

# Matthew Cole

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🏢 Department of Computer Science

Thomas J. Watson College of Engineering and Applied Science

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## Curriculum Vitae

### Education

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|---------------------|--|
| May 2024 (expected) | <b>Ph.D. Computer Science</b> , State University of New York at Binghamton University, Binghamton, New York.<br>Dissertation: <i>Enforcing Integrity Models Through Hardware-Software Cohesive Systems</i> |
| August 2018         | <b>M.Sc. Computer Science</b> , State University of New York at Binghamton University, Binghamton, New York.<br>Thesis: <i>Integrity Models</i>  |
| May 2005            | <b>B.Sc. Computer Science</b> , United States Naval Academy, Annapolis, Maryland.<br>Graduated <i>With Merit</i> , Upsilon Pi Epsilon  |

### Dissertation

Advisor: Aravind Prakash

Integrity models are a principled defense mechanism that express a property of well-functioning software, then enforce that property continually at runtime. Unfortunately, these integrity models are often implemented in a way that compartmentalizes hardware from software. We present work that unifies these in a single cohesive view. First, we show that existing hardware resources can be repurposed to support software-layer defenses without onerous impacts to performance. Then, we present a modified LLVM compiler toolchain used to enforce a diverse body of integrity models through code and data tagging. Next, we investigate how to optimize a label-based integrity model to minimize binary size increases while maximizing expressiveness of the integrity model. Finally, we propose using tagging to enforce a read- and write-limited data model, thus bringing forward compile-time data type qualifiers as run-time assurances.

### Publications

- [1] Ravi Theja Gollapudi, Gokturk Yuksek, David Demicco, Matthew Cole, Gaurav Kothari, Rohit Kulkarni, Xin Zhang, Kanad Ghose, Aravind Prakash, and Zerkis Umrigar. Control flow and pointer integrity enforcement in a secure tagged architecture. In *2023 IEEE Symposium on Security and Privacy (SP)*, pages 2974–2989, May 2023.
- [2] David Demicco, Matthew Cole, Shengdun Wang, and Aravind Prakash. A security analysis of labeling-based control-flow integrity schemes. In *2022 IEEE 29th International Conference on High Performance Computing, Data and Analytics Workshop (HiPCW)*, pages 47–52, Dec 2022.
- [3] Matthew Cole and Aravind Prakash. Simplex: Repurposing Intel Memory Protection Extensions for Secure Storage. In Hans P. Reiser and Marcel Kyas, editors, *Secure IT Systems*, pages 215–233, Cham, 2022. Springer International Publishing.
- [4] David Demicco, Matthew Cole, Gokturk Yuksek, Ravi Theja Gollapudi, Aravind Prakash, Kanad Ghose, and Zerkis Umrigar. Generic tagging for risc-v binaries, 2022.
- [5] Anh Quach, Matthew Cole, and Aravind Prakash. Supplementing modern software defenses with stack-pointer sanity. In *Proceedings of the 33rd Annual Computer Security Applications Conference, Acsac '17*, page 116–127, New York, NY, USA, 2017. Association for Computing Machinery.

## Experience

### Research Experience

- 2018-2022      **Research Assistant** Research Foundation for the State University of New York. Binghamton, New York
- Repurposed Intel Memory Protection Extensions for generalized storage, and implemented analyses for the LLVM compiler toolchain to replace memory accesses with these inlined register operations.
  - Engineered an implementation of the RISC-V architecture employing inline code for integrity models from compiler-driven static program analysis techniques, using the LLVM compiler toolchain.
  - Extended our implementation of the RISC-V architecture and LLVM compiler toolchain to perform out-of-band data tagging, with the ability to perform relaxation and linkage resolution at link-time using a modified version of the LLD linker.
  - Developed a prototype extending data tagging for a read- and write-limited data model that specifically enforces compile-time `const` qualifiers as run-time assurances.
- 2015-2016      **Graduate Assistant** Binghamton University. Binghamton, New York
- Developed a technique for extracting design patterns from C++ source code and encoding as a finite state machine with an XML machine-readable representation
  - Researched scientific utilization of performance benchmark tools for the computer security domain.

### Research Interests

Hardware-software cohesive design for resilient system security through compiler design, program analysis, and reverse engineering.

### Teaching Experience

- 2022-Present      **Lecturer** Binghamton University. Binghamton, New York
- Fall 2023 – CS 580U: Programming Systems and Tools
  - Fall 2022 – CS 580U: Programming Systems and Tools
  - Spring 2022 – CS 458, CS 558: Introduction to Computer Security
- 2017-2018      **Teaching Assistant** Binghamton University. Binghamton, New York
- Spring 2023 – CS 458, CS 558: Introduction to Computer Security
  - Spring 2018 – CS 480, CS 580: Special Topics: Software Security
  - Fall 2017 – CS 220: Computer Systems II, Architecture and C Programming

### Courses Prepared to Teach

- Systems programming in C, Rust, and Assembly Languages.
- Compilers: lexers, parsers, optimizers, and code generation.
- Computer security: authentication and cryptographic techniques, intrusion detection, access control, security policies, reverse engineering, offensive and defensive technologies in software security.
- Programming systems and tools with C, C++ or Python.

### Professional Experience

- 2011-2014      **Instructor**, Trident Training Facility, Bangor, WA.
- Qualified as Instructor, Instructor Evaluator and Course Supervisor. Served as Navigation Department Director, managing a department of 40 instructors and 11 labs. Awarded Navy and Marine Corps Commendation Medal with Gold Star.
  - Improved annual throughput in a ship piloting simulator by 18% (75 sessions) by repairing over 30 script files and qualifying two new instructors. Created an additional 32 trainer sessions per month by guiding a comprehensive lab redesign.
  - Delivered lectures for 120 submarine officers annually (66% increase) and practical skills training for 23 ships, earning a “highly effective” rating by external auditors.

## Experience (continued)

**Intern**, United States Naval Research Laboratory, Washington, DC.

- Prototyped a Java Management Extension (JMX) for Mobile Ad Hoc Wireless Networks (MANETs) serving city-sized distributed sensor networks in real-time.

## Service

### Professional Service

2021	ACSAC Artifact Committee	<a href="https://www.acsac.org/2021/committees/artifact/">https://www.acsac.org/2021/committees/artifact/</a>
2020	ACSAC Artifact Committee	<a href="https://www.acsac.org/2020/committees/artifact/">https://www.acsac.org/2020/committees/artifact/</a>
2017	ACSAC Artifact Committee	<a href="https://www.acsac.org/2017/committees/#artifact">https://www.acsac.org/2017/committees/#artifact</a>

### University Service

2018-2019	Binghamton University Graduate Student Organization Judicial Officer
2016-2018	Binghamton University Graduate Student Organization Senate

## Skills







Languages	C, C++, Python, x86/RISC-V/ARM assembly, LLVM IR, Rust, Java
Operating Systems	Unix/Linux (Debian/Ubuntu/Solaris), MacOS
Benchmarking	SPEC CPU 2006/2017, Hayai, Google Benchmark
Testing	CUnit, Google Test, Boost.Test, Python unittest, LLVM Lit
Build/Deploy	GNU Make, CMake, Github Actions, Travis-CI, Git
Reverse Engineering	Ghidra, Hopper

## Miscellaneous

### Citizenship and Security Clearance

U.S. Citizen. Held SECRET (2001-2006) and TOP SECRET/SCI (2006-2014) clearances.

### Links

 Github Pages	<a href="https://colematt.github.io">https://colematt.github.io</a>
 Github	<a href="https://github.com/colematt">https://github.com/colematt</a>
 Google Scholar	<a href="https://scholar.google.com/citations?user=GfQ-ozgAAAAJ">https://scholar.google.com/citations?user=GfQ-ozgAAAAJ</a>
 OrcID	<a href="https://orcid.org/0000-0003-1743-1504">https://orcid.org/0000-0003-1743-1504</a>
 LinkedIn	<a href="https://www.linkedin.com/in/matthewcole4/">https://www.linkedin.com/in/matthewcole4/</a>
 Keybase	<a href="https://keybase.io/colematthew">https://keybase.io/colematthew</a>