STATE OF SOFTWARE SECURITY

Focus on Application Development

SUPPLEMENT TO VOLUME 6

VERACODE

CONTENTS

Introduction

Veracode has assessed applications for security vulnerabilities on behalf of our customers for over eight years. Our cloud-based platform has analyzed hundreds of thousands of applications and over 1.5 trillion lines of code. This has enabled us to amass a great deal of intelligence about the state of software security. This intelligence allows us to diagnose whether an organization is effectively reducing application security risk, and to gain insight into how the process of reducing application risk varies by organization and by development team.

When we relaunched the *State of Software Security* report series earlier this year, we focused on the performance of organizations through the lens of industry verticals. This provides CISOs and application security professionals with an important benchmark of how their application security programs are proceeding relative to their peers.

But this perspective is only part of the story. As we answered questions from customers and others after the release of *State of Software Security Volume 6,* it became clear that we could shed light on the story from another angle, that of the differing risks inherent in applications according to the language used and the method of their construction. The stakes are not small, and the timing is crucial. As organizations simultaneously contemplate the shift to continuous delivery and other DevOps innovations, and as they begin to feel the pressure to break their applications apart into smaller, more sustainable units, they face what could be an ideal moment to help their development teams make decisions to help improve the security of their enterprises.

When organizations are starting new development projects and selecting languages and methodologies, the security team has an opportunity to anticipate the types of vulnerabilities that are likely to arise and how best to test for them. The data in this report can inform decisions around developer training and which testing techniques to use in order to make the inevitable remediation process less onerous. This information can make it easier for security to work with development to increase the maturity of security in the SDLC and produce less risky applications.

Chris Wysopal
CTO, CISO and Co-Founder
Veracode

Executive Summary

1\.

Applications written in web scripting languages have a far higher prevalence rate of vulnerability classes like SQL injection and Cross-Site Scripting than applications written in .NET or Java. In particular, 64 percent of applications written in Microsoft's Classic ASP, 62 percent of applications written in ColdFusion, and 56 percent of applications written in PHP were observed to have at least one SQL injection vulnerability on initial assessment, compared to 29 percent of .NET applications and 21 percent of Java applications. This is of concern given the large numbers of web applications written atop PHP-based content management systems such as WordPress and Drupal.

2\.

Mobile applications had the highest rate of cryptographic issues, at 87 percent for Android and 80 percent for iOS. This suggests that while mobile app developers may be aware of the need for cryptography to protect sensitive data and thus use it in their applications, few of them know how to implement it correctly.

3\.

Applications written in different software languages have differing pass rates against common security policies like the OWASP Top 10. This discrepancy is due, in part, to different vulnerability distributions, but development teams should be aware of the statistical risks for applications written in a particular language when considering the threat model for the application.

4\.

eLearning has a big impact on remediation. Lack of developer knowledge of security is often cited as a barrier to producing more secure code. The data shows that development organizations that leverage eLearning see a 30 percent improvement in fix rate compared to those that do not. It is important to note that this may be correlative rather than causative, since eLearning use is associated with other success strategies such as use of centralized policies, remediation coaching and other aspects of a systematic program.

5\.

The choice of assessment type can make a difference in remediation as well. We see a 28 percent higher fix rate for vulnerabilities found by static analysis compared to those found by dynamic analysis. While no single assessment technology is sufficient to secure an application, understanding the tools' strengths and weaknesses as it comes to fixing — not just finding — software vulnerabilities is important.

Application Development Landscape

The application development landscape continues to change rapidly as the technology landscape evolves. What appeared five years ago to be separate development trends around web and mobile applications now increasingly looks like an integrated strategy of mobile-first development, leading to the evolution of JavaScript-heavy single page applications.

In application development practices, the ongoing debate about agile versus waterfall has turned into a discussion of going even faster, with continuous deployment pipelines enabling organizations to push hundreds of changes daily directly from check-in to production. And development organizations have started to pull security left into the development process, moving away from the old model of security as a QA or deployment gate.

Against this background of changes, this report provides an overview of applications that are being developed by Veracode customers across a wide array of industries and use cases, from large enterprises to small enterprises to independent software vendors. This section provides some context about the composition of Veracode's application repository with which to interpret the findings about application security that follow.

Programming language distribution

This report covers applications written in a wide variety of programming languages, including traditional web application development languages, compiled languages and mobile application development languages. The language breakout omits languages with small sample sizes. The biggest changes in the language distribution stem from an increase in .NET usage, the addition of new languages to the Veracode language support matrix, particularly Classic ASP (Active Server Pages); the rise in popularity of Android and iOS; and the proportionate decrease in share of portfolio of Java, PHP and C/C++.

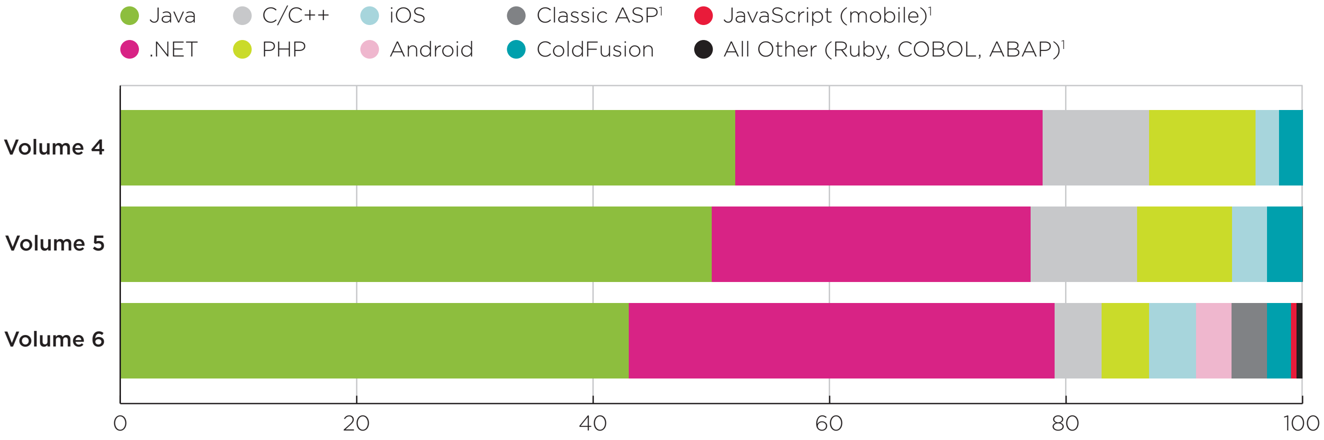

Figure 1: Programming language distribution

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[1] Not a language supported by Veracode as of the data reported in Volumes 4 and 5 of the *State of Software Security Report.*

Policy compliance by programming language

As discussed in Volume 6, the OWASP Top 10 is a list of the most important vulnerability categories in web applications, compiled through community consensus by the security practitioners at the Open Web Application Security Project (OWASP). The OWASP Top 10 is also referenced by industry standards such as PCI-DSS, which sets forth security standards for payment card processing systems. For the purposes of this study, we have defined a policy compliance rule that says that an application must be free of vulnerabilities in the OWASP Top 10 (as found by static analysis, dynamic analysis or manual penetration testing) to pass the OWASP Top 10 policy.

The pass rate for the OWASP policy can be swayed by the application type; in particular, the OWASP policy is not appropriate for mobile or client-side applications since the policy does not reflect the threat environment for these applications. This is important to bear in mind when considering the OWASP pass rate by industry, since different industries may have different mixes of programming languages.

In particular, note that applications in truly compiled application languages like C/C++ and Objective C (iOS) have a higher OWASP pass rate than general-purpose bytecode languages like Java or .NET, while scripting languages like Classic ASP, ColdFusion and PHP have a far lower pass rate.

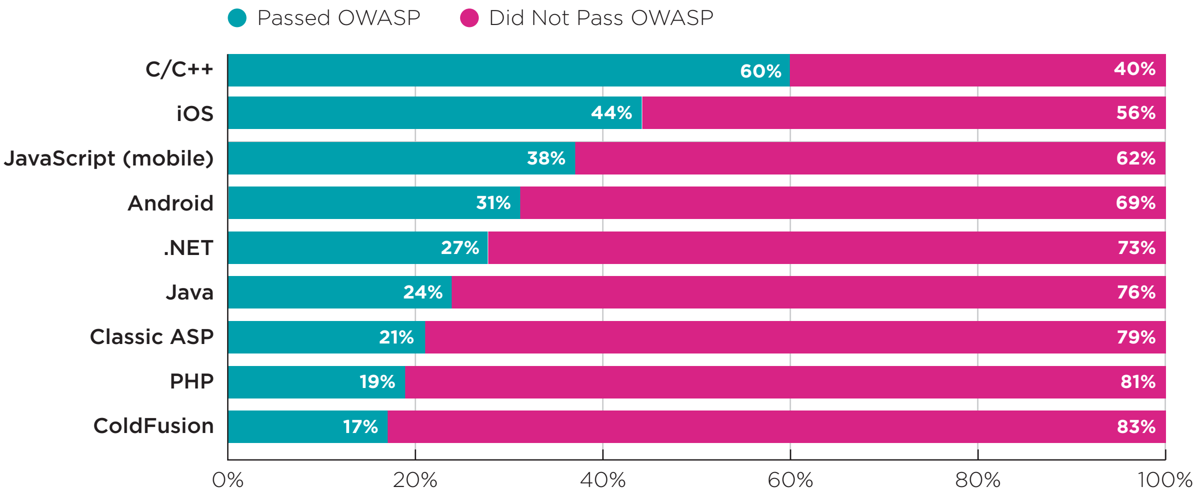

Figure 2: Policy compliance by programming language

Top 10 vulnerability categories by programming language

Next, we take a look at vulnerability prevalence by language. In this section we will talk about vulnerabilities in the context of both CWE IDs and CWE Categories. Veracode classifies vulnerabilities according to the Common Weakness Enumeration (CWE) maintained by MITRE, and for convenience groups related vulnerabilities into high level categories which are discussed below. As in prior volumes of the *State of Software Security,* there are significant differences in the percentage of applications affected by key vulnerabilities depending on the language chosen. This may reflect a few important differences:

- **Design of the language**
  Some languages are designed from the ground up to avoid certain vulnerability classes. By removing the need (and ability) for developers to directly allocate memory, languages such as Java and the .NET language family avoid (almost) entirely vulnerabilities dealing with memory allocation, most notably buffer overflows. Likewise, the default cross-site scripting behaviors of some ASP.NET controls avoid issues endemic in other web application programming environments.

- **Operating environment**
  Some vulnerabilities are only relevant in certain execution environments. For instance, some categories of information leakage are most acute in the mobile environment, which combines large volumes of personal data with a plethora of always-on networking capabilities.

Language	CWE Category	Apps Affected
OVERALL	Code Quality	63%
	Cryptographic Issues	58%
	Information Leakage	56%
	CRLF Injection	49%
	Directory Traversal	47%
	Cross-Site Scripting (XSS)	47%
	Insufficient Input Validation	37%
	SQL Injection	29%
	Credentials Management	25%
	Time and State	23%
.NET	Information Leakage	66%
	Code Quality	64%
	Cryptographic Issues	61%
	Directory Traversal	56%
	Cross-Site Scripting (XSS)	48%
	Insufficient Input Validation	46%
	CRLF Injection	38%
	SQL Injection	29%
	Time and State	20%
	Credentials Management	16%

Language	CWE Category	Apps Affected
ANDROID	Code Quality	90%
	Cryptographic Issues	87%
	CRLF Injection	79%
	Information Leakage	47%
	Directory Traversal	33%
	Time and State	28%
	Authorization Issues	28%
	SQL Injection	27%
	Insufficient Input Validation	26%
	Credentials Management	22%
CLASSIC ASP	Cross-Site Scripting (XSS)	83%
	SQL Injection	64%
	Insufficient Input Validation	59%
	Information Leakage	58%
	Directory Traversal	47%
	Session Fixation	41%
	Credentials Management	29%
	CRLF Injection	24%
	Command or Argument Injection	24%
	Code Injection	20%

Language	CWE Category	Apps Affected
C++	Error Handling	75%
	Buffer Overflow	56%
	Buffer Management Errors	53%
	Numeric Errors	50%
	Cryptographic Issues	42%
	Directory Traversal	42%
	Potential Backdoor	37%
	Race Conditions	29%
	Dangerous Functions	28%
	Code Quality	27%
COLD FUSION	Cross-Site Scripting (XSS)	87%
	Information Leakage	67%
	SQL Injection	62%
	Directory Traversal	44%
	Code Quality	43%
	Time and State	42%
	Command or Argument Injection	4%
	CRLF Injection	2%
	Cryptographic Issues	1%
	API Abuse	1%
iOS	Error Handling	84%
	Cryptographic Issues	81%
	Credentials Management	55%
	Potential Backdoor	50%
	Information Leakage	43%
	Code Quality	14%
	API Abuse	14%
	Buffer Overflow	9%
	Coding Standards	6%
	Buffer Management Errors	6%

Language	CWE Category	Apps Affected
JAVA	Code Quality	80%
	CRLF Injection	75%
	Cryptographic Issues	58%
	Information Leakage	57%
	Cross-Site Scripting (XSS)	54%
	Directory Traversal	48%
	Insufficient Input Validation	45%
	Encapsulation	35%
	API Abuse	32%
	Time and State	31%
	SQL Injection	21%
PHP	Cross-Site Scripting (XSS)	86%
	Cryptographic Issues	73%
	Directory Traversal	67%
	Code Injection	61%
	Credentials Management	58%
	SQL Injection	56%
	Information Leakage	50%
	Command or Argument Injection	34%
	Untrusted Initialization	30%
	Code Quality	9%

Figure 3: Top vulnerability categories by programming language

Comparison of critical vulnerability types

As in *State of Software Security Volume 6,* we now take a look at four key vulnerability categories: cryptographic issues, SQL injection, Cross-Site Scripting and command injection. In this volume, we compare prevalence by language to highlight differences between the languages.

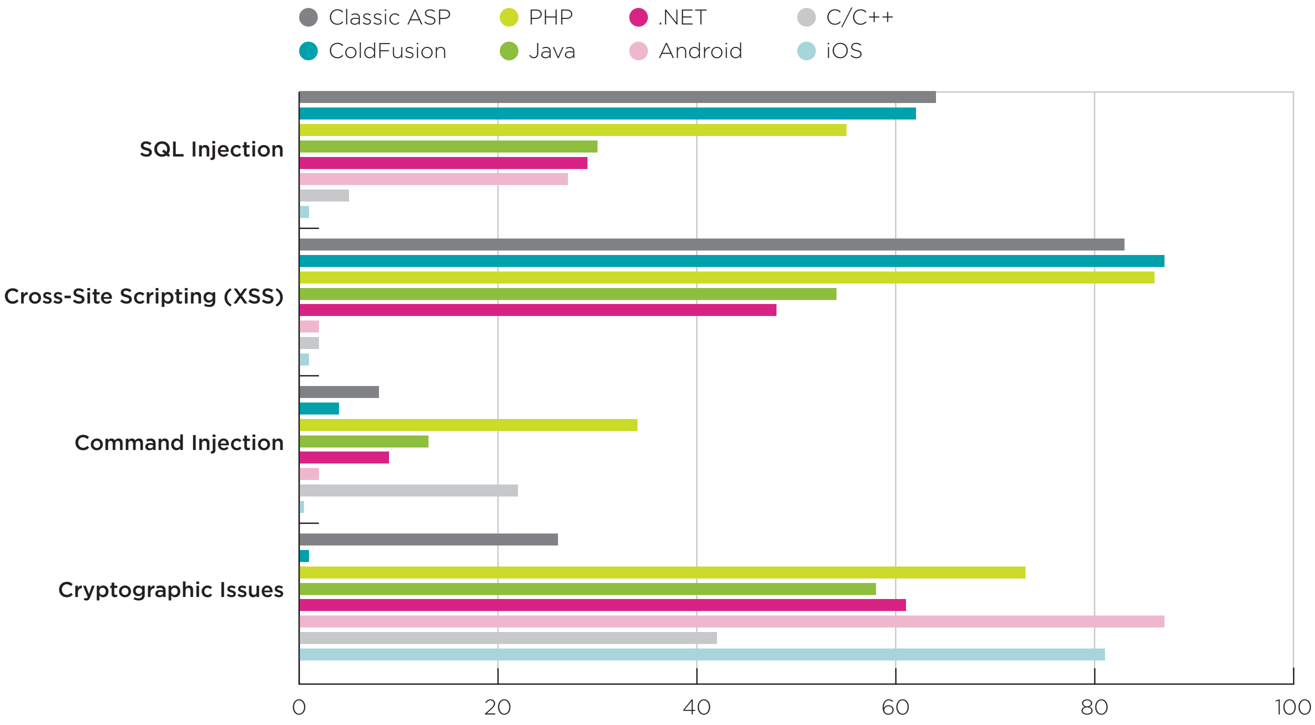

Figure 4: Comparison of critical vulnerability types

It is noteworthy that web vulnerabilities like SQL injection and Cross-Site Scripting are substantially more prevalent in applications written in web scripting languages such as Classic ASP, ColdFusion and PHP, compared to .NET and Java applications. This is very likely due to differences in the feature sets of each language. There are fewer security APIs built into Classic ASP, PHP and ColdFusion than have been provided for .NET and Java. As an example, until recently it was very challenging to bind parameters in SQL queries in PHP code, making it much harder to write code that was safe from SQL injection. ColdFusion has improved in this regard over the years, but is still more challenging to write securely than Java or .NET.

One particular concern related to this data point is the high prevalence of PHP-based applications, thanks to the widespread adoption of content management system (CMS) frameworks like WordPress, Drupal and Joomla. According to some estimates, 74.6 million web sites use WordPress, and another few million use Drupal and Joomla. The combination of the statistically higher prevalence of OWASP Top 10 vulnerabilities in PHP and the wide usage of PHP-based CMSes is a recipe for some concern in the health of the wider Internet, and means that organizations seeking to use these CMSes should carefully plan their deployments.

By contrast, a significantly larger number of mobile applications (both Android and iOS) have some type of cryptographic issue, 87 percent and 81 percent, compared to other languages.

This data does not suggest that any language will be free of vulnerabilities, but it does show that there are definite differences in the likelihood of running into these critical vulnerabilities. While it is unlikely that any development team would develop new applications in Classic ASP, it does suggest a strategy for how to prioritize assessment — or replacement — of these applications.

It is also worth investigating why there is such a high prevalence of cryptographic issues in iOS and Android applications. Digging deeper on the types of cryptographic vulnerabilities, we find this top 10 list of cryptographic vulnerability types:

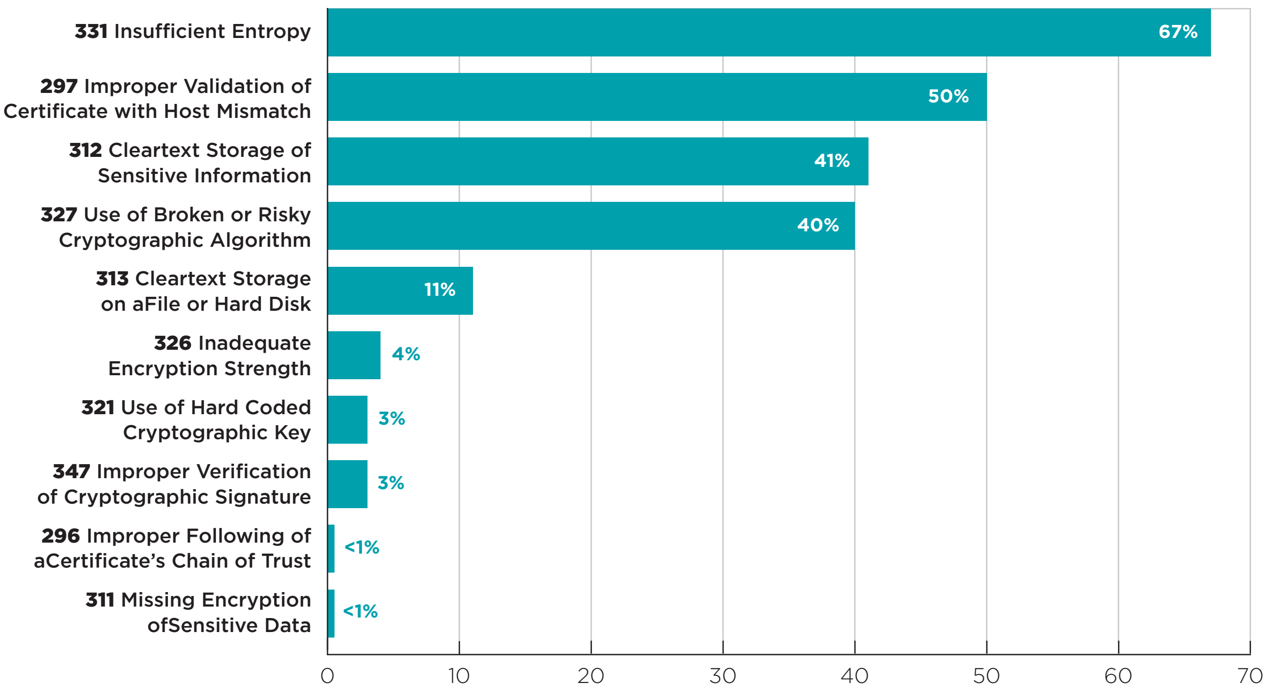

Figure 5: Prevalence of cryptographic vulnerability types by CWE (percentage of applications affected)

In this data, we see a combination of poor cryptographic practices — failure to store sensitive data properly, using poor or known broken encryption algorithms, or failure to correctly communicate with secure services. Unfortunately for developers of mobile enterprise applications, the storage and encryption of sensitive data and secure communication to secure services are the essence of what is required to correctly protect user data.

What are the consequences of poor cryptographic practices in mobile applications? Looking back at the data in *State of Software Security Volume 6: Industry Vertical Analysis,* we saw a disproportionately high share of iOS and Android applications in both the technology and healthcare industries. The issue of poor cryptographic practices in healthcare mobile applications is particularly troubling, given the rapid adoption of mobile apps in that industry as a way for doctors to more quickly address patient care issues. A 2012 Pew study reported that 19 percent of smartphone users had downloaded a health app, and 52 percent sought health information on their phone — and this was prior to Apple's introduction of a unified framework for health data in 2014. A policy brief by the Robert Wood Johnson Foundation in the journal Health Affairs predicts that health app prevalence will rise to half the mobile device users worldwide by 2018.[2]

However, any personal health data in health apps bears a higher standard for security and privacy than that in typical mobile apps, thanks to the requirements established in HIPAA in 1996. The high prevalence of crypto vulnerabilities in these applications suggests that the market trend toward more convenient mobile access to and storage of health information is likely to hit roadblocks in the form of data leakage from insecure mobile apps and the services to which they connect.

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[2] Robert Wood Johnson Foundation brief cited in Conn, Joseph. "No longer a novelty, medical apps are increasingly valuable to clinicians and patients," *Modern Healthcare,* 2013-12-14.

Security Assessment Types

One of the reasons for heightened interest in application security over the last few years is the rise in breaches that are directly attributed to attacks against web applications. Sometimes, as in the Target breach,[3] the exploitation of a web application vulnerability happens only after the user has authenticated using stolen credentials (which, themselves, are often stolen in earlier breaches using simple SQL injection). But often the first step is finding an easily exploitable vulnerability in a web application via a simple "black box" scanner.

We wanted to understand the difference between vulnerability types found in web applications at runtime via "black box" assessments (or dynamic application security testing, also known as DAST), and those found via an inside-out assessment of the application using "white box" assessments, also known as static application security testing or SAST.

Vulnerability Category	Dynamic	Static
Code Quality	n/a	63%
Cryptographic Issues	53%	58%
Information Leakage	80%	56%
CRLF Injection	n/a	49%
Deployment Configuration	55%	n/a
Server Configuration	16%	n/a
Cross-Site Scripting (XSS)	27%	47%
SQL Injection	6%	29%
Credentials Management	12%	25%
Code Injection	1%	2%
Time and State	n/a	23%
Directory Traversal	2%	47%
Insufficient Input Validation	4%	37%

Figure 6: Dynamic vs. static application security testing

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[3] Olavsrud, Thor. "11 Steps Attackers Took to Crack Target." CIO Magazine, September 2, 2014. www.cio.com/article/2600345/security0/11-steps-attackers-took-to-crack-target.html

As noted, there are several vulnerability categories that are uniquely found by each approach. Those uniquely found by DAST, deployment configuration and server configuration, include issues that are outside the application code context but comprise part of the operating runtime of the application, including misconfigurations that may cause private web application resources (such as configuration files) to leak, or that may allow downgrading to a less secure protected channel. Those uniquely found by SAST tend to be categories that are challenging to observe via black box assessments, such as CRLF attacks (log or header forging), code quality issues (including leftover debug code, use after free/double free, use of unsafe native code invocation and other vulnerability types), and time and state errors (issues with temporary file, concurrency issues and incorrect ownership assignment).

It is tempting to look at the higher reported prevalence of SQL injection and Cross-Site Scripting via SAST and draw conclusions about false positive rates. The reality is that the two assessment techniques are fundamentally different and will naturally show different prevalence. DAST relies on the ability to successfully crawl and discover the attack surface of an application, and therefore requires more time to achieve high levels of code coverage. We observe, however, that there is frequently pressure to shorten the time window for dynamic assessments, based on testing windows or operational concerns. It is also challenging for DAST to fully exercise workflows and business logic that are not easily automated, for instance, a sequence of forms that must be completed in a certain order with certain values to access business functionality. Therefore, the reported prevalence of these categories by DAST may understate the real situation. By the same token, SAST may report findings in these categories that are not practically exploitable without compromising other trusted resources. such as file systems or databases.

As has been shown many times in the industry, each of the assessment technologies available has different strengths. A mature program will typically recognize the strengths and weaknesses of each technique and use them at the appropriate times in the lifecycle. For instance, Gartner's Ramon Krikken and Ben Tomhave have suggested that organizations plan to use DAST at system test, prerelease testing, and in production, while bringing SAST further back the SDLC, beginning in prerelease testing but also in automated continuous integration driven testing and from the developer's desktop.[4]

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[4] Gartner (Ramon Krikken and Ben Tomhave), "How to perform application security testing for web and mobile applications." January 30, 2015.

Remediation Analysis

In *State of Software Security Volume 6,* we looked at remediation rates by industry and evaluated a factor that may contribute to improved remediation rates: use of remediation coaching. This report continues to evaluate other factors that may contribute to improved remediation rates, including formal developer education and type of security analysis performed.

Developer education

One of the holy grails of application security programs is to reduce the rate of introduction of security vulnerabilities. One way that industry attempts to help with this is through formal developer education. The PCI-DSS standard goes so far as to mandate developer education in secure coding practices in support of this goal.

Many application security providers offer a developer education capability as part of their offerings, either via in-house developed content or through a partnership with a learning content provider. This section of the report looks at differences in remediation practice for Veracode customers who have established an eLearning program, versus those who have not.

Note: It is challenging to obtain precise measurements of the effectiveness of developer education. To many a CISO's chagrin, it is difficult to measure prevention — that is, to determine which vulnerabilities might have been introduced but were not because a developer learned secure coding practices. In many cases, the best an application security program can do is to measure fixes made to code that existed before the program began. It can also be difficult to correlate the training experience of individual developers with fix rates in software, given that many developers may be responsible for a given application. The best we can hope for is some correlation in use of eLearning with improved fix rates.

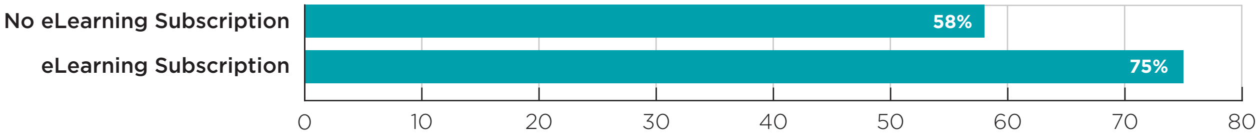


Figure 7: Percent vulnerabilities found vs. fixed

When we look at the overall fix rate of Veracode customers who have established an eLearning program, we note that the fix rate is considerably higher, with 75 percent of vulnerabilities fixed versus 58 percent, an improvement of 30 percent over the baseline rate. This suggests that eLearning is correlated with a higher fix rate. We must caution, however, that there may be other factors at play here, such as the existence of a formal application security program, effective use of application security policy or use of remediation coaching.

Type of application security analysis

An axiom of application security assessment is that it's best to conduct static assessments where possible, because it gives developers more actionable results (line of code location of the vulnerability, data flow information and so on). In this volume of the report, we looked at our data to see if there was evidence that supports this hypothesis.

To examine this hypothesis, we looked at the rate of fix, which is computed as the total number of vulnerabilities fixed divided by the total number of vulnerabilities found. Rate of fix has the advantage of applying to any assessment type, unlike a quality measure like flaw density, which is only applicable for static assessments. We compute this measure for each assessment type.

We found the following fix rates in reassessment:

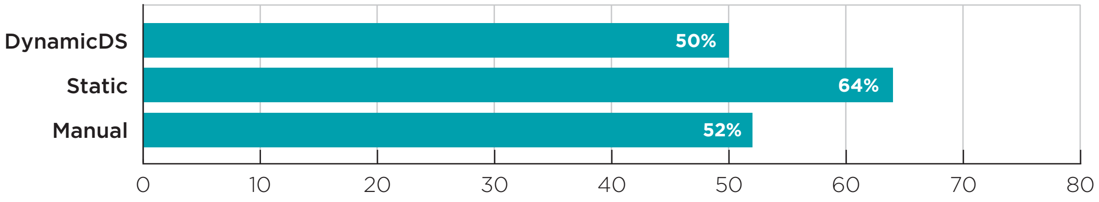


Figure 8: Percent vulnerabilities found vs. fixed

The hypothesis seems to be confirmed by the comparison of the fix rate. Developers on average fix 64 percent of static vulnerabilities, compared to 50 percent of dynamic vulnerabilities — on average, 28 percent better.

There are several possible reasons why static analysis observed a higher fix rate. The most likely is that static provides higher fidelity data about the root cause of a vulnerability, including source file and line number. But there are other possibilities, including the likelihood that a static assessment is being run on an application that is actively under development and that engineering therefore already sees fixing issues as a priority, where dynamic assessments may be run on a production system where the development team may not be actively engaged. We tried to control for this effect by only looking at applications that were rescanned, indicating some need to verify changes by the development team.

This is not to say that a security program should rely exclusively on static analysis. Some vulnerability classes can only be caught at runtime, using a technique like DAST, behavioral mobile app testing or interactive application self-testing. Some, like business logic vulnerabilities, require a skilled human tester. Some applications may not lend themselves to static assessment at all, due to lack of programming language support or the inability to obtain binaries (when the application is deployed) or source code. This data does suggest, though, that static assessment is worthwhile when possible, even when other methods have been employed, and the hypothesis that static results may be more actionable seems to be borne out.

Appendix

About the dataset

The data represents 208,670 application assessments submitted for analysis during the 18-month period from October 1, 2013 through March 31, 2015 by large and small companies, commercial software suppliers, open source projects and software outsourcers. In most analyses, an application was counted only once, even if it was submitted multiple times as vulnerabilities were remediated and new versions uploaded. The report contains findings about applications that were subjected to static analysis, dynamic analysis or manual penetration testing through Veracode's cloud-based platform. The report considers data that was provided by Veracode's customers (application portfolio information such as assurance level, industry, application origin) and information that was calculated or derived in the course of Veracode's analysis (application size, application compiler and platform, types of vulnerabilities, Veracode Level (predefined security policies which are based on the NIST definitions of assurance levels)).

Flaw density by programming language

State of Software Security Volume 6 included data about average flaw density (the number of flaws, or vulnerabilities, per megabyte of executable code) as a way to measure remediation activity. We provide the following table of average flaw density by language for reference

Note: It is important to not draw too many conclusions from flaw density differences, as flaw density is affected by many factors. Language-specific differences in flaw density may be caused by the richness of the system APIs for a scripting language, which instruction sets are enabled in the compiler, 32-bit code versus 64-bit code (64-bit executables are much larger than 32-bit ones with the exact same source files), etc. Some of the same challenges apply to other measures of defect density, such as defects per KLOC (thousand lines of code).

Language	Flaw Density per MB	Flaw Density per MB (High/Very High)
Classic ASP	1,686.60	1,112.80
ColdFusion	262.80	227.30
PHP	184.00	47.70
Java	51.80	5.20
.NET	32.50	9.70
C++	26.70	8.80
iOS	23.40	0.90
Android	11.30	0.40
JavaScript (mobile)	8.10	0.09

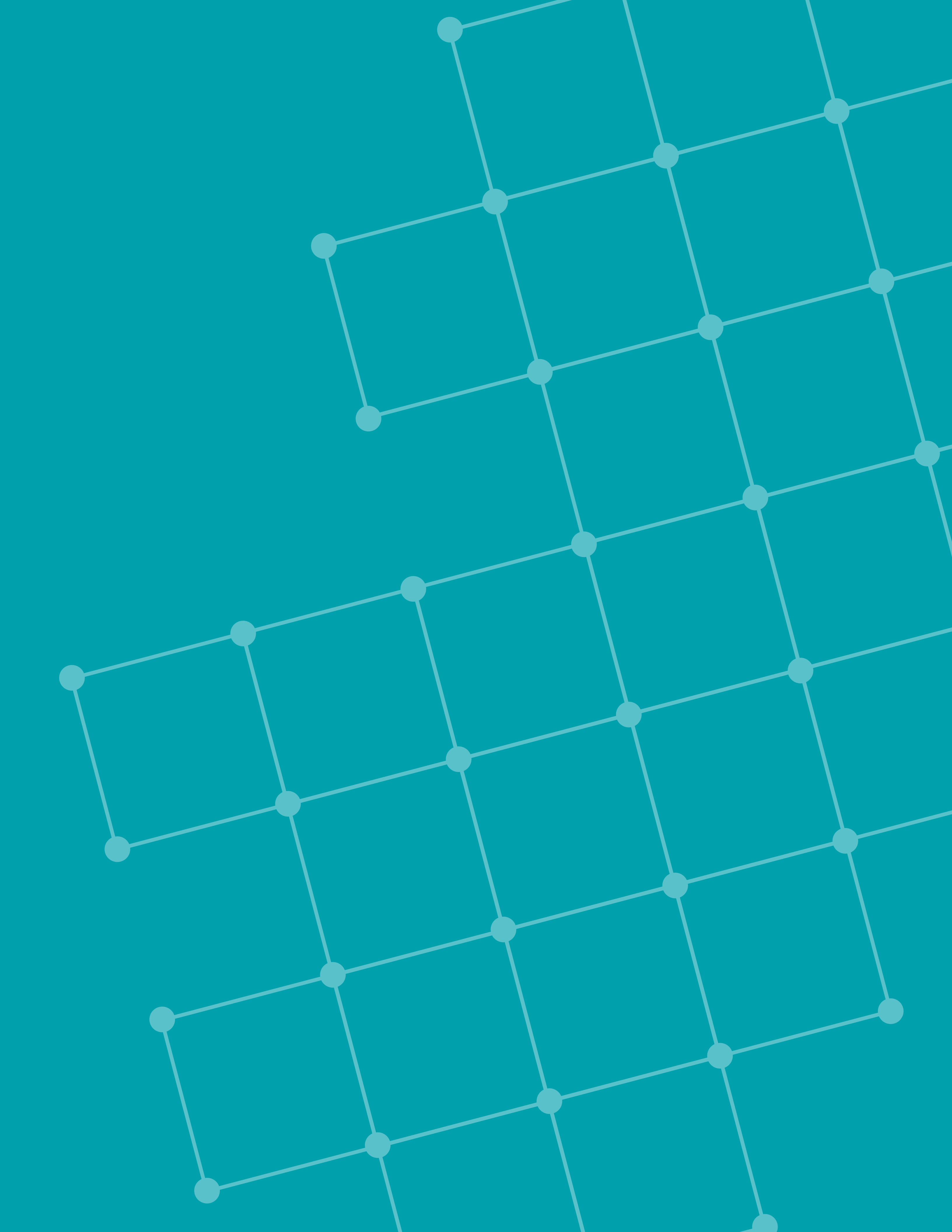
Figure 9: Flaw density by programming language

SAMPLE SIZE

In any study of this size, there is a risk that sampling issues will arise because of the nature of the way the data was collected. For instance, all the applications in this study came from organizations that were motivated enough about application security to engage Veracode for an independent assessment of software risk. We have taken care to only present comparisons where a statistically significant sample size was present.

ABOUT THE FINDINGS

Unless otherwise stated, all comparisons are made on the basis of the count of unique application builds submitted and rated.



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