CREATE
University of Southern California

S&T Analysis and Management of Innovation Activity III (STAMINA III)

Executive Summary

FY23 Annual Report

For Option Period September 24, 2022, to May 29, 2023

June 16, 2023

DHS Science and Technology Directorate (S&T)
Office of Science and Engineering (OSE)
Technology Scouting and Transition Division (TST)

Basic Ordering Agreement (BOA):
HSHQDC-17-A-B0004/70RSAT21FR0000143

Detlof von Winterfeldt, Principal Investigator (PI), Isaac Maya, Co-PI

Project Team: Richard John, Randolph Hall, Katie Byrd, Jeffrey Countryman, Susan Chavez, Kevin Kapadia, Andrew Moore, and Kaitlyn Werden

With Subcontracting Support from Virginia Tech
Michael Abbott, Lisa Garcia, Mark Mondry

Center for Risk and Economic Analysis of Threats and Emergencies (CREATE)
University of Southern California (USC)
1150 S. Olive St., 17th Floor
Los Angeles, CA 90015

This research was supported in whole or in part with Federal funds from the United States Department of Homeland Security (DHS) through the Center for Risk and Economic Analysis of Threats and Emergencies (CREATE) at the University of Southern California (USC) under Basic Ordering Agreement (BOA), HSHQDC-17-A-B0004/70RSAT21FR0000143. This report does not necessarily reflect the views or policies of DHS, nor does mention of trade names, commercial products, or organizations imply endorsement by the U.S. Government. Furthermore, any opinions, findings, and conclusions or recommendations in this document are those of the authors and do not necessarily reflect views of DHS, or USC, or CREATE.

CREATE
University of Southern California

S&T Analysis and Management of Innovation Activity III (STAMINA III)
FY23 Annual Report for Option Period September 24, 2022 to May 29, 2023

Executive Summary

The S&T Analysis and Management of Innovation Activity III (STAMINA III) project Contract Award consisted of a Base Period from September 24, 2021, to September 23, 2022, and an eight-month Option Period. The Base Period results were summarized previously in the STAMINA III FY22 Annual Report, dated December 23, 2022. This report summarizes the results from the Option Period effort, consisting of the components listed below and summarized in the subsequent sections.

Provided under Separate Cover

Appendix A. Transition Uptake Indicators of Success (IoS) Tracking
Appendix B. Knowledge Product and Technology Product Descriptions
Appendix C. Transition Milestone Writing Guidance
Appendix D. Benefit-Cost Analysis (BCA) 101 Presentation
Appendix E. BCA Pilots of SIGYN and FREJA Projects
Appendix E.1. FREYA Spreadsheet Calculational Tool
Appendix E.2. SIGYN Spreadsheet Calculational Tool
Appendix F. S&T R&D Project Benefit Categories and Potential IoS
Appendix G. R&D Logic Model for Indicators of Success (IoS)
Appendix H. Transition-Related Education and Coaching Material - Virginia Tech Annual Report

Executive Summary

ES1. Transition Product Uptake Benefit Indicators of Success (IoS) Tracking

USC/CREATE was tasked with assisting the TST Transition Branch and its supporting staff in the development of a holistic methodology for categorizing, defining, and quantifying transition uptake benefit Indicators of Success (IoS) to meet the NDAA17 [NDAA, Reference 1] requirements. The recommended methodology's process activities are to,

- Define four Knowledge Product (KP) types/categories, including examples
- Define four Technology Product types/categories, including examples
- Describe options for transition benefits along the R&D output uptake timeline
- Describe options for transition benefits tracking and assessments at Year 0 and at Years 1-3
- Examine recommended model for tracking transition Indicators of Success (IOS)
- Provide guidance for writing Transition Milestone entries for KP's and Technology Products in the STAT database [Reference 2]
- Describe approach to NDAA-mandated uptake in seven steps with recommendations on early implementation to show merit of proposed process/approach

The individual constituents of the process are shown in Figure ES1, and the overall system process flow following transition product uptake is shown in Figure ES2. S&T R&D outputs/products are categorized as either KPs or technology products. KPs are informational outputs, such as written reports, standards, data bases, and mathematical algorithms and solution techniques not yet incorporated into software form. Technology products are physical, touchable outputs, plus software that generates a tangible output. Additional details on recommended KP and technology product categorization definitions and examples are provided in Section ES2.

R&D outputs are transitioned to a receiving entity on the right of the arrow in Figure ES1 that is then responsible for use or implementation of the transition product. Examples of receiving entities are,

- DHS Components & Offices, e.g., CBP, CISA, TSA, USCG
- S&T itself, e.g., for further R&D, or the Joint Requirements Council (JRC)
- S&T's Technology Clearinghouse for distribution
- Other Government Entities, e.g., DOD, State and Local governments
- Non-Government Entities, e.g., private companies, nonprofit standards-setting entities, such as IEEE

USC/CREATE worked closely with the TST Transition Branch and staff to develop a methodology and process for tracking and assessing transition product uptake benefits to meet the NDAA17 3-year requirements. It consists of determining the Transition Outcomes, Operational Impacts, and Homeland security Enterprise (HSE) Value, according to,

- **Transition Outcome**: the direct result of an action attributed to the R&D output transition. These consist of counts of transitions with quantifiable consequential transition uptake benefit
- **Operational Impact**: effect/change of a Component's operational performance resulting from the transitioned project's outcome, according to a set of operational benefits, such as reduced operational costs, improved efficiency or effectiveness, reduced false alarm rate, increased signal detection, etc.
- **HSE Value**: importance or worth of the R&D uptake, e.g., number of lives saved, mission improvement, or monetary equivalent directly resulting from the impact of a transitioned project

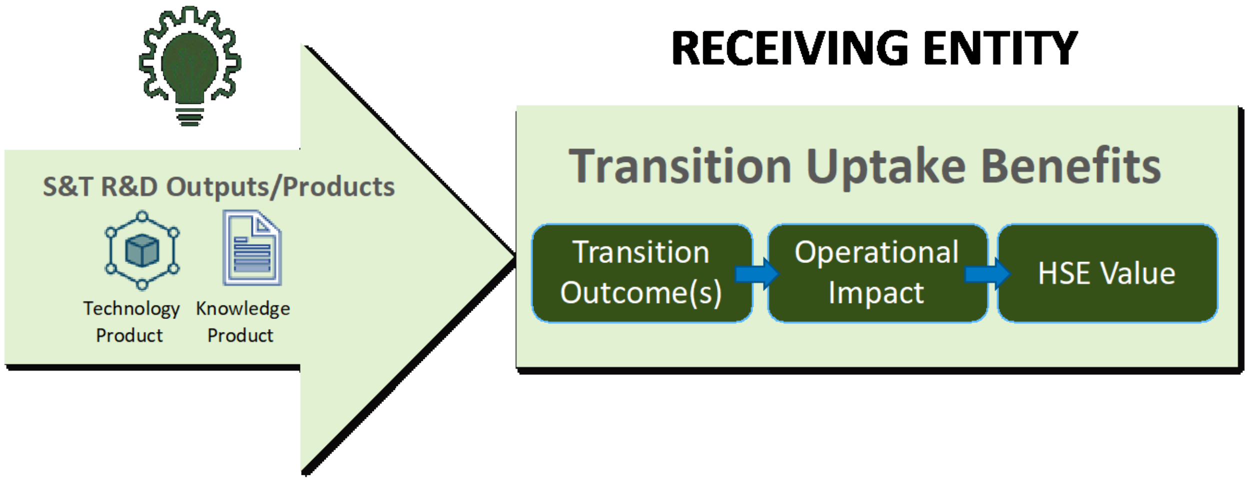

Figure ES.1. Individual Constituents of Methodology for Assessing and Tracking Transition Update Benefits.

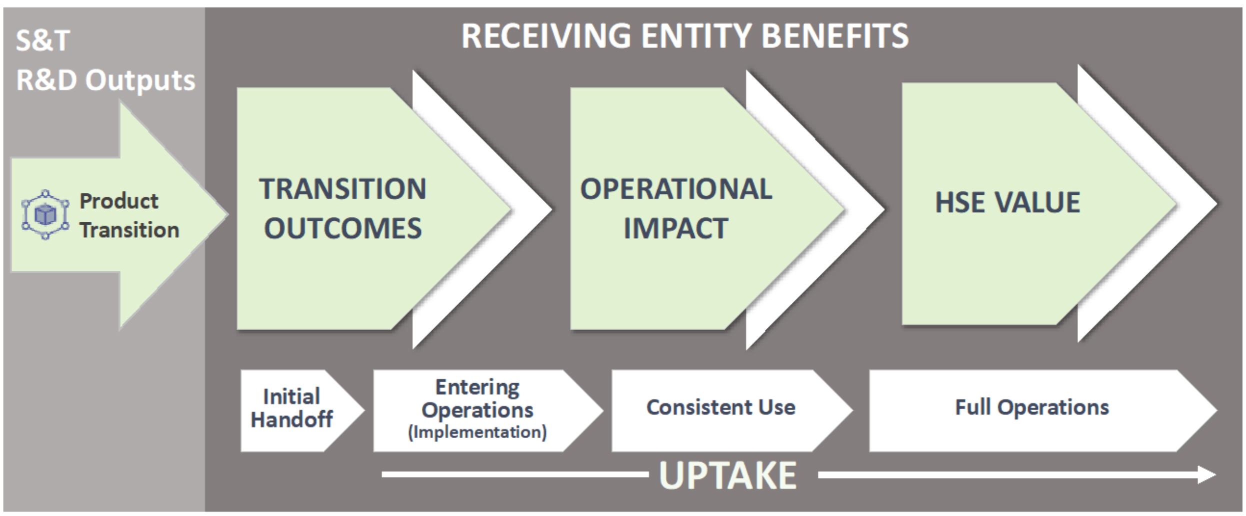

Figure ES.2. Transition Product Uptake Benefit System Analysis Process Flow Matching Transition Product Uptake.

Transition Product uptake and benefits to the receiving entity are observed and measured over time, which can range from months to years, depending on the transition pathway. For example, a receiving entity could receive a KP who's guidance can be integrated in its operations in days to weeks. In contrast, a Technology Product could be selected to enter an acquisition program for a Program of Record and take a year or more for operational integration and reduction to practice. The implemented transition product might then have a ramp-up time, during which it has limited deployment, ramping up to full operations. Thus, a transitioned product's value can be projected but may not be immediately measurable or confirmed. Understanding the projected outcome, impact, and value of a proposed transitioned product as an HSE solution can inform the prioritization and section process for R&D investments.

Regardless of the time frame for operational implementation, uptake benefits of the transition outcomes can be quantified relative to operational impact and HSE value using characterizations developed in the USC/CREATE Landscape Study [Reference 3], with five major benefit types using 10 quantification models,

- **I. Improved performance and/or cost savings**
  1. Cost savings or savings by stretching expenses
  2. Improvement of performance
- **II. Reduced risk/Increased security**
  3. Reduction of threat
  4. Reduction of vulnerability
  5. Reduction of negative consequences
- **III. Improved signal detection**
  6. Reduction of false alarm rates
  7. Improvement of detection rates
- **IV. Value of information**
  8. Reduction of uncertainty
  9. Improvement of decisions
- **V. Value of training**
  10. Improved operational performance

The Benefit-Cost Analysis (BCA) methodology for quantifying the operational uptake benefit is provided in Section ES4.

A PowerPoint presentation covering the process described in this section is provided in Appendix A.

ES2. Knowledge Product Transition Type Categorization, Definitions and Examples

During the Option year, USC/CREATE continued to assess, refine, define, and further develop the KP definitions to further clarify their usage. Previously, USC/CREATE had developed and recommended the draft descriptions of four Knowledge Product (KP) types to facilitate their STATS data entry and their post-transition three-year tracking and follow-up for NDAA purposes. The four types of KPs include,

1. **Operational analysis information** needed/requested by Component
2. **Domain-specific reports or publications** on specific domain/topic
3. **Education and Training,** including Professional Workforce Development Degree Programs, Certificate Programs, Curriculum, Plans, and Courses
4. **Progress and Annual Reports** summarizing findings of an R&D activity, project, or program not reported elsewhere

The guidance developed for adequately identifying and categorizing Knowledge Products included common examples of KP transitions, and examples of what is **not** considered a KP transition. These examples were further clarified using actual FY22 S&T projects.

Details of the updated definitions of the KP and Technology Product types and categories, with common examples are provided in Appendix B.

ES3. NDAA FY21 and FY22 Transition Milestones: Review and Analysis of S&T GPRAMA Strategic Performance Measure and Transition Milestone Writing Guidance

ES3.1 NDAA FY21 and FY22 Transition Milestones: Review and Analysis of S&T GPRAMA Strategic Performance Measure

S&T did not meet its target for the FY20 and FY21 GPRAMA Strategic Performance Measure [Reference 4,] the percent of technology or knowledge products transitioned to customers for planned improvements in the Homeland Security Enterprise (HSE). To address the root causes for this, USC/CREATE was tasked with 1) assisting the TST Transition Branch on the verification and validation of transition milestones from the STAT database that were to be used as input to the preparation of the

NDAA reports for the reference years, 2) assist in the analysis of core causes for the missed target, and 3) identify opportunities for improvement in future years. CREATE participated in developing and executing the methodology, and,

- Conducted Interviews
- Examined GPRAMA Reference Documents
- Participated in Training and Info Sessions
- Analyzed the Transition Milestone Process
- Performed STATS Transition Milestone Data Analysis

The process entailed extensive analyses of discovery discussions, reference documents, and STAT database entries for R&D projects. Output results of these analyses were documented in an FOUO PowerPoint presentation to TST leadership. Due to the FOUO designation of the material, the presentation material and supporting talking points were thus provided directly to TST, and are not included in this Final Report. One of the key findings was related to the need for improved guidance on the development of transition milestones for entry into the STAT database. The recommended guidance is provided in the next section, ES3.2.

ES3.2 Transition Milestone Writing Guidance

The review and analysis of the STAT milestones describe in ES3.1 indicated there would be significant benefit in providing more precise guidance on how to write a proper transition-related milestone. The resultant guidance is provided below, consisting of a general form of a transition milestone to initiate the writing process, and two customized forms, one for KPs, and one for technology products,

- **General Form of a Transition Milestone**: Deliver [what] on [topic] to [whom] for [outcome, + key SMART attributes: Specific, Measurable, Attainable, Relevant, Time-based *(not all SMART attributes required)*]
- **Knowledge Product Transition Milestone:**

Knowledge Product + Topic Description + Customer + Outcome

Example:

Deliver a report on HyperGovies evaluation to DHS HQ Human Capital Office to understand risks and benefits in the workplace environment and determine use of flexible telework models.

Writing Guidance:

Deliver [***Knowledge Product****: select if a Report, Publication, Assessment, Training Manual or Module*] on [**Topic Description**: *identify domain or area of focus*] to [**Customer**: *identify Recipient*] for [**Outcome**: *provide expected outcome (e.g., quantified operational improvement, enter an Analysis of Alternative, provide input to a decision on blah blah blah, an educational course for on-the-job performance improvement, etc.)*]

- **Technology Product Transition Milestone:**

Technology Product + Domain Description + Customer + Outcome

Example:

Deliver a Counter UAS system to protect component identified high priority facilities to DHS CBP USBP and the USCG to increase domain awareness and decrease the time, personnel and resources required for patrolling and defending sites.

Writing Guidance:

Deliver ~~A~~ [***Technology Product****: short title and description of technology* on [**Topic Description**: *identify domain or area of focus*] to [**Customer**: *identify Recipient*] for [**Outcome**: *provide expected outcome* *(e.g., quantified operational improvement, quantified improvement in GPRAMA measures, etc.)*]

A PowerPoint presentation covering the above guidance is provided in Appendix C.

ES4. Benefit-Cost Analysis (BCA) Methodology and S&T R&D Project Pilot Assessments

ES4.1 The Benefits, Costs and Risks of Homeland Security R&D: Introductory Benefit-Cost Analysis (BCA) 101 Methodology Presentation

S&T has funded R&D projects that have developed hundreds of tools, technologies, and knowledge products for use by DHS offices and components. S&T is increasingly asked by Congress and other agencies to justify the benefits of this research for improving homeland security operations and decisions. This is a risk management question, whether any impact occurred and whether the value weighted impact was a retrospectively beneficial choice. In response to these questions, the BCA methodology was developed to assess the costs and benefits of R&D products.

The goal of BCA is to determine the net present values (NPV) and the return on investment of R&D projects in the form of a monetized expected present value benefit-cost analysis consistent with professional standards and informed by Government guidance (OMB 1991, 2003). Budgetary impacts on DHS components and the U.S. Government were central to all the analyses, but benefits and costs to U.S. citizens were included where they could be determined. Limitations on data, especially regarding uncertainty, often lead to simplified approaches.

The introductory BCA 101 methodology presentation is provided in Appendix D.

ES4.2 Benefit-Cost Analysis (BCA) of S&T R&D Projects

A frequently asked question about government-funded R&D projects is: What is the Return on Investment (ROI)? This project addressed this question by conducting and adapting Benefit-Cost Analysis (BCA) to 25 R&D projects funded by the Science and Technology Directorate (S&T) of the Department of Homeland Security (DHS). The net benefits and the associated benefit-to-cost ratios were mostly high for transitioned and used projects. Still, substantial uncertainty existed about the benefits of projects that had not yet been implemented and used.

This effort analyzed two S&T R&D projects rated low on the Technology Readiness Level (TRL) scale yet showing great potential. The CREATE approach to conducting a BCA assumes that the R&D projects will be successfully transitioned and implemented, discounting the net benefits by the probability of success.

The first project was SIGYN, a software tool currently under development at Sandia National Laboratories that is intended to provide the Cybersecurity and Infrastructure Security Agency (CISA) of DHS with capabilities to automate threat prediction, malware recognition, identification, and mitigation. SIGYN is part of the Vanaheimr suite of six tools (also including AEGIR, FREYJA, MINISBRUNNER, ODINN, and SKADI) that contribute to CISA's Threat-Focused Reverse Engineering (TFRE) project. Staff at CISA's Vulnerability organization are expected to be the primary users of SIGYN once the tool is deployed.

The second project was FREYJA, a software tool for automating malware detection and analysis. FREYJA is intended to provide the Cybersecurity and Infrastructure Security Agency (CISA) of DHS with capabilities to automate threat prediction, malware recognition, identification, and mitigation. The primary users of FREJA are staff in CISA's Threat Hunting organization.

CREATE's BCA of these projects indicates both tools show a high net benefit and benefit-to-cost ratio if successfully transitioned and used. The mean net benefit over a 5-year period of successful use of SIGYN is $69.7 million, $43.9 million for FREYJA. The break-even point for both tools is a probability of about 10% of a successful transition and use.

Details of the BCA process for the two project pilots are provided in Appendix E.

ES5. S&T R&D Indicators of Success (IoS)

One of the major challenges facing S&T from the NDAA [Reference 1] is the development of indicators of success (IoS) of transitioned projects. The NDAA tasks S&T with developing and tracking indicators to demonstrate the uptake of the technology or project among customers or end-users, and to the fullest extent possible, to track the indicators for three-years after the project is transition to practice from R&D. This challenge is actually also an opportunity, given the relevance of the yearly S&T NDAA transitioned project report to Congress in the context of its R&D appropriations deliberations, as shown in Figure ES3. Awareness of the outsized importance of S&T's NDAA report requires that the IoS convey the full value of R&D: Beyond counts of R&D outputs, licenses, patents and royalty income to transition outcomes, operational impact, and HSE value, as detailed above in Section ES1. A clear conveyance of NDAA-compliant results of transition successes can improve future budget requests to Congress and decisions by DHS leadership for prioritization and funding by quantitatively justifying the security returns to the Nation from its R&D investments.

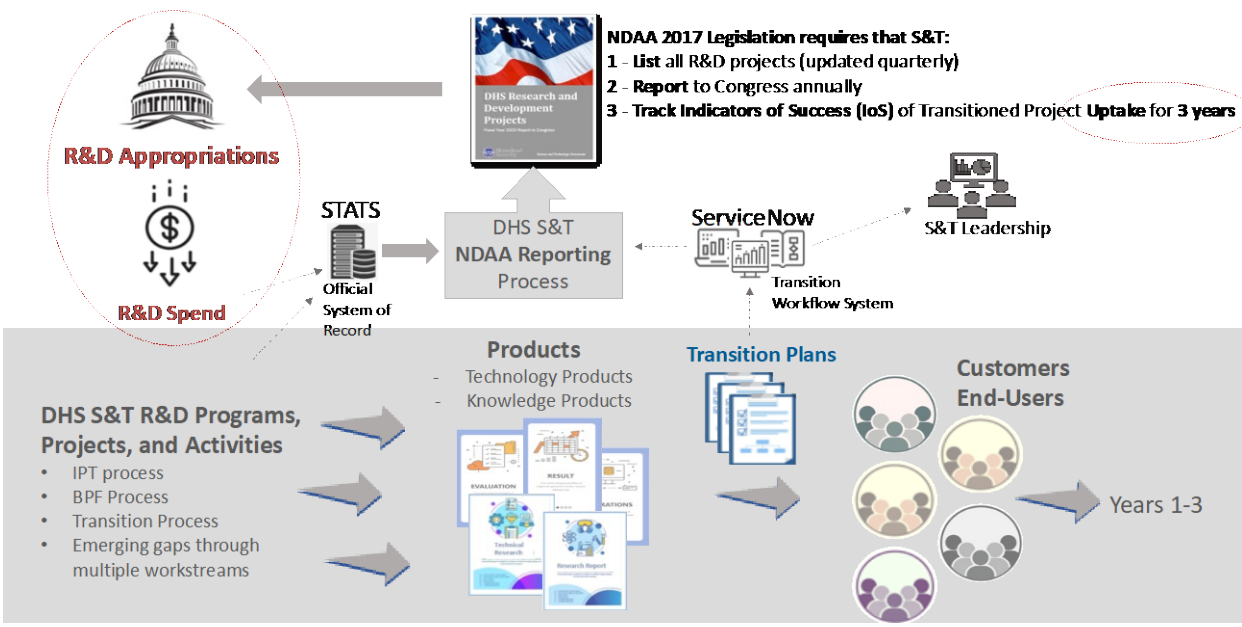

Figure ES3. Outsized Importance of S&T NDAA Transitioned Project Reporting in Informing Congress and the General Public of the Impact and Value of S&T R&D.

The challenge/opportunity then transforms into effectively translating and communicating the full value of R&D transition product quantities and benefits beyond counts of transition products, anecdotal evidence of transition success, or extended narratives by project of their adoption by the operational components. This transformation can be addressed through the development and implementation of a two-pronged framework for 1) developing methodologies for calculating impact/value, and 2) defining data needs for collecting transition quantities enabling the association of operational benefit impact and value with R&D transition product uptake.

The first part of this process framework is address by the USC/CREATE BCA methodology described in ES4. Work underway and planned aims to make BCAs a practical quantification technique applicable to all S&T R&D projects. Equally challenging is also the data collection aspect, which is not intended to be an onerous mandated collection of data of no added value / consequence / impact. On the contrary, it will be a highly valuable and motivational collection of useful data for up to the three-year requirement while transition uptake is generating value, and to stop when the specific transition is no longer in use/generating value. It will also be consistent and compliant with the Evidence Act [Reference 4.]

The recommended approach to selection of IoS for transitioned project uptake and reduction to practice includes,

- Drive toward operational and homeland security benefits impact and value as specifically indicated by transition product uptake effect on Component and DHS Operational performance measures, supporting GPRAMA
- Select IoS that reflect transition product uptake progressing from current practices of counts, anecdotes and narratives to transition outcomes, operational impact and HSE value using BCA or similar Return-on-Investment approaches
- Collect the requisite data dictated by the quantification methodology by identifying data needs and implementing data collection processes reflective of the merits of the effort to collect the data, thus enabling benefits impact and value assessments, supporting the Evidence Act

Note that IoS metrics could reflect on the full spectrum of the S&T Business Process Flow (BPF), starting with R&D project selection, through the planning, execution, IP protection, transition, transfer, and commercialization processes, and ending with NDAA reporting, reflecting scales that could include, for example,

- Absolute or relative operational impact on Component/HSE performance measures
- HSE Value per R&D $ spent, relative ROI on selected R&D projects (not always monetarily based)

To demonstrate this approach, selected actual S&T FY20 projects that had successful FY21 transitions were examined for potential IoS benefit metrics statements, based on the BCA benefit type models in Section ES4. Some examples are provided in Table ES1.

Table ES1. FY20 Projects with FY21 Transitions - Benefit Categories and Potential IoS/Metrics

Project Name	Benefit Type	Potential IoS/Metrics
Air Cargo Screening	Increased security (reduction of threat) as threats present in air cargo will be more effectively detected as well as value of information (improvement of decisions) as enhanced technology will help workers to decide what cargo needs a second screen after the first red/yellow/green recommendation	TSA cost of screening per piece of cargo, percent of threats accurately detected with red/yellow/green system
Community Resilience Testbeds	Improvement of FEMA decisions (more informed investments) and reduction of vulnerability (hazard vulnerabilities during natural disasters)	Lives saved during national disasters; monetary amount saved in damage costs after disasters

Project Name	Benefit Type	Potential IoS/Metrics
Counter UAS	Improvement of decisions (information will be used to inform future R&D efforts) and reduction of threat (with the threat being criminal UAS)	Number of UAS threats detected and defeated
Food, Agriculture and Veterinary Defense Vaccine, Diagnostics & Countermeasures	Reduction of threat (development of countermeasures if a new disease threat were to arrive) and value of information (data collected to inform future research and developmental priorities).	Lives saved during outbreaks in the United States
First Responder Technologies	Improvement of performance as improved technology will allow first responders to be more effective and perform better during missions.	Lives saved by first responders, timeliness of first responders, first responder lives saved
Ground Based Technologies	Improvement of CBP/ICE detection rates at the border and improvement of decisions through the use of additional data and tools not previously available during the decision-making process at the border.	Amount of illegal activity interdicted
Immigration Based Technologies	Improvement of performance as applications can be addressed more efficiently using new technologies and improvement of decisions related to immigration	Speed of immigration application processing
Opioid/Fentanyl Detection	Improvement of detection rates and cost savings	Detection rates of opioids; dollars saved within existing detection environments
Port and Waterway Resiliency	Improved performance (new enhancements increase capabilities) and value of information (improved decision making).	Rate at which ports and waterways stay open
Primary Screening for Passengers	Reduction of false alarm rates, cost savings	Security screening time per passenger, false alarm rates, detection rates of lost or stolen items, dollars saved at security checkpoints
Screening at Speed	Improved performance as new technology will allow for the same detection capabilities as old technology but without the need for passengers to remove their shoes	Throughout time of passengers at security checkpoints
Training and Performance Optimization	Value of information, value of training	Threat detection rates
USCG/EPA Wide Area/Vessel Decontamination Project	Value of information (improvement of decisions) through the creation of decision support tools so that the USCG knows what to do/decide in the event of an aerosolized biological attack	Rate of decontamination during biological attacks, lives saved during biological attacks

Additional examples and additional description of the projects are provided in Appendix F.

ES6. R&D Logic Model for R&D Indicators of Success (IoS)

USC/CREATE is developing an R&D logic model for the relationship between R&D spending and R&D output Indicators of Success (IoS). To baseline the model, we first examine the correlation between federal R&D spending at universities by five federal agencies – Defense Advanced Research Projects Agency (DARPA), Department of Homeland Security Science & Technology (DHS S&T), National Science Foundation (NSF), National Aeronautics and Space Administration (NASA), and ARPA - H – as they relate to current metrics of university innovation, namely invention disclosures, patents, licenses, and royalty income. The comparison is based on public information, as described on agency websites.

For the source data, we integrated data from the National Science Foundation HERD (Higher Education Research and Development) dataset tracking R&D expenditures by year, institution, and source (including federal and non-federal), with the AUTM (Association of University Technology Managers) STATT database, which tracks licenses, royalty income, invention disclosures and patents by institution. The novel integrated dataset enabled analysis of relationships between investment and the listed innovation metrics over time through multivariate statistical analysis. The focus during this phase was on enabling understanding of the relationship between R&D expenditures to universities by funding source and two innovation metrics Indicators of Success (IoS): licensing income and licenses issued.

We found that the gross licensing model had the highest R^2 value and F-Statistic. High R^2 and F values mean that innovation output in terms of licenses executed and licensing income received follows research funding at American universities. The results showed that NSF funding had the most impact on the selected IoS. Thus, the developed linear regression model can use used to predict innovation output as a function of funding by source.

Furthermore, we found that outliers had a significant effect on the prediction of the number of licenses and removing these outliers produced a significantly better fit. The outliers are nevertheless important as they may represent effective technology transfer practices at individual universities. Universities that perform significantly above (or below) the predicted output associated with research funding can be examined for systemic causes for best practices (or underproduction.)

In future work, we will combine more years of data for analysis for a multi-dimensional linear regression. We will extend the data cleaning pipeline for past years to capture additional syntax changes. Furthermore, due to the complexity of predicting the dependent variables, we will look into using tree-based methods for prediction. These tree-based methods including Random Forest Regressor and XGBoost to detect smaller discrepancies (and non-linearities) that might go unnoticed with simpler models. The robustness of tree-based methods to outliers makes them a very useful method for looking at the integrated dataset.

Given the success of the current model, future work will combine analysis of agency R&D practices with new indicators of technology transfer success beyond inventions, patents, and licenses. Thus, the current model will be refined, expanded, and applied to examine correlations of R&D characteristics and practices to the IoS applicable to transition project output uptake benefits, such as operational improvements over baseline operations prior to R&D transition.

Details of the R&D Logic Model are provided in Appendix G.

ES7. Coaching and Education Materials for S&T's Technology Scouting and Transition Division (TST) Transition Branch

This effort delivered transition-related coaching material covering the scope of objectives established for the program. The program adapted transition-specific guidance along the generalized R&D lifecycle to the specific transition-related needs of S&T's Business Process Flow (BPF). The material developed provides transition best practices coaching to DHS S&T in the form of short and extended narrative- and video-based education sessions. The sessions capture best practices in transition-related customer interaction as an integral part of transition planning, execution, and reporting from Gap Analysis to Transition Tracking and Reporting.

The Virginia Tech (VT) team worked closely with the Technology Scouting and Transition Division (TST) Transition Branch to provide support, guidance, and directional contributions in response to the evolving transition-related training needs of DHS S&T. Of particular importance was the adjustment from scheduled in-person sessions to an asynchronous remote-based approach, through which DHS S&T can reach a larger number of personnel. Further, the effort focused on developing transition-specific coaching assets that align with the larger objective of complying with the 2017 NDAA requirements for transition reporting for all projects in which R&D is reduced to practice.

The Virginia Tech – USC team developed the training materials and identified additional topics that are recommended and planned as part of a future effort. The final report provides details both what has been produced and what is planned. Due to the size of the deliverables, these were provided to S&T electronically at this LINK.

Details of the Coaching and Education Materials prepared by VT are provided in Appendix H.

ES8. References

1. NDAA17
2. STAT Database
3. USC/CREATE Landscape Study
4. GPRAMA
5. Evidence Act