National Institute of Standards and Technology
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Security Mindsets in Organizations that Develop Cryptographic Products

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Visualization & Usability Group

Championing the Human in Information Technology

- Public Safety
- Biometrics Usability
- AI User Trust & Usability
- Usability Standards
- Usable Cybersecurity & Privacy

NIST Usable Cybersecurity

Championing the Human in Cybersecurity

- Conduct research and usability testing at the intersection of cybersecurity and human factors
- Provide actionable guidance so that the human element can be considered in cybersecurity decisions, processes, and products

Usable Cybersecurity Projects

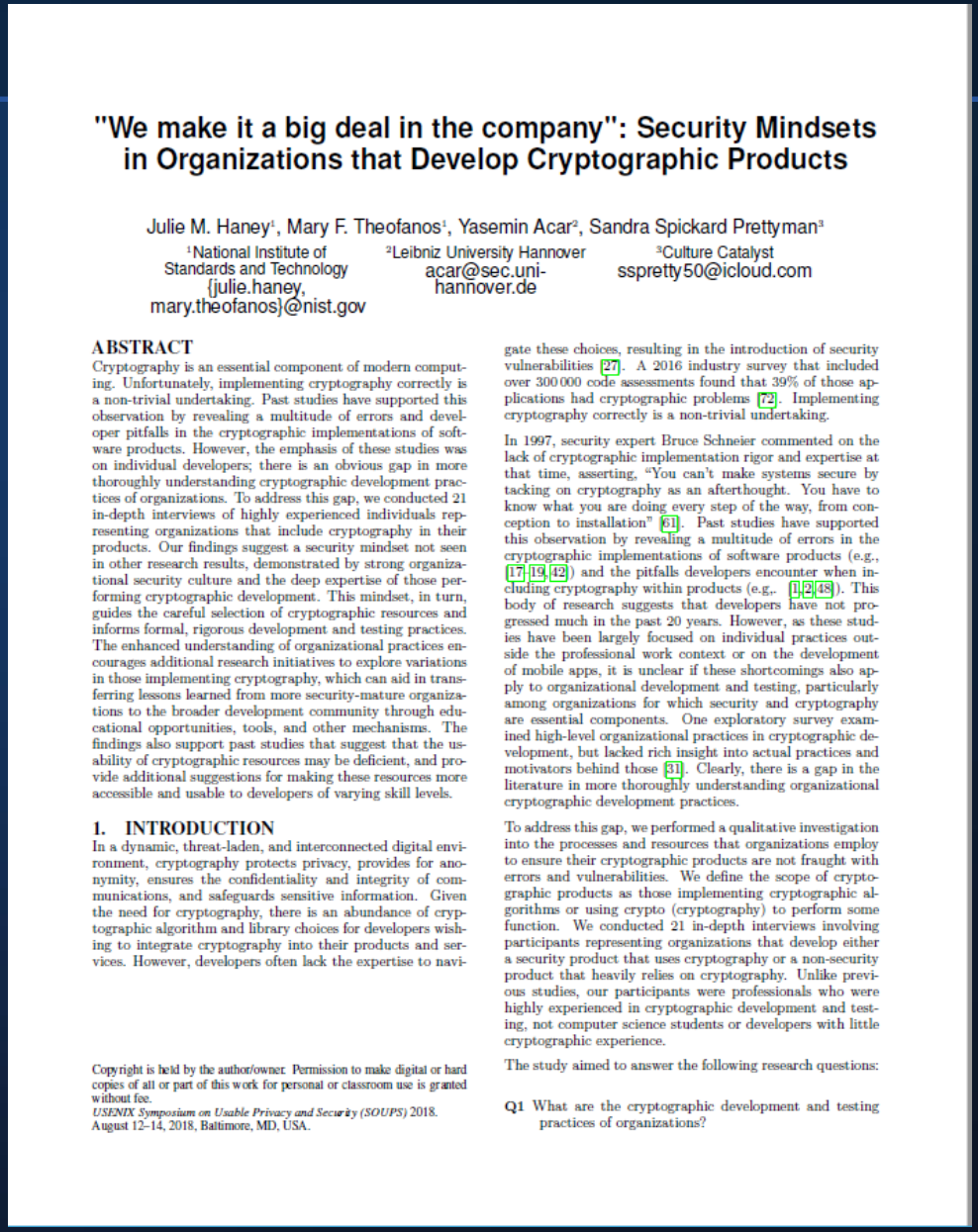
Past Efforts

- Authentication
- Security & privacy perceptions
- Cryptographic development
- Social media privacy

Current Efforts

- Youth passwords & security
- Phishing difficulty & susceptibility
- Smart home security & privacy
- Security adoption & awareness

“We make it a big deal in the company”: Security Mindsets in Organizations that Develop Cryptographic Products



"We make it a big deal in the company": Security Mindsets in Organizations that Develop Cryptographic Products

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ABSTRACT

Cryptography is an essential component of modern computing. Unfortunately, implementing cryptography correctly is a non-trivial undertaking. Past studies have supported this observation by revealing a multitude of errors and developer pitfalls in the cryptographic implementations of software products. However, the emphasis of these studies was on individual developers; there is an obvious gap in more thoroughly understanding cryptographic development practices of organizations. To address this gap, we conducted 21 in-depth interviews of highly experienced individuals representing organizations that include cryptography in their products. Our findings suggest a security mindset not seen in other research results, demonstrated by strong organizational security culture and the deep expertise of those performing cryptographic development. This mindset, in turn, guides the careful selection of cryptographic resources and informs formal, rigorous development and testing practices. The enhanced understanding of organizational practices encourages additional research initiatives to explore variations in those implementing cryptography, which can aid in transferring lessons learned from more security-mature organizations to the broader development community through educational opportunities, tools, and other mechanisms. The findings also support past studies that suggest that the usability of cryptographic resources may be deficient, and provide additional suggestions for making these resources more accessible and usable to developers of varying skill levels.

1. INTRODUCTION

In a dynamic, threat-laden, and interconnected digital environment, cryptography protects privacy, provides for anonymity, ensures the confidentiality and integrity of communications, and safeguards sensitive information. Given the need for cryptography, there is an abundance of cryptographic algorithm and library choices for developers wishing to integrate cryptography into their products and services. However, developers often lack the expertise to navigate these choices, resulting in the introduction of security vulnerabilities [27]. A 2016 industry survey that included over 300 000 code assessments found that 39% of those applications had cryptographic problems [72]. Implementing cryptography correctly is a non-trivial undertaking.

In 1997, security expert Bruce Schneier commented on the lack of cryptographic implementation rigor and expertise at that time, asserting, “You can’t make systems secure by tacking on cryptography as an afterthought. You have to know what you are doing every step of the way, from conception to installation” [61]. Past studies have supported this observation by revealing a multitude of errors in the cryptographic implementations of software products (e.g., [17, 19, 42]) and the pitfalls developers encounter when including cryptography within products (e.g,. [1,2,48]). This body of research suggests that developers have not progressed much in the past 20 years. However, as these studies have been largely focused on individual practices outside the professional work context or on the development of mobile apps, it is unclear if these shortcomings also apply to organizational development and testing, particularly among organizations for which security and cryptography are essential components. One exploratory survey examined high-level organizational practices in cryptographic development, but lacked rich insight into actual practices and motivators behind those [31]. Clearly, there is a gap in the literature in more thoroughly understanding organizational cryptographic development practices.

To address this gap, we performed a qualitative investigation into the processes and resources that organizations employ to ensure their cryptographic products are not fraught with errors and vulnerabilities. We define the scope of cryptographic products as those implementing cryptographic algorithms or using crypto (cryptography) to perform some function. We conducted 21 in-depth interviews involving participants representing organizations that develop either a security product that uses cryptography or a non-security product that heavily relies on cryptography. Unlike previous studies, our participants were professionals who were highly experienced in cryptographic development and testing, not computer science students or developers with little cryptographic experience.

The study aimed to answer the following research questions:

Q1 What are the cryptographic development and testing practices of organizations?

USENIX Symposium on Usable Privacy and Security (SOUPS) 2018. August 12–14, 2018, Baltimore, MD, USA.

Problem

Correct, secure crypto implementation can be hard

> You can’t make systems secure by tacking on cryptography as an afterthought. You have to know what you are doing every step of the way, from conception to installation.

-- Bruce Schneier, Why cryptography is harder than it looks

Purpose

To develop a deeper understanding of organizations' practices and associated challenges when developing and testing products that use cryptography

Research Questions

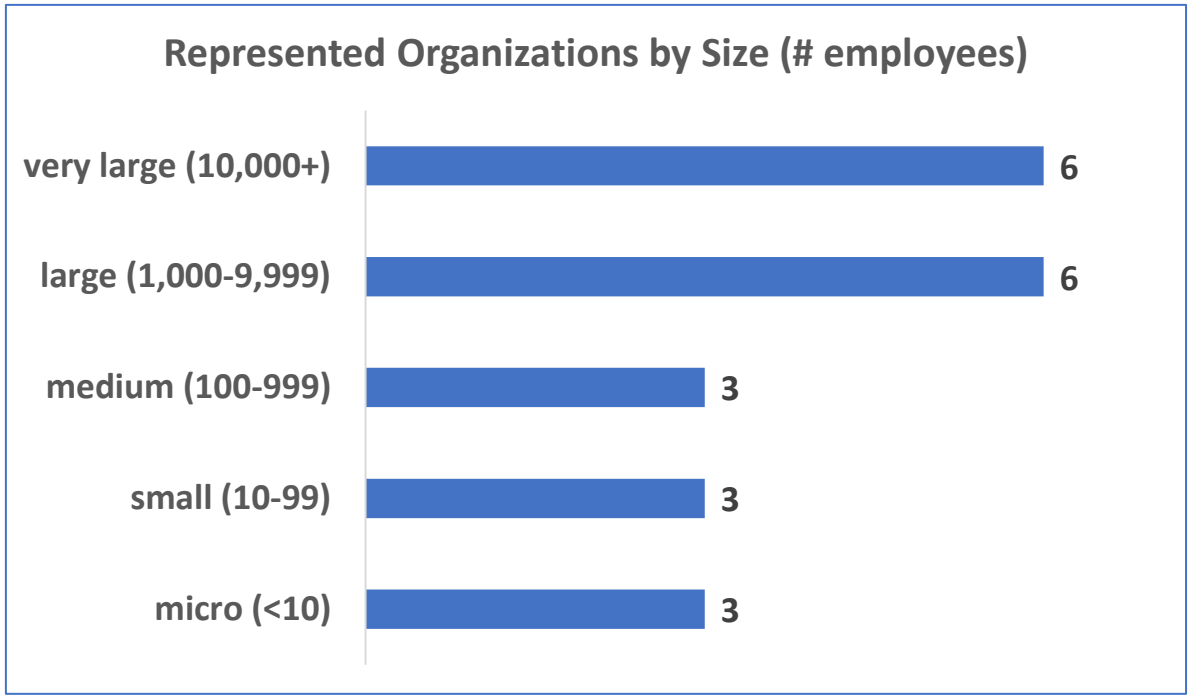
- What are the cryptographic development and testing practices of organizations?
- What challenges do organizations encounter while developing and testing cryptographic products?
- What cryptographic resources (e.g., standards, certifications, libraries, documentation) do these organizations use, and what are their reasons for choosing these?

Methodology

- Interview study of 29 representatives from 21 organizations that develop products that use cryptography
- Interview questions
  - Professional background and org information
  - Development and testing practices
  - Challenges
  - Use of and suggested improvements to crypto resources

Organizations

- Varying sizes
- All developed either a security product that used crypto or a non-security product that heavily relied upon crypto to protect it
- Hardware and software products
- Customers included home consumers, internal org groups, orgs/companies in multiple sectors



Participants

- All had 10+ years of experience
- At least one from each org either currently worked on crypto/security as major component of their jobs or had worked on crypto extensively in the past
- All had STEM degrees, but most had learned crypto on-the-job
- 4 had been involved in crypto standards groups

Overarching Theme

Compared to developer populations in prior studies, the organizations in our study appeared to have a stronger security culture and were more mature in their crypto and security experiences.

These security mindsets permeated the entire development process as they informed selection of crypto resources and rigorous development practices.

Security Mindset Characteristics

Emphasis on Experience and Maturity

> The level of education somebody needs to attain to be effective at doing crypto is relatively high. So, it's not like I can put somebody who's fresh out of school on something and expect good results.

Recognition of the Complexity of Cryptography

> Crypto algorithms are already very highly optimized…It's like balancing a supertanker on a 40,000-foot-high razor blade, and if you make one small change, you destroy the performance. If you make it the other way, you just destroy the security.

Security Culture

Commitment to security

> All engineers get training on secure design, and we make it a big deal in the company.

Perpetuating a security mindset

> We take smart people who care about doing good work, and we foster an environment where they're not afraid to receive constructive criticism.

Size doesn't matter

> Being a small company, we're trying to gain credibility…We cannot afford for this thing not to work properly.

Selection of Resources

Standards

Standards are vetted and provide assurance.

> The standard, because it's out there and everybody's looking at it and testing it, we depend on that as kind of a layer of security.

But they can be difficult to use.

> The standards were a challenge to use because they were very divorced from the implementation day-to-day details that I encounter when I'm trying to plug all the pieces together.

Certifications

Some orgs believe certifications provide assurance.

> You have a lot of assurance that everything's going to be tested and get that nice, kind of warm and fuzzy.

Others are more skeptical about the value of certifications.

> FIPS 140 is…not focused on how to use crypto securely. It's focused on how to safely provide crypto functionality.

Third-Party Implementations

> [Crypto libraries] in general don't provide enough to be able to use them correctly out of the box…But there's many out there that think that they can just use AES. "I included it and I'm using it." But I'm not using it correctly, and then I'm leaving myself open to attack.

Academic & Research Resources

> We don’t reference academic papers. They’re not where we are in understanding the test problem…
> There’s a six-year gap between the methods that we developed being identified in academia.

Development & Testing Rigor

Formal Processes

> We have architects that do security reviews, that do threat modeling. And it's not just about the crypto but more in general, how do you use the product? Who gets to do what? What are the risks? How do we mitigate those risks?...And one of the items for the engineering gate release is making sure...we mitigated anything that needs to be mitigated.

Development & Testing Challenges

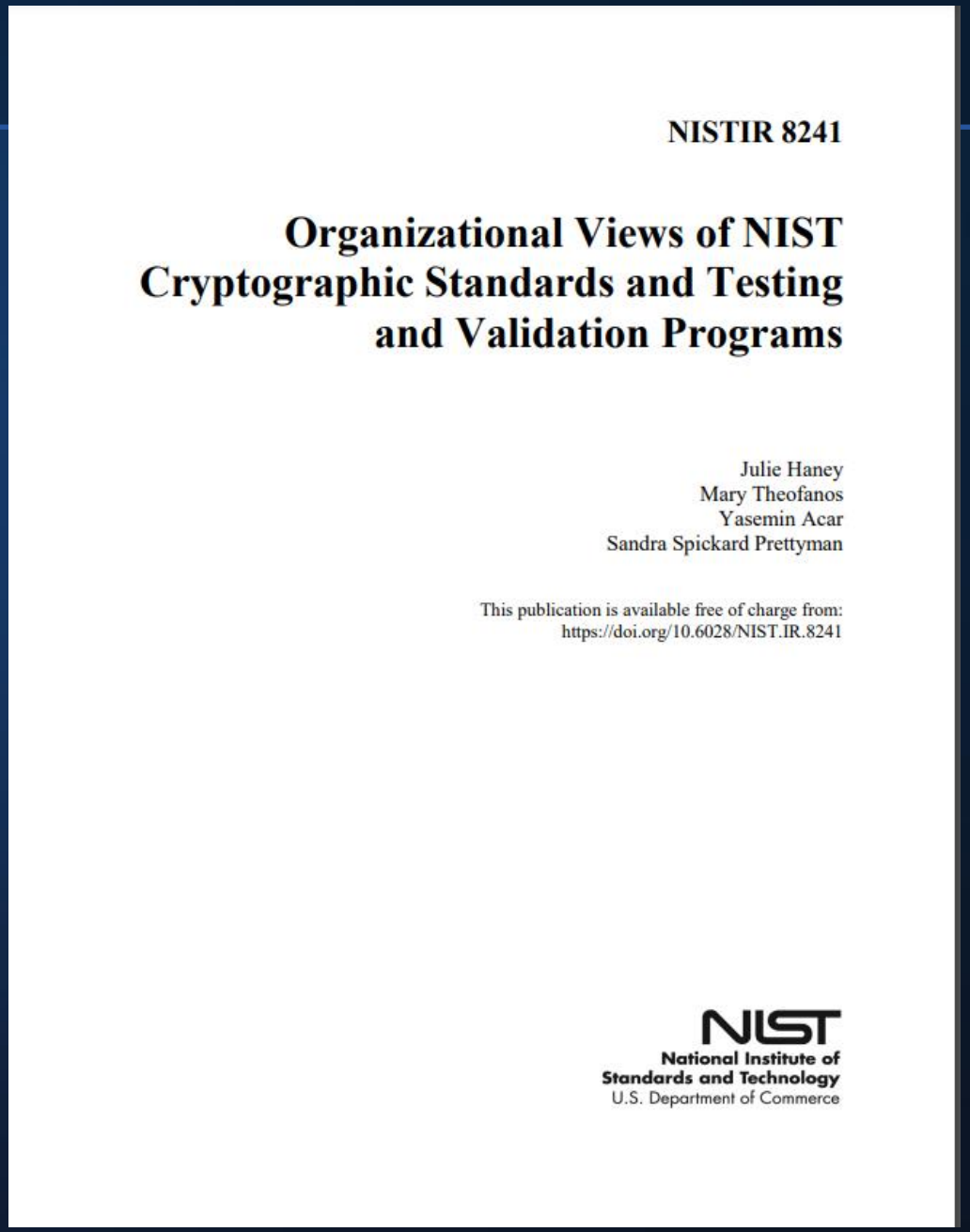
- Time to market vs. security
- Vulnerability testing
- Longevity of products
- Product updates
- Test vectors
- Keeping up with standards
- Multiple platforms

Takeaways

Contributions

- Explores crypto development practices and security mindsets in *organizations* from viewpoint of those with extensive experience in the field
- Provides systematic validation to anecdotal point that good crypto is the result of a concerted effort
- Aids in transferring lessons learned from more security-mature orgs to the broader development community
- Suggests usability improvements for crypto resources

NISTIR 8241 Organizational Views of NIST Cryptographic Standards and Testing and Validation Programs



NISTIR 8241

Organizational Views of NIST Cryptographic Standards and Testing and Validation Programs

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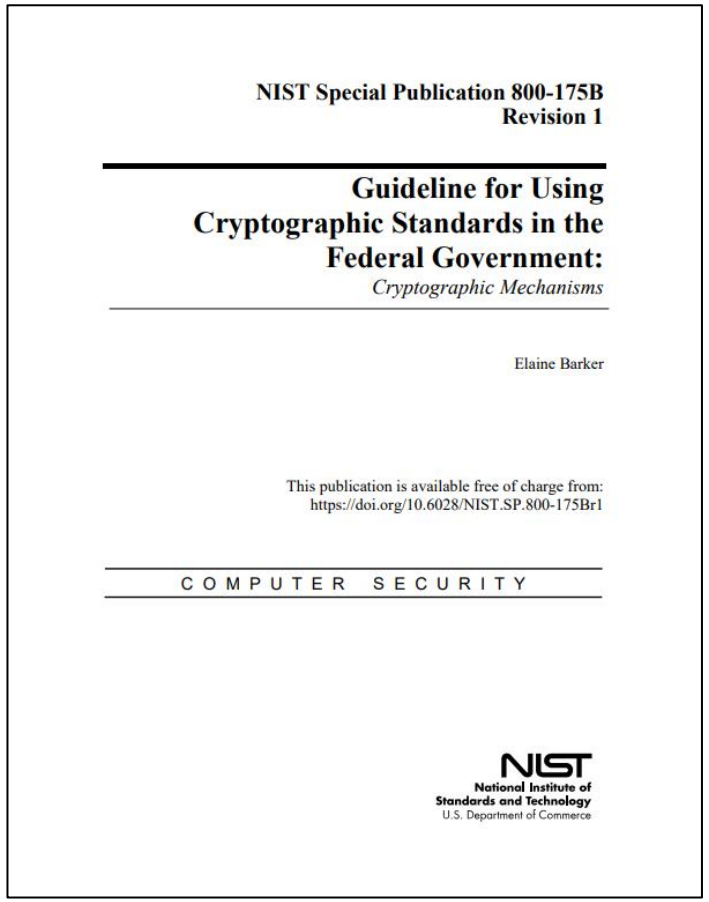
NIST Crypto Standards



NIST Special Publication 800-175B
Revision 1

Guideline for Using Cryptographic Standards in the Federal Government:
Cryptographic Mechanisms

Elaine Barker

This publication is available free of charge from:
https://doi.org/10.6028/NIST.SP.800-175Br1

COMPUTER SECURITY

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- Benefits
  - Solid implementation basis
  - Quality
- Challenges
  - Complexity
  - Lack of context
  - Updates to standards
  - Inadequate test data/vectors

NIST Testing/Validation Programs & Certifications

- Benefits
  - Added assurance/confidence
  - Customer acceptance
- Challenges
  - Complexity of requirements
  - Resource burden
  - Perceptions of lack of value added
  - Product updates
  - Certification status of third-party components

Education and Awareness

Product customers

> What our customers want is they ask for FIPS-compliant software…They don't mention any particular profile…They just want to do FIPS. That's what their understanding is.

Developers and engineers

> Maybe there's a series of crypto for beginners…I bet NIST has a ton of experts that they could either do this in slides or a video. And then maybe those folks…would actually kind of get guided up, and then they'll figure out how to get ot the next level.

Trust of NIST and Governments

Many trust and respect NIST's expertise

> I'm repeatedly impressed by working with people at NIST how competent they are, and how easy it is to work with them compared to a lot of other organizations.

But others distrust government standards

> Governments who with their consistent attempts to make bad standards – to impact standards, break cryptography – get bad cryptography into specs

Thank you!

Whitfield Diffie

Pioneer of public-key cryptography and 2015 recipient of Turing Award

https://primetime.bluejeans.com/a2m/live-event/uvyugstq

Questions?

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https://csrc.nist.gov/usable-cybersecurity

Haney, J.M., Theofanos, M.F., Acar, Y., & Prettyman, S.S. (2018). “We make it a big deal in the company”: Security Mindsets in Organizations that Develop Cryptographic Products. *Proceedings of the Symposium on Usable Privacy and Security*. https://www.usenix.org/system/files/conference/soups2018/soups2018-haney-mindsets.pdf

Haney, J., Theofanos, M., Acar, Y., & Prettyman, S.S. (2018). NISTIR 8241 Organizational Views of NIST Cryptographic Standards and Testing and Validation Programs. https://nvlpubs.nist.gov/nistpubs/ir/2018/NIST.IR.8241.pdf