

# **Navigating the Future of Software Supply Chain Security: A NIST SP 800-204D Perspective**

Securing the Software Supply Chain in  
the DevOps Era: A Practical Guide





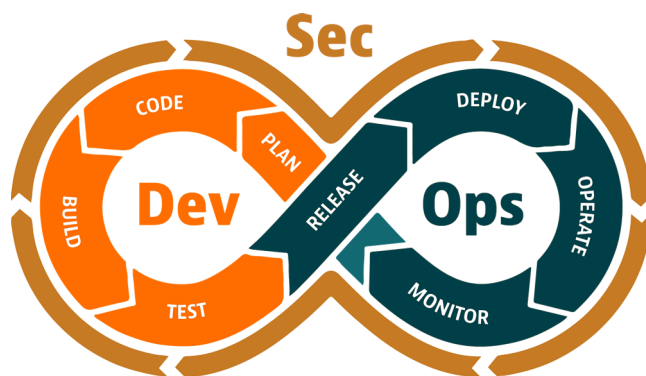
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# Introduction

DevOps, a transformative movement that revolutionized software development and operations, has evolved from a mere methodology to a deeply ingrained culture. To fully comprehend the significance of Software Supply Chain Security (SSCS) within the context of DevOps, it's crucial to delve into the evolution of DevOps itself.

The National Institute of Standards and Technology (NIST), recognizing the growing importance of SSCS, has developed a new draft publication, NIST SP 800-204D, providing invaluable guidance on integrating SSCS into DevSecOps CI/CD pipelines. This document meticulously outlines strategies for seamlessly embedding SSC security measures into CI/CD pipelines, the intricate processes that transform source code into deployed software, traversing various stages such as building, testing, packaging, and deployment.







# CHAPTER 1

## **A Brief Overview of the Evolution of DevOps**

DevOps, as many in the industry know, is not just a methodology or a set of practices; it's a culture. The movement fundamentally reshaped our thoughts on software development and operations. But to truly understand the significance of Software Supply Chain Security (SSCS) in the context of DevOps, we need to take a step back and look at the evolution of DevOps itself.



# 1. The Future of DevOps

## The Genesis of DevOps and the Cultural Shift

The term “DevOps” emerged as a fusion of “Development” and “Operations.” At its core, DevOps was born out of a need to bridge the gap between software developers and IT operations. Traditional software development models often saw these two teams working in silos, leading to inefficiencies, miscommunications, and delays.

In the early days, software was developed in long cycles. Developers would write code, and once they believed it was ready, they’d hand it off to operations to deploy. This “throw it over the wall” approach often led to issues in

production, as the environment in which the code was written was often vastly different from the production environment.

DevOps sought to change this by emphasizing collaboration between developers and operations. The idea was simple: by working together from the start of a project, many of the issues that arose from the traditional model could be avoided. This wasn’t just about speeding up software delivery; it was about improving the quality of the delivered software.

### Automation and Continuous Integration (CI)

As the DevOps movement grew, so did the associated tools and practices. Automation became a cornerstone of DevOps. Instead of manual deployments, which are error-prone and time-consuming, automated deployment tools ensure that code can be seamlessly moved from development to production.

Continuous Integration (CI) took this a step further. With CI, developers could merge their changes into a central repository multiple times daily. Automated build and test tools would then check this code, ensuring

### The Advent of Continuous Deployment and Delivery (CD)

While CI focused on automating code integration, Continuous Deployment and Continuous Delivery (often called CD) focused on automating releases. Every change that passed the automated tests could be automatically deployed to production with CD. This meant that software could be developed, tested, and released far more quickly than ever.

## The Need for Software Supply Chain Security in DevOps (SSCS)

With the rapid pace of CI/CD, the software supply chain has become more complex. The software wasn’t just being developed in-house; it often included multiple third-party components. If not adequately vetted, each of these components could introduce vulnerabilities into the software.

This is where Software Supply Chain Security (SSCS) comes into play. As DevOps evolved, it became clear that its speed and efficiency could also introduce risks. SSCS seeks to address these risks by ensuring that every component of the software supply chain is secure.

While DevOps revolutionized how we develop and deliver software, SSCS is set to revolutionize how we secure it.

For seasoned DevOps professionals, the integration of SSCS is a daunting task. But it’s a necessary evolution. Just as DevOps bridged the gap between development and operations, SSCS seeks to bridge the gap between speed and security. As we move forward, those in the DevOps field will find that a deep understanding of SSCS is not just beneficial; it’s essential.



## CHAPTER 2

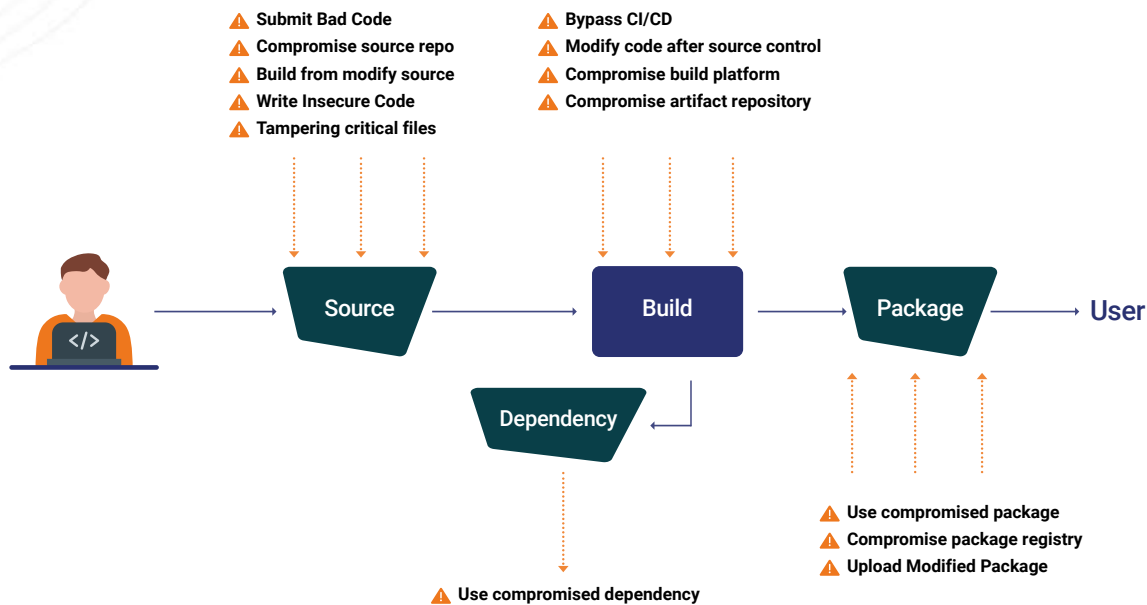
### Understanding Software Supply Chain Security (SSCS)

Software Development is a complex process that involves integrating multiple components, libraries, and services from various sources. This intricate web of dependencies and integrations is what we refer to as the Software Supply Chain that is susceptible to risks.

## 2. Understanding SSCS

Before diving deep into SSCS, let's first unpack the concept of the software supply chain. Imagine building a car. You wouldn't manufacture some parts from scratch. Instead, you'd source various components – the tires, the engine, the electronics – from different suppliers in a factory - machinery, assembly line protocols, and people. Similarly, developers rely on numerous external components when developing software, be it open-source libraries, third-party APIs, or cloud services. They use from Integrated Development Environments (IDE) to continuous integration tools and from code repositories to deployment automation tools. Their 'assembly protocols' are coding standards, best practices, testing protocols, and deployment guidelines.

Each of those third-party components, while aiding in the rapid development of software, also represents a potential point of vulnerability. If one component is compromised, it could potentially affect the entire application. At the same time, elements of the assembly line represent a potential vulnerability or point of entry for malicious actors.



SSCS is the discipline of ensuring the integrity, authenticity, and security of each element in the software supply chain. It's about vetting third-party components, ensuring secure coding practices, continuously monitoring for vulnerabilities and securing our Software Factory. But why is this so crucial?

### Increasing Complexity

Modern software applications leverage many third-party components, each of which can be a potential vulnerability. As software becomes more complex, the attack surface expands.

### Notable Breaches

Several high-profile breaches have resulted in vulnerabilities in third-party components or lapses in the software assembly process over the past few years. Such incidents spotlight the critical need for a fortified supply chain.

### Regulatory Compliance

With data privacy and security regulations becoming stringent globally, ensuring the security of the software supply chain isn't just a best practice; it's often a legal requirement.





## CHAPTER 3

### SSCS: Guarding the Factory

Software Supply Chain Security is akin to safeguarding the sanctity of a car's production line. It's about ensuring that every part, every process, and every individual involved is geared towards a singular goal – producing secure, robust, and reliable software. As the digital realm grows, the importance of SSCS will only amplify, making it a central tenet of modern software development.

#### Core Strategies for Protecting Our Software Factory

##### Component and Tools Vetting

Every tool, be it a code repository or a deployment automation tool, and before integrating any third-party component, it's essential to vet them rigorously. This involves checking for known vulnerabilities, understanding its maintenance history, ensuring regular updates, and evaluating its security posture.

##### Process Optimization

Processes should be continuously refined to incorporate the latest security best practices. This might involve updating coding standards or tweaking deployment protocols to enhance security regulations becoming stringent globally, ensuring the security of the software supply chain isn't just a best practice; it's often a legal requirement.

##### Collaborative Defense

Just as DevOps emphasizes collaboration between development and operations, SSCS requires collaboration between developers, security teams, and operations. Developers, security experts, operations teams, and even third-party vendors must collaborate to ensure the security of the entire software assembly line.

##### Observability and Traceability

Maintaining a clear record of every component, tool and build or delivery process in the software supply chain is vital. This traceability ensures that an issue can be traced back to its source and addressed promptly.

##### Automated Security Checks

Automation is at the heart of DevOps and equally crucial in SSCS. Automated tools scan for vulnerabilities, check for updates, monitor for anomalous activity and ensure compliance with security policies.

##### People Training

Regular training sessions should be conducted to keep the team updated on the latest threats and best practices. A well-informed team is the first line of defense against potential security breaches.

##### Continuous Monitoring

The software landscape is dynamic. SSCS emphasizes the continuous monitoring of all components, ensuring they remain secure throughout their lifecycle and ensuring the assembly line's integrity.





## CHAPTER 4

# SSCS Risk Factors and DevOps Mitigation Measures

Understanding the myriad of risks and actively implementing mitigation measures is paramount. Organizations can fortify their software supply chain by addressing each risk factor in detail. Software Supply Chain Security is about ensuring that the speed and efficiency of DevOps do not come at the cost of security.

# 4. SSCS Risk Factors and DevOps Mitigation Measures

For seasoned DevOps professionals, embracing SSCS is the next step in the evolution, ensuring they remain at the forefront of safe, efficient, and secure software delivery.

Navigating the complex landscape of Software Supply Chain (SSC) security requires a deep understanding of the various risk factors and the strategies to counteract them.

Let's explore each risk factor and its specific mitigation measures recommended in NIST SP 800-204D.

## 1. Developer Environment

Developer workstations and their environments are susceptible to compromise. Implicit trust in these workstations can lead to vulnerabilities being introduced into the software supply chain. Some mechanisms that could help us face these risks are:

- **Segmentation:** Ensure that developer environments are isolated from critical production networks. This reduces the risk of potential threats spreading from a compromised developer workstation to critical systems.
- **Regular Audits:** Periodically audit developer workstations for vulnerabilities, outdated software, and unauthorized applications. Ensure that all software is patched and up-to-date.
- **Zero Trust Model:** Implement a zero-trust security model where every access request is fully authenticated, authorized, and encrypted before granting access.

## 2. Threat Actors

Both external attackers, such as foreign adversaries and cyber-activists, and internal threats, like disgruntled employees, pose significant risks to the SSC. We can protect ourselves by:

- **User Behavior Analytics (UBA):** Gather relevant events and use this information to monitor and analyse users' behaviours to detect anomalies that might indicate potential threats in real time.
- **Strict Access Controls:** Ensure access to critical systems and data is restricted based on roles. Regularly review and update access permissions to ensure the principle of Least Privilege.

## 3. Attack Vectors

Various methods, including malware, social engineering, network-based, and physical attacks, can target the software development environment. We still can rely on:

- **Endpoint Protection:** Deploy advanced endpoint protection solutions that can detect and block malware in real time.
- **Security Awareness Training:** Regularly train developers and staff on recognising and avoiding social engineering tactics, such as phishing.
- **Network Monitoring:** Use intrusion detection systems (IDS) and intrusion prevention systems (IPS) to monitor and block suspicious network activities.
- **Physical Security:** Ensure development centers have robust physical security measures, including surveillance cameras, biometric access controls, and security personnel.

## 4. Attack Targets (Assets)

Critical assets like source code, credentials, and sensitive data can be targeted by attackers for theft, manipulation, or sabotage. Some configurations the DevOps teams can implement are:

- **Data Encryption:** Encrypt sensitive data at rest and in transit to ensure that even if data is accessed, it remains unintelligible to unauthorized users.
- **Multi-Factor Authentication (MFA):** Implement MFA for accessing critical systems and databases, adding an additional layer of security beyond just passwords.
- **Regular Backups:** Ensure critical assets, especially source code, are backed up regularly in secure, off-site locations.

# 4. SSCS Risk Factors and DevOps Mitigation Measures



## 5. Types of Exploits

Various tactics, from injecting vulnerabilities to using stolen credentials, can be employed by attackers to compromise the software supply chain. To mitigate these tactics, the teams should adopt:

- **Code Review:** Implement strict code review processes where multiple developers review code changes to detect potential vulnerabilities or malicious injections. Repository Security: Ensure that code repositories have strict access controls. Monitor repositories for unauthorized changes or suspicious activities.
- **Secure Development Practices:** Train developers in secure coding practices to reduce the chances of vulnerabilities being introduced in the first place.
- **Secure DevOps Infrastructure:** Incorporate security testing and scanning tools into the CI/CD infrastructure and establish secure configuration management practices to ensure all infrastructure elements are adequately configured with robust security settings from access management controls until secure communication channels.

## 6. Forking & Repository Manipulation

Attackers can “fork” or copy a repository, make malicious modifications, and then attempt to merge these changes back into the original project through a pull request. If not adequately reviewed, this can introduce malicious code into the repository. Some critical mechanisms to detect or avoid these attacks are:

- **Pull Request Reviews:** Implement a mandatory multi-person review process for all pull requests, especially those from external contributors. This ensures that changes are thoroughly vetted before being merged.
- **Automated Testing:** Use automated testing tools in the CI/CD pipelines to check pull requests for potential security vulnerabilities, security flaws or anomalies to identify them early and address them promptly.
- **Repository Access Control:** Limit who can approve and merge pull requests. Ensure that only trusted, trained individuals have this capability.

## 7. Lack of Code Integrity in Public Repositories

When using open-source code, there’s no guarantee that the pulled code is the same as the developer initially authored. Modifications could have been made, introducing vulnerabilities or bypassing checks in the CI/CD process. Avoid them with:

- **Digital Signatures:** Ensure code commits and trusted developers digitally sign releases. This provides a level of assurance about the code’s origin and integrity.
  - **Dependency Scanning:** Use tools to scan dependencies for known vulnerabilities, ensuring you’re not inadvertently introducing risks.
- Source Verification: Whenever possible, verify the integrity of open-source code by comparing it with multiple trusted sources or repositories.

## 8. Insecure Build Systems

The systems and processes used to build software can be targeted by attackers to introduce vulnerabilities or malicious code. Avoid it via:

- **Build System Hardening:** Ensure that build systems are hardened against attacks. This includes patching software, restricting access, and regularly scanning for vulnerabilities.
- **Immutable Build Environments:** Use immutable build environments created fresh for each build and destroyed afterwards. This reduces the risk of persistent threats.

## 9. Bypassing CI/CD Checks

Continuous Integration/Continuous Deployment (CI/CD) processes can be bypassed, allowing potentially harmful code to be deployed without undergoing necessary checks and tests.

- **Mandatory CI/CD Checks:** Implement policies that make CI/CD checks mandatory for all deployments. No code should be deployed without passing through this pipeline.
- **Monitor CI/CD Tools:** Regularly monitor and audit CI/CD tools for any signs of tampering or unauthorized access. In essence, while the challenges in SSC security are multifaceted, with a proactive, detailed approach, we can ensure that each potential vulnerability is addressed, ensuring a robust and secure software development environment.





## CHAPTER 5

# Why SSCS is Crucial for Modern DevOps Practices

To appreciate the significance of SSCS, we first need to understand the essence of DevOps. At its core, DevOps is about continuous integration and continuous delivery (CI/CD). It's a culture where code changes are automatically tested, integrated, and deployed to production, ensuring faster release cycles and immediate feedback.

This continuous flow, while efficient, also means that vulnerabilities can quickly move from development to production if not detected early.

### The Expanding Attack Surface

Modern DevOps practices involve many tools and third-party components. The software supply chain has grown complex, from container orchestration tools like Kubernetes to package managers like npm or pip. Each integration, while enhancing functionality, introduces potential vulnerabilities.

It's akin to adding more doors and windows to a house – each new addition can be a potential entry point unless adequately secured.

### The Expanding Attack Surface

Recent years have witnessed a surge in supply chain attacks. Malevolent actors, recognizing the potential vulnerabilities in third-party components, have targeted them to compromise larger systems. For instance, a single vulnerable library, if widely used, can affect thousands of applications.

In a DevOps environment, where changes are continuously integrated, such vulnerabilities can rapidly propagate, making the need for SSCS even more pronounced.

### Maintaining trust and credibility

In DevOps isn't just about speed; it's about trust. Stakeholders trust that the continuous flow of changes will maintain services. Integrating SSCS ensures that as code flows through the DevOps pipeline, it's continuously vetted for vulnerabilities, ensuring that trust is maintained.

# 5. Why SSCS is Crucial for Modern DevOps Practices



## Regulatory and Compliance Pressures

As data breaches become more common, regulatory bodies worldwide are tightening software security requirements. For many organizations, ensuring software supply chain security isn't just about best practices but compliance. Failing to meet security standards can lead to hefty penalties, making SSCS integration not just a technical requirement but a legal one.

## The Proactive Approach of SSCS in DevOps

SSCS isn't about reactive measures; it's proactive. It's about identifying and addressing vulnerabilities before they become threats. In the DevOps world, where feedback loops are tight, SSCS provides immediate insights into potential security issues, allowing teams to address them in real-time.

## The Essence of SSCS and CI/CD Pipelines

SSCS is the backbone of modern cloud-native application development and deployment. DevOps is a journey that begins with code sourced from various repositories, be it in-house or third-party, open-source, or commercial. This code undergoes a series of meticulously orchestrated tasks, from building and packaging to testing and deployment.

Imagine the CI/CD pipeline as a sophisticated assembly line. Code, akin to raw materials, is transformed through various stages. It's built based on application logic-driven dependencies, creating build artifacts stored in specific repositories. These artifacts undergo rigorous testing, leading to the generation of deployable packages. Before these packages reach their final destination, be it a testing or production environment, they're scanned meticulously for vulnerabilities.

This entire transformation, from raw code to deployable packages, is facilitated by workflows within CI/CD pipelines. Platforms like GitHub Actions, GitLab Runners, and Buildcloud are the powerhouses supporting these workflows.

The robustness of software pipelines has gained significant attention lately as incidents targeting software supply chains have risen. Organizations must meticulously select third-party software, products, and tools for their software frameworks. Simultaneously, they must implement strategies to safeguard the authenticity of their software components and the processes of building and deploying them. Constructing software that possesses confirmable security stands as a pivotal element of SSCS.



## CHAPTER 6

### Implementing SSCS in DevOps

SSCS is a critical component of overall cybersecurity. By implementing SSCS practices, organizations can help to protect themselves from the risks of malicious code injection, supply chain compromise, and data breaches. This can help to improve the security and reliability of their software and protect their business from reputational damage and financial losses.



## 6. Implementing SSCS in DevOps



In cybersecurity, the term “Zero Trust” has gained prominence. It’s a paradigm shift, focusing on protecting assets and resources, from services and applications to hardware systems like servers. Unlike traditional models where trust is implicit, Zero Trust demands verification. Every entity, a user, service, or server, must prove its legitimacy through robust authentication. Only then they are granted access based on well-defined enterprise policies.

However, when we pivot to SSC, the focus narrows down to the integrity of artifacts and their storage repositories. It’s a world where trust is a byproduct of assured integrity. As artifacts traverse through various repositories, evolving and integrating, they eventually shape the final product. Ensuring the unblemished integrity of these artifacts and repositories is paramount, for this integrity fosters trust.

Platforms like GitHub Actions exemplify the integration of security measures within CI/CD platforms, enabling developers to automate and secure their entire software lifecycle seamlessly. Regarding SSCS, two primary security objectives stand out:

- **Defensive Measures:** The pipeline should be fortified with many defensive strategies, ensuring that malicious entities can’t tamper with the software production processes or sneak in harmful software updates. Think of it as having a secure foundation for the entire build process.
- **Integrity Assurance:** Every artifact within the SDLC, from repositories to the tiniest piece of code, should maintain its integrity. It is achieved by defining roles and authorisations for every actor involved in the process. It’s about ensuring that every piece fits perfectly, maintaining the sanctity of the final product.

The framework established for CI pipelines must be robust and versatile. It should be adept at supporting not only the avant-garde, cloud-native software development environments but also the more traditional, legacy (and even on-premises) systems. Adherence to standard evidence structures, such as metadata and digital signatures, is non-negotiable.

Furthermore, this framework should be versatile enough to be compatible across a myriad of hardware and software platforms. It should be designed with an inherent capability to generate evidence that validates its processes.

# 6. Implementing SSCS in DevOps

## Ensure Security Configuration in DevOps Tools

The tools and platforms that underpin DevOps operations play a pivotal role in Continuous Integration. Their utility isn't just in facilitating seamless development and deployment; they are also instrumental in ensuring the security and integrity of the entire process. Central to this is the meticulous configuration of security settings within these tools.

For instance, branch protection is a crucial feature in version control systems like Git. By safeguarding critical branches, it ensures that inadvertent or malicious changes don't compromise the codebase. This protection can be further bolstered by mandating code reviews before any merge, ensuring that a second pair of eyes scrutinise every change. Such mandatory reviews not only catch potential security vulnerabilities but also uphold coding standards and prevent technical debt.

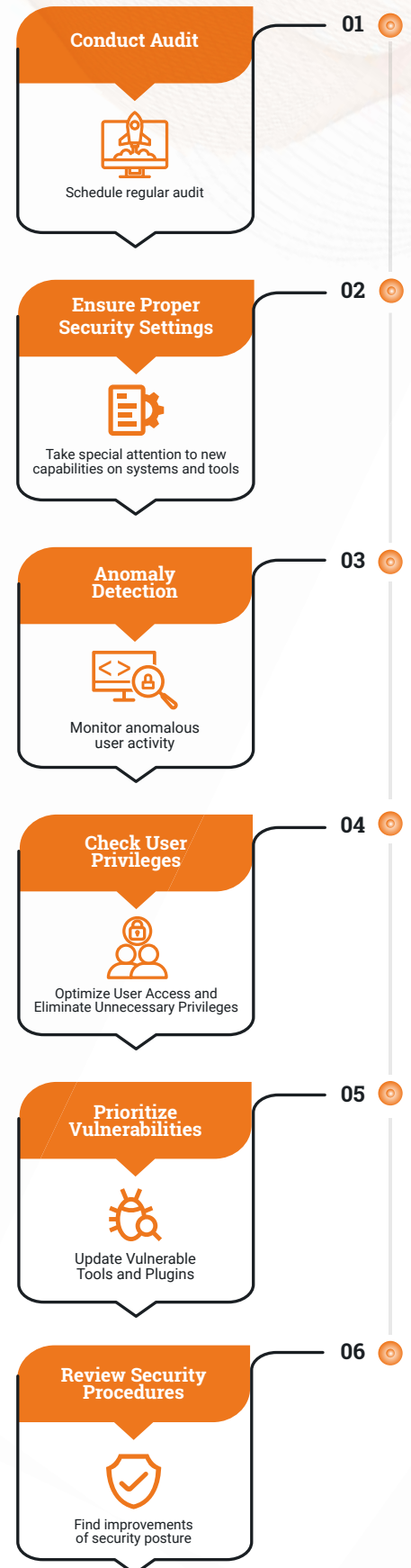
Moreover, settings that prevent force pushes can protect the commit history, ensuring a transparent and traceable lineage of code changes. This is invaluable for audits and understanding the evolution of the codebase. Similarly, integrating automated security checks and scans as part of the pull request process can catch vulnerabilities before merging.

Furthermore, platforms like Jenkins, GitLab, and others have become the cornerstones of many CI pipelines, largely due to their extensibility through plugins. However, this very strength can also be a potential Achilles' heel if not managed with caution.

Every tool or plugin integrated into a CI system introduces potential vulnerabilities. Some might be outdated, others could be poorly maintained, and a few might even be malicious or have known security issues yet to be addressed. Such vulnerable components can jeopardize the entire CI pipeline, making it susceptible to breaches, data leaks, or even complete takeovers.

To mitigate these risks, organizations must adopt a proactive approach. Regularly auditing and updating tools and plugins is a start. Automated vulnerability scanners should be employed to continuously monitor for known issues in the tools and plugins in use. When vulnerabilities are detected, immediate action, patching or replacing the vulnerable component, is essential.

### PROACTIVE RISK MITIGATION





# Strengthen the Security of Continuous Deployment (CD) pipelines

Continuous Deployment is the place where the culmination of development efforts meets the real-world environment. A series of due diligence measures is indispensable to ensure the sanctity of this transition. These measures, often articulated as verification policies, serve as the gatekeepers, determining which artifacts are fit for deployment.

One of the foundational controls during deployment revolves around the build information. Suppose an organization has invested in establishing a secure build environment. In that case, it becomes imperative to ensure that any artifact, such as a component, an executable, or a container image, earmarked for deployment is a product of this trusted process. It is not just about trust but about maintaining a consistent security posture throughout the software lifecycle.

SSCS proactive measures empower DevOps

teams to ensure that only vetted and verified software assets are integrated into the environment, maintaining their trustworthiness even during runtime. Even code that has been stored in repositories, primed for deployment, should be subjected to security scans, especially to detect embedded secrets like keys and access tokens. Additionally, before any pull request merges, a thorough review should be conducted to identify any vulnerabilities, ensuring the codebase remains pristine.

SSCS approach is holistic, encompassing everything from scanning any artefact as soon as it is built to managing it using tools seamlessly integrating with CD pipelines.





## 6. Implementing SSCS in DevOps

### Enhanced Security and Integrity in Continuous Integration (CI) pipelines

Continuous Integration stages encompass build operations, where raw code metamorphoses into executable software; push/pull operations, which dictate how code is managed across both public and private repositories; software updates to ensure the software remains current and functional; and code commits, which finalize and store the changes made to the software.

#### Secure Code Commits

Before any piece of code is committed, it undergoes a series of tests. These tests, conducted using Static Application Security Testing (SAST) to detect any vulnerability of malicious pieces of code or backdoors, should be tailored to the unique demands of cloud-native applications. If the code relies on open-source modules, dependencies must be meticulously detected using Software Composition Analysis (SCA) tools.

A pivotal SSC security measure during code commits is the vigilant prevention of secrets being inadvertently embedded within the code or dangerous configuration on the IaC files. This is achieved through a vigilant scanning operation, resulting in a feature termed as push protection.

#### Secure Pull-Push Operations

In the intricate dance of CI/CD pipelines, code doesn't exist in isolation. It resides in repositories, waiting to be extracted, modified, and then returned. These actions, termed pull and push operations, are gateways that need vigilant guarding. Ensuring the security of these operations hinges on two pivotal checks:

- A rigorous authentication protocol that verifies the developers' credentials and
- A mechanism to vouch for the integrity of the code within the repository.

But how does one ensure this trustworthiness? The answer lies in a multi-pronged approach. It involves running automated checks on all pull requests, ensuring CI pipelines are triggered only when the source code's origin is beyond reproach, and leveraging built-in protections in source code management systems.

#### Secure Building

In the realm of Software Supply Chain (SSC) security assurance, the build process is paramount. It demands a clear delineation of policies that touch upon the platform used for the build, the tools employed, and the authentication protocols required for developers overseeing the build process. But setting these policies is just the beginning. They must be rigorously enforced, monitored, and, if necessary, adapted to the ever-evolving software development landscape.

A cornerstone of this process is creating an evidence trail that spans the entire Software Development Life Cycle (SDLC). This isn't just a passive log but a dynamic record, encompassing details from the hash of the final build artifact to the minutiae of events that transpired during the build. Once collated, this evidence is securely signed, serving as an unimpeachable testament to the software's quality.



### The integrity of attestations and evidence in Software Update Systems

A significant threat to these software update systems is the potential targeting of the evidence generation process. Adversaries aim to obliterate the traceability of updates, making it challenging to ascertain the legitimacy of the updates. In essence, they seek to blur the lines between genuine and malicious updates, thereby compromising the integrity of the software.

Software update systems manifest in various forms, each catering to specific needs:

- **Package Managers:** These are comprehensive systems responsible for managing all software installed on a device or system.
- **Software Library Managers:** These systems manage and install software extensions, such as plugins or specific programming language libraries.
- **Application Updaters:** These specialised systems oversee updates for individual applications.

At the heart of a software update system's operation is the identification and subsequent downloading of essential files for a given update. While it might seem that verifying the signatures on the metadata of files or packages would suffice to establish trust, the reality is more nuanced. The process of signature generation itself can be susceptible to various attacks, necessitating a plethora of additional security measures to ensure the integrity of signatures and their verification.

As the landscape of threats evolves, so does the framework designed to bolster the security of software update systems. This framework, a composite of libraries, file formats, and utilities, is tailored to fortify new and existing software update systems. Several consensus-driven goals underpin this framework:

- **Robust Protection:** The framework should be adept at shielding software update systems from all recognized threats. It includes threats to metadata generation, the signing process, management of signing keys, and the integrity of the signing authority. Furthermore, it should ensure the validity of keys and the verification of signatures.
- **Mitigating Key Compromise:** The framework should be designed to minimize the ramifications of a key compromise. This entails supporting roles with multiple keys and implementing threshold or quorum trust mechanisms. Notably, roles associated with highly vulnerable keys should be insulated from significant impacts. As a testament to this, online keys, which are used in automated processes, should never be employed for roles that have clients' trust for installing files.



## CHAPTER 7

### **Attestations for Secure Software Development**

Amidst the myriad of security measures and protocols, one concept emerges as the cornerstone of trust and reliability: attestation. Serving as the bedrock of verification, attestation provides a tangible, verifiable assurance that each component and process within the software ecosystem adheres to the highest standards of integrity.



# 7. Attestations for Secure Software Development



## Critical Components of a Software Attestation Solution

### Evidence Collector

Think of this as the detective in a crime novel. The evidence collector's role is to meticulously gather evidence from every nook and cranny of the software development lifecycle. Whether logs from a CI/CD pipeline, configurations of a deployed instance, or test results from a QA phase, the collector ensures nothing slips through.

### Secure Storage

Once evidence is in hand, it's imperative to keep it safe. This is where secure storage steps in. More than just a digital locker, this encrypted and often distributed storage ensures the evidence remains untampered and always available for scrutiny.

### Verifier

But how do we know if the judge isn't biased? Enter the verifier. It's an independent component that validates the attestations, ensuring they are genuine and backed by a trusted authority.

### Reporting Dashboard

For those who want a bird's eye view of the entire process, the reporting dashboard offers a transparent and comprehensive overview. It's a window into the software's security posture, presenting stakeholders with insights into every piece of evidence and every attestation.

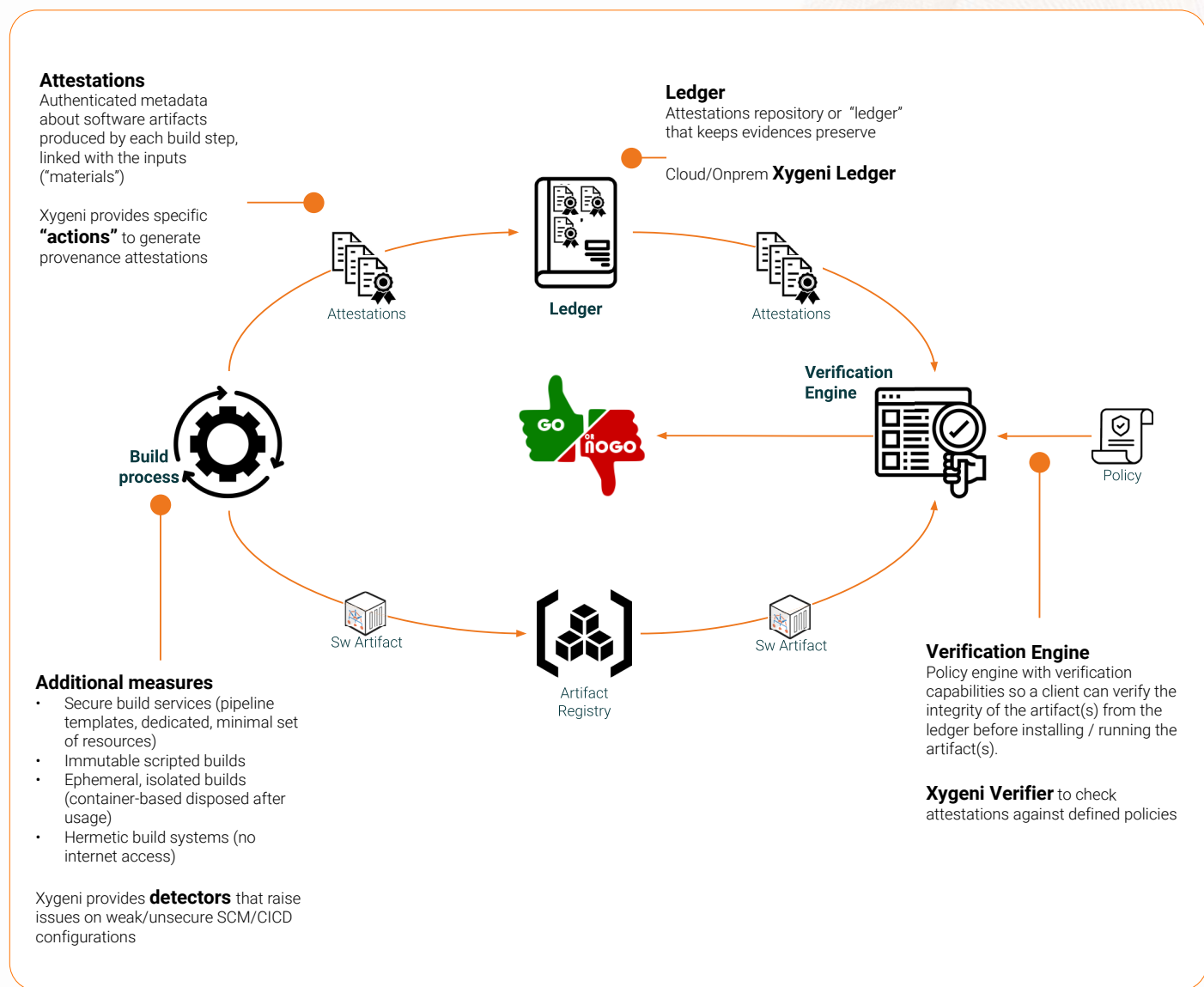
### Attestation Engine

If the evidence collector is the detective, the attestation engine is the judge. It weighs the collected evidence, assesses its integrity, and generates attestations based on this assessment. These attestations, in essence, are digital affirmations that vouch for the software's security and compliance.

# 7. Attestations for Secure Software Development

## The Attestation Workflow: From Collection to Verification

Attestation workflow stands as the sentinel of software integrity, orchestrating a series of checks and validations to ensure every component's authenticity. This systematic process forms the backbone of trust, bridging the gap between security protocols and their real-world implementation. The usual steps for generating and gathering attestations are:



# 7. Attestations for Secure Software Development



## 1. Defining the contract

The build Contract in Xygeni defines the expectations regarding the content a build must send as part of their attestation. It could include specific details like the URI@digest of the generated container image, the container rootfs used during the build, and the Software Bill of Materials (SBOM) of that container image. Contracts are an essential piece of the attestation process. In essence, Contracts are like safety nets, ensuring that every building process meets the set standards and expectations. They are composed (among other less relevant) of:

- **Materials:** This is the core of the contract. It specifies the types of evidence or artefacts the build should include in its attestation. Whether it's a container image, an artefact, or a specific SBOM format, the materials section ensures that nothing is missed.
- **Environment Allow List:** This is a curated list of environment variables. When the build sends its attestation, only the variables on this list will be included, ensuring irrelevant or sensitive data is left out.
- **Runner Context:** This specifies where the attestation process will run. For instance, if you're using GitHub Actions, the runner type would be "GITHUB\_ACTION", ensuring the attestation is tailored to that environment.

## 2. Integration into Pipelines

Before we can embark on the journey of attestation, it's crucial to lay a solid foundation. It involves weaving the attestation solution into the very fabric of the CI/CD pipelines. By configuring the pipelines with the necessary hooks, triggers, and listeners, we pave the way for a smooth interaction with attestation tools.

## 3. Generation of Attestations

With the stage set, we move to the heart of the process: generating attestations. Using the attestation predicate, such as the in-toto attestation predicate format, a narrative of the software's journey is crafted. This narrative, or attestation, is a testament to the software's integrity, detailing every step it has undergone. For instance, in-toto's layout files define the expected software supply chain steps, painting a clear picture of the software's journey from conception to deployment.

## 4. Safekeeping the Evidence

Once the attestations are generated, they are not left adrift. They are securely stored, ensuring their integrity remains untarnished. Think of this as a vault, where every piece of evidence, every attestation, is kept safe from prying eyes and malicious intents. Solutions like Xygeni offer robust storage options, ensuring the attestations remain unaltered and ready for validation.

# 7. Attestations for Secure Software Development

## 5. Verification

With the attestations safely stored, they are then put to the test. The mere presence of attestations isn't enough. Their validity and authenticity need to be verified. This validation process is where the software's narrative, the attestations, are cross-examined against the actual steps the software underwent, the contract.

Verification is the act of cross-referencing the attestations against a predefined contract. It's like a gatekeeper that checks each visitor's credentials before allowing them entry. The contract, in this context, is a set of rules or criteria that the attestations must meet. If they do, the workflow progresses; if not, it's halted or flagged.

One of the foundational principles of verification is monotonicity. In simple terms, monotonicity dictates that a system should be inherently secure by design. If there's any ambiguity or uncertainty, the system should default to a "fail-closed" state rather than an "open" one. This means that if there's any doubt about the validity of an attestation, the system should assume it's invalid.

Imagine a security system at a high-profile facility. If a visitor's credentials are questionable, the system shouldn't grant them access by default. Instead, it should deny access until the credentials are verified. The same principle applies to attestation verification. If an attacker manages to delete or obscure an attestation, the verifier should automatically flag it as "deny" due to the missing required attestation.

Upon verification, there are two primary responses:

- **Enforced Denial:** This is the strictest form of denial. If an attestation doesn't meet the policy's criteria, the associated artefact cannot run. It's a hard stop, ensuring potential threats are nipped in the bud.
- **Alerted Denial:** This is a more lenient form of denial. The artefact is allowed to run, but a warning notification is emitted. It's like allowing visitors into a facility but keeping a close eye on them.

Tools like Xygeni come into play here, offering a meticulous validation process that leaves no stone unturned.

## 6. Reporting and Insights

Post-validation, a detailed report is generated. This report is not just a testament to the software's integrity but also offers insights into its journey. The reporting and insights come into play, offering a panoramic view of the software's security posture and providing actionable intelligence to fortify it further. The system must proactively bring potential threats to the attention of relevant stakeholders. Key features of this alerting mechanism include:

- **Real-time Notifications:** The moment an anomaly is detected, be it a missing attestation or a mismatch, the system should trigger instant notifications to designated personnel.
- **Multi-channel Alerts:** Notifications should be sent across multiple channels – emails, dashboard alerts, or even integrations with platforms like Slack. It ensures that no alert goes unnoticed.
- **Contextual Alerts:** Every alert should be accompanied by contextual information. Which part of the workflow triggered it? What's the potential impact? This context empowers teams to act swiftly and decisively.



## CHAPTER 8

### **Benefits of Embracing SSCS in DevOps Environments**

The integration of Software Supply Chain Security into DevOps is a game-changer. It amalgamates the agility and efficiency of DevOps with the robustness of advanced security frameworks, paving the way for software solutions that are not just high-performing but also secure and trustworthy.

# 8. Benefits of Embracing SSCS in DevOps Environments

The integration of Software Supply Chain Security into DevOps is a game-changer. It amalgamates the agility and efficiency of DevOps with the robustness of advanced security frameworks, paving the way for software solutions that are not just high-performing but also secure and trustworthy. Here's a deep dive into the multifaceted advantages of this integration:



## Enhanced Security Posture and Shift Left

At its core, SSCS is designed to safeguard every phase of the software development lifecycle. By integrating SSCS into DevOps, organisations can ensure that vulnerabilities are identified and mitigated early, reducing the risk of security breaches and ensuring the integrity of the software.



## Streamlined Compliance

Regulatory landscapes constantly evolve, and non-compliance can result in hefty penalties. SSCS frameworks often align with industry standards and regulations, making it easier for organisations to adhere to compliance requirements and confidently navigate audits.



## Increased Trust and Credibility

In an age where data breaches are commonplace, organisations that prioritise security are often viewed more favourably by clients and stakeholders. By adopting SSCS, businesses can bolster their reputation, instil trust in their clientele, and differentiate themselves from competitors.



## Cost-Efficiency

Addressing security issues post-deployment can be a costly affair, both in terms of financial implications and reputational damage. SSCS, when integrated into DevOps, ensures that security is baked into the process from the outset, leading to significant cost savings in the long run.

# 8. Benefits of Embracing SSCS in DevOps Environments



## Accelerated Deployment

One of the hallmarks of DevOps is rapid deployment. With SSCS in place, security checks and validations become part of the continuous integration and deployment pipeline. It means that secure code can be deployed faster without compromising on security.



## Collaborative Security Culture

SSCS promotes a culture where security is everyone's responsibility. By integrating it into DevOps, security becomes a collaborative effort, bridging the gap between development and security teams and fostering a more cohesive and proactive approach to security challenges.



## Future-Proofing

As cyber threats become more sophisticated, having a robust SSCS framework ensures that organisations are not just responding to current threats but are also prepared for future challenges. This proactive approach ensures longevity and resilience in an ever-changing digital ecosystem.





# CONCLUDING REMARKS

## Concluding Remarks: Integrating Security Supply Chain Practices into DevSecOps with NIST SP 800-204D

In the ever-shifting digital landscape, software supply chain security (SSCS) stands as a crucial pillar of cybersecurity for organizations of all sizes. As DevOps practices gain prominence, the demand for SSCS will only intensify. Organizations that prioritize SSCS will be well-equipped to safeguard their supply chains and avert vulnerabilities from infiltrating their applications. By implementing robust SSCS measures, organizations can mitigate the risk of data breaches, reputational damage, and substantial financial losses.

The ebook has provided a comprehensive overview of SSCS, encompassing the inherent risks and challenges, along with effective strategies to mitigate those threats. It has also underscored the significance of NIST SP 800-204D as a guiding framework for SSCS implementation.

In the intricate dance of CI/CD pipelines, code doesn't exist in isolation. It resides in repositories, waiting to be extracted, modified, and then returned. These actions, termed pull and push operations, are gateways that need vigilant guarding. Ensuring the security of these operations hinges on two pivotal checks:

- SSCS is a dynamic and evolving domain. New vulnerabilities emerge regularly, and attack vectors evolve constantly, necessitating vigilant adaptation of SSCS strategies.
- SSCS transcends mere technical expertise; it demands a cultural shift within organizations. Developers, security teams, and other stakeholders must collaborate seamlessly to establish a secure supply chain.
- SSCS investment is a sound decision yielding substantial benefits, including reduced costs, enhanced security posture, and improved customer satisfaction.

In conclusion, SSCS is an indispensable asset for organizations seeking to safeguard their software and businesses from cyber threats. By embracing best practices and continuous improvement, organizations can construct a resilient and secure software supply chain capable of navigating the complexities of the modern digital landscape. As DevOps continues its transformative journey, organizations must prioritize SSCS to maintain their competitive edge and enduring success.




## **Navigating the Future of Software Supply Chain Security: A NIST SP 800-204D Perspective**

**Securing the Software Supply Chain  
in the DevOps Era: A Practical Guide**

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