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# High School Cybersecurity? Challenge Accepted – Radford University's RUSecure CTF Contest for High School Students

# Goal of Scare, Prepare, and Dare

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- Increase the number of students motivated to pursue further study in Computer Science and Information Technology, and more specifically Cybersecurity

# Challenges in K-12 Cybersecurity

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- The barrier of teacher preparation
- The need for long prerequisite chains
- Lack of computing resources

# Approach

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- RUSecure CTF was developed to adapt the strategies of *just-in-time* and *active learning* to Cybersecurity
- Teams of students are provided challenges that start from very basic and progress to quite advanced.
- To obtain the flag, students must solve the challenge and if they do not have the required background knowledge for the challenge, they can refer to short multi-media lectures or notes.

# Approach

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- Eliminate the barrier of teacher preparation by providing easily accessible, short, high impact materials associated with each challenge.
- Eliminate the need for long prerequisite chains by providing prerequisite knowledge in a just-in-time manner associated with each challenge.
- Eliminate the barrier of lack of computing resources by providing student teams access to a secure, isolated cyber-range hosted by Radford University.

# Related Work



This project was greatly influenced by several related efforts in teaching Cybersecurity to high school students. These efforts broadly fall into two categories:

- ***Extra-curricular programs*** *(after school, summer camps, summer workshops, informal clubs and competitions)*. By far, these programs seem to be the most popular. These include:, the Air Force Association's CyberPatriot, the CSAW-Cyber high school forensics competition, Hacker High School, the National Board of Information Security Education cyber camps, and SANS CyberAces to list a few.
- ***Formal computer-security curriculum for K-12***. These include curricula developed in schools with technological and personnel resources to support such courses as well as comprehensive courses such as those from Teach Cyber – from DARK enterprises, Hacker High School that teach the basics of Cybersecurity in K-12. https://teachcyber.org/about/

# RUSecure Contest History

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- The RUSecure Contest began in 2014 with approximately 35 students from partner high schools and with support from a series of NSA MEPP grants as well as in-kind support from Cypherpath
- Contest is open to high school, home school, and community college students
- Contest has expanded through the years in terms of schools participating, total number of students, topics included, and from local to regional, and now national, footprint
- Participation in the RUSecure Contests is free.  Contest has been supported by funding from NSA, NSF, Commonwealth Cyber Initiative (CCI) as well as Radford University

# Growth of the Contest

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| Year | Number of Teams | Number of Students | Number of Schools |
|---|---|---|---|
| 2014 | 9 | 36 | 4 |
| 2015 | 13 | 56 | 7 |
| 2016 | 18 | 81 | 9 |
| 2016-2017 | 70 | 303 | 32 |
| 2017-2018 | 130 | 546 | 58 |
| 2018-2019 | 345 | 1449 | 106 |
| 2019-2020* | 505 | 2057 | 123 |
| 2020-2021* | 302 | 1233 | 70 |

# Scare, Prepare, and Dare

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It is interesting to note that the numbers dramatically changed in 2016-2017 when the Contest was expanded from one round to three rounds:

- Preparatory Round - open to all participants; includes hints and educational materials (motivation and education – Scare and Prepare)
- Qualifying Round - open to all participants but without the hints and educational materials (motivation and assessment – Dare)
- Final Round which is open to the top teams from the Qualifying Round (motivation and assessment – Dare and Celebrate).

# RUSecure Contest Organization

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- The RUSecure CTF Contests challenge students in a wide variety of topic areas including
  - Anatomy of an attack
  - Networking
  - Cryptography
  - Hashing
  - Forensics
  - Web security
  - Windows/Linux security
  - Reverse engineering.
- Contests have also included challenges involving hacking of IOT devices as well as securing systems and devices from attack.

# RUSecure – Preparatory Round

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- The Preparatory Round, which is several weeks in duration, provides an opportunity for students to learn a great deal of material in a short period of time, motivated by challenges and supported by hints, videos, and other educational materials
  - The points do not matter!
- Beginning in the fall of 2019, the Preparatory Round was expanded to 12 weeks in order to give teachers maximum flexibility on how to integrate the Contest into their classroom

# RUSecure – Qualifying Round

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- The Qualifying Round, generally limited to two weeks, provides an opportunity for students to test their mettle against their peers and continue to hone their skills while competing for an invitation to the Final Round
- When the Final Round was introduced in 2017, only the top 7 teams from the Qualifying Round were invited to the Finals
- Beginning in 2019, in order to make sure that all areas of the Commonwealth of Virginia had the opportunity to participate, we began inviting the top placing team from each of Virginia's eight VDOE Regions, as well as the top 7 remaining teams, regardless of location.

# RUSecure – Final Round

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- The Final Round is a 1-day, typically on-campus event, where the top-placing teams from the Qualifying Round compete for prizes and scholarships
- The 2019 Final Round was live-streamed on the front page of Twitch.tv
- More information is available about the RUSecure CTF Contest at https://www.twitch.tv/rucsat/video/406645013
- The 2021 Final Round was a virtual event.

# RUSecure – The Challenges

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- The RUSecure CTF Contest is made up of a variety of challenges
- Each challenge is constructed with the challenge itself, the required flag, and any hints or associated educational materials
- The contests are built upon an open-source product called CTFd.
- CTFd also provides back-end features allowing administrators to monitor the contest in real-time, analyze how teams are performing on each challenge, look at submissions including incorrect answers, and adjust on the fly
- The CTFd environment also includes a Scoreboard to allow teams to keep track of their relative performance in the contest.

# RUSecure – The Challenges

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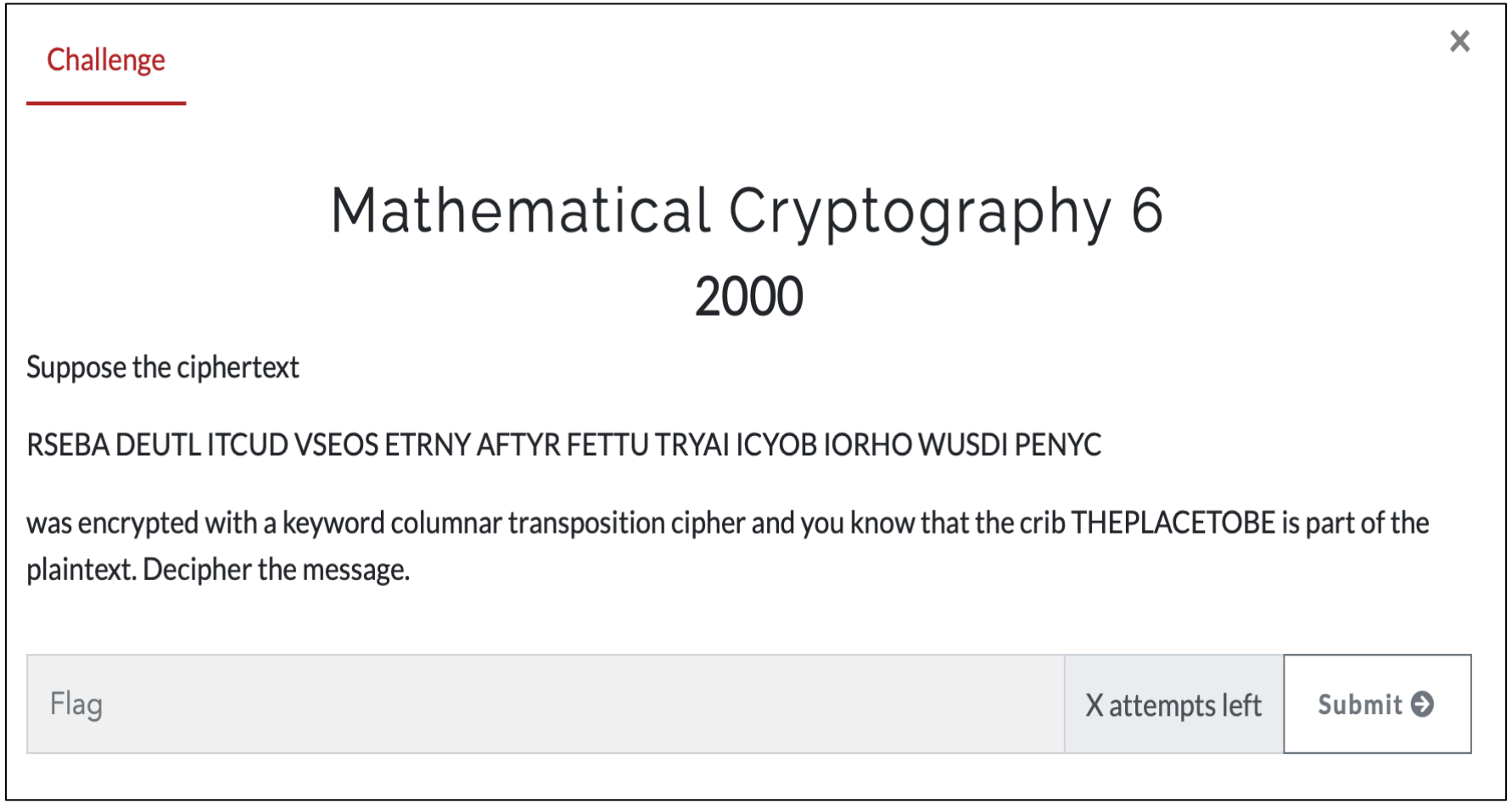

# RUSecure – The Challenges

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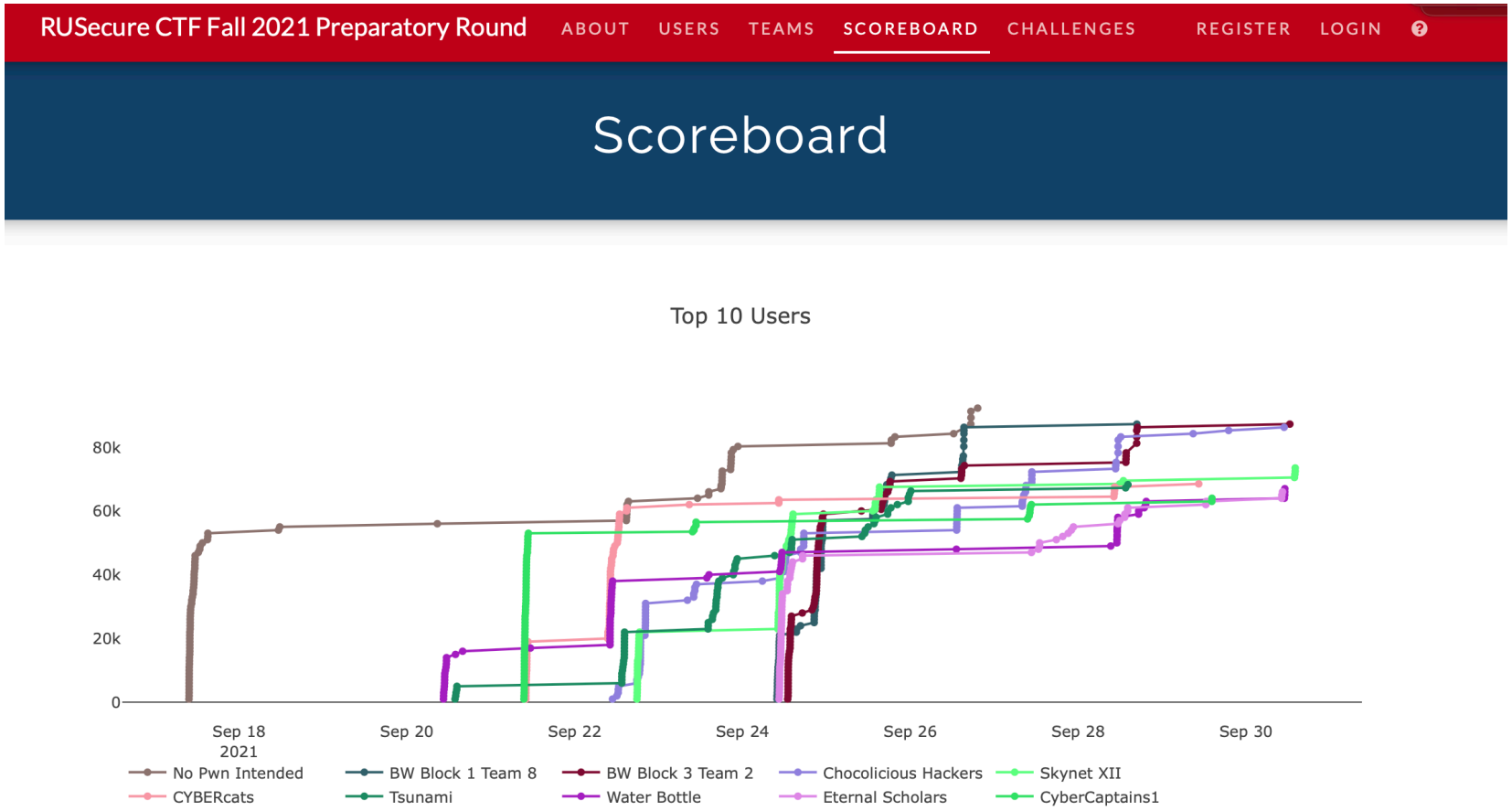

# RUSecure – Impact

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- It is difficult to directly measure the effectiveness of the CTF strategy separate from coursework and other preparation
- We have collected a great deal of evidence of the impact of the RUSecure strategy through
  - surveys of coaches and students
  - direct discussions with coaches and students
  - observing the choices and success of some of the RUSecure CTF contestants

# RUSecure – Impact

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- We measure our success through the following questions:
  - Market Penetration – What is the reach of the Contest within the Commonwealth of Virginia?
  - Utilization – How are high school and community college instructors making use of the Contest to support their classrooms?
  - Effectiveness – What is the impact of the Contest for those that participate?

# RUSecure – Market Penetration

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- Our goal is to ensure that a student's zip code should not determine their opportunities in Cybersecurity
- Early on in the development of the RUSecure Contest, it became apparent that there is a large disparity in the opportunities available to high school students
  - Simply put, the large suburban school districts have more resources available in the area of Cybersecurity
  - This has been demonstrated repeatedly by both the participation in the Contest and the success in the Contest (i.e. making it to the Final Round)

# RUSecure – Effectiveness

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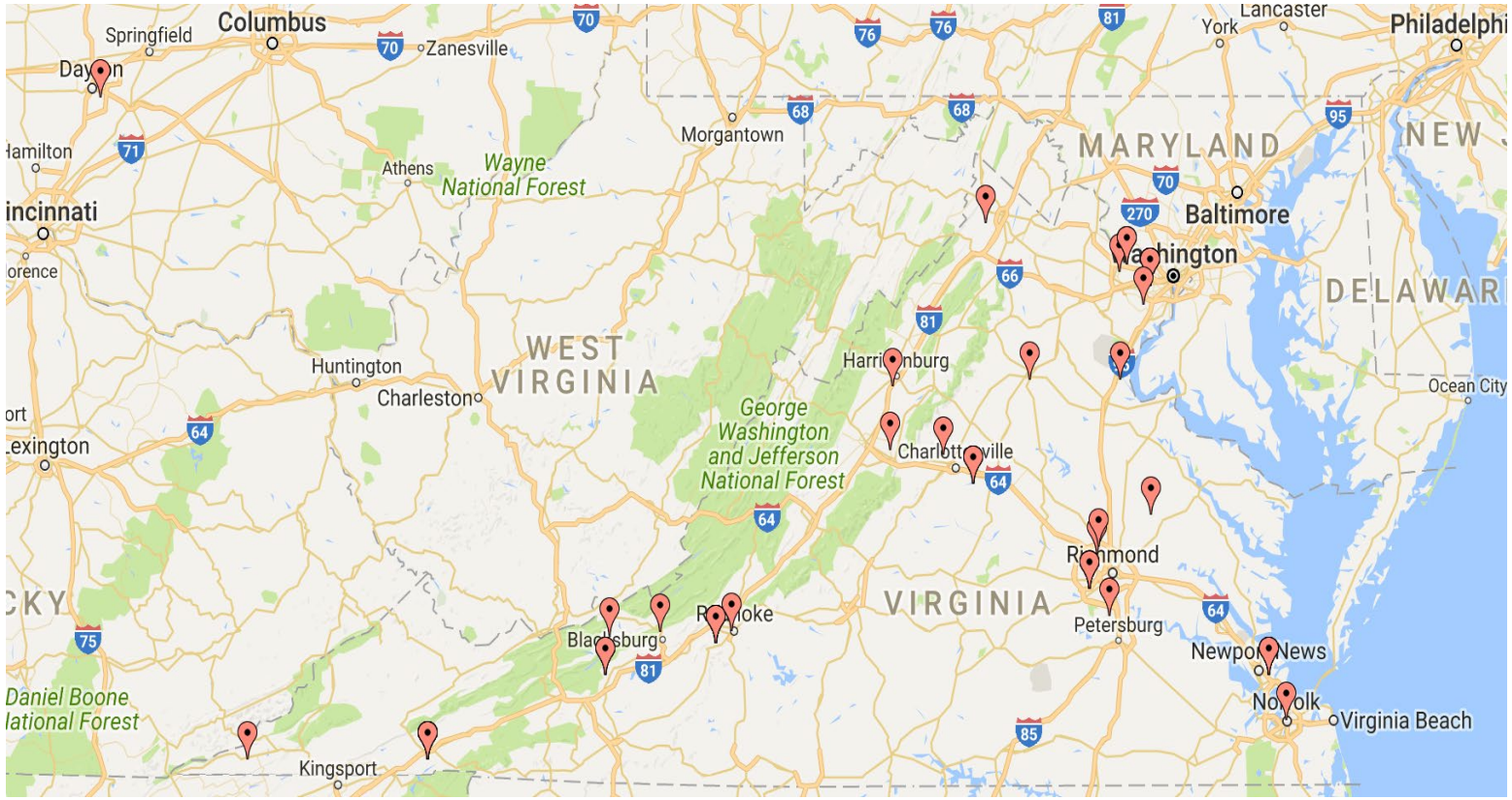


Locations of teams competing in the 2018 RUSecure Preparatory Round

# RUSecure – Effectiveness

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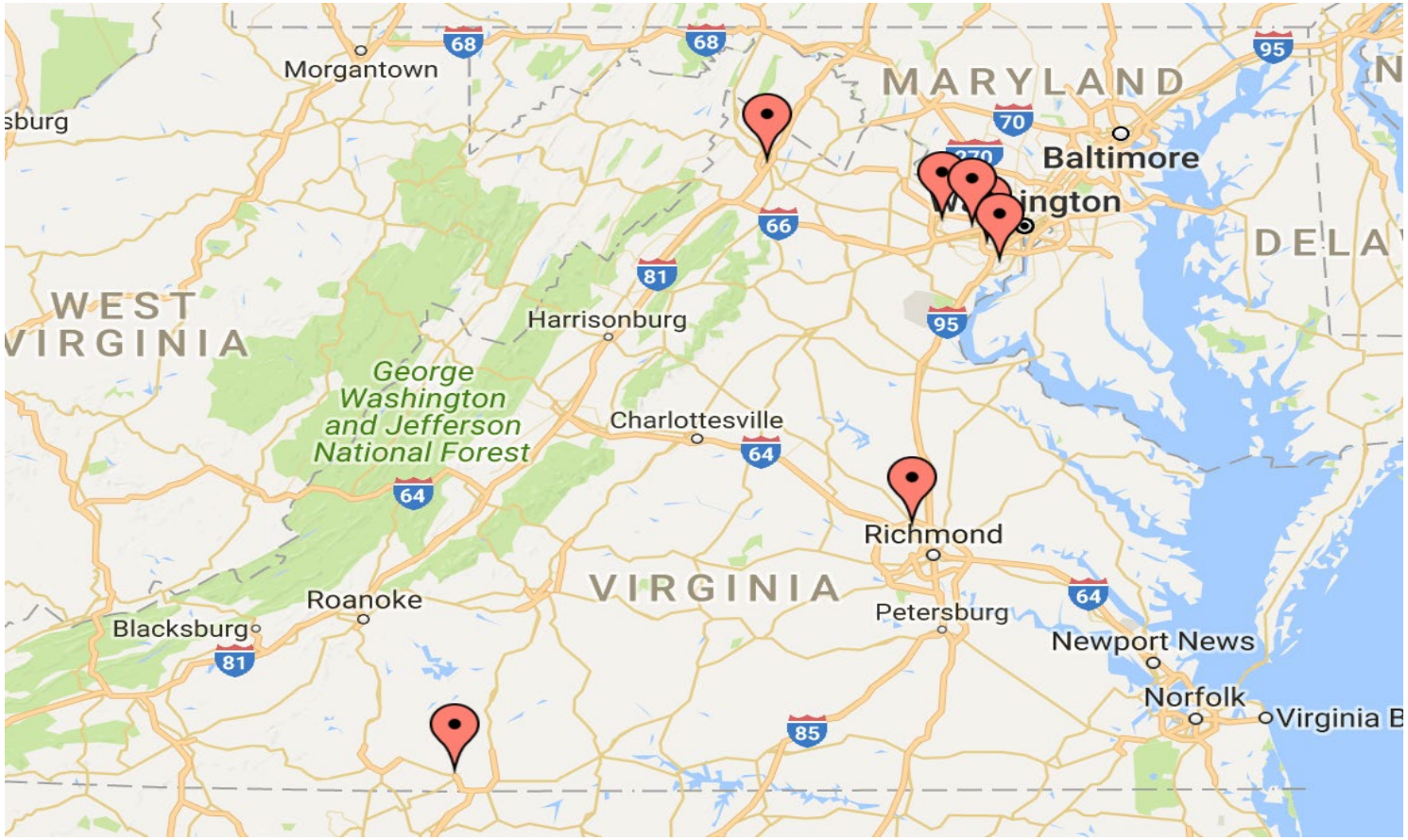


Locations of teams competing in the 2019 RUSecure Final Round

# RUSecure – Utilization

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- We intentionally redesigned the Preparatory Round starting in the fall of 2019 to expand it to three full months to allow teachers more freedom to incorporate the Contest into their classroom more effectively.
- Multi-year survey results tell us that teachers have used the Contest as both graded and ungraded work, both inside and outside of the classroom, and as part of Cybersecurity club activities.
- We have also seen an expansion of the utilization of the Contests by grade level.
  - In the initial contest, virtually all of the participants were high school seniors or community college students.
  - Teachers are now registering students as young as the 8$^{th}$ grade meaning that the same students are participating year over year .

# RUSecure – Effectiveness

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- In their comments about the contest both in formal surveys and informal conversations, teachers/coaches rave about the motivation, engagement, and time on task for their students participating in the contests
- That deeper level of understanding is also reflected in the scores. In the 2018 Preparatory Round, two teams cleared the board (i.e. solved every challenge) and several more teams were very close. This had not happened in any of the prior contests
- While direct measure of the effectiveness of the contests themselves remains challenging, we have been able to measure the CTF strategy in other ways. For example, the same strategy was applied to a graduate course to prepare K-12 teachers to teach Cybersecurity. 92% of the educators who participated in the CTFs among those who responded to the survey indicated that *the CTFs helped them to understand the material faster than a traditional lecture*.

# RUSecure – Conclusions

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- The CTF approach which implements the just-in-time strategy of teaching is highly effective in keeping students motivated and helps in covering a vast array of topics without requiring extensive pre-requisites
- Our efforts indicate that not only is it possible to provide an introduction to Cybersecurity to students with a very limited IT/CS background, but it is possible to do so in a highly engaging manner
- Live Preparatory Round Contest is happening now at https://rusecurectf.Radford.edu

# Questions?

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