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Assessing the Effectiveness of AFWERX Ability to Influence Regional Participation Rates and Capture Cluster Specific Technological Innovations

Colin M. Sandor

ASSESSING THE EFFECTIVNESS OF AFWERX ABILITY TO INFLUENCE REGIONAL PARTICIPATION RATES AND CAPTURE CLUSTER SPECIFIC TECHNOLOGICAL INNOVATIONS

THESIS

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DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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Colin M. Sandor, BS.

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Colin M. Sandor

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Abstract

The 2018 National Defense Strategy (NDS) emphasized capturing innovation through partnerships with non-traditional defense contractors. Furthermore, the NDS outlined the need to rapidly acquire new technologies to maintain a competitive advantage against our adversaries. The AFWERX program is the Air Force's attempt to accomplish these goals. AFWERX seeks to capture innovations occurring within the private sector of the United States by placing itself geographically within top innovation ecosystems. An approach that creates a setting where the Air Force is one of many investors, who benefit from the learning and investments across the entire network.

The research within this paper examines the effectiveness of this approach by evaluating AFWERX's 1) effect on participation rates by companies within given regions; 2) ability to capture specific technologies from within the areas that they have located. Analysis in this paper focuses specifically on the AFWERX Austin & Washington D.C. locations.

Participation rates were analyzed using a statistical comparison of population proportions by companies, within a given region, participating in the AFWERX program. Participation in AFWERX was compared to participation in the traditional Small Business Innovation Research (SBIR) program. To test the acquisition of cluster specific technologies, all projects from within 150 miles of Austin & Washington D.C. were classified for fit into the respective technology clusters. Each cluster was formally defined by the top patent types that emerged from the respective area. Overall, the analysis showed that AFWERX was effective in both increasing regional participation and targeting cluster specific technologies; location matters.

ASSESSING THE EFFECTIVENESS OF AFWERX ABILITY TO INFLUENCE REGIONAL PARTICIPATION RATES AND CAPTURE CLUSTER SPECIFIC TECHNOLOGICAL INNOVATIONS

I. Introduction

General Issue

Technological innovations are currently occurring within the United States at unprecedentedly quick rates. The bulk of research and development (R&D) investments are from companies within the private sector. This is a relatively new phenomenon; domestic innovations have historically been driven and funded by the government and the Department of Defense (DoD), also known as the public sector. Since the early 1980s, the percentage of government spending on Research and Development (R&D) as compared to total U.S. Gross Domestic Product (GDP) has been constantly decreasing. At the same time, the percentage of spending from the private sector on R&D has shown a constant increase with a large acceleration in spending since 2009 (Foote & Atkinson, 2019). The changing landscape in research and development spending has led to a shift in the locus of innovation from the public to the private sector.

The current rates that technologies are being developed outside of the DoD has created potential opportunities for the defense sector. Many of these new technologies have defense related use-cases. These dual-use technologies (relevant in both the public and private sectors) represent areas where the DoD can leverage existing commercial investments. The government can utilize private sector spending to acquire innovations without being responsible for the overhead and development costs of the projects. Thus, the potential to lower cost burdens to the DoD while directly benefiting from investments and innovations by private companies is present.

However, there are inefficiencies in the current DoD acquisition process that prevent this opportunity from being effectively leveraged. The mean acquisition timeline from program inception until the program reaches initial operating capability (IOC) is 72 months (Bilvas et al., 2020). A delay of nearly six years for new technologies to become operational creates an issue where a technology is frequently outdated before it is employed. Also, this timeline does not favor smaller or startup companies. These types of companies are driving much of the innovation in the private sector. Small businesses produce, on average, 13 times more patents per employee than large firms (Mielach, 2012) in the United States. Smaller companies typically have a "runway", or cash available to maintain operations, of nine months or less. These businesses do not have the capital or manpower to wait numerous months, let alone years, to be awarded a contract to receive funding for their work (Lauver, 2020). Furthermore, studies have shown that barriers exist that prevent small businesses from wanted to pursue defense contracts. For example, small businesses have expressed that DoD acquisition regulations favor larger companies as they do not have the power manpower to comply with the complex requirements (Shilling et al., 2017).

Leaders within the Air Force knew that something needed to change to allow this opportunity to be effectively leveraged. The ability to capture organic innovation from the private sector would allow the United States to maintain its competitive advantage against our adversaries. In 2017, to help combat the issue of long acquisition times and to enhance the DoD's ability to tap into innovative ecosystems, the Secretary of the Air Force established the AFWERX program. This program was created as an offshoot of the already functioning Air Force Small Business Innovation Research (SBIR) platform.

AFWERX aims to capture innovative investments that are being fostered within the private sector of our nation by lowering the barriers of entry to doing business with the government. Secretary of the Air Force Heather A. Wilson stated, "the pace of change is accelerating and that the Air Force has to engage the next generation of innovators, young scientists and engineers, and smart businesspeople to take us into our future. The Air Force has to engage with those innovators who want to help the warfighter to be able to defend our vital national interests" (SECAF, 2017). AFWERX is experimenting with new tactics, processes, and policies to quickly acquire advancing technologies from industry without the typical acquisition timelines.

AFWERX has strategically located its program offices in various technology clusters across the country. Theoretically, this method will allow the program to take advantage of the technology spillover effect by directly placing themselves within innovation hot spots (Kerr & Kominers, 2015). AFWERX located offices in Austin, TX, Washington D.C, and Las Vegas, NV. Each of these cities is known and classified as technological or information clusters. Additionally, AFWERX is creating an office location in Dayton, OH. This location will be within 60 miles of both Cincinnati, OH & Columbus, OH which are two more of the top innovation clusters within the United States. The cities or clusters represent communities with established industries, academics, and research in specific technology areas (e.g., Silicon Valley). The close proximity to these locations creates a setting where the Air Force is one of many investors, benefiting from the learning and investments across that entire ecosystem. Of the top 100 largest clusters in the world, twenty-six of them are located within the United States. Washington D.C. is 13th largest technology cluster while Austin is the 77th (Bergquist et al., 2018). By locating in technical cluster communities, the Air Force is aiming to improve the performance of its technological investments and keep up with the advancing technologies that are being produced.

The AFWERX program aims to capture learning and innovation generated within these ecosystems. By placing themselves within these innovation hubs AFWERX creates a conducive environment for technology transfer from what is known as spillover mechanics. Spillover mechanics are the increased ability for firms to share innovation and learning due to a closeness in distance or proximity (Kerr & Kominers, 2015). Ultimately, this strategy aims for quicker adaption of new technologies within the DoD while boosting the lethality and effectiveness of vital operations. The rapid procurement of new technologies afforded by the AFWERX program should allow the Air Force to quickly obtain newly advancing technologies. Thus, granting the Air Force increased capacity to accomplish their missions and maintain a competitive advantage against adversaries.

Problem Statement

The AWERX program was built upon four main pillars of focus. These four pillars are to organize, prioritize, integrate, and invest. More specifically: Organize to develop an internal organizational structure to support innovative efforts of Airmen across the command. Prioritize to design a process that takes ideas from all Airmen, then prioritizes and resources the highest potential ideas. Integrate to create strong internal and external communication pathways to increase collaboration and leverage shared resources toward common problems. Invest to contribute the financial and human resources necessary to achieve these goals using modern innovation tools and processes (Leavitt, 2020). The articles contained within this paper examine two areas of effectiveness from directly within the Integrate pillar of the program. More specifically, AFWERX's ability to create external communication pathways and increase collaboration to leverage shared resources. The program's effectiveness of leveraging this pillar was assessed by determining 1) the ability to drive increased participation from companies geographically located near their offices and 2) the ability to capture the specific technologies that are emerging from technology clusters where they have located.

The research was conducted through the development of two separate articles for publication. The first of the two articles examines the geographical effectiveness of the AFWERX Austin and AFWERX D.C. campuses. These locations were tested for their ability to influence increased participation from companies within given distances of the offices. The participation rates of companies from those areas were tested against the participation rates of companies from the baseline SBIR program in the same technology area. This method tests AFWERX's core integration pillar by determining the effectiveness of the program to create strong external communication pathways and increase collaboration in each region.

Prior research showed the locations of the AFWERX offices were able to increase participation from companies within the state of Texas and the states surrounding Washington D.C. (Gist, 2019). Clusters are identified by areas of highly localized areas of research and patent activities. Considering the size of Texas as a whole may not provide the granularity needed to assess cluster participation. For example, one campus in Austin, TX may not be a reason why there was increased participation from companies all over the state. Using states as boundaries of technological clusters left a gap in the research and created the need for a more comprehensive examination.

A more in-depth examination was conducted to test participation rates of companies within 50, 100, and 150 miles of both office locations. The distances were calculated as the straight-line distance from the most central zip code in both Austin, TX and Washington D.C. to the zip codes of the participating companies. The proportion of companies within the given distance of each technology cluster for AFWERX was then statistically compared to the number of companies within the same area that were participating in the SBIR program. This method shows whether or not AFWERX is able to stimulate high participation rates within a region on a smaller scope than the previous research.

The second article analyzes AFWERX program's capture of specific innovations emerging from each technology cluster. Technology clusters tend to specialize in specific fields as similar companies group together to allow for easier sharing of information. Even though clusters have varied technologies and innovations, they tend to be homogeneous toward overarching major areas of research. The research within this article uses United States patent data to define each technology cluster and then examine AFWERX ability to capture those technologies. Using an inter-rater and group consensus classification method, AFWERX projects from both Austin and Washington D.C. were mapped to the top technological innovations, determined by patent data, emerging from the given area. This method shows how effective the AFWERX program is with their ability to influence the types of technologies that are developed for use. More specifically, it shows how the technology types are influenced by the locations of AFWERX campuses. Additionally, this approach measures how effetely the integration pillar is being utilized by determining increase collaboration to leverage shared resources within each region.

Research Questions

This thesis addresses three research questions:

1. *What is the effect of the AFWERX office on company participation within 50, 100, or 150 miles of Austin, TX? (Article 1)*
2. *What is the effect of the AFWERX office on company participation within 50, 100, or 150 miles of Washington, D.C? (Article 1)*
3. *How do the AFWERX office locations influence capturing technologies from within a cluster? (Article 2)*

Scope

This thesis expands upon previous research conducted by 1st Lt Evan Gist. The studies in both articles dive further into the already shown increased participation rates provided by the AFWERX program as compared to the status quo SBIR method (Gist, 2020).

The first article, in chapter two, uses data from all Phase I and Phase II funded AFWERX projects from 2019 and all Phase II SBIR projects from 2017 to 2019. The project data is used to statistically compare population proportion rates of companies within given distances for technology clusters. Companies within 50, 100, and 150 miles of AFWERX Austin and Washington D.C. locations participating in the AFWERX program was compared to the participation rates of companies in the traditional SBIR program in that same area. This method expands upon the previous research by showing how rates of participation are affected at different distances from the AFWERX locations between the two programs.

In chapter three, the second article, AFWERX projects are tested for their ability to effectively capture specific technology types from within the clusters in which they are located. To do this, data of all AFWERX Phase I programs from 2019 was utilized. This data shows the types of companies that are participating in the program, the locations of each company, and the technology that each company is providing for the Air Force.

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II. Analyzing AFWERX Effect on Regional Company Participation Rates Based on the Locations of AFWERX Offices

Description

Chapter II consists of an article written on the research used to test the AFWERX program's ability to influence increased company participation based on their office locations. The research is a statistical comparison of participation rates for the AFWERX program vs. the status quo SBIR program in regions where AFWERX has offices. Chapter II answers the first and second research questions listed in Chapter I.

Publication Details

This paper will be submitted for publication.

ANALYZING AFWERX EFFECT ON REGIONAL COMPANY PARTICIPATION RATES BASED ON THE LOCATIONS OF AFWERX OFFICES

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Introduction

Advancements in technology are currently occurring at rapid rates within the United States. This is a relatively new trend within our country. Historically, innovation has been driven and funded by the government and the Department of Defense (DoD). However, this trend has been shifting toward the majority of research and development spending occurring in the private sector. The reversal of this trend started in the early the 1980s but there has been exponential acceleration in private sector spending since 2009 (Foote & Atkinson, 2019).

Many of these new technologies, being produced by private companies, have use-cases within the United States Air Force and other departments of the DoD. However, the current acquisition timeline from program initiation until initial operating capability (IOC) of 72 months (Bilvas et al., 2020) creates a problem. This delay creates two major issues when it comes to the DoD successfully capturing and utilizing private sector innovation. First, by the time new technologies are ready for operational use they are frequently outdated or obsolete. Second, this timeline does not readily allow the participation of small businesses in the acquisition process. This nearly 6-year purchase period makes it virtually impossible to successfully capture and quickly utilize the smaller companies that are driving innovation across the nation. Leaders within the Air Force knew that a change needed to be made. The ability to effectively capture this organic innovation would allow for the Air Force and DoD to maintain our competitive advantage against our ever-advancing adversaries.

To help combat this issue of long acquisition times and enable the United States Air Force to tap into the growing innovative ecosystems, the Secretary of the Air Force established the AFWERX program in 2017. The program was created as an offshoot of the already functioning Air Force Small Business Innovation Research (SBIR) platform. AFWERX aims to capture a portion of the innovative investments that are being made within the private sector of our nation. It also employs new policies and processes to reduce the timelines that are associated with the current acquisition process. This ultimately creates a new opportunity for the Air Force and DoD to benefit directly from innovative investments being made by private companies.

The AFWERX program was formed on the foundation of four main pillars to drive increased innovation. These four pillars are to organize, prioritize, integrate, and invest. Each of the pillars are further broken down in the AFWERX charter by Col (ret.) Craig "Yogi" Leavitt (2020):

- Organize: develop an internal organizational structure to support innovative efforts of Airmen across the command.
- Prioritize: design a process that takes ideas from all Airmen, then prioritizes and resources the highest potential ideas.
- Integrate: create strong internal and external communication pathways to increase collaboration and leverage shared resources toward common problems.
- Invest: contribute the financial and human resources necessary to achieve these goals using modern innovation tools and processes.

The research within this paper is most directly focused on AFWERX ability to accomplish the goals from within the Integrate pillar. More specifically how effectively the program is able to drive strong external communication pathways to increase collaboration.

In an attempt to accomplish this goal, AFWERX has strategically located its program offices in several technology clusters across the country. Theoretically, this method will allow the program to take advantage of the technology spillover effect by directly placing themselves within innovation hot spots (Kerr & Kominers, 2015). AFWERX offices have been placed in Austin, TX, Washington D.C, and Las Vegas, NV. Each of these cities are known and classified as top technological and innovation clusters in the United States (Bergquist et al., 2018). The cities or clusters represent communities with established industries, academics, and research in specific technology areas (e.g. Silicon Valley). The close proximity to these locations creates a setting where the Air Force is one of many investors, benefiting from the learning and investments made across the entire ecosystem. By collocating in these areas, the Air Force is aiming to leverage these technological investments to drive innovation for use within the DoD.

Technology spillover mechanics, created by this collocation, create an the most conducive environment for new technologies and learning to flow most easily to companies nearby (Kerr & Kominers, 2015). Placing AFWERX offices at the front door of innovation should, in theory, allow for quicker adoption of new technologies while building a strong communication network within the innovative ecosystems. Ultimately, this should allow the Air Force and DoD to quickly acquire new technologies to further boost the lethality and effectiveness of vital operations.

This paper examines the geographical locations of the AFWERX Austin & AFWERX D.C. offices. These sites were tested for their ability to influence increased participation from companies within three given distances (50, 100, & 150 miles) of each campus. The participation rate of companies within each distance of an AFWERX campus was tested against the participation rates of companies from the baseline SBIR program within the same area. This method tests the effectiveness of AFWERX's core pillar of integration and the ability to create strong external communication pathways that increase collaboration within a region.

A statistical comparison of independent populations was used test the program's ability to drive increased participation, from companies within a given technology cluster, as compared to the baseline SBIR program. Furthermore, results of the testing will either support or undermine the tactic of placing offices directly within technology clusters across the United States. It will be determined whether the AFWERX program is able to successfully drive increased participation rates from nearby companies through the locations of their offices.

Background

The AFWERX program provides new paths to reduce the timeline to bring new technologies into operational use within the Air Force. The program intends to increase rates of participation by private companies within various identified technology clusters. By tapping into already developing technologies, the DoD and Air Force will be able to share the investment burden for the research and development (R&D) costs of new innovations. Overall, the program expects to tap into the knowledge, learning, and expertise of various industries by co-locating their offices within technology hubs around the country. Doing this allows AFWERX the ability to utilize a technology "push" method rather than the original taxonomy of the "pull" method that is in use by the conventional SBIR process.

Technology clusters have not been defined by regulatory organizations. However, Bergquist et al. (2018) provide an approach to defining different technology clusters from across the world. Their method used the number of patent fillings and total amount of scientific publications emerging from a given area. This density-based approach became known as "DBSCAN algorithm" which was originally suggested by Ester et al. (1996). DBSCAN enabled

Bergquist's group to identify 198 different technology clusters world-wide. Each cluster had a minimum baseline of 4,500 datapoints (patent fillings or scientific publications) within a 15-kilometer radius during a given calendar year. Twenty-six of the top 100 largest clusters were located in the United States. For the two AFWERX office locations of interest, Washington D.C. has been classified as the 13th largest technology cluster world-wide while Austin is the 77th largest. Furthermore, this shows that the Air Force has properly chosen two of the top innovation clusters in the world to place AFWERX campuses.

The close proximity created by co-locating the offices directly in these areas favors the transfer of innovations through interaction with firms. Definitions of innovation type differ by technology types. However, in the broadest sense, innovation is "the implementation of a new or significantly changed product or process" (Bloch & Bugge, 2013; Gault, 2018). Nearness to explosive innovation clusters enables easier development of contacts in the area and creates an environment for easy information exchange. Knowledge transfer becomes increasingly more difficult as the distances between the firms increases (Boschma, 2005). This relationship of easier knowledge transfer by proximity became what is known as "spillover mechanics." Empirical studies suggest that knowledge externalities are geographically bounded: firms near knowledge sources have an increase in innovative performance compared to firms located elsewhere (Jaffe et al., 1993; Audretsch and Feldman, 1996). Furthermore, prior research by Kerr and Kominers (2015) has shown that firms who cite one another in the patent filings of new technologies are most likely to cite companies who are closest to their location. This was found during their research on spillover mechanics of the sharing information between firms within different technology clusters all over the United States. This provides further logic and sound reasoning to AFWERX's approach of locating themselves within technology clusters.

Two typical strategies used to capture and develop new technologies are known as technology "push" and technology "pull". A technology push approach is better suited for use when developing new technologies. This strategy will seek already developed technologies, that are being used in other markets, to purchase and utilize to accomplish needs of the buyer. Whereas, the technology pull method is a better fit when the end user or needed capability is already known (Di Stefano, Gambardella, & Verona, 2012). The pull strategy will define a need and have a new technology developed to meet the given need. Typically, the AFWERX program does not have a given capability or requirement that they need to meet. The premise behind the AFWERX open topic approach, allows the freedom to capture commercially available technologies that may be useful to the Air Force. A strategy that allows for the most flexibility when exploring new technologies and innovations. Utilizing a technology push policy enables AFWERX to identify and fund new capabilities found within the market, without the constraints of prior requirements.

Previous research has shown the AFWERX program creates a statistical increase in regional participation rates of companies. However, this research only shows increased participation rates in the entire states in which offices have been located. Gist (2019) found the AFWERX Austin and AFWERX D.C. campuses encouraged higher rates of company participation within the state of Texas and the states surrounding Washington D.C. as compared to the participation rates of companies in the baseline SBIR program. However, a gap remains in the research on whether these AFWERX campuses are able to capture technological advancements from within the clusters that they are located. The regional participation rates needed to be further examined, at a more granular level (within 50, 100, or 150 miles of an AFWERX campus). A deeper examination will further evaluate the program's ability to increase participation directly for companies from within the respective technology clusters. The state also contains three of the top 100 identified technology clusters in the world. There could have been several other factors that drove the increased rates of participation from companies within the entire state of Texas. However, examining participation within a much closer radius will help to, yet again, further support the program's claim and test their ability to tap into these innovative ecosystems.

Methods

The research in this paper statistically analyzes regional participation rates by companies in the AFWERX & SBIR programs. The two regions of interest are Austin, TX and Washington, D.C. AFWERX located in these two locations to increase industry participation in those areas. The participation rate seen by companies in the AFWERX program from these two locations was compared to the participation rates of companies in the traditional SBIR platform from the same areas. Comparisons were done for the participation rates in each location separately. For example, the rate of participation for companies in the AFWERX program, within 50 miles of Washington D.C., was compared to the rate of participation of companies from the SBIR program within the same 50 miles. Ultimately, this comparison would show if AFWERX is able to stimulate a statistically significant increased participation rate. It is important to note that this comparison was done for projects in participating in each program from 2017 to 2019. The utilization of data of the same time period could create the potential issue of cannibalism between the two programs. However, due to the use of a technology pull method by SBIR and a push method by AFWERX the programs will tend to attract different companies. SBIR will attract companies who are willing to develop new projects for the Air Force while AFWERX will attract organizations who pushing an already established technology into the market. This alone will minimize the potential amount of cannibalism by companies participating in these regions.

The AFWERX core pillar of Integration aims to create strong communication networks to increase collaboration. One method employed by the program to accomplish this goal is collocation. Placing offices directly within technology clusters will drive increased innovation by fostering higher rates geographical participation (Ingram et al., 2020). To evaluate this claim, the participation rates, as described above, were compared for statistical differences. The locations of each company (from both AFWERX and SBIR) was determined and categorized by their physical distances to both the AFWERX D.C. and AFWERX Austin offices.

Two sets of data were used to obtain the physical locations of the companies that were participating in either program. The first dataset is all Phase II projects funded through the baseline SBIR process. Projects within this dataset received funding through the SBIR program between 2017 & 2019. This data was obtained online through the official Small Business Innovation Research Office at SBIR.gov. The second set of data consists of all Phase I and Phase II AFWERX open-topic funded projects in 2019. This data was obtained directly from the AFWERX office as it is from their internal tracking system.

Both the AFWERX and SBIR datasets required further cleaning to ensure unbiased and accurate results for our given analysis. The cleaning of the data involved the removal of duplicate participants and companies located outside of the continental United States. The removal of these datapoints allowed for the most accurate comparison of participation by unique companies in a given region. There were numerous companies for both AFWERX and SBIR that have received multiple contract awards. Duplicate awards had the potential to show false spikes or drastically skew the participation rates within a region. For example, one company many been awarded as many as nine different SBIR contracts. This company would create an overestimate of participation within that distance from the technology cluster. This was an issue that needed to be corrected because in reality there was only one participating entity for the nine different data points. Correcting this issue in the data further allows for a more accurate test of regional participation. All companies who received multiple awards only counted once for our analysis.

The next step was to remove any outliers from the data. These outliers were identified by physical distance from either of the technology clusters of interest. After further identification, both programs had funded companies from outside of the continental United States. For example, there were participating companies from Hawaii, Alaska, and Guam. These entities were too far away to be useful for this analysis. Companies outside of the continental United States were treated as outliers and removed from our analysis due to their vast distance for either of the two technology clusters

The distance from a given company to each AFWERX office location was calculated using postal zip codes. The zip of a participating company was used to find the or straight-line distance from that business' location to the most central zip code in both Austin, TX (78701) and Washington, D.C. (20001). Zip codes provide a specific location of the company within the United States. These locations allowed a specific calculation of a company's distance to an AFWERX location. This method of measuring distance provided the data needed for our deeper analysis of company participation rates.

Regional participation rates were measured by counting the number of companies that received funding within 50, 100, and 150 miles of both Washington, D.C. and Austin, TX. Participation rates were calculated individually for each of the two technology clusters. There were six total rates of participation calculated for each cluster. For example, there were three rates calculated for AFWERX participation in Austin, one rate for company participation within each of the three distances. Three more rates were calculated in Austin for the participation of SBIR companies within the same distances.

Final rates were calculated by counting the number of participating companies at each distance of 50, 100, and 150 miles. The number of companies at a given distance was then divided by the total number of companies participating in the respective SBIR or AFWERX program. This method produced a proportion of participation, or participation rate, within the given distances of both technology centers. The calculated rates of participation were then compared for each program at a given distance from a cluster to test for a statistically significance difference in participation rates. A statistical comparison was done using the proper hypothesis testing methods for comparing two independent population proportions. Our test was conducted at an alpha level of .05 or 95% confidence. The hypotheses used in the test are shown in Figures 1 & 2.

Figure - 1	Figure - 2
H_o: $p_{\text{AFWERX (D.C.)}} = p_{\text{SBIR (D.C.)}}$ H_a: $p_{\text{AFWERX (D.C.)}} > p_{\text{SBIR (D.C.)}}$	H_o: $p_{\text{AFWERX (Austin)}} = p_{\text{SBIR (Austin)}}$ H_a: $p_{\text{AFWERX (Austin)}} > p_{\text{SBIR (Austin)}}$

In this examination, if the null hypothesis (H_o) were to be rejected, the alternative hypothesis (H_a) would show that there is a significantly higher rate of participation for AFWERX in the given distance of the tested city. To calculate the z-score for the comparison of the two hypotheses, the equation in Figure 3 was used.

$$z = \frac{p_A - p_B}{\sqrt{pq/n_A + pq/n_B}}$$

Figure - 3

The hypotheses to be tested were set up as a one-tail test. This test would show if a higher proportion of participation was generated by AFWERX than the traditional SBIR program. At an alpha of .05, we needed to see a z-score above 1.64 to show statistical significance between the participation rates between the two programs. A calculated z-score above 1.64 would give basis to reject the null hypothesis and conclude that there is a statistically significant increased rate of participation by AFWERX with at least 95% confidence (Illowsky et al., 2013.)

To use this method of hypothesis testing, three basic assumptions must be met by the data. These assumptions ensure the analysis produces statistically accurate results. First, the two samples must be independent of one another. This is true for our two sets of data as they come from differing programs. The AFWERX and SBIR programs typically have no direct effect on each other for the companies that are participating. Second, the number of success and failures for each set of data must be greater than the general rule as explained by Illowsky which is 5. For both sets of data, the number of successes (participating companies) within any of the three distances used for comparison is greater than 5. This is also true for the number of failures. Third, the total population must be at least ten times greater than the sampled proportion or the entire population must be used in the comparison. This assumption keeps the data from becoming over sampled which could produce incorrect or skewed results (Illowsky et al., 2013.) To meet this assumption, the entire populations of both AFWERX and SBIR contracts from 2017 to 2019 were used. Both populations of contract data will provide the needed information for company participation rates across the same period of time. Ultimately this will allow for the most accurate and complete comparison of the two programs since the inception of the AFWERX program in 2017.

Results & Conclusion

This section discusses the results from the statistical comparison of participation rates from the methods section. The statistical comparison of two independent population proportions yielded evidence that AFWERX is garnering higher rates of participation by companies in the technology clusters that surround both Austin, TX and Washington, D.C.

However, both data sets required removing outliers and duplicate companies to provide the most accurate analysis for regional participation, by unique companies, as possible. The original SBIR data set contained 621 entries. Of the 621 awards, four were removed as outliers (outside of the continental United States) and 239 were removed due to being duplicate companies. The final SBIR dataset contained 378 unique data points. For the AFWERX data, the same process took place. The set started with 1533 data points. Eight of the contracts were removed as outliers and another 503 were taken out as non-unique companies. The final population ended at 1022 AFWERX projects.

The participation rate of companies within 50, 100, and 150 miles of both Austin and Washington D.C. were calculated for the data sets. These calculated participation rates, or proportions, and are shown in Table 1 and Table 2.

The proportion of participating companies within each analyzed distance for both programs were then tested for statistical differences. For example, the proportion of companies within 50 miles of Austin funded through AFWERX was tested for significant participation increase against the proportion of participating companies within 50 miles of Austin in the SBIR program. The testing of the population proportions was done using the statistical methods described in the previous section. Once again, any calculated p-value below .05 showed a statically significant increase in the AFWERX rate of participation at that distance for the given hub. The results of these statistical comparisons are shown for Austin, TX in Table 1 and Washington, D.C. in Table 2.

Table 1

Miles from	Austin, Texas						
	AFWERX	**P (Rate)**	**SBIR**	**P (Rate)**	**Z-Score**	**P-Value**	**Signif?**
50	36 of 1022	.035	9 of 378	.024	1.075	.1411	No
100	46 of 1022	.045	12 of 378	.032	1.105	.1344	No
150	62 of 1022	.061	14 of 378	.037	1.732	.0416	**Yes**

Table 2

Miles from	Washington, D.C.						
	AFWERX	**P (Rate)**	**SBIR**	**P (Rate)**	**Z-Score**	**P-Value**	**Signif?**
50	126 of 1022	.123	33 of 378	.087	1.884	.0297	**Yes**
100	143 of 1022	.140	37 of 378	.098	2.086	.0184	**Yes**
150	165 of 1022	.165	47 of 378	.124	1.719	.0427	**Yes**

The analysis showed a statistically significant increased rate of participation by companies through the AFWERX process within 50, 100, and 150 miles of Washington D.C. However, there is no statistical increased rate of participation in Austin, TX until the radius reaches 150 miles from the city. This result is not surprising, however. Texas has a much lower population density as compared to Washington D.C. This could create some urban effects that would benefit companies from spreading out further from the city. For example, warehouse and workspace for a company would be much cheaper outside of Austin rather than locating within city limits. These effects would tend to produce a larger distance between companies as there is more geographical space for people to spread. Nonetheless, it has been shown that AFWERX is able to produce an increased rate of participation in both Washington D.C. and Austin, TX as compared to the SBIR program.

As discussed in methods section, this first comparison is based on unique companies. After finding significant results, the analysis was conducted again. However, this time it was done without removing the duplicate companies. Once again, results of statistically significant increases were held at each distance. Retesting the data without the removal of duplicate companies shows that our test provides a robust conclusion with or without the presence of duplicates. This provides further evidence of AFWERX's ability to drive increased participation through the location of its offices.

The results are useful to the United States Air Force and its vision for the AFWERX program for several reasons. First, we have found support for the hypothesis that the co-location tactic is increasing rates of participation around areas where offices have been placed. Nevertheless, different technology clusters around the United States have differentiated areas of expertise. If in need of a certain type of technology, the Air Force or DoD can place an AFWERX office within a technology cluster holding that specialization. The strategic location of this office placement will likely drive increased participation by companies within that area. Increased participation from companies within that technology specialization should drive an increase in Air Force or DoD access to the technology. For example, if the Air Force decided that its next upgrade in technology related to Artificial Intelligence (AI), an AFWERX office could easily open an office in the San Francisco Bay Area. San Francisco is the leading producer of AI technology within the United States. It is estimated that more than one third of all AI researchers currently reside within that given technology cluster (Gagne, 2019). The new location could potentially drive increased AI technology acquisition for the Air Force. The effectiveness of AFWERX to capture the specific technology expertise from within a cluster is further explored in another paper.

While conducting the statistical comparisons, there were several other interesting outcomes that were noted. Each of these observations is a prime area for further research. First, it was observed that spikes in participation of both the AFWERX and SBIR program occurred at different distances from Austin and Washington D.C. After further study, it was noted that spikes in SBIR participation rates typically occurred at distances that related to other existing Air Force acquisition bases. Figure 4 shows SBIR participation spikes (annotated by the red columns) around 650, 800, 1050, and 1750 miles from Austin, TX. Interestingly enough these distances corresponded with several existing Air Force acquisition centers. The acquisition centers that corresponded, by each distance, to a spike in the SBIR participation rates are shown in Figure 5 within the red columns.

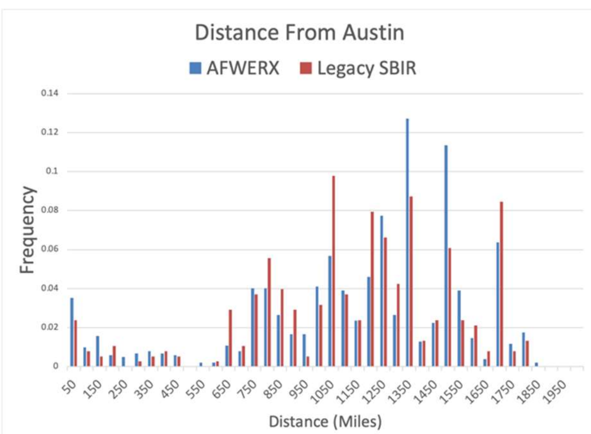

Figure - 4

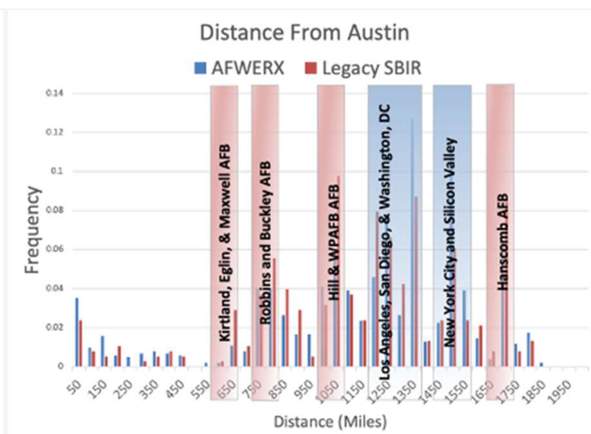

Figure - 5

During our research, we also noted that there were several major AFWERX participation spikes by certain distances from Austin. These spikes however occurred in clusters between 1200 – 1350 miles and 1450 – 1600 miles from the AFWERX campus. Each of these distances tended to correspond with a number of the top technology & innovation clusters, as defined by Bergquist et al. (2018), in the United States. The spikes in AFWERX participation rates and corresponding technology clusters are annotated in Figure 5 above by the blue columns.

The trend of seeing spikes in participation rates continued into the analysis of distances from Washington D.C. as well. Again, in Figure 6 below, you see the spikes in SBIR participation (red) rates around 400, 1500, 1650, and 1850 miles from D.C. and AFWERX participation (blue) rates around 200, 1350, and 2250-2450 miles from the AFWERX Washington D.C. location.

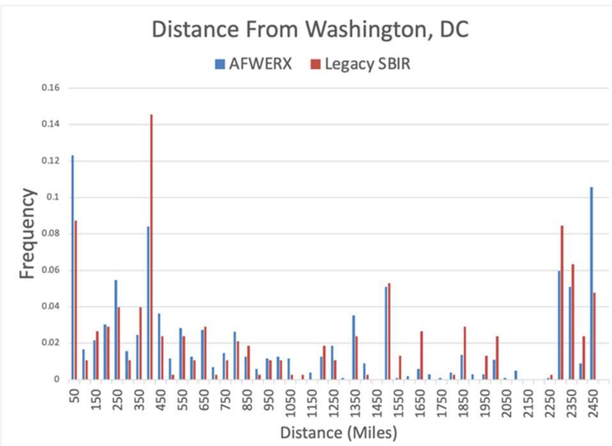

Figure - 6

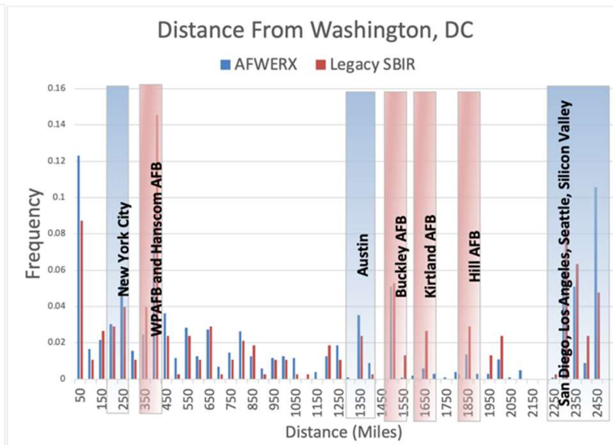

Figure - 7

Once again, distances that corresponded with spikes in SBIR participation directly lined up with various Air Force acquisition centers and spikes in AFWERX participation rates continued to parallel the distances to top technology clusters across the country. Corresponding acquisition centers (SBIR spikes) are shown within red columns in Figure 7 above while the AFWERX spikes and related technology clusters are displayed by the blue columns.

Next, evidence tends to support that hypothesis that the locations of AFWERX offices and Air Force acquisition centers drive increase economic participation within their given regions. This boost in economic activity is yet another benefit that must be further explored. When the Department of Defense places an acquisition center or AFWERX campus in an area, it will drive economic stimulus. The stimulus can lead to benefits within local communities such as boosts within the economy, neighborhood restoration, and increased development. Each of these benefit are typical results seen in areas of sudden monetary influx. Leaders and decision makers could potentially use these added benefits to help make future decisions on the locations of these programs. However, this is an area for further research.

In conclusion, evidence supports the notion that AFWERX is able to generate a significant increased rate of participation by companies surrounding both Washington D.C. and Austin, TX. There are several advantages of these increased rates of participation within technology clusters that the DoD and United States Air Force should be able to leverage. The ability of the Air Force to influence the types of technologies participating in the program and being developed for operational use or their ability to drive economic stimulus need to be further researched. However, these effects would help to leverage an increased operational advantage within the United States and against our constantly advancing adversaries.

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III. Assessing AFWERX Ability to Capture Cluster Specific Technological Innovations Based on Program Office Locations

Description

Chapter III includes results from a study analyzing AFWERX ability to influence and capture the specific technology specialties of the clusters in which they have located. The chapter highlights the potential effects of choosing where to place office locations to help influence advancements in certain technology types. This chapter helps to answer the third research question specified in Chapter I.

Publication Details

This paper will be submitted for publication.

Assessing AFWERX Ability to Capture Cluster Specific Technological Innovations Based on Program Office Locations

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Introduction

In 2017, the United States Air Force established the AFWERX program as an offshoot of the Small Business Innovation Research (SBIR) program. The program's inception came directly from several years of senior leadership noticing flaws in the Department of Defense's (DoD) acquisition process. A typical DoD acquisition timeline is about 72 months before a the newly procured item is able to receive funding from a typical government contract (Bilvas et al., 2020). This is an untenable timeline - especially at the rapid pace that technological advancements are currently occurring within the United States. The delay creates two major issues when it comes to the DoD's ability to successfully utilize private sector innovation. First, new technologies are frequently outdated or obsolete by the time that it is ready for operational use. Second, the timeline does not easily allow the participation of small businesses in the acquisition process.

During the summer of 2017, Air Force Leadership publicly announced their priority to "Drive innovation to secure our future" (Ingram & Maue, 2020). The AFWERX program is a direct attempt by the Air Force to leverage innovative investments being made in the private sector. Since the early 1980s, the percentage of government Research and Development (R&D) spending as compared to total U.S. Gross Domestic Product (GDP) has been constantly decreasing. At the same time, the percentage of spending of R&D by the private sector has steadily increased with an exponential acceleration since 2009. The changing landscapes has led to a shift in the locus of innovation from the public to the private sector (Foote & Atkinson, 2019). The shift in R&D spending has left an open opportunity for the Air Force and DoD to utilize investments from other sources. AFWERX set out with the goal of providing a better pathway for the Air Force to capture these technological innovations from private ventures. The program aims to make create an easier path for non-traditional defense companies to do business with the DoD. This is done by removing typical bureaucratic layers and overwhelming processes that are involved in reaching contractual agreements with the DoD through traditional methods (Parker et al., 2020). A path to effectively and quickly capture new technologies will boost the overall operational capabilities for the Air Force.

AFWERX aims to capture learning and innovation generated within these ecosystems through the use of a collocation tactic. By placing offices directly within these innovation hubs AFWERX creates a conducive environment for technology transfer from what is known as spillover mechanics. Spillover mechanics are the increased ability for firms to share innovation and learning due to a closeness in distance or proximity (Kerr & Kominers, 2015). The close proximity that AFWERX is able to leverage through its use of multiple office locations creates the best environment for easier and quicker transfers of technological innovations and learning.

Currently, AFWERX has offices located in Austin, TX, Washington D.C, & Las Vegas, NV. Each of these cities is known as a technological or information cluster. These innovation-oriented cities, or clusters, represent communities with established industries, academics, and research in specific technology areas (e.g. Silicon Valley). Prior studies have already shown that the AFWERX program is able to elicit increased company participation within the regions that they have placed one of their offices. It was first shown that the program increases participation rates of companies within the same state as an AFWERX office (Gist, 2019). After a deeper dive, a further study found increased participation rates within certain mileage radiuses from the offices themselves. However, there remains a large gap in the research. This gap lies with the question as to whether or not the program is able to capture the respective technology types that are emerging from a given innovation cluster.

The study within this paper intends to fill in this gap in the research. AFWERX is examined for its effectiveness to capture technological innovations that are directly related to the technology clusters in which their offices are located. By using United States patent data, the top technologies emerging from both Austin, TX and Washington D.C. were identified. AFWERX projects were then mapped against these top technology types to determine if the technology emerged directly from the cluster. This method is able to determine how effective the AFWERX program is able to influence the type of technologies that are developed for the Air Force. More specifically, it is able to demonstrate how the Air Force is able to influence technological advancement by the locations of their AFWERX campuses.

Background

Each AFWERX program office is built upon four core pillars that are aimed to drive both internal and external innovation. The four pillars, as defined by Col (ret.) Craig "Yogi" Leavitt (2020), are shown in Table 1.

Table 1

Pillar	**Definition**
Organize	develop an internal organizational structure to support innovative efforts of Airmen across the command.
Prioritize	design a process that takes ideas from all Airmen, then prioritizes and resources the highest potential ideas.
Integrate	create strong internal and external communication pathways to increase collaboration and leverage shared resources toward common problems.

Invest	contribute the financial and human resources necessary to achieve these goals using modern innovation tools and processes.

Former Secretary of the Air Force Heather A. Wilson stated that “the pace of change is accelerating and that the Air Force has to engage the next generation of innovators, young scientists and engineers, and smart businesspeople to take us into our future. The Air Force has to engage with those innovators who want to help the warfighter to be able to defend our vital national interests” (SECAF, 2017). This quote comes directly from her remarks at the opening event for AFWERX Las Vegas charter and shows the drive and initiative of Air Force leadership to capture innovations from within the private sector.

AFWERX needed to adopt and implement further changes to the current DoD acquisition process. The typical 72-month timeline is far too long for small companies to remain competitive. This issue dissuades smaller businesses from attempting to compete for government funding. Most startup companies have enough cash to stay in business for nine months or less. Small businesses do not have the capital or manpower to wait months, let alone years, to be awarded a contract (Lauver, 2020). AFWERX knew that changes needed to be made to not only the acquisition process, but also to the stigma of doing business with the government. Many private small companies have a negative outlook on doing business with the federal government due to the government’s seemingly endless bureaucratic layers and processes (Parker et al., 2020).

To accomplish the tasks of creating an easier path to doing business with the Air Force and capturing cluster specific technologies, the AFWERX program adopted the use of what they called "Agile Contracting and Acquisition." An agile methodology aims to connect new and growing innovations with an accelerated route to funding from the Air Force and Department of Defense. As shown by previous research by both Gist (2019) and Sandor (2020), there is increased participation rates by companies located near AFWERX office locations. This effect could be a result of easier access--with AFWERX placing themselves on the doorstep of these companies. However, there may be another effect increasing these rates of participation. Through agile methods and shortened procurement timelines, the barriers to entry have been lowered for small businesses to receive funding from the government. Lowered barriers to entry created by the AFWERX program along with easier technology spillovers created by the collocation in innovation hubs should allow the program to tap into the specific technologies that are being developed in each area.

Technology clusters were defined by Bergquist et al. in their 2018 research using a density-based approach. This method identified specific areas all over the world as technology clusters by the total number, or density, of patent filings and scientific publications for the location in a given year. The approach provides a unique yet standardized method of defining and quantifying hubs. Furthermore, it allowed the team to track the most active technology clusters from year to year. The method became known as "DBSCAN algorithm" which was originally suggested by Ester et al. (1996). DBSCAN enabled Bergquist to identify 198 different technology clusters world-wide. Each cluster had a minimum baseline of 4,500 datapoints (patent fillings or scientific publications) within a 15-kilometer radius during a calendar year. Of the top 100 largest clusters, the twenty-six of them were within the United States. Washington D.C. was identified as the world's 13th largest technology cluster while Austin, TX clocked in at

77th largest cluster worldwide. This evidence shows that AFWERX has properly located themselves within two of the most active technology clusters. However, it is yet to be shown whether they are able to influence the types of technologies that participate in the program by the location of their offices.

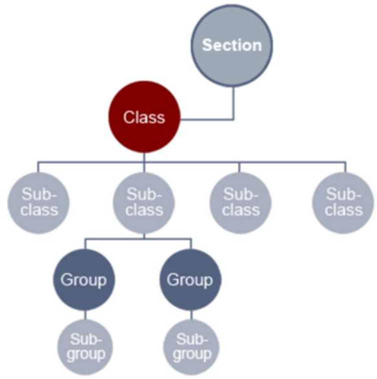
The phenomenon of technology spillover shows that firms who are most closely located to each other are far more likely to cite one another in their filings for new patented technologies. The further distance firms are away from each other the less likely they are to work together or share information organically (Kerr and Kominers, 2015). This methodology works the same when it comes to sharing already developed technologies. The closer firms are to one another, the easier the transfer of information and ideas (Boschma, 2005). Empirical studies are able to confirm that knowledge externalities are geographically bounded: firms near knowledge sources have an increase in innovative performance compared to firms located elsewhere (Jaffe et al., 1993; Audretsch and Feldman, 1996). As pointed out by Verspagen (1997), firms do not necessarily need to have similarities in their expertise to experience the greatest technology spillovers. Once again, it was found that the most important factor is their proximity. Proximity is a better predictor for a firm's ability to capture this technological spillover or learning rather than their similarities in research. Each of these is a reason that supports AFWERX's method of placing itself directly in booming technology centers to capture some of the innovations that are fostering within these areas.

To test how well AFWERX is able to capture these technology spillover effects, a method for defining the technologies had to be identified. As previously mentioned, research by Bergquist et al. (2018) has shown that technology clusters are best defined by the types of patents and technological publications that are emerging from a given area. Additionally, Jun and Park

(2013) identified the most frequent patent classifications emerging from a technology cluster is the best representation of the specialty markets of that region. Because there is no centralized location to easily track all publications that emerge from an area, the research in this paper focused specifically on the patent types developed from the given clusters. Patent classifications using the world-wide Cooperative Patent Classification (CPC) system were used to create both our formal definition of the technology clusters in Austin and D.C. while also evaluating the fit of any AFWERX project into the specific cluster.

In 2015, the United States Patent and Trademark Office (USPTO) switched from their legacy classification system of the United States Patent Classification System (USPC) to a new Cooperative Patent Classification (CPC). The CPC is a joint classification system that was developed by the European Patent Office (EPO) and the USPTO together to better incorporate best practices from both offices. Furthermore, the new CPC classification system is International Patent Classification (IPC)-compliant. The IPC was created in 1971 under the Strasbourg Agreement and is maintained by the World Intellectual Property Organization (WIPO). It is the only classification system that is used by all patent offices worldwide. Being compliant of the IPC ensures that CPC classifications are understood and respected universally by all audiences internationally (EPO, 2012).

Both the CPC and IPC, like the previous USPC, use a hierarchy method of classifying technologies. However, the CPC is more detailed than both the IPC and previous USPC. The classification naming convention of the CPC uses sections, classes, subclasses, groups and subgroups. Each of the segments and their location within a CPC classification along with their position within the hierarchy are shown in Figure 1 and Figure 2 below.



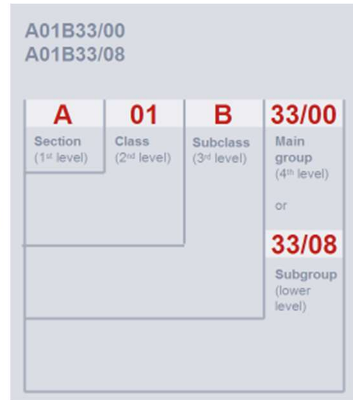


Figure - 1 Figure - 2

There are nine sections that have been created within the CPC system. Each section is identified by a single letter from A to H or the letter Y. For example, section A incorporates all technologies that would be considered "human necessities" while section E is all "fixed construction" items. Section Y is used for any technology that would fit into multiple section groupings. The remaining class, subclass, main group and subgroup are lower hierarchy levels that afford the ability to classify the exact function of a new technology. To further clarify, we can break down the CPC classification for an armored vehicle, F41H7/00. This classification represents section F, mechanical engineering (lighting, heating, weapons, blasting), class 41, weaponry, subclass H, armor, main group 7/00, armored vehicles. For our purposes, each technology cluster and AFWERX project was defined to the third level classification. From the armoured vehicle example above, that would mean F41H (armour) would have been the final classification that was used.

To ensure proper classifications, individual raters were used as the method to map each AFWERX project against the top CPC classifications (cluster type) from the given city. This method of coding uses human coders (raters) to determine if a project fits into the grouping of technology types. Human coders inherently bring large amounts of variation and biases due to their individual thought processes. However, there is a very specific method to counteract these effects and ensure proper results and maintain intercoder reliability. The steps are laid out by

Lombard, Snyder-Duch, and Bracken (2002) and Lombard, Snyder-Duch, and Bracken (2003). This full process is detailed further in the methods section below.

Methods

Research in this paper is centered on the analysis of AFWERX's ability to capture specific technologies from the innovation clusters in which they have chosen to locate. Once again, the two centers of interest for the study are Austin, TX and Washington, D.C. From these two areas, the AFWERX dataset was narrowed down to focus specifically on projects that were identified to have emerged from one of the two centers of interest. These projects were categorized as coming from that area due to their close proximity. Each of the technologies contained within the projects of interest were mapped against the most common CPC classifications, from that city. This process is able to create a test or measurement for the program's ability to capture specific innovations or technological developments that are most prevalent from a given technology cluster.

The first step in the process was to define the technology clusters for both Austin, TX & Washington, D.C. As previously discussed, both of these cities have been identified as technology clusters through the volume of patents and publications emerging from the areas. Research has shown that a proper method for classifying technology clusters is through the types of patents and technical publications that are emerging from the given area (Bergquist et al., 2018). Using patent data is exactly how each of the technology clusters were defined for our purpose. Technical publications were not used to define the clusters as there was no accessible way for us to obtain records of all publications from the areas.

An exhaustive list of patents filed between 2017 and 2020 from Austin, TX and Washington, D.C. was obtained from the United States Patent & Trademark Office. The dataset for Austin contained 165,508 individual patent filings while the D.C. dataset contained 45,505 individual patent fillings. All projects from both cities were then sorted and counted by their three-level CPC classification code. There were 120 individual three level CPC classifications for the 165,508 projects out of Austin, Texas. However, the top ten classifications (by number of patents) accounted for 133,676 or 81% of all patents. These top ten CPC classifications were used to define the Austin technology cluster for our mapping purposes and are shown in Table 2 below.

Table 2

3 Level CPC Code	Definition	Count	Percentage of Total
G06	Computing; calculating; counting	46386	28.03%
H04	Electric communication technique	29847	18.03%
H01	Basic electric elements	17746	10.72%
A61	Medical or veterinary science; hygiene	14284	8.63%
H03	Basic electronic circuitry	7426	4.49%
G01	Measuring; testing	6444	3.89%
G11	Information storage	3153	1.91%
Y02	Technologies or applications for mitigation or adaptation against climate change	2915	1.76%
H02	Generation; conversion or distribution of electric power	2895	1.75%
H05	Electric techniques not otherwise provided for	2580	1.56%

In Washington, D.C. there were 117 individual three level CPC classifications for the 45,505 patent filings. In this case, the top eighteen three level CPC distinctions accounted for 36,459 or 80.12% of all patents filed from this location. These eighteen CPC codes were used as our definition of the Washington, D.C. technology cluster and are shown below in Table 3.

Table 3

3 Level CPC Code	Definition	Count	Percentage of Total
A61	hygiene	6739	14.81%
G06	Computing; calculating; counting	6424	14.12%
H04	Electric communication technique	4103	9.02%
H01	Basic electric elements	3930	8.64%
G01	Measuring; testing	3834	8.43%
C07	Organic Chemistry	2151	4.73%
C12	Wine, Vinegar, microbiology,	1574	3.46%
G02	Optics	1097	2.41%
B01	for Mixing or Separating	1036	2.28%
B64	Aircraft; Aviation; Cosmonautics	807	1.77%
C08	Compounds; Their preparation or	742	1.63%
C04	Stone; Ceramics; Refractories	690	1.52%
C10	Industries; Technical Gases	680	1.49%
B32	Layered Products	678	1.49%
Y02	Adaptation Against Climate	628	1.38%
F42	Ammunition; Blasting	516	1.13%
F41	Weapons	415	0.91%
C01	Inorganic Chemistry	414	0.91%

The next step narrowed the list the complete dataset of all AFWERX projects between 2019 and 2019. The original AFWERX data set contained all Phase I and Phase II AFWERX contract awards since 2017. A Phase I AFWERX project is the initial investment in a company to test the viability of acquiring the technology for use within the DoD. A Phase II project is an additional investment into a Phase I project that has shown the ability to be acquired for use in the Air Force. The total number of AFWERX contracts in the entire dataset was 1291.

As the main interest of this research is AFWERX's ability to effect technology types by the location, the choice was made to use only Phase I projects. Phase I projects would include all Phase II projects along with other companies who have not or will not make it as far into the funding cycles. However, the Phase I projects are a better measurement of all companies that are participating in the overall AFWERX program. After removing the Phase II contracts there were 1104 Phase I projects remaining.

Next, projects of interest were further narrowed by their distance to the two AFWERX locations. Using zip code data, the distance of each company corresponding to a Phase I AFWERX project was calculated in miles to both AFWERX offices in D.C. and Austin. Zip (postal) codes of the given company, from their project proposals, were used to calculate the direct distance to the most central zip codes in both Austin, TX (78701) and Washington, D.C. (20001). At this point, a list of projects within a 150-mile radius of Austin and Washington were gathered to be analyzed against the previously defined CPC classifications for these technology clusters. Furthermore, companies that received duplicate contract awards within 150 miles of either location were removed at this time. Removing these data points allowed for the most accurate analysis without having the numbers inflated one way or another by projects or companies that may have received funding multiple times. Ultimately, there were 55 AFWERX project within 150 miles of Austin and 157 within the same radius of Washington, D.C.

After defining our projects of interest for each cluster, the technologies from each projected needed to be coded against the respective top three level CPC codes from that cluster. To accomplish this task, a panel method of coding was used. This method uses human coders to classify each project. Human coders bring a variety of biases and disagreements to the table. Because of this, a very specific process must be used to properly evaluate and ensure inter-rater reliability and agreement. The process is formally defined by Lombard, Snyder-Duch, and Bracken (2002) and Lombard, Snyder-Duch, and Bracken (2003).

The first step in the process was to select an appropriate index for classifying the different technologies form the AFWERX projects. In our case, the index used is the Combined Patent Classification (CPC) process. This is the same process that is used world-wide to classify technologies for patents and fits directly into our area of research. The next step in the process was to find and select our group of raters. Once selected, each rater had to be given the proper training to classify AFWERX projects. The selected group of raters consisted of seven individual people. Five of the raters are prospective graduate degree students while the remaining two raters were PhD level instructors. Each rater received the same CPC training and conducted a group technology classification as an example.

The next step in the process was to conduct an initial alpha test to determine a preliminary inter-rater reliability and agreement rate. An appropriate level of inter-rater agreement and reliability was set at .75 or 75% (Hartmann, 1977; Stemler, 2004). The test was performed on 24 individual yet random AFWERX projects from the 55 technologies that originated within 150 miles of Austin. These 24 projects were divided among the seven raters. Neuendorf (2002) argues that in addition to being a necessary, although not sufficient, step in validating a coding scheme, establishing a high level of reliability also has the practical benefit of allowing the researcher to divide the coding work among many different coders.

Each of the 24 projects received individual coding by two different raters. This meant that overall, in the alpha test, each rater had eight projects to classify. Once classified the project coding from both of the raters were compared for agreement. This is how our inter-rater agreement rates were calculated. A detailed review of how these 24 projects were divided among the seven different raters is shown in Appendix A.

The coding process evaluated the technologies from each AFWERX project. The raters were informed of each technology through the abstract and expected DoD benefits as provided by the preparing companies. Figure 3 shows an example abstract and the expected DoD benefits of one technology that was coded for this research.

Abstract	Description of Anticipated Benefits
In this SBIR Phase I program, we propose to evaluate the use of our novel optical neural network technology to enable efficient, low latency, edge-enabled artificial intelligence (AI) applications within the Air Force. As intelligence systems grow, their SWaP grows to an unmanageable point, due inherent inefficiencies in using conventional Complementary metalâ€"oxideâ€"semiconductor (CMOS) based general purpose processors or AI accelerators like GPUs. Although, photonic AI accelerators have been attempted, the current approaches are lacking and are unable to operate at light speed due to numerous conversions back and forth between electrical and photonic domain, to enable non-linear activation. GenXComm technology enables photonic AI accelerators to which are low power, high throughput, and operate purely in the optical domain, enabling operation at light speed, with a SWaP enabling deployment on small Airborne platforms.	There are multiple benefits of Optical Artificial Intelligence platform. The company is working to apply its Optical neural networking technology across multiple market segments, including optimal computing, WiFi, Internet of Things (IoT) and next generation cellular communications. The company is working closely with chipset manufacturers in the communications space to bring our Silicon photonics platform to market. We are including our solution as part of a reference design together with these chipset manufacturers to enable standards-compatible solutions in each of these segments. Communication industry is our primary market today, however as our Optical neural network technology matures we will enable edge and high throughput AI solutions.

Figure - 3

After learning of the prospective technology, the raters were instructed to go one by one through the top ten CPC three level codes that were defined as the Austin technology cluster. If the rater believed that the prospective technology fit into the category of a given CPC code, a "1" would be placed in the corresponding column for that CPC code. If the rater determined that the technology did not fit, a "0" would be input for that classification category. When prospective patent technologies are classified by the United States Patent Office, they often receive more than one CPC code. Because of this, our raters were able to classify a given AFWERX project into more than one CPC grouping if they saw fit. An example of a classified project is shown in Figure 4.

		Computing; c	Electric com	Basic electri	Medical or w	Basic electro	Measuring; t	Information	Technologies	Generation;	Electric
Abstract	Description of Anticipated	G06	H04	H01	A61	H03	G01	G11	Y02	H02	H05
In this SBIR Phase I program, we	There are multiple benefits of	1	1	0	0	1	0	0	0	0	0

Figure – 4

If a given technology fit into any of the top CPC classifications, it fit into the Austin technology cluster. Once again, in terms of this research, each of the technology clusters was formally defined by the top 80% of patents that emerge from the location. If a technology received ten

“0”s meaning that it did not fit into any of the top three level classifications, it did not fit into the cluster. Again, these top CPC classifications account for over 80% of all technologies and innovations emerging from Austin, TX.

The initial alpha test yielded an inter-rater agreement rate of approximately 85%. This rate exceeded the standard of .75 or 75% and it was found that individual coding by the different raters was a viable option to assess the entire dataset. This led to the next step of coding the remaining 31 projects from within the Austin radius and 157 from within the radius of Washington, D.C. and assessing the final inter-coder agreement rate.

Using the same process from the alpha test, the remaining projects were divided equally among the seven raters. The complete breakdown for all Austin and D.C. projects is shown in appendix B and appendix C, respectively. Validity of the inter-rater method had already been shown in the alpha test leading to only 20% of the remaining projects received a double coding by two raters. These 20% projects were once again compared to determine the final inter-rater agreement rates. At this point, it was also noticed that 2 of the projects within the 157 from Washington D.C. did not have enough of the required technical information to be properly classified. For example, the abstract provided from project 127 in the dataset just stated “Proprietary.” These two projects were removed from that data and the Washington D.C. projects of interest were down to 155 total contracts.

When one of the double coded projects had a disagreement between the raters on whether the technology fit into the given cluster, a group panel process was used to make a final decision. This group process involved each of the seven raters sitting down together. The technology abstract and expected benefits were read aloud. At this point, the group of raters went through the same coding process for each of the top CPC classifications in the perspective technology cluster. The group came to an agreement for each classification code. Once again using a “0” for a non-fit and a "1" for a fit. These final group consensus codes were used to determine if that project fit into the given cluster. This process was used on a total of nine projects. Three of the projects came from the Austin technology cluster and the remaining six were from disagreements on project in the Washington D.C. cluster.

Results and Conclusion

Using the inter-rater classification and group consensus processes that was described above, the capture rate of AFWERX's ability to capture certain technologies was determined. This capture rate is the percentage of projects, from within 150 miles of the technology clusters, that were determined to have emerged directly from the given innovation hubs. Between the two specified clusters, it was shown that 80% of all Phase I AFWERX projects emerged from cluster specific technologies. Overall, there were 210 projects within 150 miles of both cities. Of these 210 projects, 167 were classified to mirror the defined technologies of the two clusters. Furthermore, the inter-rater classification process yielded an overall rater-to-rater agreement of 91%. Once again, this well above our stated validity level of 75% interrater agreement.

For the Austin AFWERX location, there were 55 individual projects with the 150-mile radius. Of these 55 projects, 47 were classified as technologies from directly within the expertise of the cluster. These results yielded a capture rate of 85.5%. This shows strong support for the program's ability to capture cluster specific technologies within the Austin, TX technology cluster. In Washington, D.C., there were 155 individual projects within the given radius around the technology cluster. 120 of these projects were coded as fitting into the specific technological expertise of this cluster. The results in Washington, D.C. yielded a capture rate of 77.4%. These results show that AFWERX has less of an ability to capture cluster specific technologies in

Washington as compared to Austin. However, a 77.4% capture rate still shows a strong ability to capture technologies directly relating to the innovation hub.

Capture rates for both AFWERX locations and the total capture rate between the two locations combined was tested using the hypothesis test shown in Figure 5. An alpha value was set at .05 to give a 95% confidence level in the concluded outcomes.

H_o: AFWERX Capture Rate = Prevalence of Technologies
H_a: AFWERX Capture Rate < Prevalence of Technologies

Figure 5

A simple one-tailed test was conducted. The one-tailed test was used to show if the program was able to capture at least the prevalence of technologies from the area. Prevalence of technologies is defined as the percent of total patents covered by our formal definition, or the top CPC codes, for each cluster. A rejection of the null hypothesis would show statistical evidence that AFWERX was not capturing technologies of at least a rate equivalent with the prevalence of technology covered in that area.

For Austin, TX, the prevalence of technology was 81% and the AFWERX capture rate was found to be 85.5%. Utilizing the 5% alpha to create the rejection region for this null would mean that a capture rate of less than 76% would be needed. Due to our calculated rate above 76%, there is no statistical evidence that the AFWERX Austin location is capturing technologies as a rate lower than the 81% prevalence.

In Washington, D.C., the prevalence of technology was 80% and the AFWERX capture rate was found to be 77.4%. Again, utilizing the 5% alpha to create the rejection region. A calculated AFWERX capture rate would need to be less than 75% to reject null. The calculated capture rate above 75% provides no statistical evidence that the AFWERX Washington D.C. location is capturing technologies at a rate lower than the 80% prevalence.

For the combination of both locations, the prevalence of technology was 80.5% and the AFWERX capture rate was found to be 79.5%. This would create a rejection region of any capture rate below 75.5%. The overall AFWERX capture rate above the 75.5% provides no statistical evidence that the AFWERX is capturing technologies below the overall prevalence of 80.5%.

The overall capture rate of 80% highlights AFWERX ability to influence the types of innovative technologies that are participating in the program. From our research, it was shown that this ability is influenced by the location of AFWERX campuses and the clusters in which they are located. These results are useful to the United States Air Force and its vision for the AFWERX program. Support for the hypothesis that the co-location tactic allows for the effective ability to capture cluster specific technologies has been shown. Each technology cluster around the United States has differentiated areas of expertise. When the United States Air Force is in need of innovation in a certain type of technology type, an AFWERX office can be placed within a technology cluster holding that specialization to bring advancements in that given area.

Appendix A (Breakdown of Alpha-test project classifications)

Project #	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	Rater 6
1	x	x				
2	x	x				
3	x	x				
4	x	x				
5	x		x			
6	x		x			
7	x		x			
8	x		x			
9		x		x		
10		x		x		
11		x		x		
12		x		x		
13			x		x	
14			x		x	
15			x		x	
16			x		x	
17				x		x
18				x		x
19				x		x
20				x		x
21					x	x
22					x	x
23					x	x
24					x	x

Appendix B (Austin Projects)

Project #	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	Rater 6	Rater 7
1	x	x					
2	x	x					
3	x	x					
4	x	x					
5	x		x				
6	x		x				
7	x		x				
8	x		x				
9		x		x			
10		x		x			
11		x		x			
12		x		x			
13			x		x		
14			x		x		
15			x		x		
16			x		x		
17				x		x	
18				x		x	
19				x		x	
20				x		x	
21					x	x	
22					x	x	
23					x	x	
24					x	x	
25							x
26							x
27							x
28							x
29							x
30							x
31							x
32							x
33							x
34							x
35							x
36							x
37							x
38							x
39							x
40							x
41	x						x
42	x						x
43	x						x
44	x						x
45	x						x
46	x						
47	x						
48	x						
49	x						
50	x						
51	x						
52	x						
53	x						
54	x						
55	x						

Appendix C (Washington, D.C. Projects)

Project #	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	Rater 6	Rater 7
1		x					
2		x					
3		x					
4		x					
5		x					
6		x					
7		x					
8		x					
9		x					
10		x					
11		x					
12		x					
13		x					
14		x					
15		x					
16		x					
17		x					
18		x					
19		x					
20		x					
21		x					
22		x					
23		x					
24		x					
25		x					
26		x	x				
27		x	x				
28		x	x				
29		x	x				
30		x	x				
31			x				
32			x				
33			x				
34			x				
35			x				
36			x				
37			x				
38			x				
39			x				
40			x				
41			x				
42			x				
43			x				
44			x				
45			x				
46			x				
47			x				
48			x				
49			x				
50			x				
51			x	x			
52			x	x			
53			x	x			
54			x	x			
55			x	x			

Appendix C Continued (Washington, D.C. Projects)

Project #	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	Rater 6	Rater 7
56				x			
57				x			
58				x			
59				x			
60				x			
61				x			
62				x			
63				x			
64				x			
65				x			
66				x			
67				x			
68				x			
69				x			
70				x			
71				x			
72				x			
73				x			
74				x			
75				x			
76				x	x		
77				x	x		
78				x	x		
79				x	x		
80				x	x		
81					x		
82					x		
83					x		
84					x		
85					x		
86					x		
87					x		
88					x		
89					x		
90					x		
91					x		
92					x		
93					x		
94					x		
95					x		
96					x		
97					x		
98					x		
99					x		
100					x		
101					x	x	
102					x	x	
103					x	x	
104					x	x	
105					x	x	
106						x	
107						x	
108						x	
109						x	
110						x	

Appendix C Continued (Washington, D.C. Projects)

Project #	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	Rater 6	Rater 7
111						x	
112						x	
113						x	
114						x	
115						x	
116						x	
117						x	
118						x	
119						x	
120						x	
121						x	
122						x	
123						x	
124						x	
125						x	
126						x	x
127	OMIT						
128						x	x
129						x	x
130						x	x
131							x
132							x
133							x
134							x
135							x
136	x						x
137	x						x
138	x						x
139	x						x
140	x						x
141	x						
142	x						
143	x						
144	x						
145	x						
146	x						
147	x						
148	x						
149	x						
150	x						
151	x						
152	x						
153	OMIT						
154	x						
155	x						
156	x						
157	x						
158	x						

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IV. Conclusions and Recommendations

Chapter Overview

This chapter provides the answers to our three initial research questions. Furthermore, it provides recommendations for future research in several areas pertaining to the AFWERX program and the locations of its offices. Lastly, this final section states the overall significance of the research that has been presented in this thesis paper.

Evaluation of Research Questions

This section re-states the three initial research questions and provides a discussion that expands on the findings for each.

1. *What is the effect of the AFWERX office on company participation within 50, 100, or 150 miles of Austin, TX? (Article 1)*

Participation rates of companies partaking in both the SBIR & AFWERX programs was calculated by the number of companies participating within the three given mile radiuses around Austin, TX. The distance of a participating company to Austin, TX was determined by the straight-line distance from the zip code of that company to the most central zip code in Austin (78701). The population proportion of AFWERX participation rates was compared to population proportion rates of SBIR companies at each of the three distances. Evidence was able to show that the AFWERX location in Austin, TX was able to provide a statistically significant increased rate of participation by companies within 150 miles of Austin.

2. *What is the effect of the AFWERX office on company participation within 50, 100, or 150 miles of Washington, D.C.? (Article 1)*

Participation rates of companies partaking in both the SBIR & AFWERX programs was calculated for both programs by the number of companies participating within the three given mile radiuses around Washington, D.C. The distance of a participating company to D.C. was determined by the straight-line distance from the zip code of that company to the most central zip code in Washington, D.C (20001). The population proportion of AFWERX participation rates was compared to population proportion rates of SBIR companies at each of the three distances. Evidence was able to show that the AFWERX location in Washington, D.C. was able to provide a statistically significant increased rate of participation by companies within 50, 100, and 150 miles of Austin.

3. *How do the AFWERX office locations influence capturing technologies from within a cluster? (Article 2)*

By utilizing United States Patent data, the technology clusters for both Austin, TX & Washington, D.C. were able to be defined. The clusters were formally defined by the top patent classifications or technology types that were emerging from each location. After defining both clusters, each Phase I AFWERX project from within 150 miles of either cluster was classified. The classification was done using an inter-rater classification process which was able to determine whether or not the technology fit into the specified cluster. It was determined that 80% of all Phase I projects within 150 miles of either cluster was comprised of technologies that directly mirror the specialties of each innovation hub. These results show an ability for AFWERX to influence technology types based on geographic locations of their offices.

Areas for Future Research

The research conducted for this paper has uncovered several areas of interest for future research. More specifically, there are three major topics that would benefit from deeper research and analysis. These three topics are:

1) Does AFWERX have the ability to drive economic stimulus is areas due to increased rates of company participation in the region?

2) What is driving the observed spikes in AFWERX participation in other private technology clusters as compared to the SBIR participation spikes seen near DoD acquisition centers?

3) Why did companies in these regions choose to participate in the AFWERX program rather than SBIR? Do companies closer to AFWERX locations have a high rate of transitioning to use within the Air Force?

4) When is it beneficial for the Air Force to create an AFWERX office location within a technology cluster rather than financing and developing the needed innovation internally?

First, it has been shown that the location of AFWERX offices drive increased company participation within the region. Along with this increased participation may come a boost in economic stimulus due to an influx of capital being injected into the area. This stimulus could be very beneficial to certain areas all over the United States. Further, decision makers can use this as an added benefit when deciding where to place future AFWERX office locations. However, this benefit is in need of further research to determine how much stimulus an office location is able to drive and how the benefits can be leveraged for good within the economy and United States Air Force.

Second, the research revealed AFWERX participation spikes in distances that corresponded with several other known technology clusters across the United States. Furthermore, SBIR spikes were seen in distances that would line up with existing Air Force Acquisition centers across the country. Additional research as to why these two different spikes are occurring would be beneficial to both programs. The ability to understand factors creating these participation spikes in different locations would ultimately help to drive more effective marketing for each program. An increase in the effectiveness of either program would help to boost technology acquisition and innovation as a whole for the Air Force.

Third, a deeper dive into why companies chose to participate in the AFWERX program would be beneficial. One of the priorities of the AFWERX program directly mirrors the 2018 National Defense Strategy, which is to lower the barriers of entry for non-traditional defense partners to start doing more business with the Department of Defense. An analysis as to why participating companies choose to participate in the program could shed light on the progress of this initiative by the program. Furthermore, it would be interesting to determine if companies who are closer to an AFWERX campus have a higher than usual rate of transitioning products for full use within the Air Force or DoD.

Fourth, a fiscal comparison or economic analysis is crucial to determine decisions future innovation development decisions within the United States Air Force. The Department of Defense is entrusted to be good fiscal stewards of the citizens' taxpayer dollars. Because of this, research in the benefits of creating new AFWERX office locations versus internally funding innovation must be conducted. Within this paper it has been shown that AFWERX locations are able to generate increased participation and ability to capture cluster specific technologies. However, it is still to be determined whether these benefits are cost effective to the United States. An in-depth cost-benefit analysis would be beneficial to decision makers when deciding on the locations and operations of the AFWERX program into the future.

Significance of Findings

The findings within this paper are significant to the AFWERX program for several reasons. First, it has been shown that AFWERX is effective at both creating increased rates of participation by companies in the areas in which they have chosen to locate. Second, the program has seen success at capturing the cluster specific technological innovations from within these regions.

Both of these conclusions show that AFWERX has been effective in their tactic of increasing collaboration through placing themselves at the front door of technological innovations. AFWERX is able to effectively create external communication pathways and increase collaboration to leverage shared resources. The success of the collocation can be further used by the United States Air Force as well as other service components within the DoD to streamline the ability and efficiency of capturing new technologies for use against our adversaries. Once again, this is directly aligned with objectives from the 2018 National Defense Strategy to allow for the continued supremacy of the United States.

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13. SUPPLEMENTARY NOTES

14. ABSTRACT
The 2018 National Defense Strategy (NDS) emphasized capturing innovation through partnerships with non-traditional defense contractors. Furthermore, the NDS outlined the need to rapidly acquire new technologies to maintain a competitive advantage against our adversaries. The AFWERX program is the Air Force's attempt to accomplish these goals. AFWERX seeks to capture innovations occurring within the private sector of the United States by placing itself geographically within top innovation ecosystems. An approach that creates a setting where the Air Force is one of many investors, who benefit from the learning and investments across the entire network.

The research within this paper examines the effectiveness of this approach by evaluating AFWERX's 1) effect on participation rates by companies within given regions; 2) ability to capture specific technologies from within the areas that they have located. Analysis in this paper focuses specifically on the AFWERX Austin & Washington D.C. locations.

Participation rates were analyzed using a statistical comparison of population proportions by companies, within a given region, participating in the AFWERX program. Participation in AFWERX was compared to participation in the traditional Small Business Innovation Research (SBIR) program. To test the acquisition of cluster specific technologies, all projects from within 150 miles of Austin & Washington D.C. were classified for fit into the respective technology clusters. Each cluster was formally defined by the top patent types that emerged from the respective area. Overall, the analysis showed that AFWERX was effective in both increasing regional participation and targeting cluster specific technologies; location matters.

15. SUBJECT TERMS
Human-Agent Teaming; Adaptive Agent Response Time; Agent Predictability

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