VMware Product Security

An Overview of VMware's Security Programs and Practices

TECHNICAL WHITE PAPER

vmware®

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Executive Summary

VMware, the industry-leading virtualization software company, empowers organizations to innovate and thrive by streamlining IT operations. VMware is radically transforming IT with technologies that make your business more agile, efficient and profitable. We deliver value to more than 500,000 customers as diverse as Ducati, Southwest Airlines, the New York Stock Exchange, and Revlon through virtualization software, professional services, and a robust ecosystem of more than 55,000 partners. Our unique solutions drive outstanding application interoperability and customer choice.

VMware understands that the integrity of its products is of utmost importance to our customers and recognizes that unless its products meet the highest standards for security, its customers will not be able to deploy them with confidence. To achieve this, VMware has established oversight and policy structures that identify and mitigate potential product security risks during development and has instituted programs and practices that support both the development of secure products and solutions and drive security awareness across the enterprise. In response to risks to critical infrastructure, intellectual property, and sensitive information posed by the constantly evolving threat landscape, VMware has developed comprehensive and rigorous software security assurance processes and procedures that demonstrate the integrity of its products and address potential vulnerabilities.

This white paper provides an overview of how our commitment to building trust with our customers is present in every facet of our comprehensive, risk-based software assurance process and is reinforced in our program structure.

VMware's approach to product and information security addresses potential vulnerabilities within areas such as:

- Software product development
- Software supply chain
- Technology partnerships and ecosystems

Software Product Lifecycle Management

The VMware Software Product Lifecycle includes the framework, governance, and set of executive checkpoint reviews, tools, artifacts, and guidance that enable VMware product business units (BUs) to ensure business readiness at the time of product availability and throughout the product lifecycle. Central to the framework is an integrated and predictable approach to product and cross-functional planning, release/program management, execution, measurement, risk management, and decision making at each phase of the product lifecycle.

The VMware Software Product Lifecycle provides the framework for addressing critical decision points as a product proceeds through the lifecycle phases from Concept to Sustaining state.

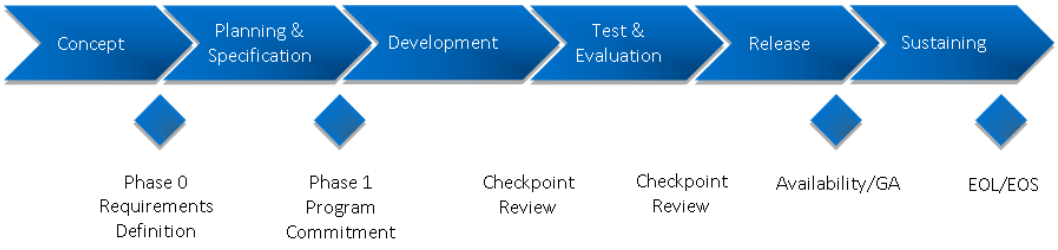

Figure 1 Enterprise Product Lifecycle Management Workflow

Protecting the Privacy of our Customers

VMware is committed to protecting the privacy of its customers, with the overall goal of earning and maintaining the trust of VMware customers, employees, and others, in how VMware collects and uses their personal information.

VMware's Privacy Policy document details what personal information VMware collects online and can be found at http://www.vmware.com/help/privacy.html.

This privacy policy applies to data collected through the vmware.com site and other webpages that are linked to it. For personal information relating to individuals in the European Economic Area and Switzerland, VMware adheres to the U.S.-EU Safe Harbor Privacy Principles, and this commitment extends to all personal data it receives from the EU and Switzerland. These principles are described in more detail in the VMware General Safe Harbor Privacy Notice. The privacy team has developed the following initiatives to build out its Privacy Program.

Privacy by Design

The VMware Privacy Program utilizes a "privacy by design" framework to promote the consideration of privacy and transparency as integral parts of its products and to help ensure that VMware products and services are examined for privacy purposes before they go live. As part of the program, the privacy team works with the engineers during product development to:

- Evaluate where security and privacy risks may emerge
- Provide guidance for making critical privacy changes in a timely fashion

This practice of reviewing privacy implications early in the development process has helped promote a privacy-conscious approach and culture.

Building Security into VMware Products and Practices

VMware has established programs and practices that identify and mitigate security risks during and throughout the software development process. Through these activities, VMware delivers secure products and solutions for its customers.

Based on industry-recognized best practices and standards, and developed in consultation with trusted industry participants, VMware's programs and practices focus on:

- Building secure software
- Protecting the intellectual property related to software products
- Managing software security supply chain risks
- Managing technology partner and ecosystem risks
- Delivering secure product support

Product Security

The Product Security group, VMware Security Engineering, Communications & Response (vSECR), develops and drives software security initiatives across all of VMware's R&D organizations to reduce software security risks. Their goals and practices oversee a product development process that employs a comprehensive approach to assist in the delivery of secure products. The teams and efforts described in this section represent VMware's commitment to promoting a security-conscious approach and culture to foster positive cross-functional collaboration in security.

VMware has a comprehensive approach to security which includes collaboration with many teams across our organization, including Research and Development, Corporate Legal and Privacy, as well as Support and Field organizations. VMware also works closely with Industry Organizations, Security Analysts and Researchers, etc. to stay current on the Industry threat landscape and security best practices.

Figure 2 VMware Product Security

The vSECR group develops and drives software security initiatives across VMware's R&D organizations to reduce software security risks. The vSECR programs and engineering functions include:

- **VMware Security Development Lifecycle (SDL)** – A comprehensive program to identify and mitigate software security risks during the software development lifecycle
- **Security Response Center (VSRC)** – A mature process to investigate and remediate reports of product security vulnerabilities identified once products have been released to customers
- **Security Engineering** – An engineering team focused on solving complex software security problems, developing common security toolkits, and supporting SDL and security response activities
- **Security Certifications** – A program to drive key products through appropriate security certifications such as Common Criteria, FIPS 140-2, and DISA STIG
- **Security Evangelism** – A program to raise security awareness and competency within the broader VMware R&D community through formal and informal training
- **Software Supply Chain Security** – A program to develop policy and standards to manage constantly evolving supply chain risks

Security Development Lifecycle

VMware's Security Development Lifecycle (SDL) program is designed to identify and mitigate security risk during the development phase of VMware software products. The development of VMware's SDL has been heavily influenced by industry best practices and organizations such as SAFECode (the Software Assurance Forum for Excellence in Code) and BSIMM (Building Security In Maturity Model).

VMware is active in the broader software industry security community, becoming an early member of BSIMM in 2009. VMware has undergone several reviews by BSIMM of its Software Security Program (e.g., VMware uses BSIMM reviews to build further improvements into VMware SDL), and VMware participates in the annual BSIMM conference as a way of learning through other industry participant's experiences. VMware is also active in the security research community and its Security Evangelism team works to actively cultivate relationships in this community. For example, VMware regularly brings speakers from the research community onto the VMware campus in Palo Alto, CA, to present technical talks on security topics, and VMware hosted its first 2-day internal security engineering conference in late 2013, which included external security researchers and internal security experts from across the globe In 2014, VMware joined SAFECode, an organization driving security and integrity in software products and solutions.

VMware SDL is continuously assessed for its effectiveness at identifying risk and new techniques are added to SDL activities as they are developed and mature.

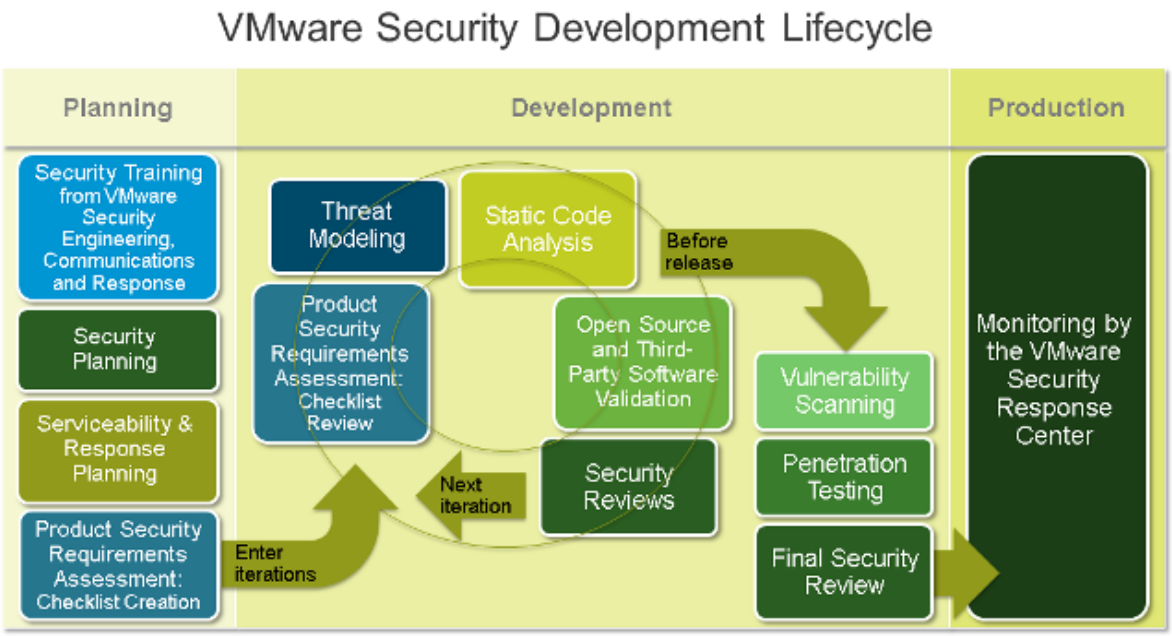

Figure 3 VMware Security Development Lifecycle

Current VMware SDL activities include:

- **Security Training –** vSECR works with R&D Education to create and maintain training programs about product security. Managers, developers, and quality engineers can avail of these courses early in the lifecycle of their product.
- **Security Planning –** Good security starts with early planning, at the genesis of the SDL process. The SDL planning template forms the basis of the Security Review activity, where milestone and final security reviews of the product are conducted and security evaluated at development milestones.
- **Serviceability and Response Planning –** This activity helps product teams plan their products' servicing model from a security perspective, including the ability to ship secure patches, key open source and third-party software servicing, end of life support, and security and management contacts for security response.
- **Product Security Requirements Assessment –** This activity examines how a product adheres to VMware Product Security Requirements (PSR), which includes standards for:
  - Authentication
  - Authorization
  - Encryption
  - Certificates
  - Network security
  - Virtualization
  - Accountability
  - Software packaging and delivery
- **Threat Modeling –** This activity identifies security flaws and incorrect design assumptions present in the

architecture of a product.

- **Open Source and Third-Party Software Validation (OSS/TP) –** This activity validates that OSS/TP software with known vulnerabilities is fixed before being included in a product release.
- **Static Code Analysis –** This activity uses automated tools to detect defects and security flaws in code.
- **Vulnerability Scanning –** This activity uses automated tools to detect security vulnerabilities in running systems.
- **Penetration Testing –** This activity uses outside consultants to try to break systems in isolated environments.
- **Security Review –** This activity examines the output and completion of all the other activities.

The vSECR group owns the definition and practice of SDL processes. The SDL is the software development methodology that vSECR and VMware product development groups use to help identify and mitigate security issues so that the development group's software is safe for release to customers. The vSECR group updates the methodology in regular releases, and the vSECR and VMware product development groups apply the methodology as an end-to-end set of processes to use at specific times in the development group's software development lifecycle, with the goal of helping teams to remediate these security issues early in the lifecycle.

The SDL's end-to-end set of lifecycle processes help product development groups perform these tasks:

- Reduce their component's risk profile and attack surface
- Identify and remediate costly security-related design flaws early in the development process before much coding has taken place
- Discover and remediate security vulnerabilities prior to availability
- Educate their teams on security issues and security best practices

Figure 4 illustrates the timeline of SDL activities and product release milestones.

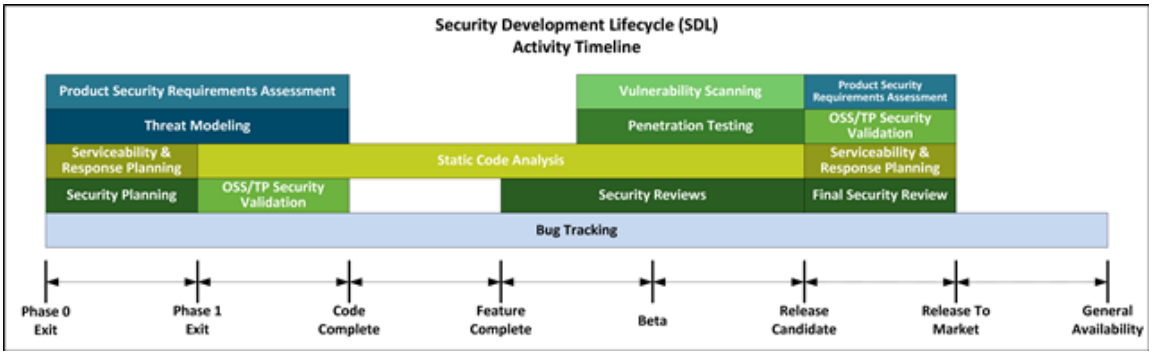

Figure 4 vSECR Security Development Lifecycle (SDL) Activity Timeline

The SDL processes include these activity phases:

Planning

During this phase, the development team documents its security plan (strategy, risks, initial schedule, etc.) for the release, utilizing the Security Development Lifecycle Standards (SDL process to help in identifying and mitigating security issues). Also, any exceptions to the Security Development Lifecycle must be called out in this plan.

As part of VMware's abiding commitment to ensuring influence and support around security early in the development process, Security Training offers courses for VMware managers, developers, and quality engineers in:

- Security concepts
- Security design and testing
- Secure coding techniques for specific languages
- Various security tools

Design

During this phase, the development team utilizes the VMware Product Security Requirements (PSR) to identify and remediate security issues in VMware products before release and is an integral part of each development team's Plan of Record (POR) for any specific release.

Additionally, the development team formally develops their threat model that identifies potential security flaws and incorrect design assumptions present in the architecture of a software application or component. Threat modeling occurs early in the development process, and thus allows adequate time for teams to remediate any design-related security issues. VMware requires that development teams have a Threat Model available to document the state of their publicly available software products.

Implementation

During this phase, the development team utilizes automation tools as part of Static Code Analysis (SCA) to detect defects, including security flaws, in software components that are not running or are "at rest". At the minimum, VMware development teams must conduct a Static Code Analysis at least twice during a component's release cycle:

1. At Code Complete (CC)
2. To verify that issues found after the first scan are fixed (before designating the component as a Release Candidate)

Additionally, VMware requires that its development teams publish the names and release levels of each Open Source/Third-Party Software (OSS/TP) product or library that the team uses in building VMware products or components. VMware requires that its development teams include the latest, fixed versions of the OSS/TP software in all product releases.

Validation

During this phase, the development team employs automated Vulnerability Scanning processes to identify security vulnerabilities in computing systems running in a network to determine the specific ways the system can be threatened and/or exploited. The VMware development team must complete an initial vulnerability scan after Feature Complete (FC). Also, the development team must scan its code periodically until it becomes a Release Candidate (RC).

Additionally, the development team uses Penetration Testing (pentest) assessment to determine if a malicious intruder can successfully attack a software product or solution. VMware conducts these tests with the help of outside consultants who use an isolated, mock customer environment, a review of the product architecture and source code, and various commercial and/or custom vulnerability detection tools to do their tests. A pentest is an important third-party validation of the security of VMware's products, and contributes greatly to achieving customer trust in our products and solutions.

Lastly, during this stage, the Security Review is conducted to establish whether the subject software has undergone the required SDL activities adequately, and has addressed security risks such that the software is suitable for release to customers. Formal Security Reviews occur before the Beta, Release Candidate (RC), and Release to Market (RTM) milestones.

Security Review

The Security Review establishes whether the subject software has undergone the required SDL activities adequately in order to identify security risks and to address these risks such that the software is suitable for release to customers.

While the data that the Security Review presents is monitored throughout the entire security development lifecycle of the software, formal Security Reviews occur before the Beta, Release Candidate (RC), and Release to Market (RTM) milestones.

Production

When a VMware product has reached the general availability milestone, the product enters the production stage of its lifecycle, and remains in production until it reaches the end-of-life milestone.

The VMware Security Response Center (VSRC) is charged with monitoring the landscape for all reports of security issues concerning VMware products.

The internal role of VSRC is to investigate reported vulnerabilities and provide information on security issues to the appropriate teams. The external role of VSRC is to provide security researchers, customers, partners, and other external parties with a point of contact for reporting vulnerabilities in VMware products (security@vmware.com).

When VSRC detects or receives a report of an issue with a VMware product, VSRC works with the development team to investigate the issue. VSRC continues to coordinate the remediation and communication of the issue with the appropriate product and support teams. VSRC is additionally responsible for communication and dissemination of all relevant VMware Security Advisories. VMware Security Advisories can be found at http://www.vmware.com/security/advisories/.

Security Response Center

Established in 2008, VSRC is responsible for managing and resolving security vulnerabilities in VMware products once products are released to customers. VSRC has a mature process to investigate reports, coordinate disclosure activities with researchers and other vendors when appropriate, and communicate remediation to customers via security advisories, blog posts, and email notifications. VSRC is well established within the security research community and participates in many external security events in order to foster strong working relationships with the security research community. For example, VMware participates at major security conferences such as RSA, Black Hat, DEF CON, and CanSecWest, and is involved in the Bay Area security community, which includes sponsoring BayThreat, holding community security gatherings on the VMware campus, and running its own security conference with external speakers. VMware's security response policies are well established and are publicly documented on the VMware website at http://www.vmware.com/support/policies/security_response.html.

Security Engineering

Part of vSECR, the Security Engineering team has deep technical expertise both in domain areas such as systems, networking, and web applications, and in products such as VMware's vSphere product line, Management Products, and VMware's End User Computing product lines. This engineering team is responsible for investigating and developing long-term risk reduction technologies and techniques that can be applied to VMware products. In addition, it acts as a center of expertise for security engineering and is often called upon to solve complex software security challenges. As an example of the Security Engineering team creating preventive controls that anticipate potential future vulnerabilities, the NoScape project is a method and strategy designed to prevent and/or contain VM escapes, and ensures that even if an escape were to take place, the malicious user is prevented from contaminating other guests.

Security Evangelism

The long-term goal of the Security Evangelism team is to increase the level of software security awareness and competency within VMware's R&D community. This allows the SDL process to be scaled effectively. The team uses several programs to achieve this:

- Regular technical talks to VMware's R&D community highlighting specific classes of software security vulnerabilities that have historically occurred in VMware products
- Brown bag sessions with key engineers to discuss software security
- An R&D wide, multi-level online and classroom-based software security training program
- Participation as speakers at VMware's annual Research & Development Innovation Offsite (RADIO) conference
- Software security challenges, competitions, and hackathons focused on VMware products
- An internal 2-day VMware security conference that involves industry-recognized speakers from both academia and the security research community as well as speakers from within VMware

Security Certifications

VMware has a long history of participating in the Common Criteria standard with the first VMware product being certified in 2008. The Security Certifications team drives the certification of major VMware products as well as participates in the development of these standards. The Security Certifications team is a key contributor to the development of the Virtualization Protection Profile that is currently under review by NIAP (National Information Assurance Partnership) in the U.S. Common Criteria scheme.

Products that have achieved Common Criteria certification include:

- VMware vSphere 5.5
- VMware vSphere 5.1 U1c
- VMware vSphere 5.0
- VMware vCNS 5.5.0a
- VMware ESXi 4.1 and vCenter Server 4.1
- VMware ESX 4.1 and vCenter Server 4.1
- VMware ESXi 4.0 Update 1 and vCenter Server 4.0 Update 1
- VMware ESX 4.0 Update 1 and vCenter Server 4.0 Update 1
- VMware ESX Server 3.5 and Virtual Center 2.5
- VMware ESXi Server 3.5 and Virtual Center 2.5
- VMware ESX Server 3.0.2 and Virtual Center 2.0.2
- VMware ESX Server 2.5.0 and Virtual Center 1.2.0 VMware ESX 4.0 Update 1 and vCenter Server 4.0 Update 1

For a complete list of VMware's Common Criteria validated products, visit http://www.vmware.com/security/certifications/common-criteria.html.

Software Supply Chain Security

With the global expansion of the software industry, security concerns have increased that a product or service could be compromised by malicious code introduced during product development or maintenance. Technological innovation and changes in sourcing and supply chain strategies have made software supply chain security a global challenge. Threats ranging from risks associated with using third-party code and open source components to IP theft have dramatized the vulnerability of this new risk domain. VMware is

actively engaging in proactive measures to minimize the occurrence of these risks and has launched several initiatives to address the security of our supply chain.

Managing Supply Chain Risk

VMware is working to formalize a Supply Chain Risk Management program that is primarily focused on secure sourcing and hardware, firmware, and software integration relating to building solutions. It is developing an approved vendor list for several of its BUs and functions. Also, VMware's recycle program for hardware products addresses supply chain risk by securely recycling equipment that may hold information sensitive to the supply chain. For example, hard drives that are at end of life and were used in the source control systems are properly recycled to ensure that the data from the source control systems is removed.

VMware has established processes around partnerships with entities deemed to be of increased supply chain risk and around the sharing of source code with third-parties. With respect to partnerships, VMware has an established process to validate if a partner is considered to be of increased security risk. If a partner meets certain criteria, they may be excluded from certain programs that permit direct access to VMware IP.

Both inbound and outbound contracts that have software supply chain security implications are reviewed by the Legal and Product Security teams. VMware includes terms that set minimum software security standards in its OEM (original equipment manufacturer) and third-party software license agreements that are in keeping with or exceed industry best practices.

Industry Participation

VMware is active in the broader software industry security community. VMware is a participant in the BSIMM process and has undergone several BSIMM reviews. VMware is also active in the security research community and its Security Evangelism team works to actively cultivate relationships in this community. VMware is also a member of the SAFECode organization.

Protecting Product Source Code

Product source code managed by the Source Code Management (SCM) team follows processes designed to safeguard the integrity of VMware's product-related intellectual property while providing engineers access to source code required to develop and maintain its products. Also, the SCM team manages the source code systems environments.

Code Integrity

These controls can allow for code integrity problems to be identified and remediated in a timely manner for perpetual software.

TABLE 1 CODE INTEGRITY CONTROLS

Control	Current Process
Code review	Well-adopted practice within teams
U.S.-Based Builds	All products TAA compliant
Security Reviews	Security Reviews conducted prior to release.
Risk Management of Open Source Software (OSS)/Third-Party Software (TPS) supply chain	Contract provision to allow security testing of TPS; Involvement in industry initiatives to improve OSS

The following sections describe processes aimed at supporting product integrity for a VMware product that achieved Common Criteria Certification. The process extends to other VMware products.

Source Code Management

Source code control protects the security and integrity of code that is written, developed, tested, and evaluated. Source control covers code creation, modifications, deletion, and incorporation of the code into

larger parts. Audit controls within the source control system automatically track what changes have been made, who made them, when a change was made, as well as other consequences of those changes. Access to the source code is controlled by a network access and security policy and is controlled on a per-user basis, by means of user permissions and roles.

The product source code is stored on centrally managed servers in a secure area and protected behind a network firewall. Strict physical and access controls are enforced.

Secure Delivery

Several procedures are necessary for VMware to maintain security when distributing the product to a customer's site. For a valid delivery, the product received must correspond precisely to the product master copy, without tampering, or substitution of a false version. The delivery procedures ensure that the integrity and authenticity of the product are maintained and that they are verifiable by the customer and by VMware after delivery has been completed. The product is delivered via VMware's websites by electronic distribution only. The end user is supplied with the product, product documentation, and product license.

Issue Remediation

Customers report security issues to VMware's Product Security group (security@vmware.com) when a problem is encountered in the normal operation of the product. Product issues are also reported, captured, and filed through VMware's Global Support Services (GSS). Internal wiki pages are used to track security related bugs reported from the security@vmware.com mailing list.

Any bug discovered during product development, design change, testing, or by a customer must be triaged, documented, and a solution offered before the bug report can be closed. These bugs include suspected and/or confirmed security flaws.

VMware vCloud® Air™

VMware vCloud® Air™ (vCloud Air) has implemented a risk and compliance program that includes baseline security controls that are managed through VMware's Information Security Management System (ISMS). VMware has a formal risk management process that is governed by its Risk Framework and Methodology Policy. All risks are evaluated based on likelihood and impact to the organization. Risk treatment plans are created to address risks that are above our defined threshold. If a risk is above our threshold and there is no risk treatment plan available, the risk must be accepted by our management team. Within its ISMS, VMware has a defined set of metrics to measure the effectiveness of compliance and security controls. These metrics are reported to the management team on a quarterly basis.

Providing Secure Product Support Services

VMware's Global Support Services (GSS) organization is global and as part of standard practice engages the necessary resources wherever they are in the world. VMware has established a variety of process and procedures to protect data while working to resolve customer support issues. For a more in-depth overview of Global Support Services and more on their expertise in Virtualization and Cloud Infrastructure, see http://www.vmware.com/files/pdf/support/VMware-Support-GSS-BR-EN.pdf.

Vulnerability Management

VMware has a Vulnerability Management program backed by approved and tested policies and procedures. Vulnerability scans are performed regularly on internal and external systems.

System and application owners are required to address critical and high vulnerabilities with a plan of corrective action within 5 days of vulnerability discovery. Other vulnerabilities need to be addressed with a plan of corrective action within a reasonable period of time.

Risk analysis and acceptance are performed on vulnerabilities to confirm the vulnerability, and to determine the appropriate means of addressing the vulnerability. Senior management within the applicable BU – as

well as IT and Information Security senior management – are required to approve the existence of all risks associated with vulnerabilities that are not patched with vendor provided fixes.

Penetration Testing

VMware utilizes trained and experienced internal Information Security staff as well as third parties to periodically perform full penetration testing of critical systems and applications. VMware Information Security makes every effort to have third-party testing performed annually. Findings from penetration testing are handled in the same manner as vulnerabilities as discussed above. Penetration test results are considered VMware Private/Protected information and are not shared outside of the organization.

In order to achieve more meaningful test results, VMware uses both white and gray box testing. A gray box approach is a mixture of black box and white box testing. White box testing means that all the source code will be made available and black box testing means that the actual pentest will be performed without any source code access. The gray box method enables the vendor performing the pentest to have source code available to assist with penetration testing. This results in a more robust set of tests because the consultants can achieve deeper and broader access since they spend less time breaking into targeted assets. The third-party vendors have signed NDA agreements with the company and are allowed access to view source code at approved VMware facilities to help with finding attack vectors

Privacy

Privacy Policy: The VMware Privacy Policy can be reviewed at http://www.vmware.com/help/privacy.html.

Data Protection Agreement: Although this may be negotiated by certain vendors, as a general matter, VMware requires third-party vendors to agree to abide by the VMware DPA, which outlines the security controls and methods required by third-parties when handling VMware or its customers' data.

Safe Harbor: VMware is EU Safe Harbor certified and reviews this certification annually.

Conclusion

VMware strives to build products that its customers trust in the most critical operations of their enterprises. To promote this, VMware has established oversight and policy structures that identify and mitigate potential product security risks during development and has instituted programs and practices that drive software security initiatives and awareness across the enterprise.

VMware’s focus on product security strategy and our security development lifecycle ensure our ability to continuously evolve common practices and policies and so protect sensitive customer information from product vulnerabilities.

In closing, this document represents VMware’s innovative, cooperative approach to security for its world-class virtualization software products and solutions. As such it also represents VMware’s continuing commitment to its customers’ success.

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