Exploring the Vocational Interests of Cybersecurity Competition Participants

Masooda Bashir
University of Illinois at Urbana Champaign, Graduate School of Library & Information Science

April Lambert
University of Illinois at Urbana Champaign, Graduate School of Library & Information Science

Jian Ming Colin Wee
University of Illinois at Urbana Champaign, Department of Educational Psychology

Boyi Guo
University of Illinois at Urbana Champaign, Department of Statistics

Nasir Memon
New York University Polytechnic School of Engineering, Computer Science and Engineering Department

Abstract - The demand for cybersecurity professionals grows each year, and so do efforts to attract students to cybersecurity. One way educators, industry, and government have come together in a joint effort to train and attract talent is through cybersecurity competitions. However, it is unclear whether cybersecurity competition participants share similar interest profiles with those already employed in the field. This paper begins to explore that issue by assessing the vocational interests of cybersecurity competition participants using Holland's RIASEC model. Our results demonstrate that cybersecurity competition participants have vocational interests that can be characterized as investigative, social, and creative.

Keywords*: cybersecurity, competitions, vocational interests, RIASEC*

1. INTRODUCTION

The demand for cybersecurity professionals grows each year, and so do efforts to attract students to cybersecurity. In late 2014, the United States Congress passed several bills aimed at increasing the nation's cybersecurity. The Cybersecurity Workforce Assessment Act of 2014 (Pub.L. 113-246) directs the Department of Homeland Security to assess its cybersecurity needs and develop a plan to meet those needs. Congress also authorized a pay increase for government cybersecurity professionals, in an effort to attract talent and compete with the private sector. These efforts join the ranks of other government programs intended to increase the cybersecurity workforce and train these professionals, such as the Federal Cyber Service: Scholarship for Service Program, which awards scholarships to promising students interested in working for government upon graduation. Despite these efforts, both government and industry continue to struggle to fill professional cybersecurity positions.

Educators recognize this demand for cybersecurity professionals and have expended great effort over the last decade to identify and prepare students for cybersecurity careers. One way educators, industry, and government have come together in a joint effort to train and attract talent is through cybersecurity competitions. Such contests generally aim to (1) train the next generation of cybersecurity specialists using hands-on competition, and (2) enhance the interest of individuals already attracted to the field. Tens of thousands of young adults have participated in these contests worldwide; and there is widespread anecdotal evidence that shows the benefits of individual competitions [1, 2]. However, it is unclear whether cybersecurity competition participants share similar interest profiles with those already employed in the field. This paper begins to explore that issue by assessing the vocational interests of cybersecurity competition participants using Holland's RIASEC model [3] and, in particular, the interests of those students who have competed and then obtained professional employment in the cybersecurity field. The RIASEC model "is generally recognized as one of the most important and influential in the field of career development and vocational psychology" [4] and has been applied to myriad occupations. A 2014 review of RIASEC literature

located more than 2,000 articles on RIASEC theory [4] and a Google Scholar search of Holland's 1997 update of the model (originally published in 1985) generates over 4000 citations [5]. The U.S. Department of Labor's Employment and Training Administration has also integrated RIASEC into its O*NET Online career exploration tool [6].

As discussed in this paper, the RIASEC model assists with identifying vocational personality characteristics and matching them with congruent occupations. Understanding students' vocational interests, and whether they are a match for the cybersecurity field, would assist educators in identifying students who may need particular encouragement to attend cybersecurity competitions in an effort to increase their interest in a career in the field. Further, understanding the vocational interests of cybersecurity competitors and professional is one element that could contribute to the development of an assessment tool for identifying students well suited for the cybersecurity profession.

2. BACKGROUND AND RELATED WORK

While vocational and career assessment measures have a long history in the area of educational psychology, these tools have only recently been used to identify the particular interests and traits of computer science students. Even more rare are efforts to use these tools to assess cybersecurity students. Holland's RIASEC model has become a standard used to assess vocational interests [3]. This model assumes six vocational personality types – **R**ealistic, **I**nvestigative, **A**rtistic, **S**ocial, **E**nterprising, and **C**onventional. There are also six work environments that can be characterized in the same way. The best fit or congruence for workers and workplace occurs when the three-letter code matches. Using a standard measure, people can be assigned a three-letter code that identifies the three areas in which they score the highest. Workplaces can be assessed by determining the most common personality type in that workplace. Each of the six types describes personality characteristics that manifest in "an increasing differentiation of preferred activities, interests, competencies, and values" [3]. Holland's typology includes the following:

1) Realistic – a preference for activities that include the explicit, ordered, or systematic manipulation of object, tools, and machines;

2) Investigative – a preference for activities that include the observational, symbolic, systematics, and creative investigation of physical, biological, and cultural phenomena;

3) Artistic – a preference for unsystematized activities that include the manipulation of physical, verbal, or human materials to create art forms or products;

4) Social – a preference for activities that include the leading or manipulation of others to inform, train, develop, cure, or enlighten;

5) Enterprising – a preference for activities that include the manipulation of others to attain organizational goals or economic gain; and

6) Conventional – a preference for activities that include the explicit, ordered, and systematic manipulation of data.

Other researchers have found that Holland's RIASEC model is stable across ethnic groups and gender [7, 8, 9] and that it is useful for students as young as middle school age [10].

The RIASEC model has been included in the U.S. Department of Labor's O*NET career exploration tool, which provides detailed descriptions of a broad range of career options for jobseekers [6]. Using the Standard Occupational Classification system to define particular careers, the O*NET Online application allows jobseekers to search for particular occupations and learn about the skills and characteristics necessary to be employed in that field. Business can also use the database to assist them with developing job descriptions and refining recruitment techniques. For each occupation, the RIASEC model is included as a three-letter "interest code" meant to represent the closest fit for job satisfaction. The closest entry for "cybersecurity" in the O*NET Online database is "Information Security Analyst," which is described as those tasked to "Plan, implement, upgrade, or monitor security measure for the protection of computer networks and information.

May ensure appropriate security controls are in place that will safeguard digital files and vital electronic infrastructure. May respond to computer security breaches and viruses." [11] This description is includes tasks beyond those necessary for a cybersecurity competition, and, as discussed below, the "interest code" reported in the database of CIR differs from what we found in our research, as well as what other researchers have found in related areas. The O*NET codes were developed by expert researchers matching tasks and job descriptions to particular codes, not by assessing a population of those employed in the occupation [11]. Whether this accounts for the differences in finding described herein, or whether cybersecurity competitors are not representative of the broader cybersecurity profession, needs to be determined through future research.

Several researchers have applied the RIASEC model to understand computer science students and professionals [12, 13, 14] though as far as we can tell only one other research team has looked specifically at cybersecurity students. A common finding of the researchers who have applied RIASEC to computer science is the high frequency of the investigative personality type, though one paper [12] reported detailed three-letter codes for a number of subgroups in computer science. Turner et al. [15] assessed high school students using several psychological measures before, during, and after a "cyber science" residential camp program to determine whether their interest in and perceived value of the subject changed. They noted that several factors differed between the male and female students, particularly with regard to how interest levels changed during the camp, and that the investigative vocational interest, which was the dominant RIASEC type, and self-efficacy factors were mediated by situational interest. Turner et al. reported only that high school cyber science students scored most highly on the investigative part of RIASEC – they did not report the three-letter code for the students. Do cybersecurity students have a different vocational personality profile than other computer science students? Do those who pursue cybersecurity careers after attending a cybersecurity competition differ from those who choose other career paths? This paper seeks to answer those questions.

3. METHODS & MEASURES

To obtain respondents for this survey, 8,000 participants of the longest-running cybersecurity competition, associated with the Cyber Security Awareness Week (CSAW) Conference held annually at New York University Polytechnic School of Engineering, were emailed a link to an online survey. An incentive of a $10 Amazon gift card was offered to each participant who completed at least 70% of the survey. The survey asked for a range of information about the participants, including (1) demographic information, (2) competition experience, (3) hacking practice, (4) intentions or actuality of pursuing a cybersecurity career (depending on age), and (5) responses to several standard psychological, career inventory, and cultural measures, including RIASEC.

In all, 588 people responded to the survey, and 360 participants (306 Males and 48 Females) completed the RIASEC-related portion (as they were not required to complete the entire survey). Our results are thus limited not only by the fact that our population includes only those who have competed in this particular competition, but also that only a subset of that population responded to our survey request . The RIASEC measure employed was constructed by truncating the O*NET version of the RIASEC assessment measure from 60 to 30 items by random selection of items from each subscale [16]. Twelve participants were identified as inefficient effort responders and thus removed from the analysis because they responded identically for all items throughout the survey. The shortened scale had an internal consistency of Cronbach's Alpha = .904. The RIASEC participants included high school, college, and graduate students, as well as those employed both in cybersecurity careers and non-cybersecurity careers.

4. RESULTS & ANALYSIS

Overall Group

As shown in Figure 1 below, the average three-letter high-point RIASEC code for competition participants was ISA, with investigative being the dominant interest. That social and artistic interests were the next highest scores for students and

employees in the cybersecurity field differs from that found for most general computer science populations. For example, Haliburton et al.'s assessment of computer science faculty and students found that, while every subgroup scored highest on investigative, only female computer science faculty members scored ISA [12]. Several of the other groups they assessed (which included computer science faculty and graduate students, and undergraduate students who either majored or minored in computer science) came out high on social, but no other group had artistic in their three-letter code. This difference between cybersecurity students and computer science students could be attributed first to the fact that the competition involved group work and thus could have attracted those with a higher social score, and also to the notion that cybersecurity may attract those in computer science seeking a fit for their creative interests. This result is also different from the CIR code listed in the O*NET Online tool for Information Security Analysts. Again, this may be explained by noting that cybersecurity competitions require social and artistic skills not reflected in as broad a classification as O*NET is using. It is also possible that the Information Security Analyst category is not the most appropriate one for assessing cybersecurity careers. Future research should be done to explore this.

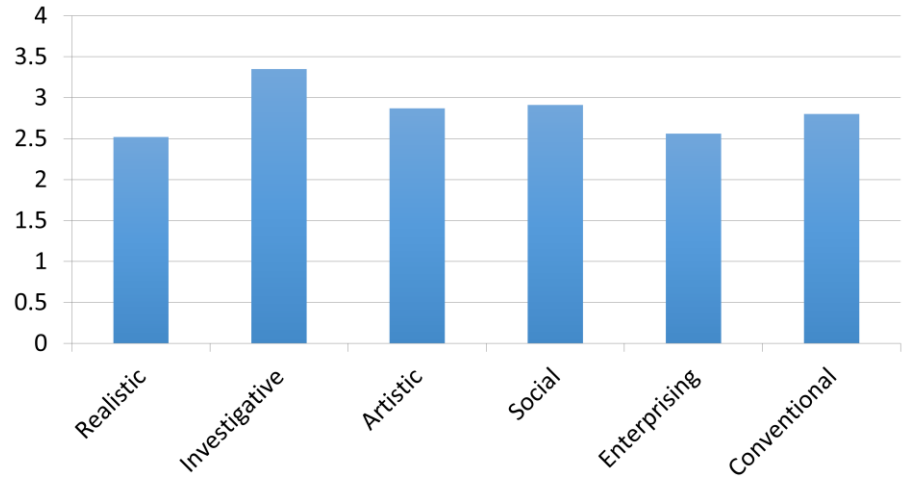

Figure 1. Means of Interest Scores (N=360)

Gender Differences

As Figure 2 shows, the average three-letter high-point code was ISA for males and AIS for females. Females showed generally higher interest scores for all six subscales, and independent samples t-tests for each subscale between sexes showed that females had significantly different scores on the artistic, social, enterprising and conventional subscales but not the realistic and investigative subscales. Further subgroups analysis for females and males was not conducted because the sample size for females would become too small for meaningful analysis.

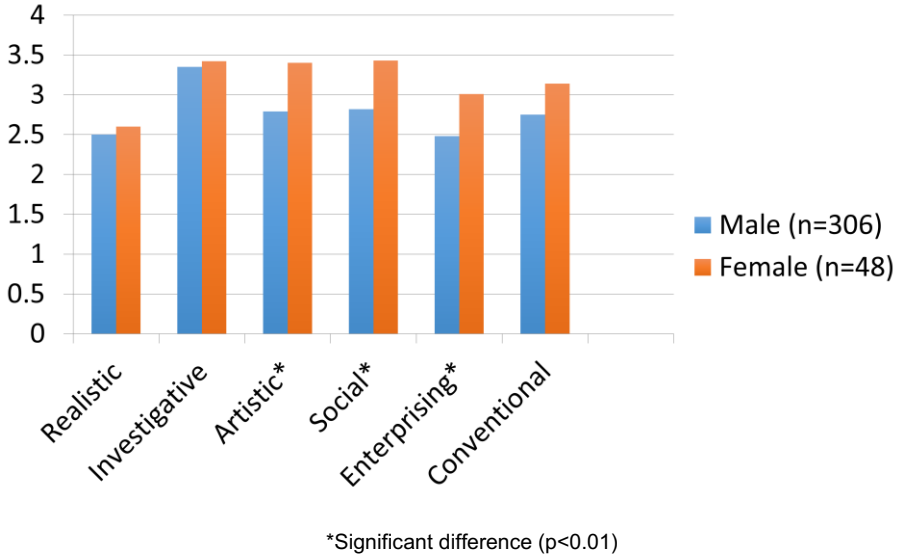

Figure 2. Means and Standard Deviations of Interest Scores

The higher scores for female participants overall, and the significant difference in a number of the types could be explained by differences in the perceived obstacles for male and female students in STEM fields. In a stereotypically male-prevalent field such as cybersecurity, only the upper percentile of the normal distribution of interested females might choose to venture into this discipline or vocation. Conversely, males who are less interested towards many activities overall might still choose cybersecurity because of their same-sex peers and similarity towards the

stereotypical employee of cybersecurity [17]. That female students have to be even more interested in their male peers to pursue a particular career is not unique to cybersecurity in the computer science, or even more generally STEM, field [12, 13]. Turner et al. examine this problem at length in their assessment of high school students participating in a cybersecurity-related camp.

Differences between Students and Full-Time Employees

In the survey, participants reported if they were primarily high school students, undergraduates, graduates, or full-time employees. Those who reported as both students and part-time employees were classified as students. This section examines the interest profiles of each of these demographics to better understand the types of people that cybersecurity competitions attract. As Figure 3 shows, the interest profiles for the different groups varied. Not one group itself was the same as the overall group's ISA code. High school participants scored IAC, which introduces the creative type at a loss of the social type. The interest profile for undergraduates was ISC, which also introduces creative, but this time at the loss of artistic. The interest profile for graduates was SIC – the only one not to score highest on investigative. By the time competitors reach the graduate level, social activities predominate even over investigative activities. This differs from the general computer science graduate students examined by Haliburton et al. [12], who all tested highest in investigative. The interest profile for employees in cybersecurity careers was IAS and did not differ from those former competitors now employed in non-cybersecurity careers. Post-hoc Tukey tests from a multivariate ANOVA showed that graduates had significantly higher social scores compared to both full-time employees and high schoolers ($F = 3.59$, $p = .01$). Post-hoc tests from the MANOVA also showed that graduate students also had significantly higher enterprising scores than undergraduate participants and full-time employees ($F = 3.39$, $p = .02$). Again graduate students who participate (or have participated) in cybersecurity competitions stand apart from the others.

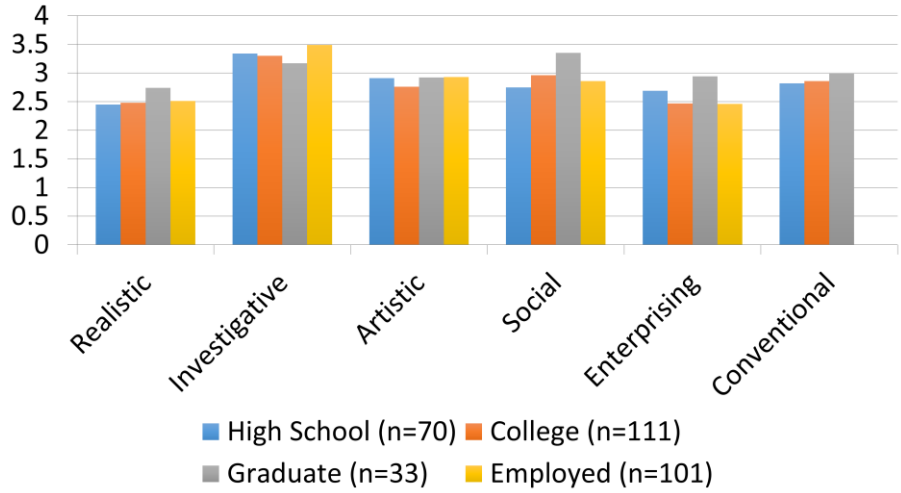

Figure 3. Descriptive Statistics by Student or Employment Group

All of these differ from the O*NET Information Security Analyst profile and from many of the profiles of computer science faculty and students found by Haliburton et al. But is it cybersecurity itself or competitions that are attracting the higher percentage of students interested in social activities? Only an assessment of a broader population of cybersecurity professionals, not just those who attended competitions, can answer this question.

Cybersecurity Employees & Students Who Want to Pursue Cybersecurity Careers

On the survey, participants were asked whether they were interested in pursuing a cybersecurity career after having participated in the competition. A total of 233 (65.63%) people responded "yes," 48 (13.52%) people responded "no," and 74 (20.85%) were unsure. We also collected data on each participant's student or work status. One way to evaluate if competitions are successful in drawing like-minded, interested newcomers into the field of cybersecurity would be to examine the interest profiles of employees already in the field of cybersecurity and the different kinds of students who answered 'yes' on their willingness to join the cybersecurity field. One limitation here is that we only have data from cybersecurity employees

in the competition, which may not be representative of the entire cybersecurity employee population.

To do this, we first refined the full-time employed participants to select only those who are in the cybersecurity field. As Figure 4 shows, the average interest profile for full-time employees in the cybersecurity field who participated in this competition was IAS – almost the same as the overall group of ISA. The average profile for high school students who said they would like to pursue a career in cybersecurity was IAC. The average interest code for undergraduate students who want to pursue cybersecurity was ISC, while the average interests for graduate students pursuing a cybersecurity career was SIC (again graduate students were the only group not leading with investigative). While the three-letter high-point codes were different between each demographic, a multivariate analysis of variance showed that there were no differences in the mean interest scale scores between demographics (see Table 1).

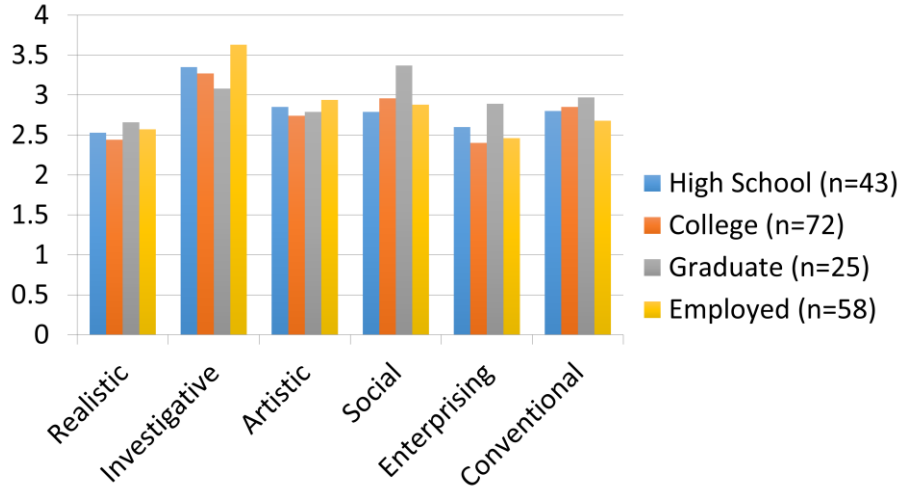

Figure 4. Subgroup Descriptive Statistics of Those Interested in Pursuing a Cybersecurity Career

	Wilks' Lambda	F	df1	df2	Sig.
Real	.993	431	3	194	.731
Invest	.961	2.590	3	194	.054
Artist	.992	.542	3	194	.654
Social	.968	2.168	3	194	.093
Enter	.969	2.100	3	194	.102
Conven	.989	.709	3	194	.548

Table 1. Tests of Equality of Group Means

While the dominant interests and order of interests may differ between cybersecurity employees, highs schoolers, undergraduates, and graduates who expressed their desire to enter the cybersecurity field, the magnitude of their interests on the six different RIASEC scales are not significantly different from one another. This lack of a significant difference in interest scores suggests that participants who say that they would like to join cybersecurity after the competition are on the whole similar in interests to those already employed in the cybersecurity field. An interesting point to note is that people with different interest high-point codes might find cybersecurity more appealing at different levels of education, but more longitudinal evidence would be needed to verify this claim.

Can we use interest scores to predict if a participant will want to join cybersecurity?

As discussed above, participants were asked whether they were interested in pursuing a cybersecurity career after attending a competition. One of our research aims was to investigate if interest scale scores could predict if a participant would respond "yes" or "no" to this question, ignoring the ambivalent responders. A discriminant function analysis with prior probabilities calculated from group sizes was performed using the six RIASEC scale scores to examine group differences in

interest scores and predict membership into "yes" or "no" responders. This analysis was carried out twice, either excluding or including the "yes" responders who were currently already employed in cybersecurity. Their removal did not change the result so we left them in. The standardized canonical discriminant function that resulted was:

Discriminant 1 = .54Realistic + .70Investigative - .77Artistic + .64Social - .40Enterprising - .15Conventional

People who said "yes" to a future in cybersecurity have high Discriminant 1 scores (centroid at .11) while those who said "no" to a future in cybersecurity had lower Discriminant 1 scores (centroid at -.52). This function was significant (Λ = .95, X^2= 14.81, p = .02), suggesting that there was a significant difference in interests between the two groups. Univariate ANOVAs showed that "yes" responders scored significantly higher in the investigative scale (M_1 = 3.38, M_2 = 3.06; F = 4.49, p = .04). Through examining the correlations between the variates and the discriminant score, high scores on the discriminant function are mainly associated with participants reporting high investigative interests, realistic interests, and social interests.

The discriminant function correctly classified 82.9% of originally grouped cases, and it tended to over-predict the number of people who would say 'yes'. To evaluate this result, we compared prediction hit rates for random classification, probability matching, and probability maximization. Random classification of half the original candidates into "yes" and half into "no" would have a 50% hit rate. Given the non-uniform marginal distribution of participants, randomly assigning 233 (i.e. 82.9%) of participants in the "yes" group and 48 into the "no" group would net a probability matching hit rate of .829(.829) + 171(.171) = 71.6%. Finally probability maximization—assigning all subjects to the majority 'yes' group, would get a hit-rate of 82.9%. Therefore, the discriminant function is better at sorting participants than random classification or probability matching, but is only as good as probability maximization. One reason for this is that a large proportion of participants entering cybersecurity competitions already have intentions and interest in pursuing a career in cybersecurity, so using interests to predict careers in

cybersecurity from a competition sample might not be as useful compared to acquiring interest data from a more general sample.

5. SUMMARY & FUTURE WORK

Our assessment of cybersecurity competition participants' vocational interests Holland's RIASEC model demonstrated the following:

1) Cybersecurity competition participants score highest in the investigative, social, and artistic areas, which differs to some extent from other computer science-related groups. The social aspects of group competition and the creative aspects of cybersecurity problem solving may explain this difference.

2) Female cybersecurity competition participants score significantly higher than their male counterparts on four of the six personality types, indicating a broader and more intense interest level for female students. This can be explained by the intensity of interest needed to overcome stereotypes and other barriers for female students.

3) While the three-letter codes of student groups and employed cybersecurity competitions participants varied, these differences were not significant. Cybersecurity competition participants who say they intend to pursue cybersecurity careers have similar vocational profiles to those who do go on to employment.

4) A discriminant function is better at determining whether students who participate in cybersecurity competitions are interested in pursuing a cybersecurity career than random chance, but only as good as probability maximization. An assessment of the vocational profile of the cybersecurity profession as a whole, not just those who attended competitions, would be necessary to develop the predictability of this function.

Overall, it seems that students with artistic and social inclinations, not just investigative skills, should be encouraged to attend cybersecurity competitions if we want to increase the cybersecurity workforce. Female students, in particular, who exhibit these characteristics should be encouraged to overcome other barriers that

hold them back from cybersecurity activities. Additionally, emphasizing the protective and helping aspects of cybersecurity careers may attract more female students to the field. To determine whether the finding here speak only to those who attend competitions, or can be generalized to the cybersecurity profession as a whole, an assessment would need to be done for cybersecurity professionals who have not attended competitions. Then we could investigate whether competitions are an effective tool for identifying future cybersecurity professionals. This would also provide some context for why our results and those of Haliburton and Turner differ from the O*NET profile. For now, however, we have determined that social and artistic personality characteristics – not just investigative ones – are congruent with cybersecurity activities.

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