Measuring the Impacts of Transitioned Solutions

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ABSTRACT

Department of Homeland Security (DHS) Science and Technology Directorate (S&T) delivers solutions with innovative tools, technologies, and knowledge products for the Homeland Security Enterprise and first responder communities to support ongoing operations and dynamically respond to emerging threats. DHS S&T faces similar challenges to DoD in transitioning solutions from research and development (R&D) prototypes to operational implementation, where (1) technology advances occur faster than acquisition requirements development and (2) widely available commercial technology allows increased adversary access to technology. These challenges combine to make it difficult to maintain a technological advantage and get the latest innovative solutions into the hands of the agents and officers on the front lines of national security. It cannot be assumed that even well designed R&D solutions will successfully transition to full operational use, as well as positively impact operational metrics of efficiency and/or effectiveness. Rather, this must be explicitly planned, funded and incrementally measured, as a method for, not only, demonstrating the operational impact of the solution, but to also iteratively inform the R&D process to ensure a successful transition. Beginning with the end in mind and clearly identifying the important metrics to the stakeholders and end users at project inception increases the likelihood of a successful transition. Shifting the traditional view of program ending at transition, to include an operational implementation and post transition performance (PTP) assessment phase, can do the same. Ending S&T involvement in programs at transition can result in solutions that are not fully integrated by the end users and/or are potentially shelved by component leadership without operations and maintenance budget planning or reach back to developers during this critical post transition operational implementation phase. S&T has recently gone through an organizational revitalization that has prioritized and shifted the view of the life of a program to include a Post Transition phase and is currently piloting Post Transition Performance (PTP) assessments as a systematic approach to not only support operational integration of delivered solutions, but also the planning and execution of assessment for operational impact. A critical part of the performance assessment process/method includes defining appropriate metrics and sampling at various stages of the R&D program. This includes project inception (to establish a baseline), mid-program (to assess operational changes that could confound measurement), at transition (to ensure the solution functions as described/intended), and after operational implementation (to assess if the solution did improve operational efficiency and/or effectiveness in the intended operating environment). The presentation will focus on demonstrating the need for PTP assessments and establishing standard processes.

ABOUT THE AUTHORS

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Background

The Department of Homeland Security Science and Technology Directorate (DHS S&T) delivers solutions with tools, technologies, and knowledge products for the Homeland Security Enterprise and first responder communities to support operations and counter emerging threats. As the threats and challenges that the Homeland Security Enterprise and first responders communities evolve, science and technology is poised to address them through programs and initiatives that not only address current operational needs, end user requirements and capability gaps, but also work towards achieving S&T's visionary goals that look well into the future. S&T deliberately focuses human and financial resources to identify cross cutting or common needs, requirements and capability gaps as a core strategy to achieve maximum return on investment. S&T remains committed to this cross-department collaboration to not only increase the return on S&T investments, but also increase the likelihood of a successful transition to operations with a repeatable solution development framework for this collaboration. However, technology transition management presents a challenge to DHS (Legault, 2017) as well as the Department of Defense (DoD) and other government agencies. For example, in 1995 an estimated 46 percent of DoD-funded IT development efforts met program management requirements of achieving a successful transition, but were not successfully used (Leishman & Cook, 2002). So while nearly half of those IT investments were successfully transitioned, they were not successfully operationally implemented by end users. Barriers that can separate the milestone of transition from the successful operational implementation and use of a candidate solution can include challenges that range from end user acceptance to customer planning program and budgeting for acquisition or operations and maintenance.

Common challenges facing all government agencies (DoD 2005) are that:

- Technology advances faster than acquisition requirements development and acquisition program lifecycles
- Widely available commercial technology allows increased adversary access to technology

Rapid advances in technology are creating an environment in which technology transition policies and procedures need to be revised to improve how technologies are transitioned to end users (Kadtke & Wells, 2014). William N. Bryan, Senior Official Performing Duties of the Under Secretary for Science and Technology, acknowledged the challenge for DHS S&T: "We no longer have the luxury of time to do traditional R&D, so we must change if we are going to get ahead of threats cycles and keep pace with rapid innovation". To address rapid advances in technology, DHS S&T engaged in a revitalization to improve its ability to more rapidly transition capabilities into operations and enable it to quickly respond to emerging threats (DHS, 2018). However, the rapid transition of technology solutions is not DHS S&T's only goal, as the transitioning of technologies is not successful unless the solutions are successfully operationally implemented by end users, operations and maintenance is accounted for within components and the impacts of those technology solutions can be qualitative and/or qualitatively measured post transition.

One of the most common barriers to technology transition from a controlled S&T environment to operational users is the Technological Valley of Death (e.g., Sullivan, 2015; Solliday, 2018). Sullivan et al. (2015) point out that the Technological Valley of Death is most often caused by a gap between a controlled S&T environment and operational users. In order to overcome the Technological Valley of Death, Sullivan et al. (2015) recommend increased collaboration between S&T organizations, acquisitions organizations, and end users. Yet S&T organizations still utilize programmatic milestones that end with transferring a technology to the acquisitions process as indicated in Figure 1. As specified by Neville et al. (2008), transition cannot be where procurement ends. Planning for and

measuring the impacts of technology solutions post transition is a key factor that directly impacts full operational implementation of the solution delivered.

Figure 1. Current DHS S&T Program Management Process

Measures of success in program execution are very different than performance measurement of the operational impact of the eventual resulting solution/technology itself. While budget, schedule and program milestones are metrics for assessment of the successful execution of a program, they can be mutually exclusive from the operational performance of the candidate technology solution. In fact, it is entirely possible that a program meets or exceeds programmatic milestones and metrics but results in a technology that reduces or potentially does not affect operational efficiency or effectiveness in any meaningful way. The current paper proposes that the use of *post transition performance assessments* as an integrated process (Figure 2) throughout the entire lifecycle of a program:

1. Decreases the gap between the controlled S&T environment and end users
2. Establishes repeatable methods to demonstrate operational impacts of delivered solutions
3. Gains stakeholder investment in solutions being developed

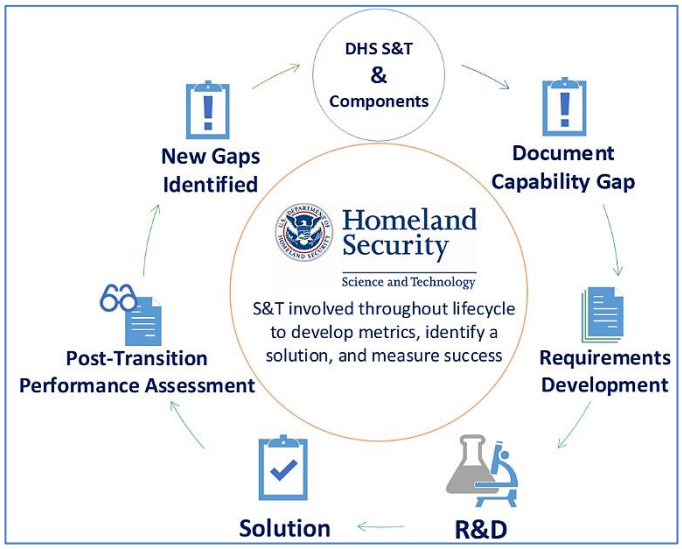

Figure 2. DHS S&T Program Management Process with Post Transition Performance Assessment

The results of DHS S&T programs/projects are either transitioned to a Federal, State or Local Government customer or transitioned to Industry to the commercial marketplace. Wherever the intended final destination of a technology solution, the need for a scalable post transition performance assessment process remains the same. Regardless of commercialization strategy, S&T program managers must work with end users and intended customers to develop effective solutions, and therefore the opportunity is present and necessary for an appropriate pre-post performance assessment with a representative sample of the targeted end user population/proposed customer base.

To be successful in the area of technology transition a paradigm shift is required in S&T's approach around the following three key objectives:

1) Common Operational Definition of a Successful Transition
2) Organizational paradigm shift to view the life of the program as not ending at transition, but ending after a post transition operational implementation phase
3) Post transition performance assessment

To truly be successful in the area of transition, S&T organizations need a common definition/understanding of what a successful transition of S&T technology looks like. More often than not, S&T transitions can be characterized by a handover/handoff of a developmental item, at the conclusion of a project/program. However, a simple handover/handoff is classified as a technology transfer as opposed to a technology transition (Solliday, 2018). Operational implementation of a technology by end users distinguishes a technology transition from a technology transfer (Solliday, 2018).

The second objective that is necessary to maximize transition potential of S&T technologies is a shift in the organizational view of the project/program lifecycle that includes a post transition performance assessment and operational implementation phase. This requires changes in the organizational worldview of a successful investment, as it shifts the point at which the mission-accomplished flag is planted. An increase in S&T senior leadership to customer senior leader engagement was also required to ensure acquisition and/or operations and maintenance (O&M) funding is included in the customer's future year resource and spend planning and budgeting. This objective requires a top down paradigm shift from senior leadership to program managers on how the organization should move forward on how it views the lifecycle of a project/program. Without Senior Leaderships' active engagement with customer leadership, to conduct the appropriate coordination and hold their leaders accountable for resource allocation planning for procurement/acquisition and O&M when S&T makes investments to develop solutions, it is difficult to move the important metrics of how or what the delivered solution's impact actually was on operational efficiency or effectiveness. This senior leadership prioritization, coordination and communication is critical to achieving successful transitions and having the results of S&T's research and developments efforts truly operationally integrated. Absent this top down direction, operational integration of S&T developed solutions can be largely out of a given program manager's control and sphere of influence. The end users that S&T program mangers work with to identify operational needs and capability gaps and then develop innovative solutions with to meet those requirements, are often not the same stakeholders that are the "customer" that have the authority to make procurement, procedure or policy decisions when it comes to operational implementation, acquisition and O&M budgeting. As a result of the absence of high level customer planning and budgeting for post transition operational implementation of S&T developed solutions, the organization is forced to gravitate to the model of the "hand off" of technology as the definition of program success and the operational definition of an official "transition". When the customer and user of a technology are different stakeholders, a program can meet or exceed all program success metrics such a cost and budget, and could get to the end of the R&D lifecycle and have a technology that is successfully transitioned, useful, needed and wanted by the end user, but still is not operationally implemented because senior leaders in the customer organization did not budget for acquisition or O&M of the transitioned technology.

For a transition to be truly successful, there must be an "Operational Implementation" phase immediately following a transition/hand off that traditionally marks the end of the R&D timeline. During this phase S&T can provide transition support to a given customer, with the developer still under contract to provide logistical support and reach-back during this critical phase. These processes often exceed the end of R&D timelines and extend beyond the initial transition. Additional time and resources are often required for a customer to complete operational integration of the solution as well as planning and budgeting for operations and maintenance (O&M) funding or even time to allow budgets to kick in at the component for acquisition/procurement dollars for the initial purchase of the product. S&T has instituted a 3 year period of time for this phase that also includes the final objective, which is to conduct a post transition performance assessment.

Concluding an S&T project/program at transition does not account for the post transition operational implementation phase that is necessary to see S&T technologies fully adopted. It also omits any opportunity for post transition performance assessment to truly measure success. Post transition performance assessment is the only way to collect qualitative and quantitative data to demonstrate that S&T investments are having an operational impact and therefore warrant equal to or greater funding in future years to continue adding value to the Homeland Security Enterprise.

Beginning a project/program with how you measure success/what metrics are important, at inception, facilitates not only objective measurement of transition success, but also provides foundational data from which the added value of S&T investments can be accurately determined. Post transition performance assessments support and bolster S&T's vision and mission by tackling many of the barriers to transition. Post transition performance assessment of S&T programs is critical to evaluating current and future S&T investments and guiding strategic planning.

Post Transition Performance Assessment Process

A post transition performance assessment includes three key phases outlined in Figure 3.

1. Establish baseline metrics at program inception
2. Re-assess metrics mid-program to validate that operational success metrics have not shifted
3. Conduct post transition performance assessment to compare new measurements with baseline metrics

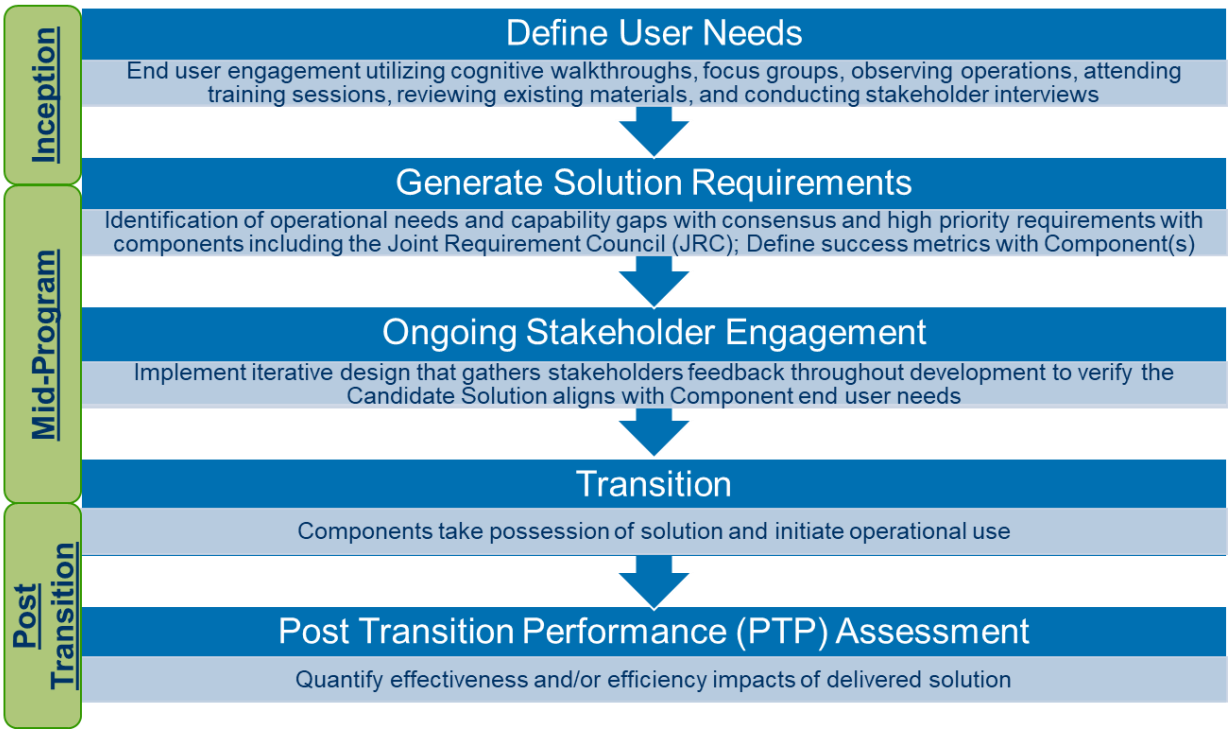

Figure 3. Post Transition Performance throughout the Project Lifecycle

Successful post transition performance assessment involves establishing a tailored plan based on the size and scope of a project/program and collecting data on consensus metrics from program inception beginning during Program Management Plan (PMP) development and in the first few months following program kick off. Ideally, as the customer and end users communicate the needs and requirements to the matrixed development team, collaboration on establishing a consensus on metrics is occurring concurrently. Even before program inception, a dialogue about metrics needs to occur and at least preliminary consensus must be reached as to how any proposed improvements to efficiency or effectiveness would be measured if a candidate solution was developed and operationally implemented. While project/program requirements define what the system will do and what capabilities it will have, the establishment of performance metrics defines the desired operational impact of the system and how it will be measured. Determining how the component customer is currently measuring performance is a critical first step, as it is important to understand what performance data is currently being collected and how they determined they had a requirement or need for a new capability in the first place. Many times DHS components or first responder organizations are already collecting operational metrics that warranted collaboration with S&T in the first place and these measurement methods and process can help in establishing the current performance baseline. Establishing a baseline of current performance in coordination with end users and customer requirement originators is what enables project or program to be able to measure the operational impact of the solution being delivered at the end of the R&D

timeline. This first step is necessary to be able to characterize the added value of the solution being delivered and position the project to have the highest transition potential possible with a clear definition of the desired future state. Performance measurements taken both before and after a candidate solution has been implemented enables S&T to measure the pre-post delta in operational efficiency and/or effectiveness and clearly demonstrate the added value of the investment, and then provide that data back to the operational component (leadership, stakeholders, end users, etc.), which is critical for organizational buy in, new technology adoption and operational implementation decision making as well as a basis for justification of broader implementation of the developed solution, if desired. Lessons learned can be applied to improvement of current and future operational technologies and optimization of training capabilities, and also serves as a critical data point for S&T leadership, administration stakeholders and appropriators in future strategic, resource and spend/budget planning activities and decision making.

Establishing a Baseline

In order to develop meaningful post transition performance impact assessment conclusions, the program must first have baseline data to compare the new performance measurements against. Establishing a baseline allows a program to assess the current operational status and starting point from which any change, ideally performance improvement, will be measured. Sometimes components/customers/users will have data on current operational performance, but when that data is not available or to the level of fidelity needed for analysis and comparison, data collection with S&T resources will be required at program inception. Establishing what, when, where, how this data will be collected, and who is responsible for collecting it, is necessary to understand how to account for these activities in cost and schedule development for a given program/project. Both objective and subjective measures are vital to collect both before transition and post transition. Subjective measures, such as end users opinions of the current techniques, tools, methods, technologies, etc. are important to collect before a new technology, training, or program is introduced for comparison with post transition data. Other measures such as knowledge, skills, and confidence before and after using the new technology can also be collected, as well as the degree to which participants apply what they learned during training when they are back on the job. Objective measures such as time on task, error rate, or metrics such as checkpoint throughput or boarder apprehensions may or may not be available and would therefore need to be measured in the field/operational environment. These activities require time and coordination and need to be scheduled and resourced accordingly.

Re-assessing Mid-Program

Despite emphasis on rapid technology changes and decreased time to transition technologies, development of innovative and effective solutions do take significant time to develop. A major barrier to transition is shifting requirements during the lifecycle of developing a new technology. For example, in 2004 the Federal Bureau of Investigation (FBI) created software in which the system requirements changed over the course of development, resulting in software that, upon transition, was not able to support the cognitive work of analysts (National Research Council, 2004; Hoffman & Elm, 2006). Maintaining an iterative end user and stakeholder engagement process throughout the program life cycle enables monitoring of operational changes that could impact post transition performance assessment as well as technology transition success. Variables that necessitate a mid-program review include unforeseen changes in administration priorities, budget changes, emerging threats, commercialization of innovative technologies, the latest news cycle, customer mission responsibilities, natural or man-made disasters, etc.

Post Transition

Ending S&T involvement in programs at transition can result in solutions that are not fully operationally integrated by the end users and/or are potentially shelved by component customer leadership for any number of reasons from cost to initial acquisition to affordability of sustained O&M. S&T leadership has identified an opportunity for post transition performance measurement to not only document the added value of the solution delivered, but also increase the likelihood of successful operational implementation. Measurement of operational impact of a transitioned solution enables quantification of efficiency and effectiveness and can also guide decisions on future investments in a respective candidate solution.

Assessment Metrics

Gilbert (1998) states that there are two major aspects of performance: (1) human behaviors (the process or means for reaching an outcome) and (2) situation consequences (the outcome or result of the behavior). Sanders and McCormick (1993) list three high level categories for performance criteria: (1) quantity (e.g., the number of tasks completed), (b) quality (e.g., rating on performance), and (3) time (e.g., time to complete an objective). These general categories provide a framework for the development of any number of general or domain specific (subjective and objective) measures of performance. Any number of objectives could be assessed along each category. For example, an objective in policing might be to "clear a room". The "clearing" behaviors could be rated on a quality scale, rated as simply observed or not observed, assessed in terms of the time to complete the clearing, or assessed according to the number of errors observed during the clearing task. You can define options for both general and domain specific measures that couple or combine these general categories of performance assessments.

There can be objective measures (time to task completion, situation awareness, number of errors, number of task completed).

There may be subjective measures (observer ratings, perceptions of own performance, perceptions of own workload).

There can be process measures (team communications, individual/team behavior assessments) that assess aspects of human performance that relate to outcome measures (e.g., situation awareness).

Examples of Performance Measures/Metrics

Domain-specific measures are shaped by the context, but a few examples are provided below:

Performance outcomes (most often direct ways to assess a construct)

- Time to task completion
- Number/count of any event (can be simple yes/complete or no/not complete)
- Number of errors
- Error rate
- Accuracy (in task completion of steps or test of knowledge)
- Reaction time
- Frequency of event
- Percent correct responses to queries (e.g., situation awareness)
- Signal detection
- Time remaining
- Attrition
- Call outs/Sick days

Performance processes (which are often indirect ways to assess a construct)

- Team Communications
- Behaviors (individual and team)

Qualitative assessments

- Rating on perceived quality of any type of performance (on scale from 1-5 or 1-7 for example) collected from observer
- Quality specific to a domain (e.g. handcuffing technique)
- Quality of situation awareness behavior (can be general or specific)

Measures of individual or team cognition

- Attention
- Perceptual speed
- Working memory
- Long term memory

Measures related to human performance

- Perceived workload
- Vigilance

- Stress (perceived or directly, objectively assessed)

What have been termed meta-competencies?

- Decision making
- Situation awareness
- Temporal awareness

Iterative Customer Involvement and End User Involvement

Engaging representative users from the beginning, and providing a forum to incorporate their feedback iteratively and often throughout the design and development process is a proven strategy to maximize the probability of a successful transition (Solliday, 2018). This same early and iterative model to structured engagement with the end user community to maximize usability has been demonstrated as a successful development model, and should also be applied to customer engagement in order to define success metrics, monitor operational changes, and conduct the post transition performance assessment. This early and iterative approach provides the customer or decision making authority with as much time possible for logistical coordination, any process or policy changes necessitated by the new solution, and conduct resource allocation planning activities required for the procurement or acquisition of the individual units, and annually fund any required operations and maintenance costs.

Conclusions

Rapid advances in technology change have resulted in a focus on rapid transitions for S&T organizations. However, rapid attempts at transition still face similar barriers to transition as previous models. The post transition performance assessment model is a paradigm shift from traditional S&T program lifecycle/plans that end at transition. DHS S&T leadership and program managers are currently transitioning to this new paradigm that includes a tailored/scaled post transition performance assessment phase for up to three years post transition. Tailoring of plans for activities in this phase must include:

- Metrics (what needs to be measured and why it is important)
- Methods (who, how, when, etc.)
- Timing for establishing baselines and data sampling frequency throughout the R&D timeline

The application of this approach is not exclusive to the Training and Education community, but can be generalized to any R& D or systems engineering process across government and industry. The end goal in solution development is not to transition the developmental item, but to deliver a solution that is operationally implemented to address an identified need or fill a capability gap, resulting in some improvement to operational efficiency and/or effectiveness. This shift in approach also has broader implications in development of organizational success metrics, policy, standards, and management process implementation, and can be generalized across all categories of potential solutions including changes or improvements to doctrine, organization, training, materiel, leadership, personnel (DOTMLPF).

Finally, post transition performance assessment includes activities that do not all occur or are conducted only at the end of a project (post transition), but necessitates activities across the R&D timeline to be effective at measuring operational impacts of transitioned technologies/delivered solutions. This post transition performance assessment process requires activities that to be integrated at stages across the R&D timeline including project inception, mid-program, and post transition. The sum of the outputs from these integrated activities and shift in how S&T views the project/program timeline, will enable S&T to better characterize the operational impact of its R&D investments and solutions it delivers.

ACKNOWLEDGEMENTS

This research was sponsored by the U.S.Department of Homeland Security Science and Technology Directorate under contract HSHQDC-17-C-00062. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the view or the endorsement of DHS.

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