makes improving efficiencies a

challenge. Over this time period, the laboratory has not achieved sustained improvements in either backlog or turnaround time; there has been some fluctuation, but the overall trend has been a lack of progress in either area. The laboratory has expanded its capacity and can therefore test more DNA cases each year, but it is still not enough to meet increased demand for testing, which stems from more types of cases being submitted for analysis (e.g., property crimes and cold cases), and additional evidence being requested (e.g., low level samples with cellular material).

The average DNA case turnaround time must be reduced to provide acceptable service to investigators. Forensic DNA technology assists criminal investigations in a variety of important ways, all of which rely upon efficient delivery of forensic test results. In cases that pose a threat to public safety, a quick DNA turnaround time and an immediate search of crime scene DNA profiles against the CODIS database may result in a DNA match. Investigators can then use DNA-generated investigative leads to rapidly apprehend a dangerous suspect and prevent future crimes. Additionally, District Attorney's Offices and the courts rely on receiving DNA results in a timely manner in order to ensure that the correct individual has been identified and is being prosecuted, as well as to meet deadlines for hearings and trials so that justice is not delayed.

DNA laboratories can increase capacity by adding instrumentation or personnel, as well as streamlining processes to improve backlogs and turnaround times. But efforts to increase capacity raise a number of questions, such as: *How much instrumentation or personnel should be added? If staffing is increased how will this impact the backlog and turnaround time? What item of equipment would net the greatest improvement? If the new scientists have limited experience when will the laboratory begin to see a return on investment (ROI) on these hires? What are the bottlenecks in the DNA process? If we address one bottleneck, where will the next occur?*

Process mapping is a valuable tool for analyzing a process and identifying bottlenecks; however, there are limitations to this approach – first, it is subjective and easy for those involved to overlook problems and solutions, and second, it can be risky because there is a lack of data to support how the proposed change will improve efficiency. Additionally, a written process map is static and two-dimensional in that it does not include time, and it is not possible to see work flowing through the process. There are a couple of options to implementing changes based on process mapping: the laboratory can implement a solution and wait to see its impact; however, this approach involves the risk of wasted time and resources. Alternatively, the laboratory can create a computer-based simulation which can test changes to the workflow and provide data about the impact *before* resources are allocated. A simulation is multi-dimensional; it includes time and movement to model the work going through the process, and can identify bottlenecks that may not otherwise be apparent. Using simulated data to demonstrate the viability of a solution is preferable, but requires resources to build and validate a working model.

Literature review:

Process mapping and simulation can be applied to any workplace that uses a process, including the forensic sciences. A number of tools and software packages are available to facilitate these processes. Jansen-Vullers and Netjes [1] examined different systems to conduct a Business Process Simulation (BPS). They utilized several different simulation methods proposed by other authors in order to evaluate six BPS tools, including: PROTOS®, ARIS Simulation®, FLOWer®, FileNet®, Arena®, and CPN Tools. Each tool was evaluated on factors such as ease of use, incorporating statistical distributions, and conducting *what-if* analyses. According to the authors, the evaluation criteria for BPS includes ease of model building, formal semantics,

control of workflow patterns, resource and data perspective, and the level of detail, transparency and suitability for communication to stakeholders.

In Richard and Kupferschmid [2], the Louisiana State Police Crime Laboratory (LSPCL) applied Lean Six Sigma (LSS) methodologies to their DNA forensic laboratory via a previous NIJ Forensic DNA Unit Efficiency Improvement project. The efficiency of the laboratory was studied through creating a detailed process map, a spaghetti chart (a graphical representation of the analysts' movements during a specific procedure), and a Value Stream Map populated with current state data. LSPCL implemented new technology, including validating a QIAgility®, adding two EZ1 Advanced XL® extraction robots, three thermalcyclers, and four thermomixers, as well as purchasing printers and barcode scanners, and forming a Business Unit to assume administrative tasks. The purchase of new instrumentation increased the number of samples processed per analyst per month by 84%. In addition to successfully increasing the laboratory's overall throughput by 102%, the study also allowed Louisiana to achieve an \$180,967 savings in changing their purchasing practice.

In 2006 the DPD Crime Laboratory Director, the DPD Division Chief of Criminal Investigations and the Denver District Attorney visited the Home Office in the United Kingdom and learned of the Scientific Work Improvement Model (SWIM), which is being used to maximize the efficiency and effectiveness of forensic science processes in the United Kingdom. The goal of SWIM was to “increase the detection of crime by better managing forensic science performance.” The study encompassed examining crime scene attendance, submission of evidence, analysis of evidence, and notification of identifications, e.g., DNA database matches, to the appropriate personnel. In partnership with the Lanner Group, the project examined the force's capabilities and response rates. The United Kingdom's Home Office published their

research on implementing SWIM within the England and Wales police force and forensic laboratories in 2007 [3]. Recommendations that resulted from the study ranged from optimizing scheduling of personnel to streamlining submission of evidence to the laboratory.

The study reports that most of the solutions they implemented using the SWIM model and simulation were of no-cost or limited cost. Simulation enabled them to identify bottlenecks, quantify the resources needed and quantify the benefits. According to the Police Standards Unit (PSU), simulation offers a number of benefits:

- Provides insight into current process performance
- Alternative solutions can be tested prior to implementation
- Secure buy-in to change, both at management and analyst level
- Reduces the risk in change
- Ensures realization of sustainable benefits

Ultimately, the simulation assisted the Home Office to more efficiently utilize forensic services during investigations. They increased crime scene response rates, developed a triage system for incoming cases, created a performance “Dashboard” which provides a high level summary of “end-to-end performance” providing more management oversight, and provided a new shift schedule to better respond to crime scenes.

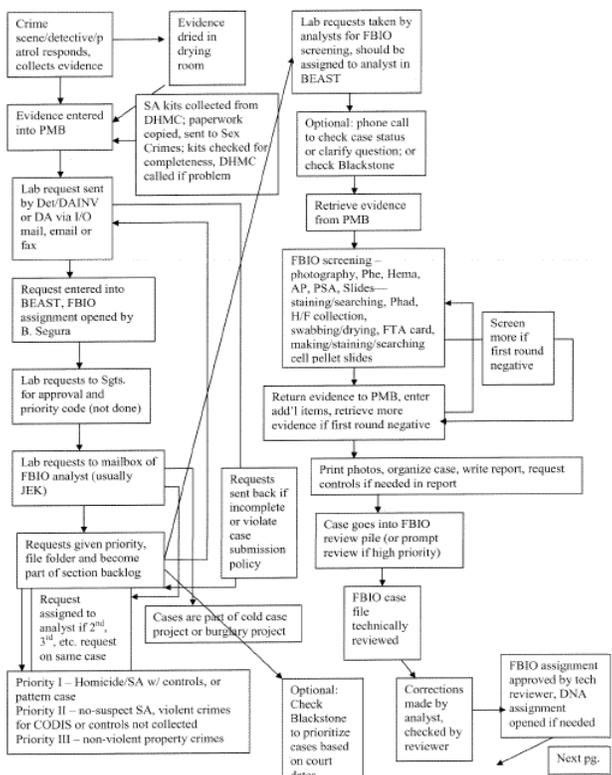
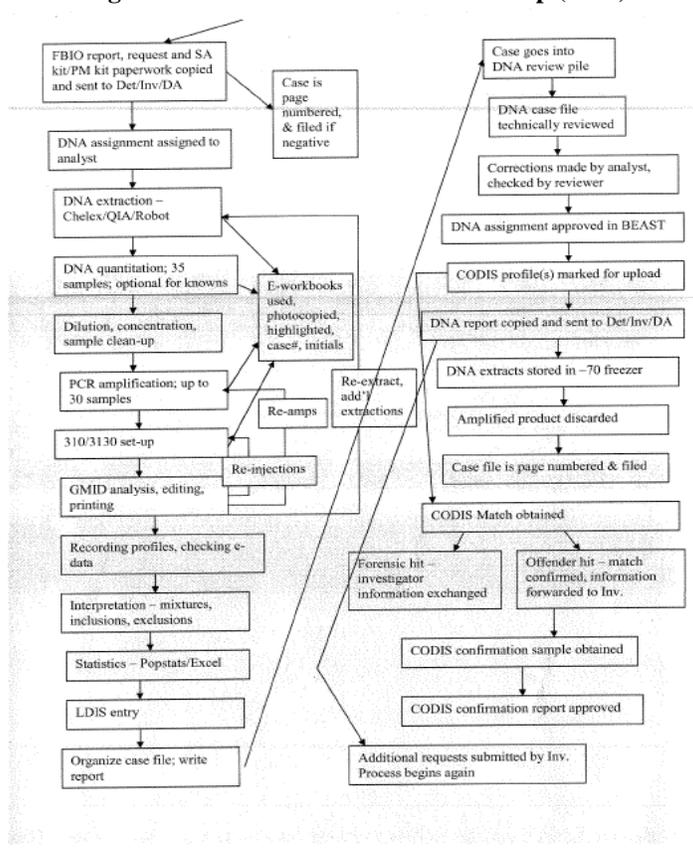
Other forensic laboratories, including the Louisiana State Police Crime Laboratory and the U.K. Home Office, have engaged in process mapping or conducted simulations to optimize their processes. The Denver Crime Laboratory determined combining these two methods using simulation software could provide innovative solutions. These solutions would aim to decrease the Forensic Biology/DNA Unit’s backlog while increasing capacity in order to prevent the

backlog from increasing in the future. Examining purchasing practices and new instrumentation might also provide a detailed cost savings analysis.

Statement of hypothesis or rationale for the research

As a result of Denver's collaboration with the United Kingdom's Home Office and learning about SWIM, the Denver Crime Laboratory DNA Unit critically examined its own processes and made significant progress in improving throughput in the years 2006 - 2009. For example, in 2006, the DNA Technical Lead created a flowchart diagram (Figure 2) to map each step of Denver's DNA analysis process, and then used this flowchart to identify bottlenecks and areas for improvement. That year, the unit validated new instrumentation and a batching system enabling the laboratory to complete 250% more cases and in 15% less time than prior to these two implementations. Using a process map, staff identified redundancies in review, which added several extra unnecessary hours to casework. Batch reviewing a set of DNA data once rather than many times for all associated cases effectively reduced the redundancies.

Figure 2: Denver DNA Unit Process Map (2006)



The DPD Crime Laboratory learned of Simul8® software through its collaborative work with the Denver District Attorney's Office, which purchased and used Simul8® to model the Denver County Court system, which handles over 20,000 misdemeanor cases annually. Their experience with the simulation software allowed them to identify bottlenecks and redeploy existing resources and staff that were not being used to optimal capacity.

Based on our laboratory's previous success with process mapping, and the benefits realized by the Home Office and Denver DA's Office, Denver's DNA Unit Efficiency Improvement project focused on finding areas for efficiency gains through process mapping and multi-dimensional simulation as well as implementing creative solutions to the bottlenecks. Simulation of the DNA workflow allows the laboratory to identify areas for improvement, to test new ideas, and to understand how the system works and tune it to optimal performance without taking any significant risks. Prior to conducting the study, the crime laboratory had limited evidence and a subjective view of how to improve its processes. Process mapping and simulation allowed a true measure of the DNA laboratory's capacity and deliverables, and provided concrete facts and ways to measure improvements.

The objectives of this project were to:

- 1) ***Identify all bottlenecks in the DNA Unit processes by first creating a flowchart of the DNA process, and then entering at least six months of DNA workflow data into Simul8®.*** Simulation/modeling is graphical so the laboratory can learn how work flows through the system and map the dynamics of the system in fast forward time. It also enables the laboratory to observe bottlenecks building up and determine underlying causes.

2) Use a teamwork approach of critical thinking, along with simulation/modeling to implement solutions to reduce DNA turnaround time, increase the number of DNA samples analyzed per analyst, and to decrease the number of backlogged DNA cases.

II. Methods

DNA Efficiency Improvement grant funding was used to hire an efficiency project manager who worked full time on the project for approximately one and a half years, and to purchase Simul8® software, along with on-site training by the company. The project was divided into four phases as follows – 1) The project manager was selected and hired, the Simul8® software was purchased, and three efficiency issues were identified through the teamwork approach; 2) The project manager and two supervisors received 3-days of on-site training in Simul8®, baseline performance measure data was collected, a process map for forensic biology was completed, and nine additional efficiency issues were recorded; 3) A process map for DNA was completed, one year of casework data was entered into Simul8® with software validation beginning, and five efficiency issues were recognized; 4) Validation efforts for Simul8® continued, but were not ultimately successful, an additional efficiency issue was discovered, and final data was analyzed with summary reports prepared.

There were two primary methods that the DNA Unit sought to identify and address efficiency issues: by identifying bottlenecks through Simul8®, and by a teamwork approach to identifying and implementing efficiency improvements. The methods for these two approaches are detailed below.

A. Identifying bottlenecks through Simul8®

In addition to the previous Simul8® work completed by the Denver District Attorney's Office, the software was evaluated to determine if its features would provide the proper tools to sufficiently analyze the Forensic Biology/DNA Unit's workflow. Because of the wide range of statistical distributions available, the customizable programming, and ability to modify resources, this software met the requirements of a successful simulation software.

In August 2010, a representative from Simul8® arrived in Denver to conduct a three-day training course on using the software at the laboratory. The DNA Technical Lead, Forensic Biology Technical Lead (both are also supervisors), and the DNA Efficiency Project Manager attended the training. In addition to the two-day hands-on training, the representative spent a third day with the group, creating the first version of the Simul8® model for the forensic biology workflow. The model in Simul8® includes the entire process for a forensic case, from the start point (receipt of a laboratory request) to the end point (delivery of a completed laboratory report with results to the customer).

During the training, Denver's team learned how to use Simul8® to program the amount of time spent on each step; the amount of work backlogged; the personnel and instrumentation involved, including the availability of each resource; the amount of work being requested; and the frequency of work requested. Simul8® software can also account for instrument down-time due to recurring events such as preventative maintenance checks. The software allows the laboratory to build a process map that is dynamic instead of static; a clock runs in the simulation (typically set at one year) and the users can watch cases flow through the process and identify where bottlenecks occur. The three-day Simul8® training was invaluable. One of the key points emphasized during the training was the flexibility of Simul8® to be applied to any process –

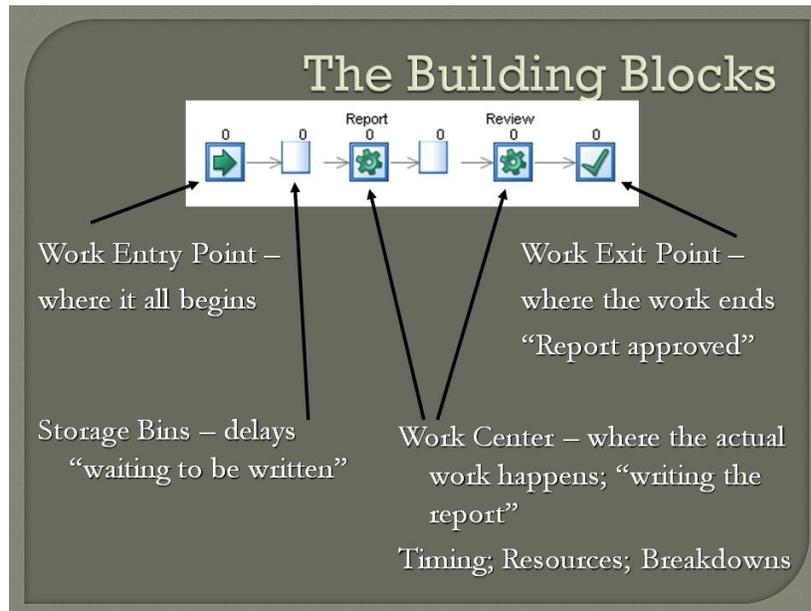
examples given include customers using an ATM at a bank, buses arriving and departing a station, manufacturing submarines, and even producing cheese.

The DNA Efficiency Project Manager brought a hard copy of a basic process map of the Forensic Biology Unit's workflow to the training to help build the model. Once the group started working with the process map and the software, they realized that creating both models (hard copy and virtual) was redundant. They decided that building the model in Simul8® only, thereby eliminating the paper copy, would capture the necessary information. The Simul8® trainer also recommended waiting to collect data to validate the model until after the model was built. This is to prevent unnecessary data collection, as well as to prevent the DNA Efficiency Project Manager from re-analyzing data. Additionally, the trainer suggested expanding the data set to validate the model from six months to one year. Because the software can run multiple simulations (up to 1,000) at a time, the validation process depended on collecting the most accurate data possible.

Multi-dimensional simulations involve examining processes and include the amount of work, time it takes to complete each step, all involved resources, and as necessary, distance. For larger, multi-site laboratories, including travel time for personnel or evidence may be of value. The Denver Crime Laboratory functions in a single building, thus distance was not a factor in the simulation. Simul8® allows for users to create their process, capture prior data, and run the model to determine outcomes and visibly identify bottlenecks. The resultant model consists of five main objects: Work Entry Point, Storage Bin, Work Center, Resource, and Work Exit Point. A new model starts as a blank screen, and similar to how a process map would be sketched on paper, the user adds the different elements of the process and connects them in a stepwise function to reflect the actual workflow. At any given point in the model, the user can add

characteristics or labels to the work item, for our purposes, the forensic case that is going through the model. These characteristics may include number of samples, type of case, or any other measurable data point.

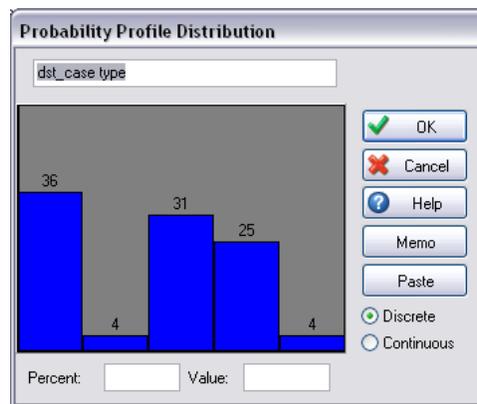
Figure 3 - The Basics of Simul8®



Entry Points are where the work item enters the system – for example, the submission of a new laboratory request for DNA analysis on one case. Most characteristics such as case priority, case type, and number of samples are assigned here. These characteristics allow the user to model differences and collect data on these differences; for example, a case with 40 samples takes more time to complete than a case with only two samples. Each characteristic is created using a distribution that is based on collection of real data from the laboratory. For instance, the Denver Crime Laboratory’s cases consist of five case types: current cases, cold cases, property crimes, reference samples only, and rush cases. Current cases consist of homicides, sexual assaults, aggravated assaults, robberies, and other types of crime. Cold cases are previously identified through the Solving Cold Cases with DNA project. References are known saliva samples collected from parties involved in a specific case for comparison purposes. Rush cases

are relatively few, but have a large impact on regular casework. These were separated from current cases to attempt to provide data on how much the rest of the caseload is impacted by one rush case. The distribution on case types was derived by examining data from DPD's Laboratory Information Management System (LIMS), BEAST, for a one year period. The case distribution was shown to be 36% current cases, 4% cold cases, 31% property crimes, 25% references, and 4% rush casework. This distribution was entered into Simul8® so that as the simulation modeled new work entering the Work Entry point over a one year period, it followed this distribution of case types (Figure 4).

Figure 4 – Distribution of Case Types Entered in Simul8®



The next object in Simul8® is a Storage Bin, which holds work items (cases) until a resource and/or work center is ready for the case to proceed to the next step in the process. For example, a case report waiting for review would be held in a Storage Bin. Storage Bins are ideal for identifying where bottlenecks occur in the process. The simulation clock can be paused at any time and the user can view a count of how many cases are being held in a given Storage Bin.

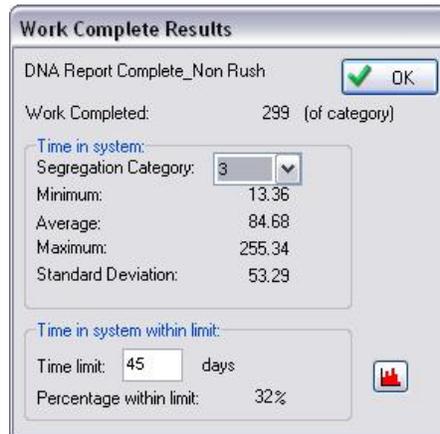
The next object in Simul8® is the Work Center, which is where steps of the process are performed and Resources are used. An example of a Work Center is review of a case report. Resources are required to complete the process, and can be people, instrumentation, or supplies. The availability of Resources is programmed into the model by the user; for example, four DPD

staff are trained to complete work at the DNA amplification work center, and their work shifts are included in the model. Another example is that two DNA quantitation instruments are available to complete work at the DNA quantitation Work Center. Depending on the complexity of the system, availability of Resources (e.g., staff vacation, instrument maintenance/down time) can be programmed to have a more accurate model. The Work Centers only hold onto cases while work is being conducted for a given time period based on the distribution entered by the user (e.g., a DNA extraction takes 2 hours based on collected data).

The final feature in Simul8® is the Exit Point, which is where cases leave the model. This is typically when all testing is completed, and an approved forensic report is sent to the customer. Other Exit Points were created, to capture when the laboratory is notified that testing is no longer required (due to case adjudication, for example) and the case exits the process mid-way through testing. Turnaround time is captured in the model as the amount of time (being captured by the model's virtual clock) from when a case enters at an Entry Point to when it exits the model at an Exit Point.

In Simul8®, each Work Center contains a “results” button which tallies the amount of work that passed through that center (Figure 5). Characteristics can be segregated in order for the user to complete a deeper analysis of the model. The figure below shows that 299 category 3 DNA reports (category 3 represents property crimes in our simulation) were completed with an average turnaround time of 84.68 days, as well as minimum, maximum and standard deviation values for turnaround.

Figure 5 - Results of DNA Report for Property Crimes (Category 3)



Steps to Create the Model

Building the Simul8® model was a two-part process. The first component was creating and presenting the model to the personnel conducting the work in the DNA Unit. This ensured all steps in the laboratory processes were captured within the model. The second step was to validate the model by collecting casework data that was entered into the simulation, and then run the simulation to compare back to real-world data and verify its accuracy.

The laboratory separates the analysis of biological materials into two stages: the forensic biology and DNA analyses. Forensic biology consists of the examination and testing of evidence for biological materials (blood, saliva, etc.) and issuing a report with the results to the lead investigator. DNA analysis includes extraction, quantitation, PCR amplification, capillary electrophoresis, interpretation, statistics, and issuing a report with the results. Some staff are dedicated to one discipline while others are cross-trained in both. For that reason, the model of the workflow was built separately for forensic biology and DNA, and then merged into the complete workflow.

The DNA Efficiency Project Manager began building the forensic biology process in Simul8® with assistance from the on-site trainer in August 2010. She conducted the first

Simul8® review meeting with the Forensic Biology Unit in September of 2010. During this meeting the simulation was displayed using a projector, and the Efficiency Project Manager provided an overview, and edited the model in real-time based on feedback from the analysts. All members attended the meeting to help create the most accurate model possible, including the amount of time it normally takes to conduct each step of the process. Having each member of the unit in the room enabled a constructive discussion about the scope of the model. Instead of basing the model on the type of biological testing, it was decided that analyzing each case type (current casework, property crimes, cold casework, reference samples, and rush cases) would result in a more effective simulation. The final follow-up meeting with Forensic Biology was conducted on October 19, 2010 and the unit was shown the model successfully completing each step as anticipated. Receiving input from the analysts who do the work every day was essential to creating an accurate model.

The DNA Efficiency Project Manager and DNA Technical Lead met in November of 2010 to begin modeling the DNA portion of the model. Each week for two hours, the two modeled and tested the software before presenting the information to the DNA Unit in December of 2010. The meeting with the DNA Unit lasted two days. The members of the unit examined the model for accuracy and gave feedback on how much time each step of the process requires. The DNA portion of the model was completed at the end of January 2011. The first versions of the model were very detailed which caused technical errors within the computer program, which unfortunately continued throughout the project. These challenges are explained and detailed in the Results section.

The Efficiency Improvement Project Manager had minor knowledge of the DNA workflow prior to starting this project. She worked in the laboratory as an assistant for two years

and knew the basic model, but had no in depth knowledge about the differences between a robotic DNA extraction and manual extraction, for example. This was beneficial in multiple ways. The lack of specific knowledge in the processes allowed her to question staff about their methodologies without set expectations on why certain steps are followed. Not having set expectations allowed her to think outside of the box and required the analysts detail their processes in a more specific way, expanding their thinking on why they perform tasks in the way they do.

In order to build the simulation, analysts provided timing estimates for how long each process should take, yet answers were rarely straight-forward. For example, when asked a question about how long an extraction takes, the analysts would consistently state, “It depends.” An 80/20 rule was quickly enforced – the analysts were asked to throw out their ideas for the 10% of the longest and 10% of the shortest times any given procedure would take. Additionally, the EIP Manager and DNA Technical Lead decided to break down the data input into the software into two larger categories: case type and priority. This helped diminish the “it depends” response and enabled an accurate depiction in the software.

The final model can be separated into six main components: Forensic Biology casework, Forensic Biology reporting, Extraction, Quantitation/Amplification, DNA casework, DNA reporting, and finally Rush casework. Because of the large impact a rush case has on instrumentation and personnel, it was necessary to separate this out in the model. The laboratory defines a rush case as case with DNA analysis completed within one week of submission. While rush cases only make up 4% of the entire caseload, their impact is significant because of the interruption to the workflow of the remaining 96% of the caseload in order to complete the rush case expeditiously. In order to allow resources within Simul8® to attend to a rush case in the

manner required, a separate extraction and quantitation/amplification section was created for these cases.

Steps to validate the model

One year's worth of data was extracted from the Laboratory Information Management System (LIMS), BEAST, for the period of August 1, 2009 to August 1, 2010. This period was selected for examination because it was the most recent available data with the start of the DNA Unit's Simul8® project in August of 2010. During the selected time period, 2,088 reports, both from Forensic Biology and DNA, were written or in progress. The DNA Efficiency Project Manager then created a spreadsheet with 67 data points to capture the most relevant information to the project model.

After information was collected from the LIMS, review of the corresponding case files further informed the dataset to show the number of days elapsed between each step (e.g., screening, writing of the report, and extraction), the average number of samples submitted on each case type (e.g., burglary versus homicide), which analyst completed the work at a particular stage in the process, as well as other pertinent information to the model. The DNA Efficiency Project Manger examined approximately 50 reports a week and concluded data collection in May 2011. Data compiled included:

- Date of assignment
- Date of completion (if one existed)
- Offense type
- Priority
- Report type (report, amended, or administratively closed)
 - If amended or closed, a comment was created to determine any common threads

- Date the forensic biologist began the case
- The reporting analyst (if the assigned analyst was still in training) - to capture trainees reporting under supervision of a qualified analyst with an additional technical review of the case
- Number of samples
- Extraction type
- Number of concentrated and/or diluted samples
- Number of analysts involved in the process at each step (extraction, quantitation, amplification, capillary electrophoresis)
- If any samples had to be re-cut, re-extracted, or re-run
- Date the DNA laboratory work was completed and electropherograms were printed/ready
- Interpretation date
- Review date
- Date samples were entered into CODIS
- Number of samples entered into CODIS
- Date of any CODIS hit(s)
- If known saliva samples were submitted after the DNA report was provided to Detectives or investigators

The DNA Efficiency Improvement Project Manager successfully created a Simul8® model, collected data for one year, and entered the data into the simulation. The next step was to run many replicates of the simulation and compare it to real casework data to see if the model was accurate, making necessary adjustments to improve the model. This final portion of the simulation component was not successful: throughout the project, the DNA Efficiency

Improvement Project Manager worked to fix ‘bugs’ in the model. As an example, analysts in the software would often become “stuck” at a Work Center, which would prevent the model from running. Other times, analysts in the model would work 24 hours straight on a specific task without a break. After internal troubleshooting, and discussing the model with Simul8® throughout September and October 2011, Simul8® determined it was an issue with the model itself (as opposed to the software). Simul8® recommended the DNA Efficiency Project Manager schedule Direct Modeling Support, which has a representative work with the laboratory to design the model. The hours were purchased and the DNA Efficiency Project Manager worked with Simul8® over the course of several months, but neither party was able to resolve these issues. Although the model was not fully validated, simulations and test runs were completed and several observations were made regarding bottlenecks and the impact of changing Resources within the model. These impacts are detailed in the Results Section.

B. Teamwork approach to identifying and implementing efficiency improvements

The DNA Unit’s hypothesis was that the success for the project would come from identifying and implementing low- or no-cost efficiency improvements. Early in the project, the DNA Efficiency Improvement Project Manager proposed confidential employee surveys as a way to collect data and to generate ideas for efficiency improvements. This allowed for candid statements about how business is currently run. Each of the 12 employees in the Forensic Biology/DNA Unit turned in a questionnaire. Topics ranged from the laboratory information management system to known bottlenecks. The questionnaire additionally had an area for comments and suggestions for improvement. After collecting all of the surveys, the DNA Efficiency Improvement Project Manager filtered the answers for discussion of key points with the section supervisor. The results were presented at a section meeting, with focus given to

themes that were repeated on multiple surveys, and to ideas that may have been noted once, but were especially innovative or beneficial. The survey is included as Appendix A.

The survey was one way in which the laboratory used a teamwork approach to identify efficiency issues and begin implementing improvements. In total, 21 issues were identified and documented during this project, and 18 of them were resolved (the remaining three were not addressed during the period of the project). The efficiency issues were identified by several means: employee feedback through the anonymous surveys (8), input from the unit supervisors (4), a combination of employee and supervisor requests (3), availability of new technologies from vendors (3), a customer request (1), a suggestion by another forensic laboratory (1), and moving to a new crime laboratory facility (1).

Each of these efficiency issues was documented by the project manager in an EIP (Efficiency Improvement Project) report compiled of five sections: Problem, Possible Solution(s), Implementation Phase, Outcomes, and Post-Evaluation. The problem statement introduced the issue, and was as detailed as possible. The possible solutions statement documented the different options brainstormed in the unit in order to improve the issue. The implementation documented which solution was chosen and what steps were taken to implement the improvement. The outcome was an analysis of the solution as well as its impact (in terms of time savings, cost savings, or any other tangible improvement).

Finally, a post-evaluation was the follow-up to the EIP. In this phase, any adjustments to the solution or unforeseen impacts were documented. The 18 completed EIPs addressed a variety of issues that are covered in detail in the Results section. An approach of teamwork and brainstorming was used to generate possible solutions for these issues. At times, the entire section discussed the pros and cons of different solutions under the direction of the project

manager or supervisor. For other issues, the project manager worked with one other analyst, or a smaller team who had the most expertise for solving that problem and implementing the solution. Two projects involved collaboration with the District Attorney's Office (consumptive testing and notification for adjudicated cases), one project involved Human Resources and the City's Career Service Authority to creation of a new forensic laboratory technician job classification, and the efforts to retain grant employees involved the Manager of Safety's Office and Budget Management Office. The DNA Efficiency Project Manager assisted with implementation for a number of the issues, and was responsible for assessing the outcome and post-evaluation, as well as documenting these reports.

Certain improvements occurred during the course of the project and contributed to an increased efficiency but were not a direct result of the efficiency project. After consultation with RTI, the independent evaluator for this project, three of these improvements were tracked in addition to the efficiencies identified by this project because of the potential to affect the performance metrics provided to NIJ. The three improvements which were a result of "outside" project influences are the QIAasympy® extraction robot validation, the Identifiler®Plus validation, and omitting testing for biological fluids; these are summarized in the Results Section.

III. Results

Overall Impact on DNA Unit Efficiency and Performance Measurement Data

Performance measure data was collected throughout the project to assess the impact on the project goals, which were to reduce the backlog, decrease turnaround times, and increase the number of DNA samples analyzed per analyst. Data was obtained from BEAST (the LIMS),

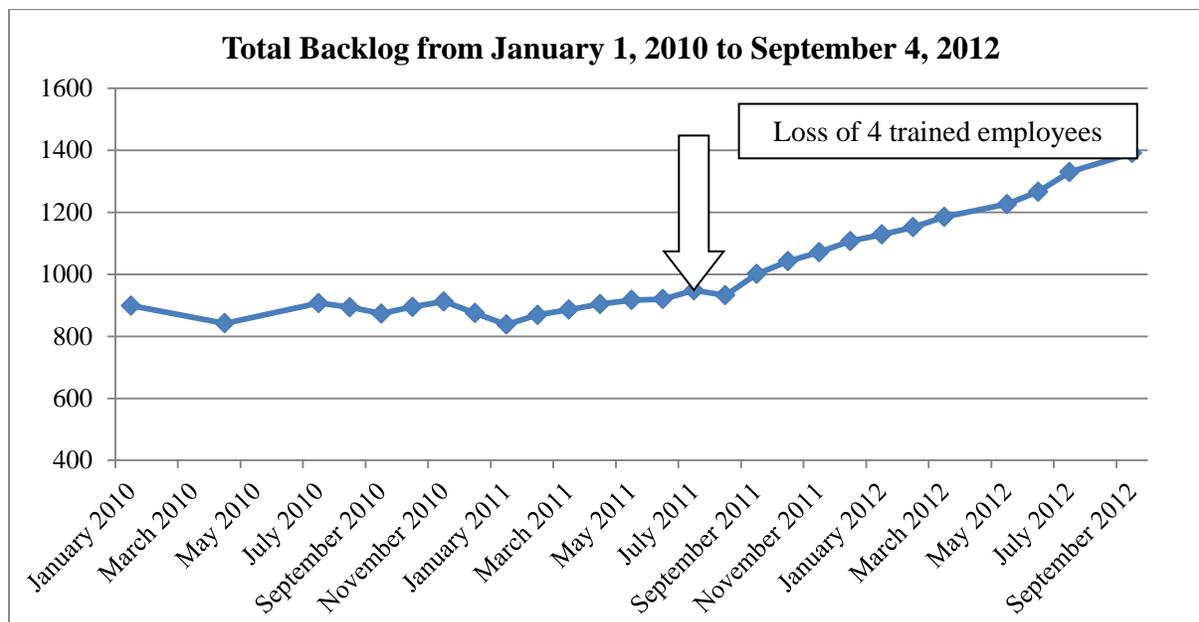
CODIS, and previously stored data for the number of samples analyzed per analyst per month (measured as the number of casework samples amplified per quarter, divided by the number of staff, and by three months/quarter to obtain a monthly average). The laboratory used data from 2009 as its baseline performance measure data – in that year the Forensic Biology/DNA Unit of the Denver Crime Laboratory completed 1707 cases; 847 requests for Forensic Biology (FBIO) and 860 for DNA. During the last year of the project period (August 1, 2011 - August 1, 2012), the units completed 810 requests; 498 in Forensic Biology and 312 in DNA. In 2009, 635 samples were analyzed per analyst for DNA compared to only 266 samples analyzed for DNA as of August 31, 2012. In 2009, the unit received 409 CODIS hits, whereas the unit received 121 as of August 2012. Overall, the turnaround time increased for all case types compared to the start of the project period. In 2009, the average turnaround time for forensic biology and DNA was 170 days as compared to 278 days in 2012. The backlog of cases also significantly increased from 2009 to 2012: 463 assignments were backlogged in 2009 versus 1,009 assignments as of August 31, 2012. This decline in performance measures was the opposite of what was intended during the efficiency study, but the reasons are understandable – the increase in backlog and turnaround time are attributed to the unit being staffed by 13 full-time employees in 2009, and had only 7 at the beginning of 2012. This highlights the greatest deficiency the unit faces: a lack of trained personnel. This trend is further highlighted in Figure 6 where the backlog is plotted between January 1, 2010 and September 4, 2012. The point where the backlog starts to increase noticeably is the summer of 2011 when the DNA Unit lost four trained employees in a 3-month period, and a fifth trained analyst left the laboratory in October of 2011. These positions remained vacant, pending hiring and training of new employees, until the middle of 2012, and the DNA Unit is only beginning to recover from these losses in late 2012.

Table 3: Performance measure data from before and after the Efficiency Improvement Project

	Samples	CODIS Hits	Completed Requests	Turnaround Time	Backlog
Before: 1/1/09 – 12/31/09	635	409	1707	170	463
After: 8/1/11 – 8/1/12	266	121	810	278	1009
Difference	-58%	-70%	-53%	64%	118%

The decrease in the average number of samples analyzed per analyst in a year is potentially caused by: 1) The crime laboratory moved to a new facility in June of 2012 and resources were diverted from casework to prepare for and complete the move; 2) The DNA Unit filled 4 vacant positions between February 2012 and May 2012, and forensic scientists who were productive on casework reduced the number of samples being analyzed to train these new hires, and 3) This metric reflects the number of samples *amplified*, but the DNA Unit had a large backlog of cases pending DNA interpretation, reporting and review in 2012. When resources are focused on the DNA reporting/review backlog, the number of samples *amplified* goes down, but cases are still being completed.

Figure 6: Total Backlog Trend from January 1, 2010 to September 4, 2012



Although the performance metrics were short of expectations, a major benefit of the project was the number of significant efficiency improvements with resulting cost-savings and time savings that we realized. The DNA Unit also implemented 18 efficiency improvements, and documented outcomes of each improvement via post-implementation evaluations. The laboratory estimates that these combined improvements saved 1 year in analyst time and over \$307,096 in salary/benefits, recruiting, training, reagents and supplies costs.

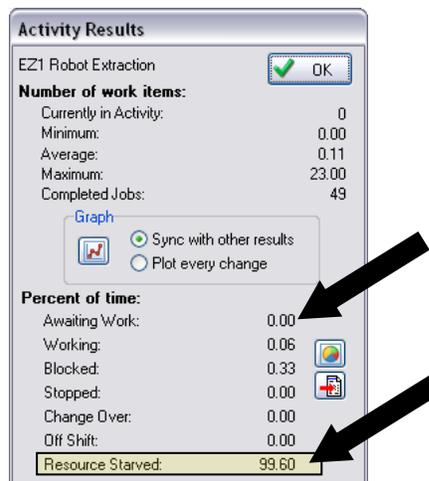
A. Results of Process Mapping and Simul8®

The DNA Unit successfully created a process map in Simul8® that was both detailed and accurate in capturing the workflow for forensic cases. This two dimensional process map (without any simulation) was comprehensive, including all steps of forensic biology and DNA analysis, from receipt of a new laboratory request, to issuance of the final report (Figure 7). The DNA Efficiency Project Manager also collected data from 2,088 laboratory reports spanning a one year time period, and entered the data into the model. Per the guidance of the in-house Simul8® trainer, the compiled data was entered into a module of Simul8® called Stat::Fit® to model the best statistical fit for the data. For most of the data, Stat::Fit® recommended a triangular distribution (incorporating the mean, minimum and maximum), and in a few instances, an exponential distribution. These distributions tell the simulation system how to statistically model the work occurring at each point. The Simul8® model was updated and revised numerous times in an effort to validate the model such that the simulation could run for a virtual year, and produce data that was consistent with real world data; however, this component of the project proved to be its most challenging, as the model was not consistent with laboratory practice. In test runs, the version of the model that was the most accurate reflected a lower number of cases

levels. At multiple points in the simulation, it was clear that personnel limitations were the limiting “Resource”, as opposed to equipment limitations.

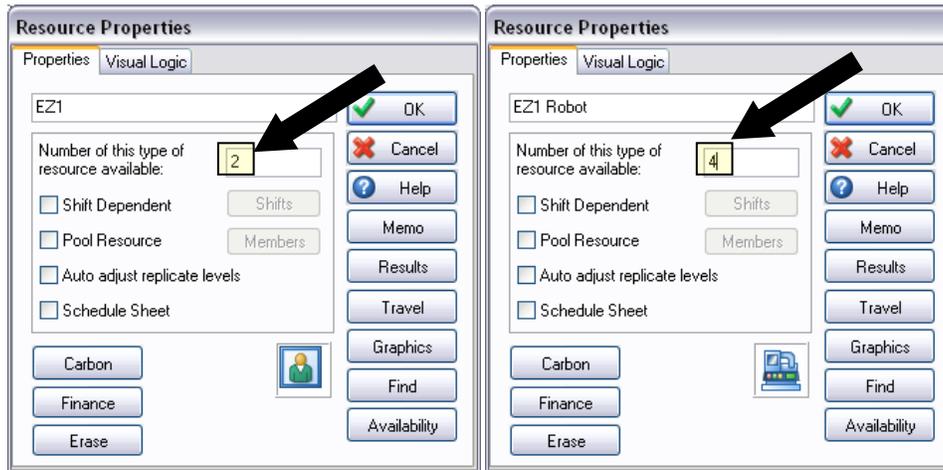
Each Work Center in Simul8® has a dialog box depicting the percentage of the time that the particular Work Center is “Resource starved” (Figure 8), meaning that the required “Resource” (either an analyst or item of equipment) is not available, and that Work Center is operating below its capacity. Examining this portion of the model depicted the DNA Extraction Robot Work Center was *awaiting work* 0.00% of the time; stated differently, there were cases pending in the preceding Storage Bin 100% of the time. The Work Center was “Resource” starved 99.60% of the time, meaning the model was waiting for an analyst to start the work.

Figure 8: DNA Extraction Robots – Work Center Results for a 1-year test simulation



Changing “Resource” levels is easy within the model. The Work Center properties are opened, and a number is changed based on the desired value. In Figure 9, the DNA Extraction robot quantity is doubled from two to four. Even when the model had personnel working 72 hours, changing the model with one or two additional DNA extraction robots during a one-year test simulation did not result in significantly reducing the case backlog, e.g., there was less than a 0.5% reduction in samples waiting for “Resources”.

Figure 9: Adding more instrumentation as Resources in Simul8®



The DNA Efficiency Improvement Project Manager examined thirty different Work Centers to understand where bottlenecks existed in the model, and the results varied depending on whether that Work Center relied on an analyst or an instrument. At the instrument-dependent steps, where instrument run time plays a role, the results show the Work Center is Awaiting Work Items the majority of the time. Examining the previous Work Center, where an analyst performs the instrument setup, the problem is more often the lack of a Resource (i.e., an analyst) to complete that step. Of the thirty Work Centers examined, twenty-two were Resource Starved. The other eight were instrument-dependent steps which spent most of their time in the simulation Awaiting Work.

Through running simulations in the model, a bottleneck was identified that was not readily apparent, or was previously considered insignificant, to staff in the DNA Unit: cases in a Storage Bin pending DNA extraction. Typically, the samples will wait two weeks to a month waiting for a DNA analyst to begin the DNA extraction. This example again illustrated that the needed Resource was not an instrument, but personnel. This initiated an efficiency issue to group extractions by case number as opposed to sample type to prevent delays in completing cases with

multiple sample types for extraction; this issue was identified late in the project period, and a solution was not implemented during that timeframe.

With knowledge that equipment was not the limiting resource, the Simul8® model was used to test the impact of additional staff on our case backlog and turnaround times. Through simulation modeling, the laboratory can definitively state the amount of DNA Unit staffing that will be required in order to meet its target case turnaround time. The Denver Police Department’s DNA Unit has stated that an “ideal” case turnaround time (defined as the time from when a lab request is received until the DNA results are reported), is seven days for rush cases, and 45 days for all other cases. Table 2 shows the laboratory’s turnaround times in 2010 by priority type, compared with the target turnaround times. Developing standardized case priority types was one of the goals of this project, and it was implemented in July of 2010 whereby all incoming laboratory requests are triaged and updated in the LIMS according to priority. Definitions of the case priorities are shown in Table 2.

Table 4 - Turnaround Times for 2010 versus Target Objectives

Priority	FBIO/DNA 2010	Target Objective
	TAT (days)	TAT (days)
Rush: Director approval required, public safety concern	77	7
High: Cases filed with DA's office / pending court dates; other expedited cases	127	45
Priority 1: Homicides and sex assaults with probative evidence	320	
Priority 2: Robberies, assaults, missing persons, hit & run with probative evidence	315	
Priority 3: Property crimes, weapon possession, harassment, arson with probative evidence	195	
Priority 4: Suicides, local CODIS entry, no DNA results, no CODIS eligible profile, all DNA matches victim	451	

Our testing in Simul8® demonstrated that the ideal number of staff for the DNA Unit’s caseload is 14 fully trained analysts, accompanied by three lab technicians, three supervisors and one staff assistant (Table 3). To obtain these results, the DNA Efficiency Improvement Project Manager ran test simulations, and in each subsequent run, added an additional qualified analyst to test the impact. The simulation was also increased to 1,084 days instead of 365 days to understand the long term effects of the additional analysts. The ideal number of new analysts was four; if eight new analysts were hired immediately, the backlog would drastically reduce, but in two years several of the analysts’ productivity levels would drop to unacceptable levels of 20% or less. The simulation was run several times to determine the best outcome for staffing levels.

The simulation revealed that when the DNA Unit reaches those staffing levels with all staff fully trained, it will take 26 weeks (six months) to eliminate the existing backlog. The DNA Unit did not include recruiting and training time in this simulation, but estimates those processes add at least a year and a half to this projection. After new staff are fully trained, assuming the number of incoming cases remains constant, turnaround times will be maintained at seven days for rush cases and 45 days for all other case types.

Table 5: Denver Police Staffing Proposal to Eliminate DNA Backlog and Maintain Turnaround Times of 7 Days for Rush Cases and <45 days for All Other Cases

Staffing as of 2011	Proposed Staffing
1 Forensic Scientist Supervisor 1 Acting Forensic Scientist Supervisor	3 Forensic Scientist Supervisors
5 Permanent Forensic Scientists 5 Grant-funded Forensic Scientists	14 Permanent Forensic Scientists
1 Grant-funded Staff Assistant	1 Permanent Staff Assistant
1 Part-time Public Safety Cadet / Support Staff	3 Permanent Laboratory Technicians / Support Staff

One of the primary difficulties in the model was the ability to produce accurate staffing data. Interruptions to the DNA/FBIO analysis process, such as court testimony and staff

meetings, caused the simulation to model the process inaccurately and not reflect the number of cases actually completed. The model has three options as far as scheduling Resources for work: finish the work regardless of the time of day, suspend work at the end of the day, but resume at the start of the next shift, or suspend staff until the next shift.

The first option resulted in an analyst in the model working for 72 hours straight without a break on a case that in practice would take a period of five days to complete. The second option was the most realistic, but the Resource (e.g., the assigned analyst) would not return to the same Work Center or case at the start of the next work shift. Instead of starting a new shift and returning to the same case, the model reflected the case left unfinished in the Work Center (which eventually caused the model to freeze), and the analyst picking up a new case to work. The final option has the analyst leaving in the middle of a task and returning to it; however, if the task required only a few more minutes of work, in reality, the analyst would extend their shift to complete it, but the model did not allow that flexibility. As a result, the model never finished these cases, causing an inaccurate number of cases completed and the simulation to ‘crash’.

Another issue was capturing the complexity of the entire process of DNA and FBI analysis within the model. Because the amount of time spent on any given step can spill over beyond the work shift – and some processes are critical to complete once it is started (e.g., a DNA extraction) – the analysts had to stay at the appropriate Work Center to complete the task. The DNA Efficiency Improvement Project Manager tried several different methods to get this to work. She attempted blocking work from coming in at certain times of the day (creating a unique schedule for instrumentation). Other programming options were attempted through writing code in the software, known as Visual Logic, but this did not work.

These issues prevented the DNA Efficiency Improvement Project Manager from making a full validation of the model through comparisons of the Simul8® results to actual results from the same time period (August 2009 – August 2010). Some of the modified versions of the Simul8® model achieved greater accuracy, however there was consistently a significant inaccuracy – for example, the DNA Unit would complete 20% fewer cases than it actually did, or the average turnaround time would be much lower than it was supposed to be. Although this software limitation may be corrected in a new version of Simul8®, the model created for the unit must be rebuilt in a more generalized way to enable a more thorough analysis of laboratory needs. Because building the model required months of work, this was not possible to complete by the end of the project timeline. The applicable “lessons learned” in using this simulation software in the environment of a Forensic DNA laboratory setting are detailed in the Conclusions section.

B. Results of Using a Teamwork Approach to Identify and Implement Efficiency Solutions

The DPD Crime Laboratory made 18 improvements over the course of the grant period. The primary way these opportunities were identified was through feedback by those most involved – the employees and supervisors of the DNA Unit. In order to brainstorm possible solutions, it was beneficial to have multiple individuals involved to propose ideas, and to weigh the pros and cons of different options. The DNA Efficiency Project Manager observed a positive feedback loop occurring with this process: through the early anonymous employee surveys, a number of complaints and concerns were aired. Several of these were successfully addressed early on in the project (a new Forensic Biology Printer, finding case files, and the worksheet for organizing pending Forensic Biology cases), which was satisfying for staff in the DNA Unit. This resulted in buy-in by the analysts, who observed that their concerns were heard, changes

were implemented, and the issues were improved or resolved. It was also helpful to have a dedicated DNA Efficiency Improvement Project Manager, who spearheaded these improvements. While she was not a forensic DNA expert, and therefore could not participate in the most technical projects, such as validations or development of DNA mixture statistical tools, she was involved in implementation of the other solutions and measuring outcomes for all of reports. This promoted an environment in the DNA Unit of continual improvement by encouraging suggestions and employee feedback, and being open to change.

A total of 21 issues were identified and 18 were resolved (Table 4). The ten with further discussion in this section are considered by the authors as most relevant and applicable as potential improvements for other forensic laboratories. The remaining eight issues are summarized in Table 4 with further information available in the Appendices.

Table 6 - Summary of 21 Efficiency Issues Identified in DPD DNA Unit

Issue Noted	Solution Implemented	Detail Provided in	Impact of Improvement
Analysts did not proficiency test in required methods	Streamlined ordering, tracking and assignment of tests	Section A, below	Zero quality issues since implementation & cost savings of >\$540 since implementation
Turnover of grant-funded DNA analysts	Brokered solution with City to transition these employees to “permanent” status	Section B, below	Tenure of grant-funded employees improved from 19 mo to 34 mo and \$337,146 savings in recruiting/training
Unnecessary analyst time spent on adjudicated cases	Weekly updates from DA’s Office; automated system to stop testing on adjudicated cases	Section C, below	Unnecessary testing was stopped on more than 50 adjudicated cases, saving >150 hours of analyst time to date
Process for testing sex assault kits was time-consuming & lacked sensitivity	Test sex assault kits for presence of male DNA instead of biological fluids	Section D, below	Increased number of sex assaults tested by 78% between 2010 and 2011
Amplification procedure	Validated single kit	Section E, below	Savings of \$14,500

required two amp kits, and re-analysis for inhibited samples	for amplification, Identifiler® Plus		annually in reagents, 27 hours instrument time, & sample re-analysis decrease 3% to 1%
STR statistical calculations performed by hand were slow & error prone	Created and validated internal STR statistics workbook	Section F, below	Saves 11 days per DNA analyst annually
No printer was available in the FBIO lab, causing interruptions to work	A printer and photo card reader were purchased for the FBIO lab	Section G, below	Cost savings of \$6,383 in first year
Lab support duties (e.g., making reagents, instrument maintenance) performed by DNA analysts	New laboratory technician jobs created and filled	Section H, below	Salary savings of \$12,830 and 12% increase in cases completed
Practices for requesting and receiving permission to consume evidence were slow	New procedure implemented with single point of contact and template for making request	Section I, below	Permission to consume evidence promptly received in 8 of 9 cases since implementation
Y-STR mixture statistics calculated slowly by hand & available tools did not meet needs	New tool was internally developed and validated	Section J, below	Reduced calculation/review time by 95% - from 3.5 hours to 10 minutes per mixture
Unnecessary analyst time spent looking for case files	Created process map, updated practices and trained all staff	Appendix D	Reduced time to find case files by estimated 75%
Differential extraction workbook format did not meet user needs	Workbook was updated	Appendix E	Saved 6.7 hours of total analyst time since implementation
Testing for biological fluids unnecessary on many FBIO cases	Updated procedure to allow analysts to omit human blood, saliva and cellular material testing	Appendix F	Saved 56 days of total analyst time and \$392 in reagent cost since implementation
Note taking during evidence exam could benefit from specialized forms	Created 5 specialized forms for note taking on certain items	Appendix G	Saved 9.8 days of total analyst time since implementation
CODIS reports contained	Created new report	Appendix H	Saved 8.4 days of total

repetitive information, and had many corrections at review stage	templates with standardized language		analyst time since implementation
Workbook for tracking pending FBIO cases had duplicate/inaccurate information	Removed duplicate information; made case priorities consistent; trained all users	Appendix I	Reduced data entry time by 20%
DNA extraction batches were limited by manual techniques or small robots	Validated 96-sample format for DNA extraction, QIA symmetry®	Appendix J	Saved \$6,063 in reagent cost since implementation
Bottleneck around 2 GeneMapper®ID analysis computers	Determined GeneMapper® was compatible with LIMS; installed on 9 analyst computers	Appendix K	Saved 22 days of total analyst time since implementation
DNA samples are extracted by sample type rather than by case #, delaying completion of some cases	Identified during the project period – resolution will occur after the grant expiration		
Analysts spend unnecessary time waiting for evidence to be pulled	Identified during the project period – resolution will occur after the grant expiration		
Forensic Biology SOP does not include overall procedures for note taking, photography, etc.	Identified during the project period – resolution will occur after the grant expiration		

A. Proficiency Testing

In the DNA Unit, 12 DNA analysts and technicians had varying levels of training and qualification, and therefore had different requirements to complete required technologies (STR and Y-STR) as well as methods (robotic and manual) on external proficiency tests. Ordering and assigning the tests were logistical challenges and time consuming, and test assignments were distributed six times each year. Four extra, unused proficiency tests were ordered in 2009 and 2010, wasting \$720. An added inefficiency was that two corrective actions had been identified

because of three instances in 2009 and 2010 in which an analyst did not test in the required method within the proper time period.

At the start of this project, proficiency tests were ordered throughout six different testing cycles of the year that were available from the test manufacturer. The DNA Efficiency Improvement Project Manager and the Deputy DNA Technical Lead (who has strong knowledge of proficiency test requirements through her experience as a qualified DNA auditor) completed the brainstorming and implementation for this issue. They questioned why tests were being ordered at so many times throughout the year. Part of the reason was to prevent analysts from being influenced on their own test by reviewing the results from another identical test. This was rectified by having analysts put their tests in a “lock box” until they were reviewed. Additionally, a spreadsheet was created for the Quality Assurance Manager and DNA Technical Lead to better track what methods analysts had completed on their tests, so that an extra proficiency test could be ordered before year’s end if there were any potential non-conformities. A proficiency test assignment sheet was newly created and is given to each analyst with their test, detailing exactly what methods each analyst/technician must perform at every step of forensic biology and DNA testing. The new system has been in place for two years and has: saved time for the DNA Technical Lead and Quality Assurance Manager who meet to assign tests twice per year rather than six times; saved money by preventing the purchase of too many tests (only 1 unused test at \$180 compared with \$720 in prior two years), and there have been no quality issues or corrective actions in this area since implementation as compared to two issues in 2009 and one in 2010 wherein an analyst did not test in the proper technology or method.

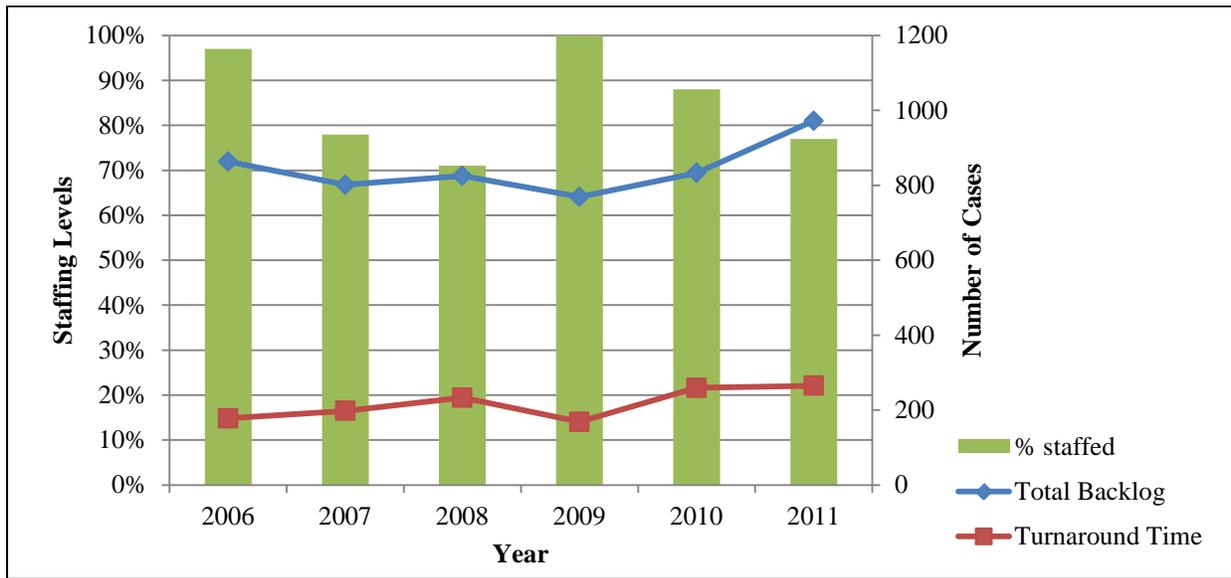
B. Grant-funded employees

A major challenge facing the DNA Unit was the retention of grant funded employees. This became apparent in the summer of 2010 when the laboratory lost four employees in less than a year. In the past five years, six Forensic Biology/DNA grant-funded employees have left the crime laboratory in order to take permanent employment opportunities elsewhere, representing a 75% turnover rate of grant employees. Five of the six are employed at other crime laboratories. In contrast, permanent employees have had 0% turnover during the past five years.

Thousands of hours were invested in recruiting and training these grant employees – an estimated 1,152 hours for recruiting and hiring, as well as 1.4 years of full-time trainer hours and the benefits were not fully realized. Starting over by recruiting and training new personnel results in inefficient and cost-ineffective operations; the DNA unit cannot make progress in improving the backlog or turnaround time. The Crime Laboratory requested additional DNA Unit positions via “expansion requests” in the City’s annual budget for several years, but had not received approval. The DNA Technical Lead communicated several times to upper management that retention of grant employees was the greatest challenge in the DNA Unit.

For example, 2009 was the only year between 2006 and 2011 when the DNA Unit was 100% staffed (with 12 analysts). That year, the trend lines for both backlog and turnaround times began to decrease. As staffing levels decreased again in 2010 and 2011, the backlog and turnaround correspondingly returned to previous levels (Figure 10).

Figure 10 - Effect of DNA Unit Staffing Levels on Backlog and Turnaround Time



The DNA Efficiency Improvement Project Manager and DNA Technical Lead spent significant time and resources analyzing the cost of the problem, trends in backlog and turnaround time, and brainstorming solutions. The following findings were brought to the attention of top-level department management:

- Average tenure for grant employees is significantly less than permanent employees (19 months for grant employees versus 4.5 years for permanent employees)
- Time spent in training is considerably higher (38% of total employment time for grant employees is spent in training, versus 13% for permanent employees)
- Grant funded employees spend less time on casework, accordingly (62% of total employment time for grant employees versus 87% for permanent employees)
- Effectiveness of full staffing on turnaround time and cases completed (*give example*)
- DNA cases with long turnaround times can have a negative impact on investigation (*give an example*)
- Current DNA Unit turnaround times are vastly different than target objectives
- The quantifiable cost of losing six grant-funded employees:

- \$593,242 on salary and benefits for the employees
- \$45,998 for recruiting, interviewing, polygraphs, background checks.
- \$149,199 in time for trainers in the DNA Unit
- \$77,128 on training sample supplies/reagents (exclusive of casework)

After presenting the situation to the Crime Laboratory Director, he saw an opportunity to present the problem and potential solutions to the Denver Police Command, including the Chief of Police and a representative from the Mayor's Office. Options included:

- Reduction in service provided by the DNA Unit (for example, eliminate DNA on assaults, harassment, and/or property crimes);
- Acceptance of large backlog and turnaround time (and associated risk / liability) by customers; or
- Create new permanent expansion positions to better retain employees

The Crime Laboratory Director presented a PowerPoint® detailing the problems retaining grant employees and potential solutions at a meeting with top-level management of the Department in November 2010 (data available in Appendix C). The presentation prompted immediate discussion by the Police Command and the Mayor's Office about creating three permanent positions. In July 2011, the proposal to transition these positions from Limited (grant funded with an employment end date) to Unlimited (permanent positions with no end date) was accepted by the City and County of Denver. The three employees were notified of this change in August 2011. Since the change, the average tenure for these employees has reached 34 months (and counting) compared with the 19 months average previously for grant-funded employees.

C. Notification of testing no longer needed

The DPD Crime Laboratory did not have an effective system for obtaining notification from customers that forensic testing was no longer needed on cases that were adjudicated. This resulted in wasted resources where all of the DNA laboratory work was completed on a case and a status check was performed by looking up the case in the District Attorney's database, at which point the lab discovered the case had been adjudicated. Typically, these cases had DNA profile data requiring interpretation, but were given the lowest priority (4) in DPD's case prioritization hierarchy, meaning the results are no longer needed. At the time this issue was identified, priority 4 cases contributed to 23% of the backlog in DNA, each requiring an average of three hours in analyst/reviewer time. Identifying these cases *before* testing was completed would save resources and improve efficiency for cases that needed testing.

The DNA Technical Lead and DNA Efficiency Improvement Project Manager met and subsequently followed up with the Denver District Attorney's office to create an automated system where a list of adjudicated cases from the DA's office is emailed to the DNA Unit weekly. The DNA Efficiency Improvement Project Manager created a Macro in a Microsoft Excel spreadsheet to efficiently check all pending/open laboratory cases against the list of adjudicated cases and stop testing on adjudicated cases. An unexpected benefit was that this system is useful for the entire crime laboratory, not only the DNA Unit. To date, the DNA Efficiency Improvement Project Manager notified the different forensic units of the crime laboratory to stop testing on over 100 adjudicated cases, approximately 50 of which were assigned to the DNA Unit, which has saved an estimated 150 hours in unnecessary analyst time.

D. Sexual Assault Kits – Male Quantitation Screen

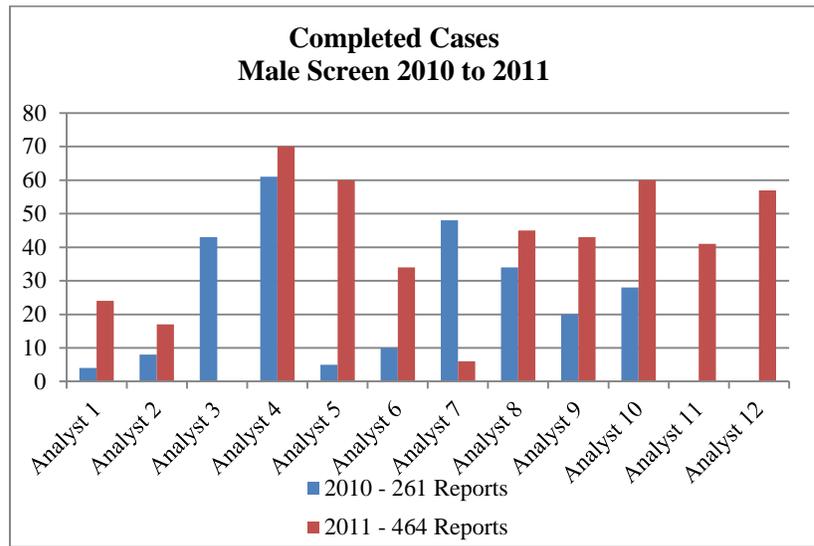
In January 2011, the DNA Unit had a large backlog of sexual assault cases pending screening (70 cases, 42 of which were over 90 days old), and an average turnaround time of 180 days (FBIO and DNA) for sexual assaults. There were two significant limitations to the workflow for sexual assault cases: 1) It was time consuming - a typical sexual assault kit took anywhere from two to eight hours to screen using traditional chemical and microscopic tests; and 2) The sensitivity was limited, and inferior to the sensitivity of DNA analysis (i.e., chemical testing can detect bodily fluids, but may not detect other sources of DNA that may be present). To prove this point, in 2010 the DNA Unit had first-hand experience with at least three sexual assaults where negative results from forensic biology testing resulted in a full Y-STR profile from a male.

Through conversations with another forensic laboratory, the Georgia Bureau of Investigation, who uses a “Male DNA Screening” method for sexual assault kits, the DNA Technical Lead saw an opportunity for a better method with a significant reduction in cost and turnaround time. The new method tests swabs for the presence of male DNA via DNA extraction and quantitation with the QuantifilerDuo® Human/Male DNA quantitation kit. Key advantages are that it allows processing to be performed in large batches (up to 72 evidence samples at a time), and it employs automated extraction and quantitation methods. Moreover, the laboratory was attempting Y-STR analysis on cases that had negative forensic biology results in order to be thorough; the “Male DNA Screening” method identifies the positive and negative cases and conserves resources being expended on negative cases with no male DNA. Finally, the DNA Unit elected to keep a sperm identification step, but was able to make it more efficient by microscopically examining samples after epithelial cells had been lysed, meaning sperm are readily identifiable without a background of other cells.

Buy-in was obtained from key personnel in the Crime Laboratory and District Attorney's Office, and the method was implemented in February 2011. Additional details and specific scientific methodologies are available upon request.

Since implementation, the laboratory has completed 77.8% more requests on sexual assault cases in 2011 than in 2010 (Figure 11).

Figure 11: Number of Sexual Assault Cases Completed – Comparison of 2010 to 2011



The demand for testing, i.e., the number of requests for DNA testing of sexual assaults increased by 36% in 2011 as compared to 2010. Fortunately, our increased capacity of 77.8% outpaced this. The improved capacity is attributed to the new Male DNA Screening method as there was no staff increase during this same time period.

During the post-implementation evaluation, one area for improvement identified by the DNA Efficiency Improvement Project Manager was the amount of time spent writing evidence examination notes. With input from the forensic scientists, the DNA Efficiency Improvement Project Manager created a new worksheet evidence examination and note taking, which was approved in March 2011. The number of note pages is now greatly reduced, and the worksheet

has many fields with information populated (see Appendix C), requiring minimal data entry by the analyst.

The first male screen plate was completed on March 24, 2011, and a second post-implementation need was revealed - a case summary sheet would assist in triaging the case, and as a reference throughout testing. This summary sheet is estimated to save each analyst about twenty minutes per case (five minutes per case per analyst, and at least four analysts will look at every case). Typically 45 to 50 cases will be processed in a batch, saving about 90 hours per plate of extra review time.

E. Identifiler®Plus Validation

An additional improvement was the transition of Profiler Plus® and COfiler® PCR Amplification kits (PP and CO) to using Identifiler® Plus. Although the validation would have occurred whether or not the efficiency project occurred, the effect the new kits may have had on backlog and turnaround time was analyzed as part of this project. Using two separate amplification kits required twice as much sample volume (making the test less sensitive), as well as twice as much reagent and instrument time compared with a single amplification kit. Additionally, the PP and CO kits often required re-processing of samples due to inhibition. The Profiler Plus® and COfiler® kits could process 250 samples and each kit costs \$2,729.50. To process one sample using only these reagents cost the laboratory \$21.84.

The laboratory examined four different single amplification kits and Applied Biosystems' Identifiler® Plus kit was chosen for evaluation and validation due to its published inter- and intra-locus peak balance and optimized ability to overcome inhibition. Identifiler® Plus costs the laboratory \$3,500 per kit, or \$14 a sample (kit cost savings of \$7.84 per sample).

Identifiler® Plus was internally validated and approved for use in casework beginning in January of 2011. Identifiler® Plus has improved discrimination power with two additional loci to be examined for comparison purposes. Testing takes half as much time instrumentation time, there is only one quality check process for the kit, one amplification procedure as opposed to two, and less analyst time is spent on GeneMapper® ID data analysis. The time and cost savings are likely even greater because the number of inhibited samples has dramatically decreased and is close to zero, resulting in the sample re-amplification rate dropping from 3% in 2009 (PP/CO) to only 1% in 2011 with Identifiler® Plus.

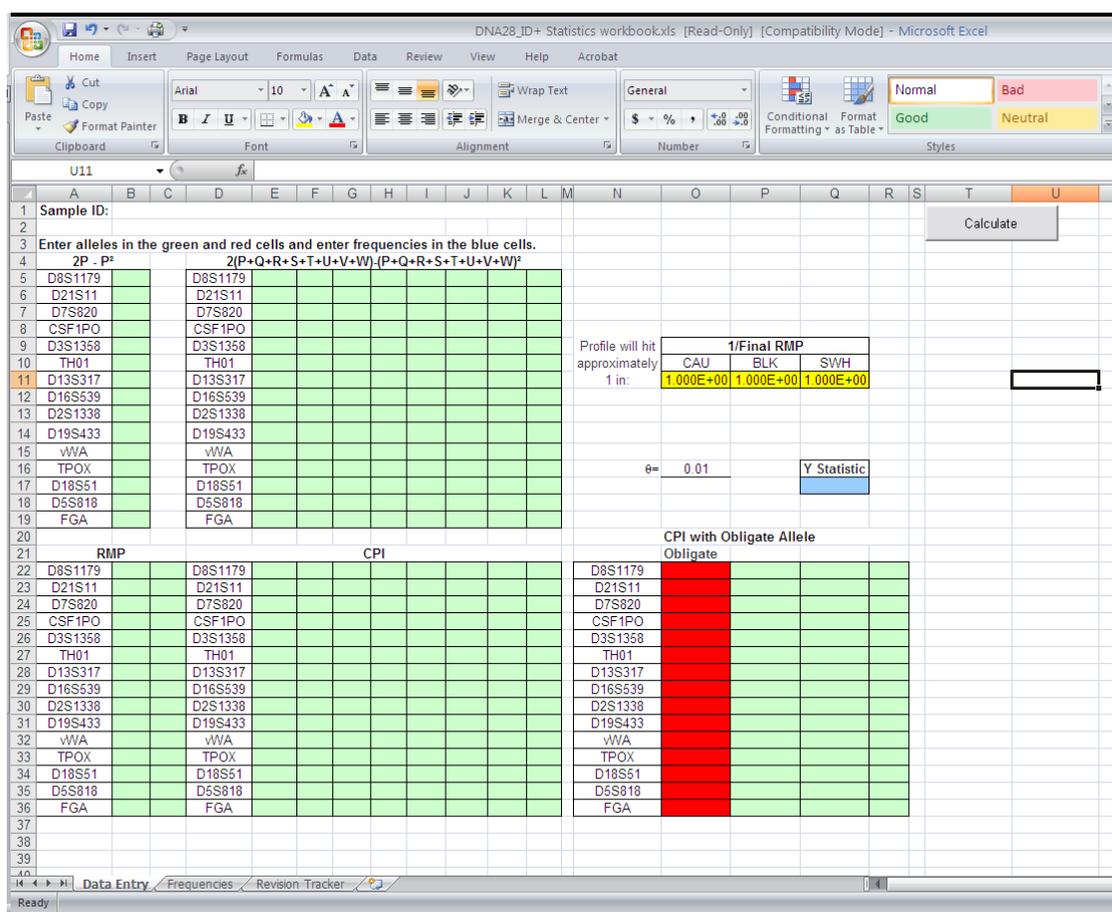
Two issues were identified during the post-implementation evaluation - a higher level of both minus A artifacts and pull-up artifacts in Identifiler® Plus data when compared with PP/CO data. This requires additional analyst and reviewer time to correctly identify and remove these artifacts. An additional validation study was performed to change the procedure by lengthening the final PCR extension time and reduce “minus A” artifacts. To address the pull-up artifacts, analysts evaluate casework data and re-calibrate the instrument as needed. Overall, this validation saves the laboratory \$7.84 per sample (or \$14,500 annually), and over 27 hours of instrument time each year.

F. STR Statistical Workbook

One efficiency issue identified through the employee surveys, as well as via supervisor input, was a request for an internal STR DNA statistics program to calculate DNA statistics on all cases in which a DNA match or inclusion was made. The current practice was to perform calculations manually in Microsoft Excel for any statistic not available in Popstats, which was time-consuming and error prone. To address this, a DNA analyst who was training in statistics at

the time worked with the Quality Assurance Manager to create and validate two Microsoft Excel workbooks with the necessary allele frequencies and formulae for the 15 Identifiler® Plus loci. The results of the validation and features of the new workbooks were presented at a DNA Unit training in January 2011. Subsequently, five DNA analysts completed competency tests, employing these new statistics workbooks. The new workbooks were approved for use with casework in January 2011, and have been used for every DNA case with statistics since that time (excluding paternity/parentage casework).

Figure 12 - STR Statistics Workbook



These improvements save analyst time – an estimated 20 minutes on a case with a single partial profile or DNA mixture, and two hours or more for a case with several mixed DNA profiles. Additionally, this reduces the amount of time the reviewer has to spend verifying the

statistical calculations. Using this workbook instead of completing calculations by hand provides each analyst in the DNA Unit at least an extra 270 hours (or 11 days) annually to conduct other steps in laboratory work. The workbook also improves quality and reduces the opportunity for error in data entry or formula creation.

G. Forensic Biology Printer

It is the DNA Unit's practice to take digital photographs of items of evidence, and print color copies for notation and inclusion in the case file. A problem with this practice was identified during employee surveys. Analysts frequently take notes directly on their printed photographs; however, it took extra time to remove personal protective equipment (PPE) and interrupt evidence examination to retrieve printed photo(s) from another area of the laboratory. The recommendation was to purchase a new printer and place it in the screening area for ease of use, as well as utilize a computer already in place in the screening area by adding a photo memory card reader.

In March 2011, a full color high capacity printer was purchased and installed using City general funds. In August 2011, the computer in the screening area had a photo memory card reader added and the computer had maintenance completed to ensure the computer would run more efficiently. The new printer allows the forensic biologists to send worksheets to the printer in the screening area prior to starting evidence examination, as well as printing LIMS evidence barcodes and photographs to notate, tasks that would have previously required them to remove PPE and walk back to their desks to complete.

Even though this was a simple and rather obvious fix, this purchase saves anywhere from five to 20 minutes a day in wasted time for each person who uses the printer. This purchase is

considered a low-cost solution to a problem that has already gained back its purchase price. Over 21 weeks, we estimate that each analyst saved a modest five minutes per day during their five day work week for a total of 525 minutes for each analyst annually (4,725 minutes for the entire Unit). This is equivalent to 10 working days, or \$2,578 based on the average analyst salary, which exceeds the cost of the printer. The Denver Crime Laboratory moved into a new facility in June 2012, and this improvement carried over with each laboratory equipped with its own printer(s) and computer(s).

H. Forensic Laboratory Technician

An important need that was repeatedly expressed in employee surveys was for a dedicated employee to perform support duties for the DNA Unit, such as quality control/quality assurance of instruments, preparing reagents, and ordering supplies. For the last eight years, these duties had been covered by two different college students who worked with the department part-time (25-39 hours/week) through the Public Safety Cadet Program. Both Cadets graduated, completed the Cadet program, and with no new Cadets available, their duties were being covered by DNA analysts within the Unit, and taking 25-39 hours/week away from casework.

The tasks of problem solving and implementing solutions were assigned to the DNA Efficiency Improvement Project Manager and the DNA Technical Lead. They agreed that recruiting and hiring a full-time employee was the best option. Research revealed that the City of Denver did not currently have a job classification that matched the prerequisites and duties for this position. With approval from top management of the crime laboratory, the DNA Unit began the process of creating a new job classification for a Forensic Laboratory Technician.

A state and national survey of like positions completed by the City of Denver Career Service Authority suggests that a typical salary range for Forensic Laboratory Technicians is between \$39,851 and \$58,164. The laboratory recruited and hired two part-time Forensic Laboratory Technicians (each working 20 hours/week and equivalent to one full-time) for a combined annual salary of \$45,000 annually.

Over the seven month evaluation period of the laboratory technician positions (May 7 – November 30, 2012), the laboratory would have spent an extra \$12,830 for a forensic scientist to complete the full-time duties they performed. During this evaluation period, DNA analysts completed 40% more forensic case reports, when compared to the previous seven month period before the Forensic Laboratory Technicians began work (October 1, 2011 - April 30, 2012: 440 assignments completed versus May 1, 2012 - November 30, 2012: 618 assignments completed). It should be noted that the DNA Unit added 3.2 new staff (a 45% increase) during this time period, with the new Laboratory Technicians accounting for 1 new position. Therefore, this improvement is *in part* attributed to the new Technicians, who are estimated to account for a 12% increase in cases completed. The turnaround time during the second seven month period increased to over 502 days for both Forensic Biology and DNA as compared to 170 days during the first seven month period; however, this is due to analysts having more availability to process older cases of lower priority.

I. Consumptive Testing Notification

Denver's laboratory wide Quality Assurance Manual requires that permission from the DA's office must be obtained to perform consumptive testing of evidence when a suspect has been identified. There were several issues with this procedure that were identified by the

employee surveys. First, the laboratory's process for requesting permission to consume the evidence was time consuming, as it involved writing a letter to the DA's Office which summarized case details from the laboratory request. Second, the waiting period for the DA's office to provide permission to consume the evidence takes days, months or in one case, up to two years to complete. The current practice was to keep an assignment in the LIMS open while waiting for approval from the District Attorney's Office, contributing to the backlog, and longer turnaround times when the laboratory did not have the authority to complete testing. Third, the DNA Unit had several cases in which the customer was notified of the need for consumptive testing in an earlier report; however the DA's Office decided they wanted the consumptive testing to be completed shortly before trial, creating a need for a rush case or refusal by the DNA Unit to perform the testing. Finally, the Cold Case Deputy District Attorneys (DA's) wanted a more stringent policy for cold cases than stated in the QA Manual where the Cold Case DA's would provide written permission to consume evidence on all cold cases (with or without a suspect identified). An overall concern was that because this process was time-consuming, DNA analysts may avoid making a judgment call that permission to consume will be required and try to proceed with testing. Only half of the evidence will be sampled, which may result in an incomplete DNA result, whereas consuming the evidence would have resulted in more information.

After meeting with representatives from the DA's Office and the Major Crimes Investigative Unit of the Police Department, the DNA Unit wrote a new procedure and implemented a number of changes to streamline the process. The new process now dictates that if the laboratory receives a lab request that will require consumptive testing in order to proceed, the assignment in the LIMS will be closed, and when/if the DNA Unit receives permission to

complete consumptive testing, a new assignment in the LIMS will be opened and testing will continue. The DA's Office provided a single point of contact to which the DNA Unit sends requests for consumptive testing. Case information is available to both the District Attorney's Office and the Denver Police Department via the Records Management System. The practice whereby the DNA Unit wrote a detailed case summary ceased, and a concise template is now used for requesting permission to consume. The laboratory-wide policy will be followed for all case types, including cold cases.

Since implementation of the new procedure in October 2011, the DNA Unit has requested permission to consume evidence on at least nine cases, and has promptly received a response from the DA's office on eight of these cases compared with much longer wait previously.

J. Y-STR Mixture Statistics

The DNA Unit's two Y-STR qualified analysts identified a need for a Y-STR mixture statistical tool to provide statistical weight when a Y-STR inclusion was made on a forensic case. The Y-STR analysts had evaluated two tools available on the U.S. Y-STR database and these did not meet the laboratory's needs. The interim solution was to perform mixture statistics through a manual search of the U.S. Y-STR database, which was performed by both the analyst and reviewer, with each Y-STR mixture search taking approximately one hour to perform and one hour to review. This method was used on eight Y-STR mixtures while this procedure was in place, and in six of the eight instances, the search and statistic was re-performed one or even two times by the analyst and reviewer to obtain an accurate result that both agreed upon.

The DNA Unit worked with the Administrator of the U.S. Y-STR database to acquire the most recent version(s) of the database to develop our tool. One Y-STR analyst worked with the Quality Assurance Manager to develop a Y-STR mixture calculator tool in Microsoft Access with a number of beneficial features:

1. Data entry may be conducted in three different formats – Yfiler, PowerPlexY or Alphanumeric.
2. The program allows for the search of duplicated loci and includes null alleles.
3. Up to eight alleles can be entered for each locus.
4. A “wild card” allele can be searched when an “*” is entered in to the text box. This allows the program to search for the entered allele(s) paired with any other allele that may have dropped out.

The tool was validated and approved for casework in July of 2011 and has been used for 7 Y-STR mixture calculations since then. It takes approximately 10 minutes for each calculation and review, totaling 70 minutes for these calculations, compared with an estimated 28 hours for the 8 calculations performed manually – time savings of 95%. This tool has also been shared with the National Center for Forensic Science and is pending upload to the U.S. Y-STR database (<http://usystrdatabase.org/>) to be shared with other forensic laboratories.

IV. Conclusions

Discussion of Findings

The operational model in Simul8®, although only partially validated, revealed two important results that confirmed the laboratory’s hypotheses. First, equipment and

instrumentation were not limiting resources, and thus, increasing capacity through additional instrumentation did not have a significant impact on backlog or turnaround time. Second, the model proved that trained personnel were the primary limiting resource for DNA Unit efficiency. While the DNA Unit's backlog and turnaround time have not decreased, it is anticipated once the unit's current staff members are fully trained (which should occur in 2014), the backlog and turnaround time will decrease as experienced in 2009 when there were comparable staffing levels.

The model enabled the DNA Unit to specifically test how many additional staff would be required to both eliminate the case backlog (and in how much time), and then subsequently handle its caseload to meet the target turnaround time of 45 days for all case types (and seven days for rush cases). Initially, the DNA Unit varied the target turnaround times based on case priority, and then determined that a best practice is to complete rush cases in 7 days, and all other case types in 45 days or less. The initial 'sliding scale' of desirable turnaround times was a compromise due to limited resources, but not ideal.

If the model had been fully validated, the laboratory could have fine tuned the results. For example, the results revealed that 14 full-time forensic scientists were required; however, optimizing work shifts, or modifying certain procedures might yield additional efficiency gains, meaning the laboratory could meet the same target objectives for turnaround time with 13 or even 12 full-time staff. Resources were the main variable that was modified and tested; however, the simulation could also be used to vary the amount of work being received at the Work Entry point. This ability would allow the DNA Unit to measure the impact of increased caseload, whether it arises from increased customer awareness of DNA testing, expanding services to more case types, re-opening cold cases or accepting new types of evidence.

The DNA Unit's efforts to use teamwork to identify efficiency issues and implement solutions was the most successful part of the project, and resulted in a number of improvements, including new procedures (statistical tools, Identifiler® Plus, male DNA screening of sexual assault kits), new equipment (a printer) and collaboration with groups outside of the Crime Laboratory (on issues related to grant employee retention, consumptive testing, and Laboratory Technician duties).

Of the 18 resolved issues, two of them (FBIO Laboratory Printer and DNA Differential Extraction Workbook) were straightforward and relatively easy, with a solution implemented by the DNA Efficiency Improvement Project Manager working alone. The other 16 required a team approach to gather input and buy-in from those affected, to consider different options, to implement the changes, and finally to evaluate and refine the new protocols. It is noteworthy that implementation of 10 of these changes included a combination of a presentation, training, and sometimes even competency testing for those affected. In terms of their qualitative impact, 10 of the issues improved work that is performed daily, 5 of the issues related to work performed on a weekly basis, and the final 3 affected work that is performed monthly, or less often.

The efficiency improvements that had the greatest impact (in terms of cost and time savings) were retention of grant employees, the Male DNA Screening validation, the Identifiler® Plus validation, hiring Forensic Laboratory Technicians, and eliminating Forensic Biology testing for human blood, saliva and cellular material on many items. One of the DNA Unit's hypotheses was that many of the solutions would be low-cost or no-cost, which held true for the majority of the improvements. All of the implementations required an investment of staff time, and the validations for Male DNA Screening and Identifiler® Plus included reagent costs that have been recovered through subsequent time and cost savings.

To implement efficiency improvement, three items of equipment were purchased, all through funding sources outside of this grant: the printer, two GeneMapper® ID licenses, and a QIAasymphony® instrument. This project supported over \$30,000 in salary and benefits for two Forensic Laboratory Technicians, which was more cost effective than using DNA analysts to conduct the same duties. The addition of the new positions also resulted in a significant improvement in cases completed.

Overall, these improvements yielded impressive results, and are estimated to have saved the DNA Unit one full year of analyst time, and \$307,096 in costs over the past two years.

Implications for Policy and Practice

The DNA Unit found that use of simulation software was instrumental in determining staffing needs to eliminate our backlog and maintain target turnaround times. The ability to add staff one at a time, and test the impact on case backlogs and turnaround times over a 3-year simulation was invaluable. This was clearly a superior method compared with our subjective predictions for the best way to add resources and what the outcomes would be. The simulation data is beneficial for presenting a compelling case to upper management that more resources are required, and that the impact of additional resources will be tangible and meaningful. Other forensic laboratories could implement simulation using Simul8®, or explore other simulation software options. A key to successful simulation is to build the process with less detail, ensure that it works appropriately, and then add detail as necessary. If simulation is not viable, a forensic laboratory can still implement any number of efficiency improvements through employee surveys, process mapping, and an environment that welcomes feedback and beneficial change.

We expect that many forensic laboratories would reach the same finding that we did: that additional personnel, rather than instruments, are the greatest need to improve case backlogs and turnaround times. However, the national trend according to a February 2011 NIJ Special Report, is to use DNA Backlog Reduction funds for equipment; Nelson notes that “federal funding covered 10% of the budget for reagents, 85% *for instrumentation*, and 20% for training”[1]. Our laboratory has previously used grant funds to address the area of greatest need and hire additional forensic scientists, but that was one of the main efficiency problems addressed through our DNA Efficiency Improvement Project. We found that funding DNA analysts on grants was not cost-effective or efficient because the positions were not sustainable, employee tenure was short, and there were significant employee retention issues. In the Denver Crime Laboratory DNA Unit, additional staff was needed, but grant funding was not an effective way to increase DNA analyst capacity. This underscores Nelson’s next point, “The degree of reliance on federal funding reported by many laboratories suggests a critical need for state and local governments to seriously evaluate investment in their own forensic crime laboratories” [1]. In order to truly improve the efficiency of forensic DNA testing, DNA analyst capacity must be built through investment at the local and state level through new, permanent positions.

Ten of the efficiency improvements outlined in the Results section are applicable to other forensic laboratories, and this report provides guidance for similar implementation or adaptation to each laboratory’s needs. Most of the issues were identified by personnel within the DNA Unit, and the initial anonymous employee surveys were an invaluable tool for identifying problems, and are highly recommended to the other laboratories as a starting point for identifying issues in their workflow. The early successes in resolving some of these issues fostered buy-in within the DNA Unit, and an environment where additional suggestions were welcome, and staff were

willing to accept the changes being implemented. Additionally, having a dedicated person who documented and analyzed each of these efficiency improvements, and then helped to implement and evaluate them, contributed to the success of this program. As a result, the scientists in the unit were able to continue to complete casework with minimal interruptions. It is unlikely that the DNA Unit would have had the focus and resources to resolve many of these issues without this program, and a dedicated Project Manager. Funding a dedicated Efficiency Improvement Manager could be difficult for crime laboratories, yet the payoff can be in the thousands of dollars in saved time and other costs.

Implications for Further Research

The DNA Unit could continue this project, and try to create a validated model by programming the six sections of the model separately and populating a more compact model (six Work Centers only) with the results of the separate models. This would allow further testing of changes to methods and processes to realize efficiency gains that may not be obvious at this time.

The Denver Crime Laboratory is expanding this study in 2012 to the Latent Print Unit to realize efficiency improvements in that section. The main lesson learned from the simulation project is to include less detail in the model, which will be applied in this next effort. The workflow in the Latent Print Unit is less complex compared with the DNA Unit due to fewer staff, no robotic methods, and cases are worked one at a time rather than batched together. These differences, as well as efforts to include less workflow detail, are expected to result in a functional and validated model.

Like the efforts in the U.K. SWIM program, process mapping and simulation could be applied to the entire criminal justice system through a “crime scene to courtroom” approach with broader performance measures, such as the number of cases solved, and changes in reported crime rates. While the City and County of Denver does not have plans to perform this research, a similar community – wherein there is a single Police Department, Crime Laboratory, and District Attorney’s Office that already works closely together – would be an ideal test environment.

V. References

1. Nelson, M. Making Sense of DNA Backlogs, 2010 – Myths vs. Reality. NIJ Special Report (February 2011).
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4. Home Office. Police Standards Unit. Summary Report of the Scientific Work Improvement (SWIM) Package. 2007.
5. Denver Police Department. Reported Offenses Using NIBRS Definitions in the City and County of Denver, 2010 to 2011. Available at: http://www.denvergov.org/Portals/720/documents/statistics/current/Citywide_Reported_Offenses_2011.pdf. Accessed: August 13, 2012.

VI. Dissemination of Research Findings:

This project's findings were presented at the 39th Annual ASCLAD Symposium in Denver, Colorado in September of 2011. Handouts of the poster were available and provided via e-mail upon request. Additionally, Dr. LaBerge presented findings during the June 2011 NIJ Grantees Summit in Washington, D.C. during a session titled "Man versus Computer – Expert Systems, Databases, and Other Software Based Methods to Improve Use of Forensic DNA Data."

Appendix A – Employee Survey

Pre-Process Map Interview questions

Please complete the following questions. If a question is not valid to your job duties, please write “N/A” in the space provided. If you have no answer or your answer is “none” to a question that applies to your job duties, please answer either “no answer” or “none.”

Use as much room as you need, but please be specific and detailed. The more detail you include will help to create a more accurate process map.

Finally, I want to discuss anonymity and confidentiality. I will be reporting a summary of the answers to the tech leads and, in some part, the answers will be incorporated in the final report to NIJ. However, **no one** else will read the original answers. I am trying to get a feel for how the unit is currently running and, as such, I want you to be as honest as possible in order to approve the processes. The summary I submit to the tech leads will be very general and I will do my best to retract any identifying remarks.

If you want to keep your answers anonymous, please print the completed document and place it in my box. Otherwise, please e-mail the completed document to me.

These are due to me by August 31st.

General Casework:

1. What tasks do you normally perform on each day of the week?
 - a. Sunday:
 - b. Monday:
 - c. Tuesday:
 - d. Wednesday:
 - e. Thursday:
 - f. Friday:
 - g. Saturday:
2. Do you have a set schedule for yourself when you will accomplish certain items (i.e. lab work on Tuesdays, write reports on Thursdays)?
3. What tasks do you feel are redundant and time consuming (if any)?
4. What duties do you feel you spend the most time on?
5. Where do you feel bottlenecks occur?
6. Where would you like to see more staff trained and assigned?

Court/Discovery:

1. What do your days look like when you are on-call to testify?
 - a. What do you typically do during these days?
2. How often do you prepare (review, gather material, etc.) discovery?

Forensic Biology:

1. What do you normally do with a case prior to getting the evidence from PMB? (e.g., read over the submission, examine the officer reports in Versadex, and check Justice Webview)
2. What information do you usually look for on the lab request?

- a. If it is not included, where do you normally find it?
3. What is your routine for getting evidence from the Property Management Bureau (PMB)?
4. Once you have evidence from PMB, how long do you store it in the lab before working on the evidence?
 - a. What factors determine your wait time to screen the evidence?
5. What days seem to be the most crowded while screening evidence?
6. What do you feel is the most tedious part of screening evidence (this is outside of the SOPs, but can be something like handwriting notes)?
7. Taking pictures of evidence:
 - a. Do you normally note on the picture while at the “bench?”
 - b. What is your procedure for this?
8. On what types of evidence do you normally perform a phadebas test?
9. What factors do you use to determine if an item needs a cell slide created?

DNA:

1. What days seem to be the most crowded while working on the robots?
2. How do you work with everyone to determine who has a certain instrument for the necessary time window?
 - a. GeneMapper®?

BEAST:

1. What do you find most tedious about BEAST?
2. Report Writing: Many people have a “report” template for themselves with standardized verbiage. Would it be easier for you if BEAST could accomplish this for you?
 - a. Pros and cons?
3. FBIO: Would you be interested in being able to take notes in BEAST while at the screening table?
4. What limitations do you see with BEAST?
5. When creating items in BEAST, do you use the supplied item codes?
 - a. If not, why?

Training:

1. Compared to your training, what do you feel you may do a little differently than you were trained to do? (This is not negative; think using a static form (FBIO_3.1) instead of a free hand worksheet (FBIO_3)).
2. How do you feel training could be more efficient?

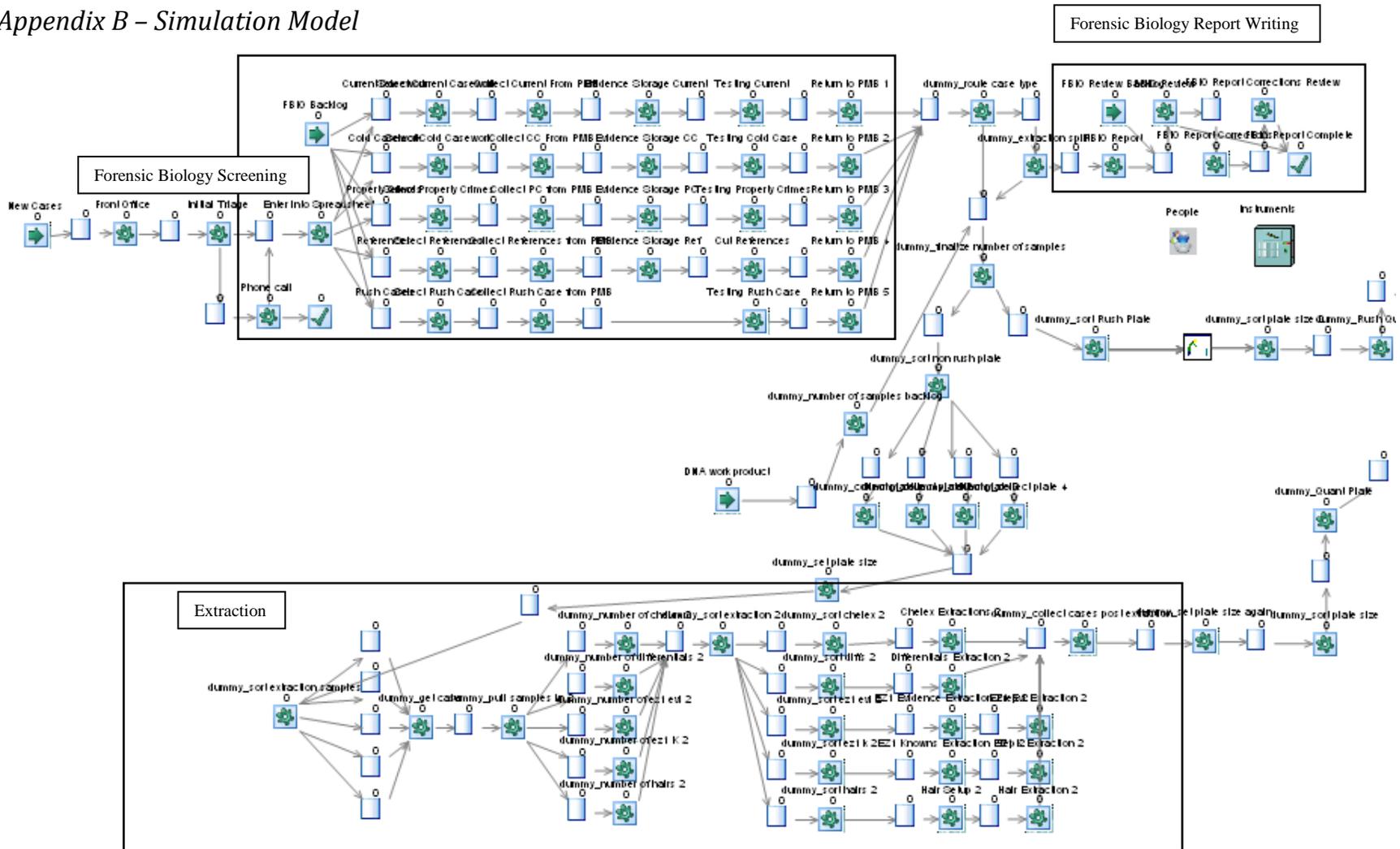
QA:

1. What aspects of the Quality System do you feel are inefficient or redundant?
2. Are there any forms/worksheets where you see an opportunity for improvement?
3. Are there any areas where you see opportunity for improvement in the report writing process (i.e. introduction of standardized language on reports as seen with the transition of the BEAST signature templates)?

Efficiency Project:

1. What steps are you taking that you feel is already an efficiency improvement (this may not currently be done by all people within the unit)?
2. What do you feel is an improvement that is currently in place (SOP or otherwise)?
3. What suggestions do you have for possible efficiency improvements?

Appendix B – Simulation Model



Appendix C – Male Screen Worksheet

FBI/O 3.5
Expiration Date: currently in use

Male Screen Worksheet

CONTROLLED DOCUMENT
Date of Issue: 3/10/2011 | Revision Date: 3/10/2011
Approved By: FBI/O Technical Lead

Case #:	
Item #:	
Date:	
Source of Evidence:	<input type="checkbox"/> Victim <input type="checkbox"/> Other:

Item Description:

One (1) Sexual Assault Examination Kit recovered from:
(name marked on all items)

Contains: The following sealed envelopes:

___ A: Known Victim Sample Contains:

1 (one) sample cut and marked:

___ swabs remain intact

___ B: Contains: swabs

1/2 of two (2) swabs cut for DNA, marked:

1/2 of two (2) swabs cut for male screen, marked same as above with prefix: A or B

___ swabs remain intact

___ C: Contains: swabs

1/2 of two (2) swabs cut for DNA, marked:

1/2 of two (2) swabs cut for male screen, marked same as above with prefix: A or B

___ swabs remain intact

___ D: Contains: swabs

1/2 of two (2) swabs cut for DNA, marked:

1/2 of two (2) swabs cut for male screen, marked same as above with prefix: A or B

___ swabs remain intact

___ E: Contains: swabs

1/2 of two (2) swabs cut for DNA, marked:

1/2 of two (2) swabs cut for male screen, marked same as above with prefix: A or B

___ swabs remain intact

Inventory of additional items that were not examined (strike out items if not present):

- ___ Head hair controls
- ___ Pubic hair combings
- ___ Pubic hair controls
- ___ Trace Evidence
- ___ Other:
- ___ Other:

Appendix D – File Storage

Problem: Analysts spend up to one hour of “locating” time when looking for a case file. When 30-40 case files need to be located for a 96-well plate of data, the process is time consuming. The common reasons for file mismanagement are the case is on another analyst’s desk waiting for review (et al), the case is in a pending box, the case is filed in the front office, the case is in the technical lead office, or the case is in a “to be entered into a database” stack. There is no central way to track where the case file may be at any given time. The tools that are available to track case files are not being fully utilized by staff due to lack of training.

Possible Recommendations:

RFID Tracking Software/Barcode system

Pros: Automatically checks in and out case files to analysts, computer software locates a file’s location instantaneously (to a certain degree)

Cons: Entire system runs anywhere from \$13,000 to \$30,000; caseload does not currently reflect a cost/benefit justification.

File Checkout Form/Electronic workbook

Pros: Cheap. The form should include the person who checked it out and when.

Cons: The analysts must remember to update the form or workbook with who has the file at any given time.

Centrally located file system for all completed files

Pros: Storing the files in one place allows for one point of contact when looking for files.

Cons: There is an additional cost for more file cabinets. Currently, there is no room in the laboratory to accommodate this option. The QA Unit stores the majority of the files on B2, but there is limited room and the room can flood. Additionally, this will not assist with finding files that are currently located on desks throughout the laboratory.

Note: Cost for this option may vary if a high-density file cabinet is purchased.

Once in the new building, this option may be the best fit.

Utilize BEAST to track who has the case file

Pros: There is no additional cost as BEAST is already purchased and all analysts have training and access. The new upgrade of BEAST allows for “additional analysts” to be listed on the assignment page. If the user takes possession of the assignment this way, anyone looking for the file can check with BEAST to locate the file.

Cons: This option only works if an assignment is open and the file is an analyst’s possession, but it cannot accommodate files that are waiting for database entry, filed in the basement, waiting to be filed, and other variables. The implementation date of the upgrade of BEAST is to be determined at this time.

Implementation process:

The DNA Efficiency Manager met with three analysts to discuss the issue on July 1, 2010. Two analysts were from Forensic Biology, one from DNA. The recommendations were discussed.

Additional suggestions from the members included:

- Utilizing BEAST barcodes to read and update an Excel spreadsheet with who has a case file at a given time.

- Use wireless scanner and a centrally located computer/laptop to check files in and out
- Restructure how everyone in the units holds on to case files.
- Electronically scanning files to a server for multiple viewing capabilities.

There are several areas where case files linger:

- In Progress:
 - Initial/Additional Submission
 - In Batch
 - Collated
 - In progress/DNA Interpretation
 - Review
 - Review w/Corrections
 - To be Marked
- Completed:
 - Property Crimes Access Database
 - Cold Case Access Database (DA's)
 - Filed
 - Discovery
 - Reviewed for Discovery
 - To be Paginated
- CODIS
- CODIS cases can be in numerous places

The most cost effective option at this time is the File Checkout Form/Electronic Workbook. Ideally, the system will work in tandem with BEAST, the Forensic Biology Pending Workbook, and the Extraction Workbook. Most of the workbook will be automated, but the analyst checking the file in or out will have to assign the file to a specific person (themselves) or a location (Filed).

Another suggestion, which seemed to appeal to all of the involved members, was to start storing files electronically. A goal of the laboratory is to move away from using paper (as best as possible) in order to save resources, however the current servers utilized by the laboratory do not have enough free space to allow for this. This option would allow for users to reference the content in the case file without having to track down the original paperwork.

In discussing the centrally-located file issue, the committee mentioned the inconvenience of having to wait at least 24 hours to receive a case file is part of the reason the analysts keep their files on their desks.

After discussing the outcomes of the meeting with the unit technical lead, it was decided a larger meeting with all members in the unit present may lead to more suggestions. Additionally, the added benefit of staff buy-in would help to resolve the issue. One of the main issues seen by the DNA Efficiency Manager is the idea that a case file belongs to one person at a given stage in the process. While this may be true to a small extent, this mindset feeds into the hoarding mentality and exacerbates the issue.

Eleven ideas for no-cost improvements were identified in this meeting:

The DNA efficiency project manager will create a guide for finding case files to be used by all staff. Staff may not look in all of the possible places that a case file might end up before sending a mass e-mail out to the unit looking for that particular case file. This guide will give staff a systematic way of searching for case files and using the mass e-mail as a last resort.

- Any outstanding cases on analysts' desks should be promptly filed.
- Analysts should confirm that everything remaining on their desk is either:
 - Assigned to them
 - Being review by them
 - Check out to them via the appropriate means
- When an analyst takes a case for technical/administrative review, they will use the review button in BEAST to identify the case is being reviewed and by whom.
- When case files are checked out of the DNA file cabinets on the 6th floor and on B1, a file checkout placeholder will be used, showing what case was checked out, by whom and the date.
- Two groups of cases require database entry after work is completed, resulting in case files waiting in stacks: property crimes and cold cases. Property crimes are entered in the database by FBIO/DNA staff within one week and then filed. Cold cases are entered by a paralegal from the Denver DA's office who completes the work on an irregular schedule, sometimes only every 2-3 months. The DNA technical lead contacted the paralegal to propose a regular schedule of case entry within the first 10 days of every month. The tech lead also spoke with the Chief Deputy DA who oversees the cold case project and supervises the paralegal, and the DA's office was accommodating and flexible in finding a solution. The backlog of cases requiring entry was promptly addressed and a more regular schedule of data entry has been established. The paralegal will complete data entry as needed when the cold case analysts contact her (at least once a month, more frequently as needed)
- Case files should be page numbered and filed promptly by the cadet and volunteer.
- Cases waiting to be re-filed in the unit's file cabinets (2007 and earlier) will be re-filed once a week by the cadet and volunteer.
- Trays will be labeled and placed in an identified location for the case files for pending SDIS and NDIS hits.
- The case files associated with a DNA tray that's in progress should not stay on the analyst's or collator's desk when they're not being used. They will be rubber-banded together and placed in the "Plate in Progress" tray.
- A new assignment status will be created and used in BEAST to identify case pending DNA interpretation. This will differentiate between cases that are in progress for DNA analysis, and those that have all of the samples analyzed and are awaiting interpretation.

The DNA TL and efficiency project manager gave a presentation on July 21st to most members of the FBIO/DNA units that covered the 11 improvements above. The project manager completed and presented the guide to finding case files, including a process map for finding case files. This meeting helped to verify all stages of locating a case file, as well as answer questions about the new procedure on finding a case file. Because some of the solutions included utilizing the LIMS, instructions were given on how to enter or update the required information. The staff was asked to begin implementing the 11 improvements on a trial basis.

A final meeting occurred on September 2nd, where the users were asked for feedback on the new policies, and reminded on the requirements for tracking and finding case files. This allowed the users to voice any concerns, comments, or suggestions in one last venue before a QA memo went into effect with the new policies.

Outcomes:

QAMEMO71 was created to reflect the best practices for tracking and locating case files. This was presented and sent to all users on 9/2/10.

All user feedback is positive at this point. As of 9/15, there are no reported instances where the no-cost solution has not helped find a case file.

Post-evaluation:

Users stated using this new method reduced their problems in finding cases by one-third. Finding case files is now much faster.

Appendix E – DNA Extraction Workbook / Differentials

Problem: There is one DNA Extraction Worksheet which must be changed and reformatted for Differential extractions.

Recommendation: Create a separate worksheet for differential extractions

Implementation process:

- Examine the changes to the spreadsheet, consulting with the two analysts who complete differential extractions.
 - Three reagents on the worksheet are not used for differential extractions. These were removed.
 - Columns were added for cell slide ratings and the number of washes performed. Previously this had to be done by the analyst every time the workbook was used.
 - The two analysts have minor differences on how they changed the worksheet. A consensus was made that satisfied both users.
- Limit the spreadsheet to 20 samples, as this is the maximum number of samples that will be completed at one time.
- Create a macro (and button) to add `_EF` or `_SF` to the sample ID for a selected cell.
 - Prior to the macro, the analyst had to edit every cell individually, which was time consuming and tedious.
- Test workbook on multiple computers to ensure process works as expected.

Outcomes:

- The DNA technical lead reviewed the workbook on 9/16/2010 and approved the workbook for use with casework.
- As of 12/30/2010, all users had no problems or errors received from the new workbook. This issue is considered complete.

Post-evaluation:

- Between September 16, 2010 and August 30, 2012, the new workbook was utilized 80 different times. Analysts reported this workbook saved approximately five minutes per workbook, which is a total time savings of 6.7 hours over two years.

Appendix F – Cut and Run Technique

Problem: The screening process for forensic biology can take anywhere from twenty minutes to several days depending on the item.

Recommendations: Advances in the technology now allows for identification of DNA using smaller amounts that traditional screening may miss. Other laboratories use similar techniques, especially when conducting testing on swabs collected from crime scenes (such as blood swabs). Using selective testing, the FBIO unit will “cut and run” swabs – or submit cuttings of swabs collected either in house or from crime scenes to determine if a quantitation value of DNA is present instead of relying solely on the presumptive and confirmatory tests in FBIO.

Implementation: The units examined specific types of evidence and their DNA results to determine if reducing or eliminating a forensic biology test would have a negative effect. Instead of creating mock evidence to test this issue, the analysts examined previous casework to determine the outcome.

Previously, cigarette butts were tested for phadabus prior to cutting and putting forward for DNA. A FBIO analyst examined her cases from the previous two years and compared her phad positive cases and the DNA results. All cigarette butts that were phad positive resulted in a DNA profile, and the decision was made to cease completing phadabus testing on cigarette butts.

Cellular slides were completed as part of examining evidence for cellular material (wearer evidence more so than handler/touch?). These slides then received a rating to determine if there was enough material to put forward for DNA. After examining data from 500 cases, it was determined that completing a cellular slide and rating added no value to the case, except in the circumstances where it may help with an investigation. By swabbing and putting forward these items and eliminating the cell slide step, this saved each analyst anywhere from 20 minutes to several hours searching a slide.

Once cellular material swabs were put forward, it was a logical step to do the same with blood swabs. Many of these swabs are collected by experienced crime scene personnel who may already perform a test in the field to determine if a substance may be blood. Evidence examined in house is treated the same.

Outcome: These steps, in combination with the male-screen approach for sexual assault examinations, have saved hours in forensic biology time on cases. While some cases still require the additional forensic biology results, this is now limited to an “as needed” basis and the standard is to cut and run swabs. Cases that require the particular testing are identified prior to testing, either between the analyst and technical lead or between the Detective and analyst. By eliminating many of these tests, analysts are now free to complete other casework or become trained in DNA to assist in that backlog.

Post-Evaluation: From March 11, 2011 to August 30, 2012, the unit completed 968 forensic biology assignments using this method, saving over 56 days in analyst time and \$392 in reagent costs.

Appendix G – Forensic Biology Worksheet

Problem: The unit started to create forms for different types of evidence (reference samples, blood swabs, sexual assault kits). It was suggested that other types of evidence could benefit from a standardized form.

Recommendation: Create new forms, standardize statements on already created forms.

Implementation Process:

- Met with the DNA technical lead to discuss what types of forms would be useful. Creating a form for cigarette butts as well as one for cans and bottles was suggested.
- Met with a high throughput user who to discuss the interest of the new forms.
 - Although the user did not see a great benefit in the cigarette butt form, we discussed what normally would appear on the form.
 - The user was more interested in the cans and bottles form after discussion.
- Examined 6 samples of each type of evidence to look for consistencies.
- Created samples of the form to discuss with the user
- Most of the users discussed issue of CDI (Case, Date, Item) versus CIDI (Case, Item, Date, Initials) as written on evidence. Discussed issue with all users and a consensus was made to match the evidence marker. The form is now organized by Case, Item, Date to prevent errors and increase consistency.
- Discussed forms with user. Fine tuned areas, language on the form.
- Sent copies of forms to the FBIO and DNA technical leads for review
- Met with the DNA and FBIO technical leads to discuss new forms.
 - Expressed concern of user that the cigarette butt form would not save time
 - Both the DNA and FBIO technical leads were concerned with some of the content on the forms. This opened a broader discussion of “Best Practices” for note taking.
 - Further discussion excluded the cigarette butt from being created. Once some statements were removed from the form, the form became unnecessary. It was decided this information (which was standard to all forms) would be included on the FBIO3 plain form.
 - The FBIO technical lead mentioned interest in creating a Clothing form.
 - Both expressed concern over the “Controlled Document” text which distorted the form. Based on other documents currently in use, it was decided to remove the watermark and place the “Controlled Document” text within the header.
- Post meeting, all forms were updated based on discussion. Created clothing form.
- Meeting with FBIO Technical Lead to fine tune form prior to introducing to all users.
 - Changed the order of some of the setup, excluded certain statements from other forms.
 - FBIO TL requested possibility of removing footer. This was a historical issue that used about an inch of space. While some of the information was required by ISO standards, other information was either redundant or unnecessary. Moved some of the information to the header and created another inch of area for report writing.
- Meeting with entire FBIO unit on 8/5 to discuss forms.

- This meeting resulted in more tweaking of the forms, including removing certain statements in order to make it less stringent.
- Requested changes were made to the form and the FBIO TL and EIP met on 9/28 to have a final look at the forms.
- More changes were made to create consistency between all forms, as well as add or change language that is not too strict to two of the forms.

Outcome:

- The forms were approved by the FBIO TL on December 1st, 2010.

Evaluation:

- The analysts used the forms for one week before changes were necessary. Because these are living documents, this was anticipated. Verbiage, space, and formatting were changed on the documents to better fit with the workflow. A second meeting occurred on December 15th to discuss changes.
- In January 2011, further changes to the workbook were a result of requiring lot numbers and expiration dates of reagents to be populated on the form. In order to better create a better fit to workflow, it was decided to use an Excel Workbook to track all of the forms.
 - Each form was recreated in Excel as a worksheet. This information included all reagents possibly used in the FBIO workflow and is linked to a reagent spreadsheet allowing the analysts to choose their current reagent, print the information on each form prior to use, and ensuring the most up-to-date form is utilized in the laboratory (meeting ISO and FBI QAS requirements).
 - An additional form was created in conjunction with the Male Screen process to provide consistent language while reducing the amount of time the analysts require in completing the form as part of casework (see Efficiency Issue 16 – Male Screen for more information on the form).
 - This new workbook format was approved on March 19th, 2011 and is currently in use.

It is estimated that using the standardized forms save the analysts five minutes per case. From March 19, 2011 to August 30, 2012, analysts completed 943 forensic biology assignments and saved 9.8 days using this new form.

Appendix H – CODIS LIMS Templates

Problem: (Identified on 9/1/10)

- The current CODIS report templates are inconsistent in design from the other report templates utilized by the DNA and Forensic Biology Units.
- The form provides repetitive information available on other reports (all accessible via the BEAST website).
- It contains language that is not used in any other reports.
- There are many corrections needed on reports thus requiring a large amount of time needed during the review process.
- The reports may be confusing to the customer. There is a lack of clarity because of lack of consistency in wording for DNA matches, making the reports difficult to understand.
- There is no way within the LIMS system to link Forensic hit cases, as the laboratory does not write multiple reports to link internal cases.
 - For example, if four cases are linked through CODIS, only one report will be written and will appear under only one of the linked cases. The other three cases have no standardized notification through the LIMS for laboratory users or customers.

Recommendations:

- Create new report templates with standardized language and formatting to match current practices within the FBI and DNA units.
- Utilize the current LIMS website system to include notification of forensic case to case hits.

Implementation Process:

- The CODIS administrator and DNA technical lead met to discuss the needed changes
 - The two updated both the Forensic Match report and the Offender Match report, creating standardized language that can be deleted from the report as needed.
 - Additionally, they modeled the format to match the style used by the other units.
- The finalized template was given to the EIP Manager/BEAST administrator to upload to the LIMS.
- The EIP Manager trained the CODIS administrator on utilizing the Crime Scene Response supplement report module in the LIMS (no longer in use by the crime scene unit due to the transition to the RMS in use by the Denver Police Department).
 - Both the laboratory case number and DPD General Offense number will be listed in a supplement report for all forensic case to case hits to provide all users a standardized location to retrieve linking case information. This information will be available in an easy to read format on the website for customers.
- The CODIS administrator and DNA technical lead tested the reports to ensure the correct information was filling in as well as the report worked as they anticipated. The new website module was tested as well to ensure easy access to the information.
- The DNA technical lead presented the new templates to the crime laboratory director and received feedback and approval.

- The CODIS administrator presented process for linking cases in the LIMS in both the internal and external modules to the laboratory director and received feedback and approval.

Outcome:

- The reports were approved for use and installed on BEAST on 9/24/10. The CODIS administrator began using the BEAST supplemental report on 10/7/10.
- The CODIS administrator stated the new reports save approximately 10 minutes of CODIS reporting and review time per case. From October 7, 2010 to August 30, 2012, 8.4 days were saved using the new report templates.

Appendix I – Forensic Biology Assignment Workbook

Problem: The MS Excel workbook created to track the status of pending unassigned cases for the Forensic Biology Unit has many issues. The workbook had two tabs to search for cases. There was no consistency between the Forensic Biology and DNA Units on prioritizing cases. Cases would update in color depending on several conditions and was too hard to read. Additional information added to the workbook (Assigned Detective, Victim and Suspect names) was duplicated from the laboratory's LIMS.

Recommendations:

- Reach a consensus on labeling case priorities
- Combine both spreadsheets into one easy-to-read spreadsheet
- Adjust conditional formatting to allow for consistent and understandable color coding based on request date
- Remove columns with duplicate information from BEAST

Implementation Process:

- A meeting between the DNA Efficiency Manager and the Forensic Biology Unit Technical Lead occurred to discuss the information on the current spreadsheet and what issues he has with the current spreadsheet
- It was decided the Forensic Biology Unit should use the same type of priority codes (Rush, High, 1, 2, 3, & 4) as the DNA Unit to provide consistency.
- The spreadsheet would color certain cells based on date, but could not factor in the priority code. A High priority case, which should turn red at 30 days, would look the same as a priority 3 case, which should turn red at 90 days. A formula was created to ensure the correct code would turn the correct color at the right time.
- The two tab system would break cases into cases with no court dates and cases with court dates. The cases with court dates were completed in a timely manner, but the cases without court dates would often be overlooked. If the analyst was pulling 4 cases of the same type of evidence to screen, they would usually only look to the cases with court dates. All cases were merged into one sheet, with additional columns to include room for court dates and court docket numbers.
 - o The cases are checked on a consistent basis in the District Attorney's database, Justice Web View. If the case already has a docket number, this is a much easier search than looking for the suspect's name, date of birth, and corresponding case each time the analyst wants to verify the status of the case with the DA's office.
- The descriptions of the cases were standardized in order to accommodate a more accurate filter process. Because the actual offense type description is captured in BEAST and due to the adjusted priority code descriptions, offenses such as Aggravated Assault or Simple Assault are now viewed as Assault. The only time an offense description will change in the spreadsheet is if the offense elevates in seriousness (i.e., Assault to Homicide).
- A consensus was made concerning the elevation in priority codes. Unless a case changes to include a court date or the offense elevates in seriousness, the priority code will not change. This is to allow accurate statistical tracking.

Outcome:

- The workbook was adjusted and enabled for complete unit use on 7/14/10. Notification of the update was sent to both the Forensic Biology Unit and DNA Unit on this date.

Post-evaluation:

- Users were reminded to remove completed cases from workbook on 7/21/10
- As of 8/2, there were no issues with the formulas or workbook set up. Standardization of case types was still successful.
- One user commented on uncertainty of assigned cases to individuals (they had not seen the case file or knew of the case that was assigned to them)
 - o Unsure of the cause or source of the discrepancy. A possible solution to prevent future issues is to add an additional column "assigned by." Will discuss with technical lead.
- Updated practice of deleting/adding rows on workbook to move completed cases.
 - o Users need to cut and paste the data from only the corresponding columns in order to keep formulas working.
- It is estimated this workbook saved approximately 20% in data entry time

Appendix J – QIASymphony® Robot

Problem: Currently extractions are performed using a Chelex (manual) method or using the EZ1 BioRobot®, which can process 6 samples at a time in approximately 20 minutes on the robot. The DPD SOP allows a batch of up to 24 samples to be extracted on the EZ1 with 1 or more reagent blank negative controls. The lab currently has 2 EZ1 robots.

These methods limit the number of extractions completed in a batch. While eliminating manual extractions is not yet possible—nor is it preferable on certain cases or evidence types—increasing the throughput from a maximum of 24 samples per batch to a maximum of 96 samples is possible with automation. The unit also completes quantitation and amplification in a 96-well format. Placing the extractions into this format earlier in the process will decrease the amount of time spent on the whole process. Although the extraction time on the EZ1 BioRobot® is 20 minutes, the manual steps of adding pre-treatment reagents and transferring samples to a spin basket or to the EZ1 BioRobot® sample tube requires additional time.

Possible Solutions: Purchase large scale instrumentation that extracts samples in a 96-well format earlier in the process, or purchase more EZ1 BioRobots®.

*QIASymphony® by Qiagen®
BioMek 3000® by Beckman Coulter®
Tecan Freedom Evo 100® by Tecan®
MICROLAB STARlet® by Hamilton Robotics®
EZ1 Advanced XL® by Qiagen® – increase sample capability from a maximum of 6 to a maximum of 14 per instrument.

The QIASymphony® Robot by Qiagen® was selected due to cost and similar chemistry to the EZ1 BioRobots®, which have shown good sensitivity and removal of inhibitors. Purchasing additional EZ1 BioRobots® does not allow for extraction in a 96-well plate format. Other instrumentation was at least \$5,000 more than the QIASymphony® and because the laboratory has other instrumentation from Qiagen®, utilizing chemistry with a proven and successful track record was preferable. The QIASymphony® will run known/reference samples, including blood, saliva, and hair, and most evidentiary samples (excluding differential or consumptive samples). After evaluating the Arizona DPS's internal validation for the QIASymphony® and attending their presentation at the AAFS meeting in February of 2009, the laboratory determined this would be a good fit for our processes. Each batch of 24 samples takes approximately 50 minutes of instrument time.

The lab was also able to trade in a Corbett CAS-1820® extraction robot (which was not sensitive enough for forensic casework needs) to Qiagen® for a trade-in value of \$19,000 toward the purchase of the QS. Qiagen® further agreed to allow the laboratory to have a demo instrument and evaluate it for a couple months prior to committing to purchasing it.

The QIASymphony® reagents cost approximately \$5.06 per sample, while the EZ1® reagents are \$7.88 per sample. 160 samples can be processed using one QIASymphony® kit, while only

48 samples can be run per EZ1® kit. This translates to less time spent quality checking extraction reagents per sample.

Implementation Process:

Due to an agreement between DPD and Qiagen®, the DNA laboratory was able to evaluate the instrument prior to purchase. Three studies were completed simultaneously to determine if the laboratory would go through with the purchase. A sensitivity study to compare the QIASymphony® to the EZ1 BioRobots® was created. The main purpose was to determine if the QIASymphony® would provide equal sensitivity, or would perform even better than the EZ1 BioRobots®. This study also challenged the two robots with inhibited samples to see if they performed comparably. The second study was to determine if cross-contamination would be a problem. This is to ensure the 96-well format would work as anticipated and the instrumentation would not be a source of contamination issues – always a concern in forensic laboratories. The final study was to determine if the expiration dates on the cartridges could be extended. The manufacturer suggested a time limit of two weeks and the laboratory was interested in determining if this could be extended to four weeks.

An initial problem with the instrumentation held up the validation much longer than anticipated. A faulty cog wheel installed during manufacturing created issues and had to be replaced. Additionally, a shallow elution plate format may have created cross-contamination issues, requiring the lab to switch to deep-well elution plates. Once these issues were resolved, it was discovered that the QIASymphony® out-performed the EZ1 BioRobots® with inhibited samples. The cartridges were evaluated and found that the kit reagent cartridge degraded steadily after being opened. As such, the laboratory decided to recommend that a new cartridge be used when performing the extraction and an open cartridge expires according to the manufacturer's 2-week recommendation.

The laboratory also selected and validated optimal sample tubes and elution plates for use on the QIASymphony® with input from Qiagen®. The lab attempted to use spin baskets for pre-treatment of samples (to remove as much liquid extract from the substrate as possible), but this was unsuccessful due to no spin baskets being available that fit in the 2ml screw cap sample tube. The lab also researched and purchased a thermomixer, which allows simultaneous heating and agitation of samples during pre-treatment. This saves the analyst time by not having to manually vortex a batch of 24 samples multiple times during pre-treatment. One advantage of the QIASymphony® is that all sample tubes are bar coded and manual data entry of sample names is not required. The bar code has limited character space and sample names were truncated so that they are still unique, but will fit in the allotted space. The lab created a system for completing a quality check between the truncated bar code label from the QIASymphony® log and the full sample name. The laboratory also researched and found a new sealing method for QIASymphony® extraction plates called X-pierce film, which minimizes evaporation, but still allows the plate to be used with other robots in the downstream process. The validation team found a new storage method for QIASymphony® extraction plates and ordered new freezer racks for space-efficient storage in the -15 to -25°C freezer. Finally, the lab worked with Qiagen® to request a custom software protocol so the sample status in the run log did not show 'Fail' because the laboratory does not use cooled elution plates.

The internal validation began in April of 2010. Due to the faulty cog wheel, the validation took longer than anticipated. Validation of the QIASymphony® created a whole new workflow for downstream quantitation and amplification from the QS 96-well plate. 5 new SOPs or worksheets were created for QIASymphony® related procedures, and 4 additional ones were updated. One user completed beta testing to test the clarity of the new SOPs prior to approval. Additionally, 4 DNA analysts completed a practice run in the virtual mode of the robotic software prior to performing their internal competency tests. The validation was completed and approved 11/22/2010. Internal training on the instrument occurred on 8/17/2010 and competency tests were completed in November 2010.

Outcomes:

The laboratory obtained funds to purchase the QIASymphony® on through the 2009 Solving Cold Cases with DNA grant (2009-DN-BX-K012). The first casework plate was run on March 1, 2011. This first batch was reference samples and expected results were received. Using this method decreases the amount of time spent on extraction by an hour each plate.

Downstream analysis of QIASymphony® extracted samples in a 96-well plate is much easier than handling ~80 sample tubes, particularly for quantitation, normalization, and amplification on the CAS-1200® liquid handling robot. To illustrate, quantitation of a QS plate requires verifying the plate name, and placing the open plate on the robot. In contrast, quantitation of extraction tubes requires spinning down, opening and verifying the sample names and sample block locations of 80 tubes prior to loading them on the robot.

One area where working from a QS plate is more challenging is for samples with low DNA concentrations that require Microcon concentration prior to amplification. The laboratory validated a method for placing the QS plate on the CAS-1200 robot and transferring the DNA from the correct QS well to the top of a Microcon® concentrator (the subsequent Microcon® steps are performed manually). The CAS-1200® requires dead space volume at the bottom of the tube and is not able to pipette the entire volume from the QS well to the top of the Microcon®, resulting in sample loss of low level samples that would not occur if this step were done manually. As a result, DNA analysts have been completing this transfer manually or attempting the transfer on the CAS-1200®, followed by manual transfer to achieve transfer of the entire volume. This is a limitation of the CAS-1200® (not the QS), but affects the lab's ability to fully implement the desired workflow. The lab plans to validate a material modification in February 2012 to improve this step.

The QIASymphony® has been used for 4 male DNA screen plates (see efficiency report #16) to date and is highly effective for this application.

The X-pierce film was found to cause some sample evaporation during short term storage of extraction plates, and the instrument was placed out of service from 5/2/11 – 6/10/11. During that time, a material modification validation was completed that showed X-pierce film plus clear plastic wrap or Parafilm® prevented evaporation. An SOP change was approved and the QIASymphony® was approved for use with casework on 6/10/11.

On 6/13/11, the QIASymphony® stopped during a casework extraction due to a robotic arm error. The instrument was placed out of service pending maintenance by Qiagen®. The lab received the protocol for manual sample recovery due to a run error, and successfully recovered 24 casework samples. Qiagen® recommended updating the robot software to version 3.5.1, stating this new software had better stability and had a lower chance for errors, as well as some feature improvements. Since our laboratory uses custom protocols it would take several days for engineers to mirror these protocols in the new software. The new software was installed 7/19/11 – 7/20/11 and the instrument was performance checked and approved for casework on 7/27/11.

Post-Evaluation:

As of August 31st, 2012, 2,150 samples were extracted using the QIASymphony®. The laboratory saved \$6,063 in reagent costs by not using the EZ1 BioRobots® (\$10,879 on the QIASymphony® versus \$16,942 on the EZ1 BioRobots®).