



nShield Security World

CodeSafe v13.4.5 Developer Guide

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Table of Contents

| | |
|--|----|
| 1. Introduction | 1 |
| 1.1. Read this guide if | 1 |
| 1.2. Conventions | 2 |
| 1.2.1. Model numbers | 2 |
| 1.2.2. Security World Software | 3 |
| 1.3. Requirements | 5 |
| 1.4. Further information | 6 |
| 1.5. Security advisories | 6 |
| 1.5.1. Contacting Entrust nShield Support | 7 |
| 2. About the Secure Execution Engine SEE | 8 |
| 2.1. Why use the Secure Execution Engine? | 8 |
| 2.1.1. Code integrity | 9 |
| 2.1.2. Code confidentiality | 9 |
| 2.1.3. Data confidentiality | 10 |
| 2.1.4. Data integrity | 10 |
| 2.1.5. Authentication and access control | 11 |
| 2.2. How SEE works | 12 |
| 2.2.1. Code specifics | 13 |
| 2.2.2. Security | 13 |
| 2.2.3. Internals | 14 |
| 2.3. SEE system architecture | 15 |
| 2.4. SEE and byte code | 17 |
| 2.5. SEE and userdata | 18 |
| 2.5.1. What is userdata? | 18 |
| 2.5.2. Creating userdata suitable for loading into the HSM | 18 |
| 2.6. SEE and Security Worlds | 18 |
| 3. Designing SEE machines and SEE-ready HSMs | 20 |
| 3.1. Writing SEE machines - Solo XC | 20 |
| 3.1.1. Designing the glibc architecture | 20 |
| 3.1.2. Designing the SEELib architecture | 21 |
| 3.1.3. SEE machines for new algorithms | 23 |
| 3.1.4. Signing userdata for additional security | 25 |
| 3.1.5. Building your SEE machine and host-side application | 27 |
| 3.2. Writing SEE machines - Solo PCIe | 30 |
| 3.2.1. Designing the bsdlb architecture | 30 |
| 3.2.2. Designing for the SEELib architecture | 33 |
| 3.2.3. SEE machines for new algorithms | 34 |

| | |
|---|-----|
| 3.2.4. Signing userdata for additional security | 37 |
| 3.2.5. Building your SEE machine and host-side application | 39 |
| 4. Example SEE machines | 43 |
| 4.1. Configure the Windows Build Environment | 43 |
| 4.2. Examples for bsdlib library | 44 |
| 4.2.1. Building the HSM-side code | 45 |
| 4.2.2. Helloworld example | 46 |
| 4.2.3. SEE-Random example | 47 |
| 4.2.4. SEE-Enquiry example | 49 |
| 4.2.5. TCP proxy example | 50 |
| 4.3. Examples for glibc library | 51 |
| 4.3.1. Building the HSM-side code | 52 |
| 4.3.2. Helloworld example | 54 |
| 4.3.3. SEE-Random example | 55 |
| 4.3.4. SEE-Enquiry example | 56 |
| 4.3.5. TCP proxy example | 57 |
| 4.4. Examples for SEELib | 59 |
| 4.4.1. Building Linux host examples | 59 |
| 4.4.2. Building Windows host examples | 60 |
| 4.4.3. Building Solo SEE module examples | 61 |
| 4.4.4. Building Solo XC SEE module examples | 62 |
| 4.4.5. Example: Hello-World | 63 |
| 4.4.6. A3A8 example | 67 |
| 4.4.7. Example: RTC | 79 |
| 4.4.8. Example: Tickets | 85 |
| 4.4.9. Example: Benchmark | 90 |
| 5. Debugging SEE machines | 99 |
| 5.1. Debugging settings and output | 99 |
| 5.1.1. Debugging authorization | 99 |
| 5.1.2. Obtaining debugging output | 100 |
| 5.2. Finding memory leaks with stattree | 102 |
| 5.3. Segment addresses for Solo | 103 |
| 5.4. Vulnerability test harness | 104 |
| 5.5. Troubleshooting guide | 105 |
| 6. Deploying SEE Machines | 107 |
| 6.1. About the Feature Enabling Mechanism (FEM) | 107 |
| 6.2. Obtaining and using export certificates | 107 |
| 6.3. Automatically loading a SEE machine | 108 |
| 6.3.1. Automatically loading a glibc/bsdlib SEE machine with userdata | 111 |

| | |
|--|-----|
| 6.3.2. Automatically loading a glibc/bsdlib SEE machine without userdata | 111 |
| 6.4. Configuring the nShield Connect to use CodeSafe Direct | 112 |
| 6.5. Configuring a SEE machine using the front panel | 113 |
| 6.5.1. Configuring a glibc/bsdlib SEE machine | 114 |
| 6.5.2. Configuring a SEElib SEE machine | 114 |
| 6.6. Remotely loading and updating SEE machines | 115 |
| 7. Utilities | 117 |
| 7.1. cpioc | 117 |
| 7.1.1. Usage | 117 |
| 7.2. elftool | 118 |
| 7.2.1. Usage | 118 |
| 7.3. loadmache | 119 |
| 7.3.1. Usage | 120 |
| 7.4. loadsee-setup | 121 |
| 7.4.1. Usage | 121 |
| 7.4.2. Output | 123 |
| 7.4.3. loadsee-setup --display | 125 |
| 7.5. hsc_loadseemachine | 125 |
| 7.5.1. Usage | 125 |
| 7.6. nfkmverify | 126 |
| 7.6.1. Usage | 127 |
| 7.6.2. Output | 128 |
| 7.7. see-*serv utilities | 129 |
| 7.7.1. Usage | 130 |
| 7.7.2. Error output from SEE machine with SEElib architecture | 132 |
| 7.8. stattree | 132 |
| 7.8.1. Usage | 132 |
| 7.8.2. Output | 132 |
| 7.9. tct2 | 138 |
| 7.9.1. Usage | 139 |
| 7.9.2. Signing | 142 |
| 7.9.3. Packing | 143 |
| 7.9.4. Encryption | 143 |
| 8. Environment variables | 145 |
| 9. Key generation options and parameters | 147 |
| 9.1. Key application type (<APPNAME>) | 147 |
| 9.2. Key properties (<NAME>=<VALUE>) | 148 |
| 9.3. Available key properties by action | 152 |
| 9.4. Available key properties by application | 153 |

| | |
|---|-----|
| 10. SEELib functions | 156 |
| 10.1. SEELib_init | 156 |
| 10.2. SEELib_RecProcessThreads | 156 |
| 10.3. SEELib_StartProcessorThreads | 156 |
| 10.4. SEELib_GetUserDataLen | 157 |
| 10.5. SEELib_ReadUserData | 157 |
| 10.6. SEELib_ReleaseUserData | 157 |
| 10.7. SEELib_InitComplete | 158 |
| 10.8. SEELib_AwaitJob | 158 |
| 10.9. SEELib_StartTransactListener | 158 |
| 10.10. SEELib_Transact | 158 |
| 10.11. SEELib_MarshalSendCommand | 159 |
| 10.12. SEELib_GetUnmarshalResponse | 159 |
| 10.13. SEELib_FreeCommand | 160 |
| 10.14. SEELib_FreeReply | 160 |
| 10.15. SEELib_ReturnJob | 160 |
| 10.16. SEELib_SubmitCoreJob | 160 |
| 10.17. SEELib_GetCoreJob | 161 |
| 10.18. SEELib_GetUserDataLen | 161 |
| 10.19. SEELib_Submit | 161 |
| 10.20. SEELib_Query | 161 |
| 10.21. SEELib_StartSEETJobListener | 162 |
| 10.22. SEELib_QuerySEETJob | 162 |
| 10.23. SEELib_ReleaseSEETJob | 163 |
| 11. Differences between glibc and bsdlb (SoloXC only) | 164 |
| 11.1. glibc Compatibility exceptions | 164 |
| 12. SEE Machines Whitelist | 166 |

1. Introduction

CodeSafe is a runtime on the Entrust nShield HSM that allows third-party developers to run their own code within the secure boundary of the module. Using the CodeSafe Developer Kit, developers write their own CodeSafe Apps, cross-compile them and package them to run on the HSM. While on the HSM, the CodeSafe App is segregated from the actual keys loaded onto the module: even the keys the App uses. This means that CodeSafe can be used without affecting the FIPS 140 validation of the module it runs on.

Where the HSMs provide security controls on key usage, CodeSafe provides control over application code. Depending on the runtime used, you're either sending nCore commands to the HSM, or designing your own protocol to send data and commands back and forth.

The CodeSafe™ Developer Kit includes the Secure Execution Engine (SEE) technology. The CodeSafe product comprises a suite of cross-compilers and support tools that allow you to develop SEE machines.

With CodeSafe, you can build and deploy Trusted Agents to perform application-specific security functions on your behalf on unattended servers, or in unprotected environments where the operation of the system is outside of your direct control. Examples of Trusted Agents include digital meters, authentication agents, time-stamps, audit loggers, digital signature agents and custom encryption processes.

Traditionally, HSMs have protected cryptographic keys within a defined security boundary; SEE allows you to extend that security boundary to include code that utilizes those protected keys. The code itself can be signed and encrypted to provide additional protection.



This manual applies to both the **nShield Solo XC** and to the **nShield Solo PCIe**.

1.1. Read this guide if ...

Read this guide if you are writing and running SEE applications in C with a SEE-Ready HSM.

This guide:

- Introduces the concept of the Secure Execution Engine (SEE)
- Explains how to use the example SEE machines provided on the installation media
- Describes how to write your own SEE applications in C using the CodeSafe Developer Kit
- Describes how to run your secure SEE applications using a SEE-Ready HSM

- Describes how to obtain export certificates for SEE applications, if required

This guide assumes that you are familiar with the concept of Security World, as described in the *User Guide*. It also assumes that you are familiar with the following documentation:

- The *Cryptographic API Integration Guide*, which describes the use of hardware security modules with third-party software products
- The *nCore Developer Tutorial*, which explains how to write applications using a hardware security module
- The *nCore API Documentation* (supplied as HTML), which describes the nCore C API.



Concepts and terminology introduced in the *Cryptographic API Integration Guide*, *nCore Developer Tutorial*, and *nCore API Documentation* are not explained in this guide.

1.2. Conventions

1.2.1. Model numbers

Model numbering conventions are used to distinguish different nShield hardware security devices. In the table below, *n* represents any single digit integer.

| Model number | Used for |
|--------------|---------------------------|
| NH2047 | nShield Connect 6000 |
| NH2040 | nShield Connect 1500 |
| NH2033 | nShield Connect 500 |
| NH2068 | nShield Connect 6000+ |
| NH2061 | nShield Connect 1500+ |
| NH2054 | nShield Connect 500+ |
| NH2075-B | nShield Connect XC Base |
| NH2075-M | nShield Connect XC Medium |
| NH2075-H | nShield Connect XC High |
| NH2079-B | nShield 5c Base |
| NH2079-M | nShield 5c Medium |
| NH2079-H | nShield 5c High |
| NH2082 | nShield Connect XC SCAP |

| Model number | Used for |
|--------------------------|---|
| NH2089-B | nShield Connect XC Base - Serial Console |
| NH2089-M | nShield Connect XC Mid - Serial Console |
| NH2089-H | nShield Connect XC High - Serial Console |
| NH3003-B | nShield Connect CLX Base - Serial Console |
| NH3003-M | nShield Connect CLX Mid - Serial Console |
| NH3003-H | nShield Connect CLX High - Serial Console |
| nC3nnnE-nnn, nC4nnnE-nnn | nShield Solo PCIe |
| nC30n5E-nnn, nC40n5E-nnn | nShield Solo XC PCIe |
| nC30nnU-10, nC40nnU-10 | nShield Edge |
| NC5536E-B | nShield 5s Base |
| NC5536E-M | nShield 5s Medium |
| NC5536E-H | nShield 5s High |

1.2.2. Security World Software

The default locations for Security World Software and program data directories on English-language systems are summarized in the following table:

| Directory name | Linux default path | Windows environment variable | Windows Server 2016 or later |
|------------------------------|------------------------------------|------------------------------|---|
| nShield Installation | /opt/nfast/ | NFAST_HOME | C:\Program Files\nCipher\nfast |
| Key Management Data | /opt/nfast/kmdata/ | NFAST_KMDATA | C:\ProgramData\nCipher\Key Management Data |
| Dynamic Feature Certificates | /opt/nfast/femcerts/ | NFAST_CERTDIR | C:\ProgramData\nCipher\Feature Certificates |
| Static Feature Certificates | /opt/nfast/kmdata/hsm-ESN/features | | %NFAST_KMDATA%\hsm-esn\features C:\ProgramData\nCipher\Key Management Data |
| Log Files | /opt/nfast/log | NFAST_LOGDIR | C:\ProgramData\nCipher\Log Files |
| User Log Files | /home/<user>/nshieldlogs | NFAST_USER_LOGDIR | C:\Users\<user>\nshieldlogs |

| Directory name | Linux default path | Windows environment variable | Windows Server 2016 or later |
|------------------------------------|--------------------|------------------------------|---------------------------------|
| Remote Static Feature Certificates | | | %NFAST_KMDATA%\hsm-ESN\features |
| Remote Static Feature Certificates | | | %NFAST_KMDATA%\hsm-ESN\features |



Dynamic feature certificates must be stored in the directory stated above. The directory shown for static feature certificates is an example location. You can store those certificates in any directory and provide the appropriate path when using the Feature Enable Tool. However, you must not store static feature certificates in the dynamic features certificates directory.

The instructions in this guide refer to the locations of the software installation and program data directories as follows:

- By name (for example, Key Management Data).
- **Linux:** By absolute path (for example, `/opt/nfast/kmdata`).
- **Windows:** By nShield environment variable names enclosed with percent signs (for example, `%NFAST_KMDATA%`).

`NFAST_KMDATA` cannot be a symbolic link.

If the software has been installed into a non-default location:

- **Linux:** Create a symbolic link from `/opt/nfast/` to the directory where the software is actually installed.
- **Windows:** Ensure that the associated nShield environment variables are re-set with the correct paths for your installation. For more information about creating symbolic links, see your operating system's documentation.



Windows only

By default, the Windows `C:\ProgramData\` directory is a hidden directory. To see this directory and its contents, you must enable the display of hidden files and directories in the view settings of the Folder Options.

The absolute paths to the Security World Software installation directory and program data directories are stored in the indicated nShield environment variables at the time of installation. If you are unsure of the loca-

tion of any of these directories, check the path set in the environment variable.

With previous versions of Security World Software, the Key Management Data directory was located by default in `C:\nfast\kmdata`. The Feature Certificates directory was located by default in `C:\nfast\fem`, and the Log Files directory was located by default in `C:\nfast\log`.

1.2.2.1. Utility help options

Unless noted, all the executable utilities provided in the `bin` subdirectory of your nShield installation have the following standard help options:

- `-h|--help` displays help for the utility
- `-v|--version` displays the version number of the utility
- `-u|--usage` displays a brief usage summary for the utility.

1.3. Requirements

To write and run a SEE C application on the HSM, you need:

- A SEE-Ready hardware security module



To determine whether your HSM is SEE-Ready, refer to the product data sheet for your HSM.



Encrypted SEE machines are not currently supported for use with nShield Connects. When the SEEMachine binary is installed on the Connect itself for automated loading at boot, the SEE Confidentiality key is not available. However, when a client host loads a SEEMachine, it has access to the SEE Confidentiality key and can cause the binary to be decrypted. In this scenario, the Connect works fine with encrypted SEEMachine binaries.

- A Feature Enable smart card for activating the SEE capabilities of your HSM
- The CodeSafe Developer Kit (supplied on this installation media)
- An appropriate GCC compiler (supplied on this installation media) for the target HSM.

You must have installed your SEE-Ready HSM (as instructed in the *Installation Guide*) and the necessary Security World for nShield for the CodeSafe Developer Kit (as instructed in the *User Guide*). You must install at least the following software component bundles

included on the installation media:

- **hwsp** Hardware Support
- **ctls** Core Tools
- **csd** CodeSafe Developer
- **gccsrc** Prebuilt PowerPC GCC for CodeSafe/C

When you have installed and configured your SEE-Ready HSM, to make full use of SEE, you must create a Security World by using one of the following tools:

- The **new-world** utility
- KeySafe
- The front panel (nShield Connects only).

For detailed information about creating Security Worlds, see the *User Guide*.

1.4. Further information

This guide forms one part of the information and support provided by Entrust.

The *nCore API Documentation* is supplied as HTML files installed in the following locations:

- API reference for host:
 - **Linux:** `/opt/nfast/document/ncore/html/index.html`
 - **Windows:** `%NFAST_HOME%\document\ncore\html\index.html`
- API reference for SEE:
 - **Linux:** `/opt/nfast/document/csddoc/html/index.html`
 - **Windows:** `%NFAST_HOME%\document\csddoc\html\index.html`



We recommend that you monitor the Announcements & Security Notices section on Entrust nShield Support, <https://nshieldsupport.entrust.com>, where any announcement of Security advisories will be made.

1.5. Security advisories

If Entrust becomes aware of a security issue affecting nShield HSMs, Entrust will publish a security advisory to customers. The security advisory will describe the issue and provide recommended actions. In some circumstances the advisory may recommend you upgrade the nShield firmware and or image file. In this situation you will need to re-present a quorum of

administrator smart cards to the HSM to reload a Security World. As such, deployment and maintenance of your HSMs should consider the procedures and actions required to upgrade devices in the field.



The Remote Administration feature supports remote firmware upgrade of nShield HSMs, and remote ACS card presentation.

We recommend that you monitor the Announcements & Security Notices section on Entrust nShield, <https://nshieldsupport.entrust.com>, where any announcement of nShield Security Advisories will be made.

1.5.1. Contacting Entrust nShield Support

To obtain support for your product, contact Entrust nShield Support, <https://nshieldsupport.entrust.com>.

2. About the Secure Execution Engine SEE

The *Secure Execution Engine* (SEE) enables application code to run within the secure environment of a SEE-Ready HSM.



To use SEE, you must order and enable it as described in the *User Guide*. You must order the developer and user environments separately. SEE machines cannot be loaded on HSMs on which SEE is not enabled.

The CodeSafe Developer Kit includes the following:

- The CodeSafe Developer Libraries
- A built GCC compiler, plus source and makefile to customize your own version, if required
- The CodeSafe Utilities (described in [Utilities](#)):
 - `tct2` (the Trusted Code Tool)
 - `elftool`
 - `loadsee-setup`
 - `loadmache` (for use with `SEELib`)
 - `hsc_loadseemachine`
 - `seessl-migrate.py`
 - a set of host utilities (for use with the Solo XC `glibc`-based/Solo PCIe `bsdlib`-based SEE machines) that enable the standard IO and socket connections:
 - `see-sock-serv`
 - `see-stdoe-serv`
 - `see-stdioe-serv`
 - `see-stdioesock-serv`.

2.1. Why use the Secure Execution Engine?

The main uses of cryptography are:

- Integrity
- Confidentiality
- Authentication

Using an HSM to protect your cryptographic keys provides all these advantages. Your keys are only ever available in unencrypted form when they are loaded into the HSM: when key blobs are stored on the host, their integrity is protected by a Message Authentication Code

(MAC). Access to the keys is controlled by using a Security World or an Operator Card Set (OCS). For additional information about the OCS, see the *User Guide*.

However, traditionally, the code that uses the keys remains on the server. This means that the code is open to attack. It is possible that the code could be modified in such a way as to leak important information or compromise your business rules. For example, it could fail to enforce such rules as “the books must balance” or “traders shall balance their positions by the close of trading”.

By implementing a solution with the SEE, you not only protect your cryptographic keys but also extend the security boundary to include your security critical code and data.

Using the techniques of code signing, data wrapping, and secure storage, the SEE enables you to maintain the confidentiality and integrity of application code and data and to bind them together so that only code in which you have confidence has access to confidential data.

2.1.1. Code integrity

In many secure applications, the primary concern is for the code to execute the correct sequence of operations and to not do anything else, such as leak information or key data. You can use the supplied Trusted Code Tool ([tct2](#)) to sign the HSM-side code and initialization data (if required) that make up a SEE machine. Application authors can use signatures to delegate authority to use key material and other resources.

2.1.2. Code confidentiality

When you use the SEE, the code that runs on an HSM can be stored in an encrypted format. The encryption key can be either a Triple Data Encryption Standard (Triple DES) or Advanced Encryption Standard (AES) key protected by either a Security World or an OCS.



Encrypted SEE machines are not currently supported for use with nShield Connects. When the SEEMachine binary is installed on the Connect itself for automated loading at boot, the SEE Confidentiality key is not available. However, when a client host loads a SEEMachine, it has access to the SEE Confidentiality key and can cause the binary to be decrypted. In this scenario, the Connect works fine with encrypted SEEMachine binaries.

The Access Control List (ACL) entry, [UseAsLoaderKey](#), enables a key to be used to decrypt SEE objects on the HSM but that does not allow you to use it for standard decryption

where the answer is returned to the host. This ensures that the code itself is not available “in the clear” outside of the HSM/SEE and; therefore, that any intellectual property embodied in the code is protected.

To load encrypted code, the user must first load the encryption key. Therefore, if the encryption key is protected by an OCS, only users with sufficient smart cards from that OCS can load the code. Because this SEE confidentiality key does not have decryption permissions (only the **UseAsLoaderKey** ACL entry), from a security standpoint, it is not essential that it be protected by an OCS.



HSM-protected SEE confidentiality keys can be useful in situations where the server or HSM is unexpectedly reset, because, in such a case, the SEE machine can then be reloaded without user intervention.

2.1.3. Data confidentiality

There are two main issues regarding data confidentiality:

- Transient confidentiality of data in the running system
- Long-term confidentiality of data when the code is not loaded.

The SEE protects the program’s information in the running system by enabling the programmer to determine the interface by which data can come in and out of the system and then rigorously enforce that interface.

Long-term confidentiality is preserved by using the non-volatile memory on the HSM. The SEE program can access this storage by using nCore API commands. Small quantities of highly sensitive information can be stored directly in the nonvolatile random access memory (NVRAM). When the amount of information to be stored exceeds the capacity of the NVRAM, data can be stored in an encrypted blob with a much smaller key stored in the NVRAM. This functionality allows the amount of secure storage to be limited only by the capacity of the host. For more information, see the *nCore Developer Tutorial*.

2.1.4. Data integrity

Confidential data is of little use if it can be changed by an attacker. Data stored in the HSM’s NVRAM could only be altered if the Access Control List (ACL) were to allow this to happen or if the physical security of the HSM were compromised. When a large volume of data is made into a blob, a hash of that blob can be stored in the NVRAM so that changes can be detected.

Another option for maintaining data that is not likely to change (such as root CA keys) is to

place it in the **application initialization space** and then use code integrity techniques to protect the **application initialization space**.

2.1.5. Authentication and access control

A key feature of the SEE is the way that it can tie the integrity of the code to access control of the resources that the code uses.

The key-management architecture controls access to objects such as keys by means of ACLs. These lists specify sets of operations and verification keys that are used to check the credentials authorizing these operations.

With SEE, you can create keys that can only be used to encrypt or sign SEE machines (the SEE HSM-side code and, if required, its **userdata**). Encrypted application code is effectively bound to the encryption key, thereby ensuring that it can only be loaded onto an HSM on which you have already loaded the key. This functionality effectively gives you OCS protection on application code.



Encrypted SEE machines are not currently supported for use with nShield Connects. When the SEEMachine binary is installed on the Connect itself for automated loading at boot, the SEE Confidentiality key is not available. However, when a client host loads a SEEMachine, it has access to the SEE Confidentiality key and can cause the binary to be decrypted. In this scenario, the Connect works fine with encrypted SEEMachine binaries.

SEE also extends the authorization credentials to include signatures on code. This simple extension turns out to be very powerful. When a body of code issues a command to use a resource that is controlled by an ACL, it may present a certificate indicating that the signatures on the code should be examined by the ACL checking system. If the signature on the code verifies with one of the keys listed in the ACL, the operations delegated to that key can be carried out in that command.

Therefore, this extension of the authorization credentials means that you can create keys that can only be used by the SEE-resident code. These keys can be protected by the Security World or by OCSs.

The SEE code has access to the HSM's NVRAM. Files stored in the HSM's non-volatile memory also have ACLs. These ACLs describe not only who can access the file but what changes can be made to the file. For example, this feature enables you to create secure counters that you know can never be zeroed or that you know can be zeroed only by a trusted application running in the SEE.

2.2. How SEE works



A hardware security module maintains strict separation between the nShield core functions and the user code.

The application starts with the code for a SEE machine stored in a file on the host. A SEE machine is a binary executable of a type appropriate for the HSM. It communicates with the nShield core by means of the **interprocess communication (IPC)** for Solo XC and by means of the **software interrupt (SWI)** interface for Solo PCIe. Applications may be written in C and compiled to form the SEE machine itself. Alternatively, the SEE machine may consist of a language interpreter and the HSM code supplied as a script or byte code by means of **userdata**. For more information, see [SEE and userdata](#).

If a separate host-side program is required, you can write the host-side code in C, using the nCore API. Alternatively, you can use the language of your choice. Example utilities written in Java are provided in the component **jhsee** in `/opt/nfast/java/examples` (**Linux**) or `%NFAST_HOME%\java\examples` (**Windows**).

These example utilities provide equivalent functionality to the C examples of similar names. You can adapt them as required. See the supplied Javadocs for full information about the Java example utilities.

The SEE machine can be signed, encrypted, or both, with the **Trusted Code Tool (tct2)**. For more information about this command-line utility, see [Utilities](#).



Encrypted SEE machines are not currently supported for use with nShield Connects. When the SEEMachine binary is installed on the Connect itself for automated loading at boot, the SEE Confidentiality key is not available. However, when a client host loads a SEEMachine, it has access to the SEE Confidentiality key and can cause the binary to be decrypted. In this scenario, the Connect works fine with encrypted SEEMachine binaries.

The first step is to load the SEE machine onto the HSM. The hardserver software, supplied on this installation media, automatically loads the SEE machine whenever the HSM is reset, provided that:

- The HSM is SEE-Ready



To determine whether your HSM is SEE-Ready, refer to the product data sheet for your HSM.

- The HSM sets the enquiry level 4 **HasSEE** flag

- A suitable machine image file is configured
- The `load_seemachine` section of the configuration file is configured to enable the loading of SEE machines on startup.



You can perform this configuration with the `loadsee-setup` command-line utility. See [Utilities](#).

For development purposes, you can also load SEE machines manually by running the `load-mache` command-line utility or, optionally, you can load SEE machines that require support from a host-side `see-*-serv` utility by specifying the `-M` option when you run the utility. See [Utilities](#).

2.2.1. Code specifics

To use the functions provided by the SEE machine, the host application creates a `SEEWorld`, supplying the initialization data, which includes the HSM resident portion of the application code, initialization flags and any other SEE World initialization information required. The functions provided by the HSM-resident code can then be accessed by the SEE machine on command from the host-side portion of the application. The SEE World is a private work space and has a handle, an `M_KeyID`. As with other identifiers, this handle is associated with a `ClientID`. A host application can only access a `SEEWorld` on the connection that created the `SEEWorld` or on connections that have the same `ClientID`.

The `CreateSEEWorlD` command takes a byte block called the `SEE user data`. This block can be used to pass initialization data when a SEE machine is started. This file also carries the signatures for the `SEEWorlD`.



Refer to the *nCore CodeSafe API Documentation* for detailed information about the `CreateSEEWorlD` command.

2.2.2. Security

When the SEE machine has been initialized, the host application can call the functions that the SEE machine provides. These calls are sent using the nCore API command `SEEJob`.

For example, if you write code to implement a custom algorithm, the host application no longer calls the nCore API `Encrypt` command. Instead, it calls the encrypt function of the SEE machine. The algorithm in the SEE machine then asks the core for the key, uses the key to encrypt the message, and returns the result. This is explained in detail for both the Solo XC and the Solo PCIe in [Designing SEE machines and SEE-ready HSMs](#).

The SEE machine can then make calls into the nShield core with the standard nCore API.

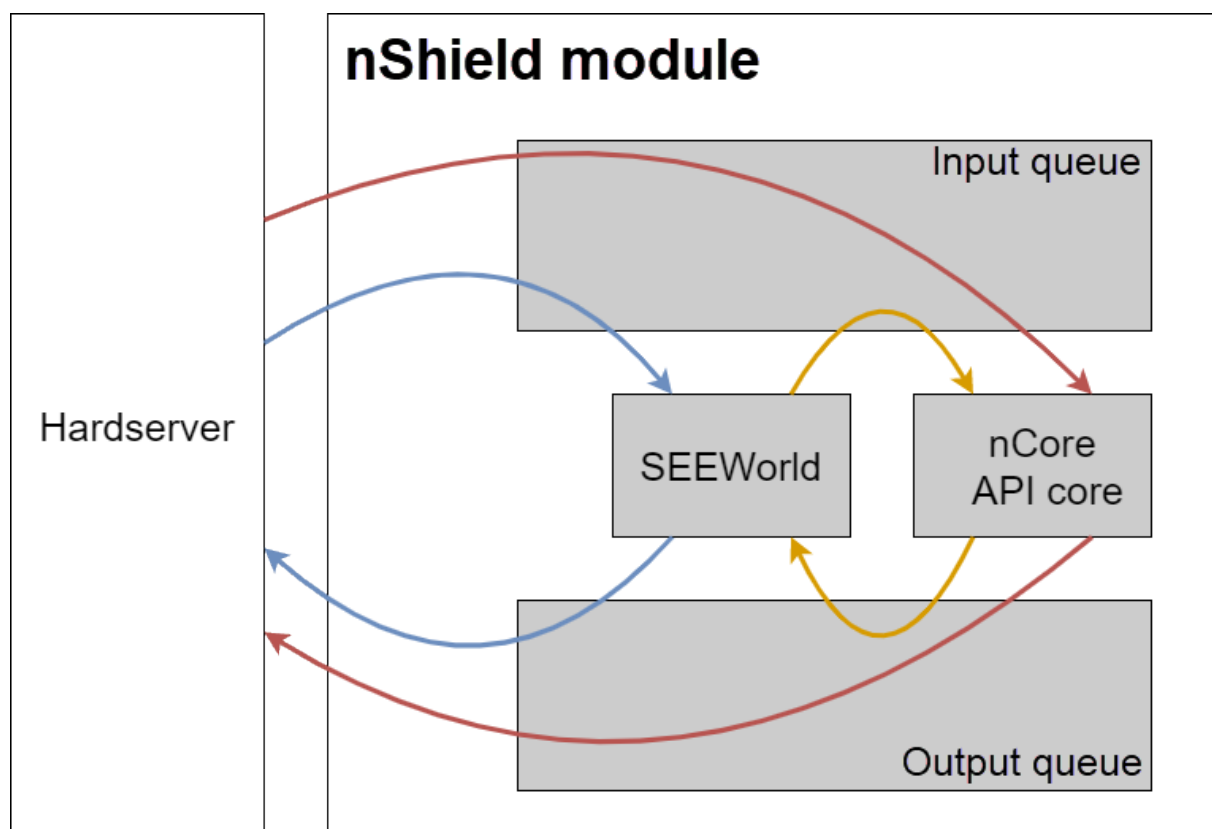
The replies are returned directly to the SEE machine without ever leaving the protection of the HSM.



The SEE machine can access keys, or other objects that are protected by the HSM, only by making nCore API calls to the nShield core. HSM-side SEE code has the same privileges and access to the cryptographic functionality of the HSM as that given to the host-side programs using the nCore API. However, it is possible to create SEE application keys that can be used only by particular SEE applications and not by the host.

2.2.3. Internals

CodeSafe uses two command queues; The following diagram gives an overview of how they function. The hardserver sends commands to the input queue. The input queue looks at the commands and directs them to either the nCore API core or to the **SEEWor1d**.



In this release you can only create a single **SEEWor1d** for each HSM at any one time.

The nCore API core takes commands from the input queue, processes them in turn, and places them on the output queue. These commands may have come from the server or

from the **SEEWor1d**.

The output queue receives the completed jobs from the core. It determines whether the command was issued by the **SEEWor1d** or the hardserver and sends the result to the appropriate place.

While any command sent to the **SEEWor1d** may cause a number of calls to the nCore API core (and these calls circulate within the HSM), a given command only ever produces a single reply that is returned to the server. After the **SEEWor1d** has completed the job, it returns a reply. The core returns this reply to the hardserver and on to the application; this is the reply to the **SEEJob** command, handled in exactly the same manner as for any other nCore API command.

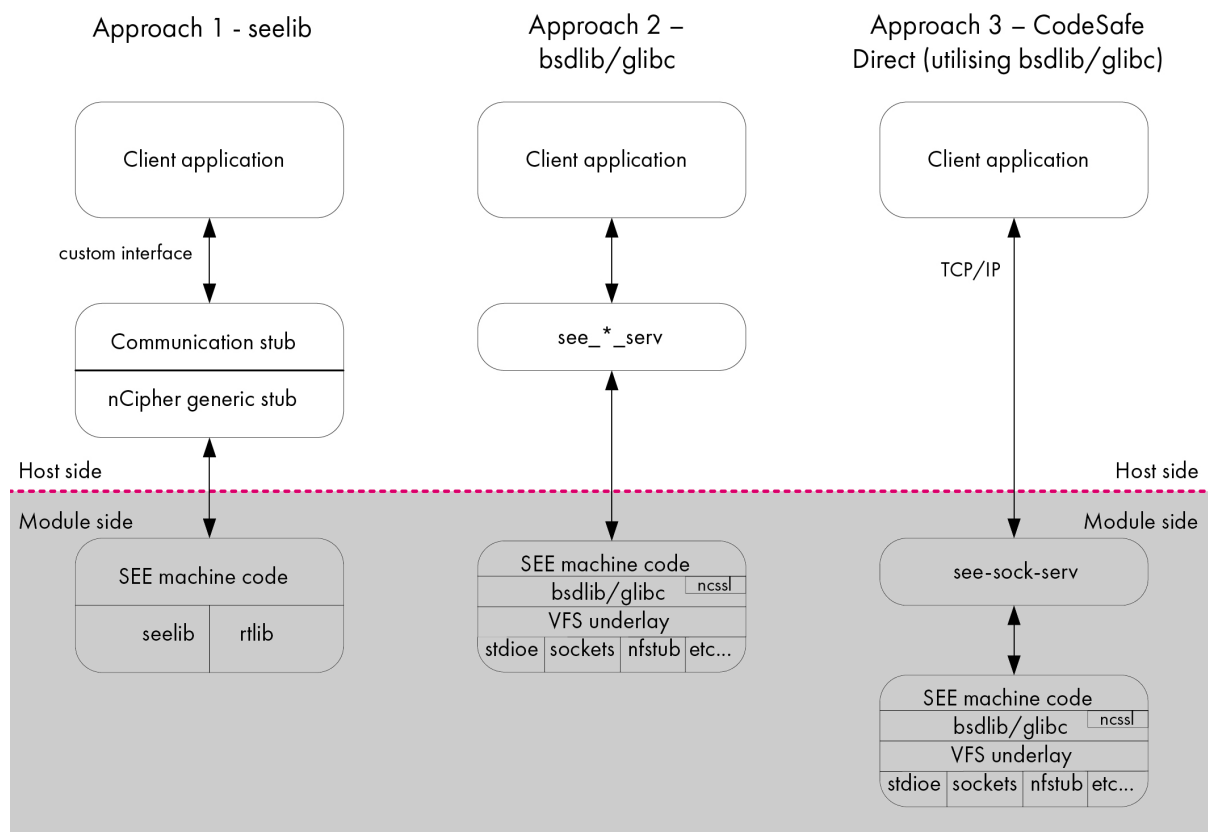
The **SEEJob** reply is returned with **Status_OK** provided that the SEE machine returns a reply to the nShield core. The return of this kind of reply does not mean that the command itself was completed successfully in the SEE machine, only that communication between the core and the SEE machine was completed successfully. The SEE machine returns its own errors (if any) in the reply.

The application running in the **SEEWor1d** does not have direct access to the user interface. Therefore, all interaction with the user must be performed by the host application. In some cases, especially when loading tokens that are protected by multiple smart cards, it can be useful to have the host application load an object and then pass control to the application in the **Status_OK**. You cannot pass the **ObjectID** because this is specific to the **ClientID**. Therefore, to pass control to the application in the **Status_OK**, you must use key tickets.

Key tickets were introduced to the nCore API specifically for SEE, although they can also be used to pass keys between different clients on the host. The client (or SEE application) that creates a key asks for a ticket for the key. It passes the ticket to the other client, which redeems the ticket for an **ObjectID**. There is only ever one copy of the object, and all commands have to comply with the ACL.

2.3. SEE system architecture

There are different architectural strategies that you can use when designing a CodeSafe SEE system, distinguished by the library they utilize:



Before designing your CodeSafe SEE system, decide which architecture best suits your requirements:

- For Solo PCIe:

bsdlib: This architecture allows the use of standard TCP sockets and a standard BSD C library in CodeSafe, making it possible to communicate with a SEE machine using a generic approach. A design using this architecture is well suited for SEE machines that implement applications such as Web servers and proxies.

bsdlib provides a familiar programming environment compared to **SEElib**. **SEElib** requires additional work on the host application to talk to SEE, whereas **bsdlib** uses standard socket and standard IO interfaces.



If you are designing a CodeSafe Direct system, you must use the **bsdlib** architecture. The **SEElib** library is not supported for use with CodeSafe Direct.



If you are designing a CodeSafe SEE system using the **bsdlib** library, you can use headers as normal for a Unix-based system (for example, **stdio.h**, **stdlib.h**, **pthread.h**).

- For Solo XC:

glibc: This architecture allows the use of TCP sockets and a high performance GNU C library in CodeSafe. This makes it possible to communicate with a SEE machine using a generic approach.

glibc can only be used if you are using an nShield Solo XC module and supports ISO C, POSIX, and System V standards.

A design using this architecture is well suited for SEE machines that implement applications such as Web servers and proxies.



If you are designing a CodeSafe Direct system, you must use the **gblic** architecture. The **SEElib** library is *not* supported for use with CodeSafe Direct.



If you are designing a CodeSafe SEE system using the **glibc** library, you can use headers as normal for a Unix-based system (for example, **stdio.h**, **stdlib.h**, **pthread.h**).

- **SEElib**: A design using this legacy architecture is well suited to protecting custom cryptography within a SEE machine. The **A3A8** example program provides a simple demonstration of how to achieve this; see [Designing SEE machines and SEE-ready HSMs](#) for additional information.



If you are designing a CodeSafe SEE system using the **SEElib** library, you can use the header file **seelib.h**, which contains wrapper functions for the software interrupts, in addition to a limited subset of the standard C library. See [SEElib functions](#) for additional information.

Unless you have a specific reason to use the **SEElib** architecture, Entrust recommend using the **glibc/bsdlib** architecture, as it provides a more familiar standards-based programming environment using standard socket and standard IO interfaces. Note that **SEElib** typically requires additional work on the host application to interface to the SEE code. This is not required when using the standards-based **glibc/bsdlib** approach.

2.4. SEE and byte code

All SEE machines must be compiled so they can run on the HSM. Additionally, SEE machines that use the **SEElib** architecture must use the IPC/SWI to communicate with the nShield core. (IPC Interface for the Solo XC and the SWI interface for Solo PCIe.) Because these requirements make writing native SEE machines difficult, SEE supports the concept of native SEE machines that are byte code interpreters.

Using a byte code interpreter has several advantages. Not only does it reduce development effort, but each interpreter can load several different byte code applications, each running in their own **SEEWorlD**. The byte code for the application is passed in the **userdata** with the **CreateSEEWorlD** command.

To prevent attackers from replacing a good SEE machine with a malicious one, the certificate for the byte code can specify that the SEE machine must be signed with a specific key. This is done by including the hash of this key in the certificate for the byte block. This certificate is created automatically by the Trusted Code Tool (see [tct2](#)). You supply the hash of the key used to sign the SEE machine when you sign your application. The Trusted Code Tool uses keys protected by an OCS for signing operations.

2.5. SEE and userdata

2.5.1. What is userdata?

A **userdata** file can contain any data that is useful to the SEE machine. For example, you can use a CPIO archive to supply many different data files in a single directory structure (examples are provided in [Designing SEE machines and SEE-ready HSMs](#)).



All SEE machines built with **glibc/bsdlb** must be provided with a valid ASCII-format CPIO archive. This archive forms the base of the file system available to your SEE machine. Even if your SEE machine does not use this file system, you must still create and supply it with dummy **userdata** as a place-holder.

2.5.2. Creating userdata suitable for loading into the HSM

You can create a **userdata** file suitable for loading into the HSM by turning it into a SAR file with the **tct2** command-line utility. Signing the **userdata** file in this way offers improved security.

2.6. SEE and Security Worlds

Within a Security World, the following actions may be configured to require authorization from the nShield Security Officer Key (K_{NSO}), or a key with authority delegated from the K_{NSO} :

- Allocation and forced freeing of nonvolatile memory

- Setting the real-time clock
- Enabling the run-time debugging options.

Each of these features can be enabled individually.

At Security World creation time, certificates may be created delegating authority from K_{NSO} to keys protected by logical tokens which are split amongst the Administrator Card Set (ACS) in the usual way, but may require a different K/N threshold to reassemble. For example, you may wish to require that only one of five Administrator Cards be presented to set the real-time clock on an HSM, but three of them to replace the ACS.

The tools that create these certificates are:

- KeySafe (version 2 and later)
- **Windows:** The nShield CSP Wizard
- The `new-world` command-line utility
- The nShield Connect front panel.

For more information about these tools, see the *User Guide*.



A Security World created using some older tools does not have any of these delegation certificates to support nonvolatile memory and real-time clock operations or to allow debugging of SEE applications. Therefore, such operations would require full K_{NSO} authorization.

To sign or encrypt the HSM-side code, the signing and encryption keys must belong to the Security World to which the HSM belongs.

To test code outside a Security World, you can use the `initunit` command-line utility to remove the HSM from the Security World. In this case you cannot sign or encrypt your code, and the code cannot access keys protected by the Security World.



If you use the `initunit` command-line utility to initialize the HSM, any user can set the clock and create or free NVRAM files. This means that any user can free an existing file and allocate another file with the same name but with different contents or with a different ACL. Most security policies forbid this.

3. Designing SEE machines and SEE-ready HSMs

This manual addresses SEE for both the Solo XC and the Solo PCIe.

For Solo XC, see [Writing SEE machines - Solo XC](#)

For Solo PCIe, see [Writing SEE machines - Solo PCIe](#)

3.1. Writing SEE machines - Solo XC

This chapter describes how to write a SEE machine for use on SEE-Ready HSMs.

An SEE machine is an executable binary file of a type appropriate for the HSM that communicates with the nShield core (which runs in kernel mode) using a defined set of software interrupts. These interrupts, and their wrapper functions, provide a run-time environment that includes memory and thread management as well as an interface for accepting and returning jobs and calling nCore API commands.

C source code is compiled using one of the GCC cross-compilers supplied with the Code-Safe Developer Kit. For details of required compiler options; see [Example SEE machines](#) and the makefiles supplied with the examples.

The compiled code can then be signed, packed, and encrypted by using the Trusted Code Tool (`tct2` utility) to produce a secure archive; see [Utilities](#).



In CodeSafe versions prior to 13.3, the Solo XC only supports SEE machines smaller than 70 MB. From 13.3 onwards, the Solo XC can support SEE machines up to 800 MB.

3.1.1. Designing the glibc architecture

The GNU C library `glibc` is supplied together with `libpthreads`, `librt` and a system call underlay for use with CodeSafe SEE development.

A rich set of C function calls is available to use in SEE machine development. Native support for Unix-based system calls is provided, only restricted by a whitelist of the system calls ([SEE Machines Whitelist](#)) allowed in the SEE environment.

A subset of the Unix-based system calls, implemented in terms of the inter-process communication interface (IPC), allows access to the cryptographic HSM kernel. The provided system calls include a virtual file system and associated set of input and output devices with

which you interact in the standard manner.

The virtual file system is supported as an extension to the file system.

Also provided are some link-time plug-ins that extend the virtual file system to provide additional capabilities:

- `hoststdio.o`: `stdin`, `stdout`, and `stderr` facility hooks; `seestream_stdio(7see)`
- `hoststdoe.o`: `stdout` and `stderr` facility hooks; `seestream_stdio(7see)`
- `hostinetsocks.o`: TCP socket facility hooks; `seestream_inet(7see)`
- `hoststdioeinetsocks.o`: TCP socket facility and `stdin`, `stdout`, and `stderr` facility hooks; `seestream_inet(7see)``seestream_stdio(7see)`



The link-time plug-in `vulnerability.o` is provided for the purposes of debugging (see [Vulnerability test harness](#)). Entrust recommends that you do not link `vulnerability.o` into a production SEE machine.

3.1.2. Designing the SEELib architecture

This section describes how to design SEE machines using the `SEELib` architecture. This kind of architecture requires host-side software to create the SEE World and communicate with the HSM.

To start the SEE machine running with a particular SEE `userdata`, the host application calls the nCore API command `CreateSEEWorld`. This command creates a SEE World using data previously loaded into the HSM with the `LoadBuffer` command from a buffer created with the `CreateBuffer` command. See the *nCore API Documentation* (supplied as HTML) for information about the nCore API commands.

You can also use or adapt the supplied example Java class `SEEWorld` to initialize the SEE machine.

When the host application calls `CreateSEEWorld`, the HSM allocates memory for the SEE World and sets up its input and output job queues. It then runs the SEE machine's `main()` function.

The SEE machine's `main()` function must:

- Call `SEELib_init()` before any other SEE library function to initialize the SEE library and to check that the HSM is running the expected version of the library
- If the machine accepts `userdata`:
 - call `SEELib_GetUserDataLen` to determine the length of the byte block that was passed with `CreateSEEWorld`

- call `SEELib_ReadUserData` to load the byte block
- determine whether the byte block is valid
- initialize any required structures
- Start at least one thread which receives and processes commands (this thread must call `SEELib_AwaitJob`)



The `SEELib_StartProcessorThreads` function can be used for this purpose.

- Call `SEELib_InitComplete` and return a status.

The status passed to `SEELib_InitComplete` is returned to the calling application in the reply to `CreateSEWorld`. The application can determine the status values, with one exception: if the machine fails before calling `SEELib_InitComplete()`, the `CreateSEWorld` command returns a value of `1` (`SEEInitStatus_MachineFailed`) in this field. You should therefore avoid choosing the value `1` to indicate successful initialization.

When the application receives the reply to `CreateSEWorld` with `Status_OK` and an acceptable `initstatus`, it can start to submit jobs with the nCore API command `SEEJob`.

You can also use or adapt the supplied example Java class `SEEJob` to submit jobs to the SEE machine.

The `SEEJob` command takes a byte block, which is passed to the `SEELib_AwaitJob` function without being interpreted in any way. It is up to the host application to assemble this byte block and the SEE machine to interpret it.

After the job has been processed, assemble the reply into a byte block and call `SEELib_ReturnJob` to return it using the nShield core.

The nShield core assembles this byte block into a reply and returns it to the host application. Provided that the job is returned before the command times out, the reply has the status `OK`. The SEE machine must include any necessary status information within the byte block it returns. The calling application must remember to check this status as well as the status of the `SEEJob` nCore API function and the transport call, for example `NFastApp_Transact()`.

The SEE machine can call nCore API functions with `SEELib_Transact` or `SEELib_MarshalSendCommand` and `SEELib_GetUnmarshalResponse`. It may submit these as part of its initialization, before it calls `SEELib_InitComplete()`. However, if it does not call `SEELib_InitComplete()` within 30 seconds of start-up, the `CreateSEWorld` command returns `SEEInitStatus_MachineFailed`. For this reason, you should not perform (for example) lengthy key generation operations during initialization.

`SEELib_Transact` has syntax equivalent to the `NFastApp_Transact` function in the C generic stub. It takes a command structure and returns a reply structure. `SEELib_MarshalSendCommand` takes a command structure and submits it. `SEELib_GetUnmarshalResponse` reads a response from a buffer and returns a reply structure.



`SEELib_StartTransactListener` must be called successfully before you use `SEELib_Transact` to communicate with the nShield core.

3.1.3. SEE machines for new algorithms

In addition to being able to perform basic cryptographic operations, any SEE machine that implements an algorithm must also be able to:

- Generate keys
- Import keys
- Store keys as key blobs.

The SEE machine can use the nCore API functions `GenerateRandom` and `GeneratePrime` to acquire random numbers and random prime numbers from the HSM's hardware random number generator.

The SEE machine can perform its own multiprecision arithmetic. Otherwise, it can use the nCore API `BignumOp` command to perform multiprecision arithmetic and the `ModExp` and `ModExpCrt` commands to perform modular exponentiation.

If you are using keys as session keys, there is no requirement for them ever to be placed in the nShield core. The only time that you need to transfer a key to the core is if you need to create a key blob for long-term storage. However, if you need to keep track of several keys, you may want to make use of the nShield core's object store rather than having to create a similar structure in your own code.

For an example of how See machines can implement a non-standard algorithm, see [A3A8XC](#).

3.1.3.1. Key type

The SEE machine stores keys using the `random` key type. This is a plain byte block with no structure.

If the key contains several values, for example, exponent and modulus, the SEE machine must implement its own routines for marshalling and unmarshalling the byte block into the correct structure.



SEE machines using standard algorithms do not use the **random** key type. Instead, they use standard nCore key types.

3.1.3.2. ACL

The ACL needs to be constructed so that the SEE machine and only the SEE machine can access the key. To transfer a key from the nShield core to the SEE machine, the key must have the **ExportAsPlain** flag set in its ACL. The permission group with **ExportAsPlain** must be protected by a certifier so that this operation can only be performed by the SEE machine.

Although one obvious solution is to use the key that was used to sign the SEE machine, K_{Integ} , as the certifier, using K_{Integ} in this way means that whoever signed the SEE machine could potentially access any key for this algorithm. A better solution is to add an extra signature to the SEE machine by using a second key, K_{Auth} . The K_{Integ} signature proves that the code has not changed since it was signed. The K_{Auth} signature is then used to control access to keys.

You can use the **generatekey** command-line utility to generate keys for use as K_{Auth} and K_{Integ} by specifying the **seeinteg** application as a key generation parameter.

The ACL must also have the correct **MakeBlob** permissions. If you want to use the standard Security World tools for key management and recovery, the host application can use these tools to create the ACL.



SEE machines using standard algorithms generally do not need to get the key as plain text in the SEE machine.

3.1.3.3. Storage

For long-term storage, the key needs to be encapsulated in a key blob that is protected by the Security World or an OCS. To provide OCS replacement and recovery, you may also require additional key blobs protected by other card sets.

You could write a function where your SEE machine calls **MakeBlob** and returns the blob to the host. Alternatively, you could write a method that returns a key ticket and have the host application create the key blobs.

If you are using a Security World, the host application can use **nfkm** library calls to create and store the key blobs.

3.1.3.4. Loading stored keys

In general, it is easier for the host application to manage tokens, because it has direct access to the user interface and can prompt the user to insert cards and enter passphrases.

When the token has been loaded, the host application can load the key and pass a key ticket to the SEE machine. The SEE machine can then redeem the key ticket for a **KeyID** and use this to access the key. If you have several keys that are protected by a token, it usually makes sense to pass a ticket for the **KeyID** of the logical token, rather than passing tickets for each key.

You should also pass in a ticket for the logical token if the host application that loads the token exits afterwards. When it exits, it destroys the logical token's ID, which invalidates all loaded keys that were using it. Passing the logical token's ID in to the SEE machine prevents its destruction when the application exits.

3.1.3.5. Run-time library

Entrust supplies a customized C run-time library (**librtusr.a**) and a corresponding set of header files (in the **include-see/module/rtlib** subdirectory) for programs operating in the SEE environment. This library contains most commonly used ANSI C functions, with the addition of the following proprietary extensions, documented in **sys/threads.h**:

- Thread creation and control functions
- Thread synchronization primitives (events, semaphores, spin-locks)

However, the **librtusr.a** library excludes:

- Any file or directory access functions
- User input functions (for example, **stdin** and **scanf()**)
- Floating-point math library functions (in **math.h**), although basic floating-point types and arithmetic are supported
- Time/date and locale-specific functions (**time.h**, **locale.h**).



Multiplexing is not available with the **rtlib/SEELib** runtime library.

Access to the raw (IPC) interface between the SEE machine and the kernel is by means of the **SWIcall()** function, documented in **sys/swis.h**. The comments in this file are provided mainly for information, because all useful SWIs have C wrapper functions presented in other header files.

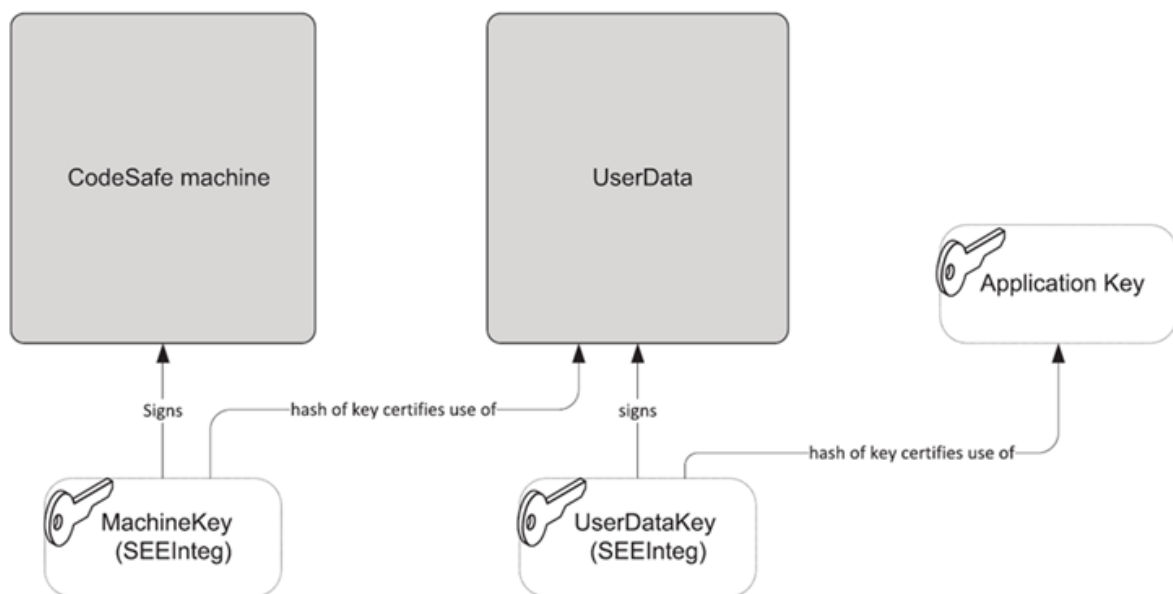
See **SEELib functions** for reference information about **glibc** functions.

3.1.4. Signing userdata for additional security

Signing **userdata** files can help increase the security of CodeSafe SEE applications. Both types of SEE machine architecture, using glibc and using SEELib, can take advantage of the security benefits offered by signing **userdata** files.

For example, if your SEE machine is intended to perform some cryptography functions using a given key, it would be advantageous to prevent that key from being accessed by any unauthorized SEE machines. This can be achieved by signing the **userdata** file for your SEE machine.

The following figure provides an overview diagram of the process of signing a SEE machine's **userdata** file.



The following sequence, in which an original SEE machine is represented by **machine.elf** and an original **userdata** file is represented by **userdata.bin**, demonstrates the process of signing a SEE machine's **userdata** file:

1. Create the key K_{seemach} of type **seeinteg** to sign the SEE machine by running a command similar to:

```
generatekey seeinteg plainname=seemach ...
```

2. Create the key K_{userdata} of type **seeinteg** to sign the **userdata** by running a command similar to:

```
generatekey seeinteg plainname=userdata ...
```

3. Run the **generatekey** command-line utility to create a key K_{crypto} (the key with which

your SEE machine is to perform its cryptography functions), specifying K_{userdata} for its `seeintegname`:

```
generatekey simple plainname=crypto --seeintegname=userdata ...
```



This example assumes K_{crypto} is being created as a Triple DES key.

4. Run the `tct2` command-line utility to sign the `userdata` file for your SEE machine with the key K_{userdata} , specifying K_{seemach} as the SEE machine key:

```
tct2 --sign --key=userdata --machine-key-ident=seemach --infile=userdata.bin --outfile=userdata.sar
```



For information about the `tct2` command-line utility, see [tct2](#).

5. Run the `tct2` command-line utility to sign the SEE machine with the key K_{seemach} :

```
tct2 --sign --key=seemach -- machine-type=PowerPCELF --is-machine --infile=machine.elf  
--outfile=machine.sar
```

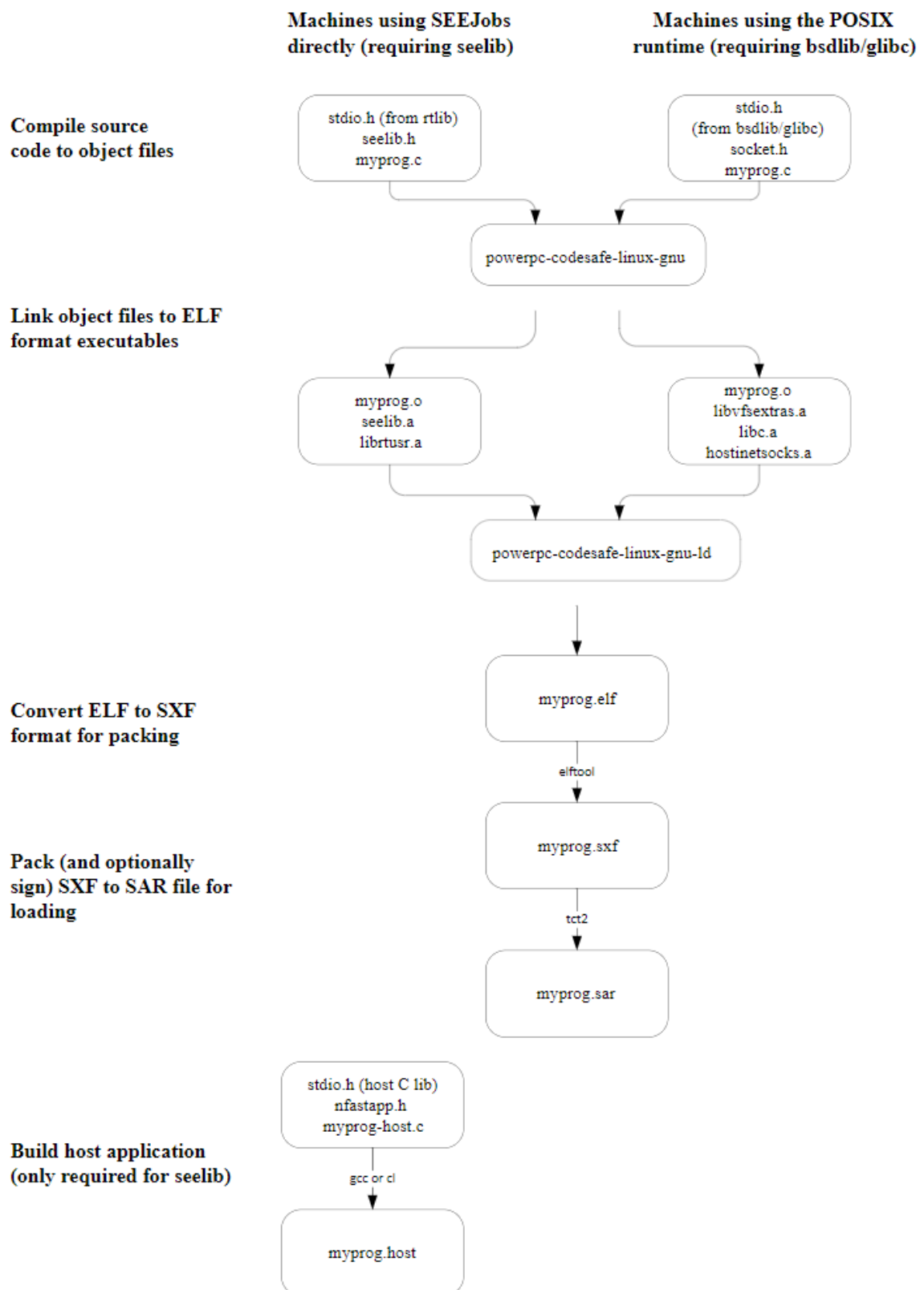
The result of the process demonstrated in this sequence of steps is that no SEE machine can use the key K_{crypto} unless at least one of the following conditions is met:

- It has been signed by the correct K_{seemach} and is used in conjunction with the correct `userdata` file
- You make use of the key recovery feature (see the *User Guide*).

3.1.5. Building your SEE machine and host-side application

The following steps provide an overview of the process you follow to use your application with SEE:

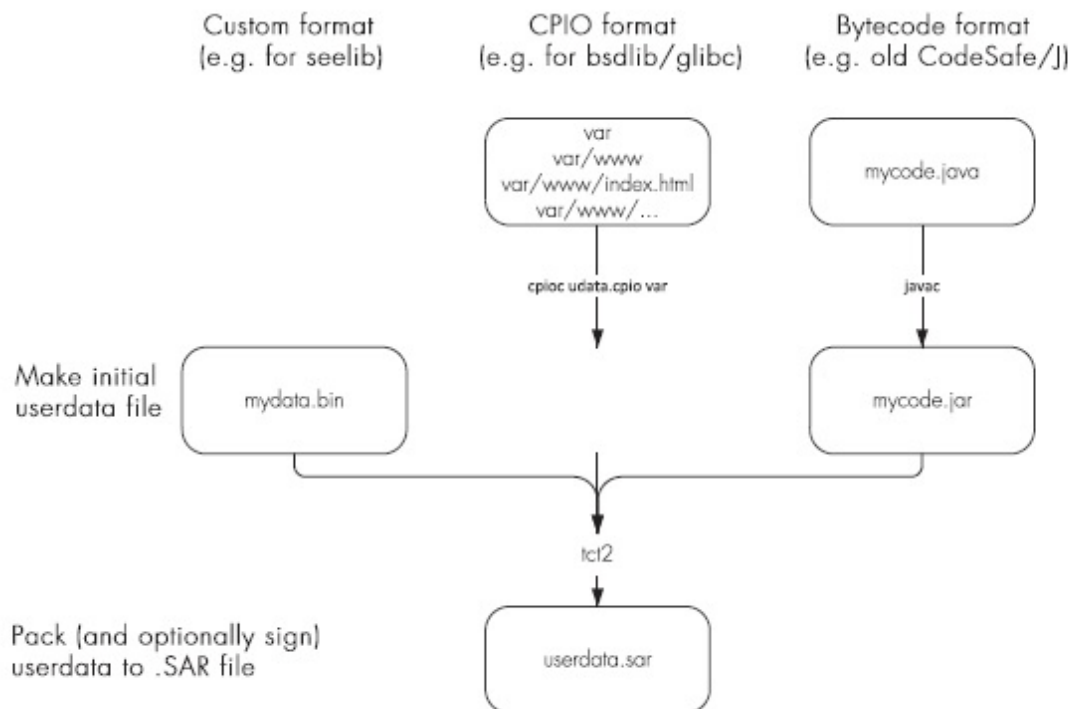
1. If you want to sign or encrypt your application, generate code-signing and confidentiality keys as applicable.
2. Compile and link the host application's source files using the native compiler on the host. See the diagram in the following step.
3. Compile and link the SEE machine source using the GCC cross compiler. See the following diagram.



- If required, use the Trusted Code Tool (`tct2`) to sign the SEE machine with the code-signing keys. See [Utilities](#) for additional information.
- Use the Trusted Code Tool (`tct2`) to pack the HSM files and create a SAR file. You must pack the binary file even if signatures are not required. See [Utilities](#) for additional

information.

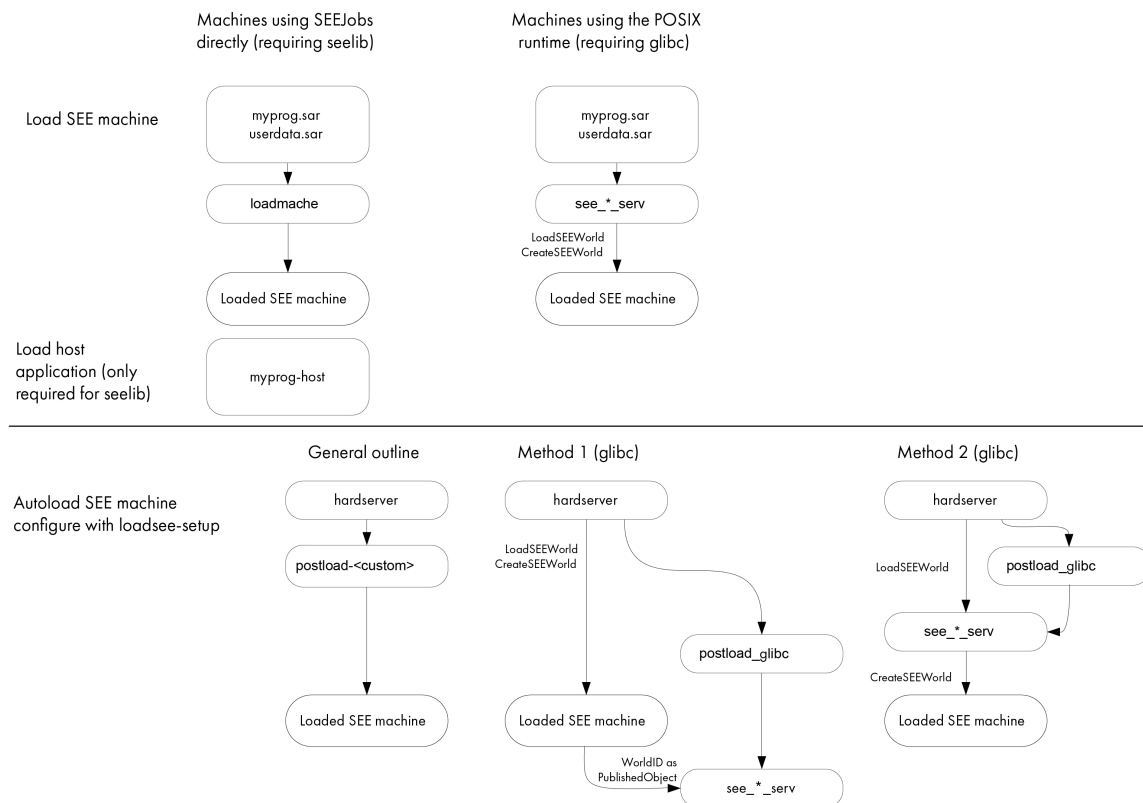
6. Use the Trusted Code Tool (**tct2**) to pack (and, if required, sign with the code-signing keys) the **userdata** file and create a SAR file. You must pack the **userdata** file even if signatures are not required (unless you use one of the **see-*-serv** host utilities with the **--userdata-raw** option. See [Utilities](#) for additional information.



7. If required, use the Trusted Code Tool (**tct2**) to encrypt the **userdata** file, using the confidentiality key.
8. Place the **userdata** SAR file and the host application in an appropriate location to be used at runtime.
9. For SEE machines using the **SEELib** architecture, **userdata** file can either be either loaded automatically or can be loaded by running the **loadmache** command-line utility.

For SEE machines that require support from a host-side **see-*-serv** utility, the host utility loads the **userdata** file automatically.

The following diagram shows these different methods for loading a SEE machine.



For more information, see [Automatically loading a SEE machine](#).

3.2. Writing SEE machines - Solo PCIe

This chapter describes how to write an SEE machine for use on SEE-Ready HSMs.

An SEE machine is an executable binary file of a type appropriate for the HSM that communicates with the nShield core (which runs in kernel mode) using a defined set of software interrupts. These interrupts, and their wrapper functions, provide a run-time environment that includes memory and thread management as well as an interface for accepting and returning jobs and calling nCore API commands.

C source code is compiled using one of the GCC cross-compilers supplied with the Code-Safe Developer Kit. For details of required compiler options, see [Example SEE machines](#) and the Makefiles supplied with the examples.

The compiled code can then be signed, packed, and encrypted by using the Trusted Code Tool (`tct2` utility) to produce a secure archive; see [Utilities](#).

3.2.1. Designing the bsdlib architecture

We supply the FreeBSD C library `bsdlib` and system call underlay for use with CodeSafe

SEE development.

Internally, `bsdlib` has three portions:

- A set of C library functions taken from the 4.6.x FreeBSD distribution
- A `pthread`s implementation that allows SEE machines built with the `bsdlib` architecture to be both multithreading and multiplexing (`select(2)` and `poll(2)` are available for multiplexing)
- A subset of the Unix-based system calls, both usable directly and used by the FreeBSD C library, implemented in terms of the SWI to the cryptographic HSM kernel. The provided subset of system calls includes a virtual file system and associated set of input and output devices with which you interact in the standard FreeBSD manner.

Also provided are some link-time plug-ins that extend the virtual file system to provide additional capabilities:

- `hoststdio.o`: `stdin`, `stdout`, and `stderr` facility hooks; `seestream_stdio(7see)`
- `hoststdoe.o`: `stdout` and `stderr` facility hooks; `seestream_stdio(7see)`
- `hostinetsocks.o`: TCP socket facility hooks; `seestream_inet(7see)`
- `coredevrandom.o`: `/dev/random` facility hooks; `fs_random(7see)`
- `procf`s.o: `/proc` file system that provides features and flags; `fs_proc(7see)`
- `getrtctime.o`: uses the HSM's secure RTC to call `settimeofday` when the machine starts up; `time(7see)`



The link-time plug-in `vulnerability.o` is provided for the purposes of debugging (see [Vulnerability test harness](#)). Entrust recommends that you do *not* link `vulnerability.o` into a production SEE machine.

3.2.1.1. Host-side utilities for SEE machines using `bsdlib`

SEE machines that require the standard I/O streams or INET domain sockets must be serviced by an appropriate host-side utility. Without the host-side utility, SEE machine operations requiring any of these streams are blocked until the appropriate service becomes available.

We supply 4 different host-side utilities, all of which have the capability to:

- Load the SAR file for the SEE machine
- Load the mandatory `userdata` file
- Provide different combinations of socket and I/O streams

These utilities are described below:

- **see-sock-serv**: Use this utility if your SEE machine requires only sockets, and if you want to make use of the CodeSafe Direct feature. (See [Configuring the nShield Connect to use CodeSafe Direct](#) for more information about CodeSafe Direct.)
- **see-stdoe-serv**: Use this utility if your SEE only requires standard output and error streams.
- **see-stdioe-serv**: Use this utility if your SEE machine requires only standard input, output, and error streams.
- **see-stdioesock-serv**: Use this utility if your SEE machine requires sockets in addition to standard input, output, and error streams.

Ensure that you select the appropriate utility for your SEE machine, because running a host-side utility with more provisions than the SEE machine was linked against causes the SEE machine to abort.

Generate the mandatory **userdata** file with the **cpio** utility. This utility takes a collection of files and packs them up into an archive file that the SEE machine can use. To generate a **userdata** file, run a command of the form:

```
cpio userdata.cpio <MyFile1> <MyFile2> <MyFile3> [...]
```

In this command, *<MyFile1>*, *<MyFile2>*, and *<MyFile3>* represent the files being packed into the **userdata.cpio** file that is generated by the command. You can specify as many files as appropriate. You can also specify one or more directories; the command automatically packs their contents (including any subdirectories) into the generated **userdata.cpio** file.

Typically, you run the host-side utilities with a command of the form:

```
see-*-serv --machine <MySEEMachine>.sar --userdata-raw <MyUserDataFile>
```

If the **userdata** file is signed (see [Signing userdata for additional security](#)), then run these host-side utilities with a command of the form:

```
see-*-serv --machine <MySEEMachine>.sar --userdata-sar <MyUserDataFile>.sar
```



Although you cannot load an encrypted SEE machine with the **see-*-serv** utilities, you can use them to start and service a previously loaded encrypted SEE machine.

For more detailed information and examples of how to apply these utilities, see [Examples for bsdlib library](#) and [see-*-serv utilities](#).

3.2.2. Designing for the SEELib architecture

This section describes how to design SEE machines using the **SEELib** architecture. This kind of architecture requires host-side software to create the SEE World and communicate with the HSM.

To start the SEE machine running with a particular SEE **userdata**, the host application calls the nCore API command **CreateSEEWorlD**. This command creates an SEE World using data previously loaded into the HSM with the **LoadBuffer** command from a buffer created with the **CreateBuffer** command. See the *nCore API Documentation* (supplied as HTML) for information about the nCore API commands.

You can also use or adapt the supplied example Java class **SEEWorlD** to initialize the SEE machine.

When the host application calls **CreateSEEWorlD**, the HSM allocates memory for the SEE World and sets up its input and output job queues. It then runs the SEE machine's **main()** function.

The SEE machine's **main()** function must:

- Call **SEELib_init()** before any other SEE library function to initialize the SEE library and to check that the HSM is running the expected version of the library
- If the machine accepts **userdata**:
 - call **SEELib_GetUserDataLen** to determine the length of the byte block that was passed with **CreateSEEWorlD**
 - call **SEELib_ReadUserData** to load the byte block
 - determine whether the byte block is valid
 - initialize any required structures
- Start at least one thread which receives and processes commands (this thread must call **SEELib_AwaitJob**)



The **SEELib_StartProcessorThreads** function can be used for this purpose.

- Call **SEELib_InitComplete** and return a status.

The status passed to **SEELib_InitComplete** is returned to the calling application in the reply to **CreateSEEWorlD**. The application can determine the status values, with one exception: if the machine fails before calling **SEELib_InitComplete()**, the **CreateSEEWorlD** command returns a value of **1** (**SEEInitStatus_MachineFailed**) in this field. You should therefore avoid choosing the value **1** to indicate successful initialization

When the application receives the reply to `CreateSEWorld` with `Status_OK` and an acceptable `initstatus`, it can start to submit jobs with the nCore API command `SEEJob`.

You can also use or adapt the supplied example Java class `SEEJob` to submit jobs to the SEE machine.

The `SEEJob` command takes a byte block, which is passed to the `SEELib_AwaitJob` function without being interpreted in any way. It is up to the host application to assemble this byte block and the SEE machine to interpret it.

After the job has been processed, assemble the reply into a byte block and call `SEELib_ReturnJob` to return it using the nShield core.

The nShield core assembles this byte block into a reply and returns it to the host application. Provided that the job is returned before the command times out, the reply has the status `OK`. The SEE machine must include any necessary status information within the byte block it returns. The calling application must remember to check this status as well as the status of the `SEEJob` nCore API function and the transport call, for example `NFastApp_Transact()`.

The SEE machine can call nCore API functions with `SEELib_Transact` or `SEELib_MarshalSendCommand` and `SEELib_GetUnmarshalResponse`. It may submit these as part of its initialization, before it calls `SEELib_InitComplete()`. However, if it does not call `SEELib_InitComplete()` within 30 seconds of start-up, the `CreateSEWorld` command returns `SEELib_InitStatus_MachineFailed`. For this reason, you should not perform (for example) lengthy key generation operations during initialization.

`SEELib_Transact` has syntax equivalent to the `NFastApp_Transact` function in the C generic stub. It takes a command structure and returns a reply structure. `SEELib_MarshalSendCommand` takes a command structure and submits it. `SEELib_GetUnmarshalResponse` reads a response from a buffer and returns a reply structure.



`SEELib_StartTransactListener` must be called successfully before you use `SEELib_Transact` to communicate with the nShield core.

3.2.3. SEE machines for new algorithms

In addition to being able to perform basic cryptographic operations, any SEE machine that implements an algorithm must also be able to:

- Generate keys
- Import keys
- Store keys as key blobs.

The SEE machine can use the nCore API functions `GenerateRandom` and `GeneratePrime` to acquire random numbers and random prime numbers from the HSM's hardware random number generator.

The SEE machine can perform its own multiprecision arithmetic. Otherwise, it can use the nCore API `BigNumOp` command to perform multiprecision arithmetic and the `ModExp` and `ModExpCrt` commands to perform modular exponentiation.

If you are using keys as session keys, there is no requirement for them ever to be placed in the nShield core. The only time that you need to transfer a key to the core is if you need to create a key blob for long-term storage. However, if you need to keep track of several keys, you may want to make use of the nShield core's object store rather than having to create a similar structure in your own code.

For an example of how an SEE machine can implement a non-standard algorithm, see [A3A8XC](#).

3.2.3.1. Key type

The SEE machine stores keys using the `random` key type. This is a plain byte block with no structure.

If the key contains several values, for example, exponent and modulus, the SEE machine must implement its own routines for marshalling and unmarshalling the byte block into the correct structure.



SEE machines using standard algorithms do not use the `random` key type. Instead, they use standard nCore key types.

3.2.3.2. ACL

The ACL needs to be constructed so that the SEE machine and only the SEE machine can access the key. To transfer a key from the nShield core to the SEE machine, the key must have the `ExportAsPlain` flag set in its ACL. The permission group with `ExportAsPlain` must be protected by a certifier so that this operation can only be performed by the SEE machine.

Although one obvious solution is to use the key that was used to sign the SEE machine, K_{Integ} , as the certifier, using K_{Integ} in this way means that whoever signed the SEE machine could potentially access any key for this algorithm. A better solution is to add an extra signature to the SEE machine by using a second key, K_{Auth} . The K_{Integ} signature proves that the code has not changed since it was signed. The K_{Auth} signature is then used to control access

to keys.

You can use the `generatekey` command-line utility to generate keys for use as K_{Auth} and K_{Integ} by specifying the `seeinteg` application as a key generation parameter.

The ACL must also have the correct `MakeBlob` permissions. If you want to use the standard Security World tools for key management and recovery, the host application can use these tools to create the ACL.



SEE machines using standard algorithms generally do not need to get the key as plain text in the SEE machine.

3.2.3.3. Storage

For long-term storage, the key needs to be encapsulated in a key blob that is protected by the Security World or an OCS. To provide OCS replacement and recovery, you may also require additional key blobs protected by other card sets.

You could write a function where your SEE machine calls `MakeBlob` and returns the blob to the host. Alternatively, you could write a method that returns a key ticket and have the host application create the key blobs.

If you are using a Security World, the host application can use `nfkm` library calls to create and store the key blobs.

3.2.3.4. Loading stored keys

In general, it is easier for the host application to manage tokens, because it has direct access to the user interface and can prompt the user to insert cards and enter passphrases.

When the token has been loaded, the host application can load the key and pass a key ticket to the SEE machine. The SEE machine can then redeem the key ticket for a `KeyID` and use this to access the key. If you have several keys that are protected by a token, it usually makes sense to pass a ticket for the `KeyID` of the logical token, rather than passing tickets for each key.

You should also pass in a ticket for the logical token if the host application that loads the token exits afterwards. When it exits, it destroys the logical token's ID, which invalidates all loaded keys that were using it. Passing the logical token's ID in to the SEE machine prevents its destruction when the application exits.

3.2.3.5. Run-time library

Entrust supplies a customized C run-time library (`librtusr.a`) and a corresponding set of header files (in the `include-see/module/rtlib` subdirectory) for programs operating in the SEE environment. This library contains most commonly used ANSI C functions, with the addition of the following proprietary extensions documented in `sys/threads.h`:

- Thread creation and control functions
- Thread synchronization primitives (events, semaphores, spin-locks)

However, the `librtusr.a` library excludes:

- Any file or directory access functions
- User input functions (for example, `stdin` and `scanf()`)
- Floating-point math library functions (in `math.h`), although basic floating-point types and arithmetic are supported
- Time/date and locale-specific functions (`time.h`, `locale.h`).



Multiplexing is not available with the `rtlib/SEELib` runtime library.

Access to the raw (SWI) interface between the SEE machine and the kernel is by means of the `SWIcall()` function, documented in `sys/swis.h`. The comments in this file are provided mainly for information, because all useful SWIs have C wrapper functions presented in other header files.

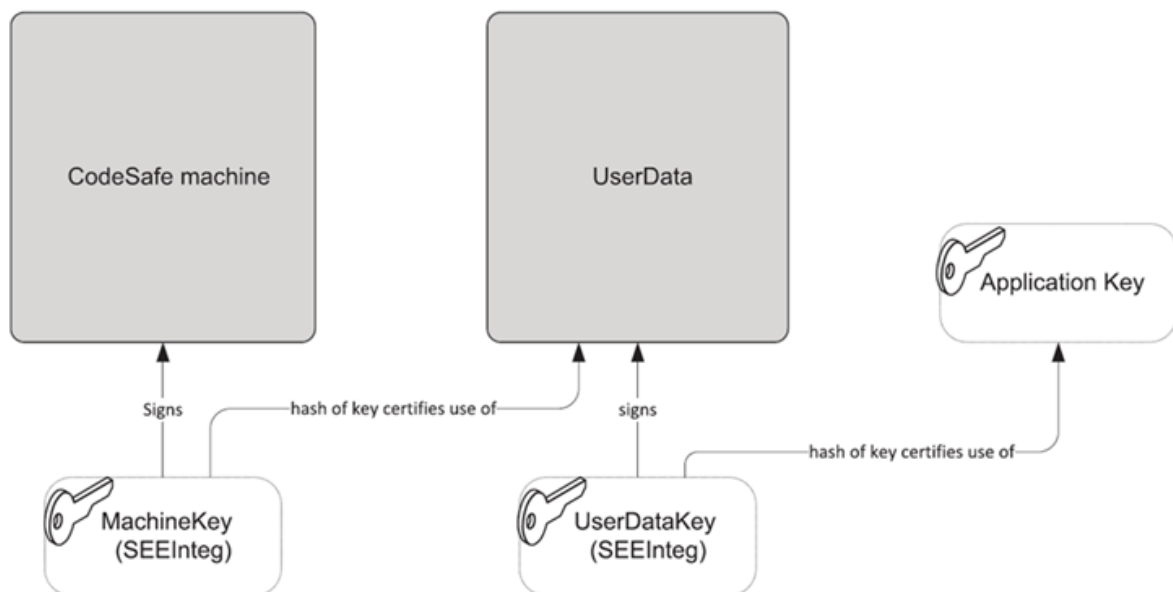
See [SEELib functions](#) for reference information about `bsdlib` functions.

3.2.4. Signing userdata for additional security

Signing `userdata` files can help increase the security of CodeSafe SEE applications. Both types of SEE machine architecture, using `bsdlib` and using `SEELib`, can take advantage of the security benefits offered by signing `userdata` files.

For example, if your SEE machine is intended to perform some cryptography functions using a given key, it would be advantageous to prevent that key from being accessed by any unauthorized SEE machines. This can be achieved by signing the `userdata` file for your SEE machine.

The following diagram illustrates the process of signing an SEE machine's `userdata` file.



The following sequence, in which an original SEE machine is represented by `machine.sxf` and an original `userdata` file is represented by `userdata.bin`, demonstrates the process of signing an SEE machine's `userdata` file:

1. Create the key K_{seemach} of type `seeinteg` to sign the SEE machine by running a command similar to:

```
generatekey seeinteg plainname=seemach ...
```

2. Create the key K_{userdata} of type `seeinteg` to sign the `userdata` by running a command similar to:

```
generatekey seeinteg plainname=userdata ...
```

3. Run the `generatekey` command-line utility to create a key K_{crypto} (the key with which your SEE machine is to perform its cryptography functions), specifying K_{userdata} for its `seeintegname`:

```
generatekey simple plainname=crypto --seeintegname=userdata ...
```



This example assumes K_{crypto} is being created as a Triple DES key.

4. Run the `tct2` command-line utility to sign the `userdata` file for your SEE machine with the key K_{userdata} , specifying K_{seemach} as the SEE machine key:

```
tct2 --sign --key=userdata --machine-key-ident=seemach --infile=userdata.bin --outfile=userdata.sar
```



For information about the `tct2` command-line utility, see [tct2](#).

5. Run the `tct2` command-line utility to sign the SEE machine with the key K_{seemach} :

```
tct2 --sign --key=seemach -- machine-type=PowerPCSXF--is-machine --infile=machine.sxf --outfile=machine.sar
```

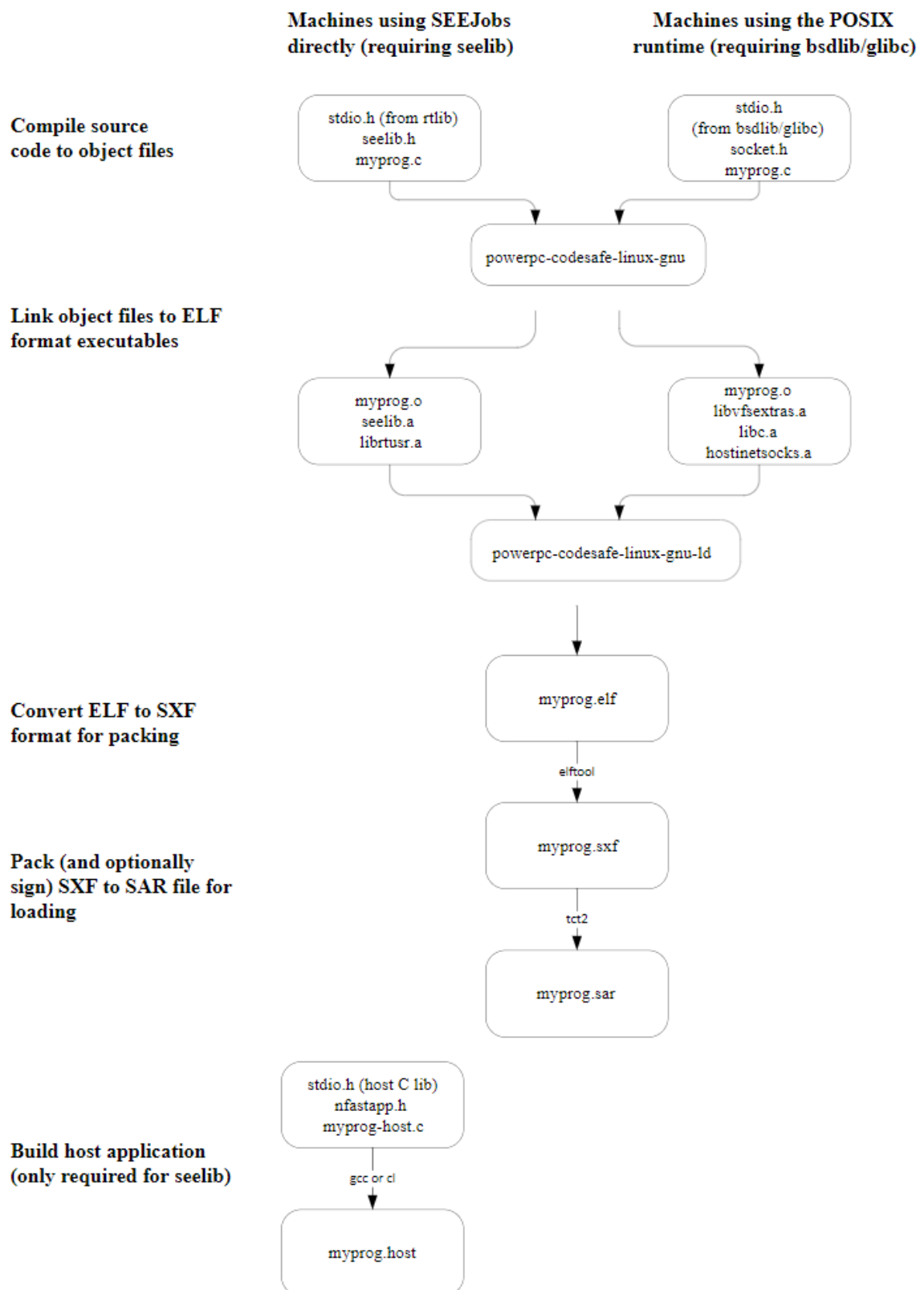
The result of the process demonstrated in this sequence of steps is that no SEE machine can use the key K_{crypto} unless at least one of the following conditions is met:

- It has been signed by the correct K_{seemach} and is used in conjunction with the correct `userdata` file
- You make use of the key recovery feature (see the *User Guide*).

3.2.5. Building your SEE machine and host-side application

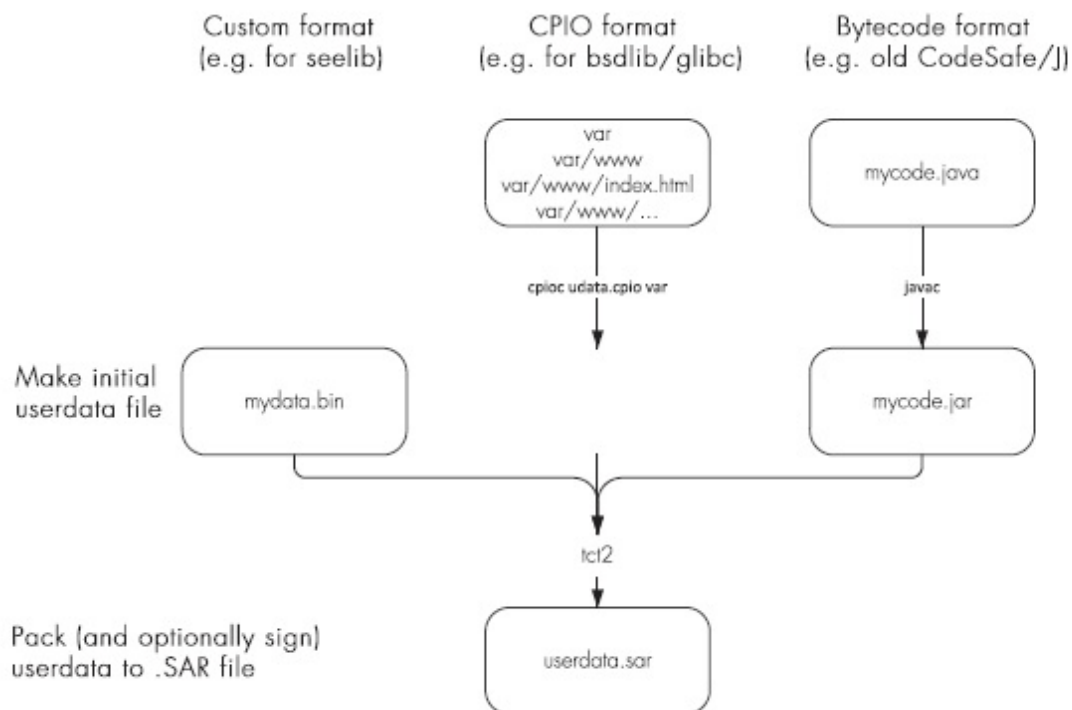
The following steps provide an overview of the process you follow to use your application with SEE:

1. If you want to sign or encrypt your application, generate code-signing and confidentiality keys as applicable.
2. Compile and link the host application's source files using the native compiler on the host. See the diagram in the following step.
3. Compile and link the SEE machine source using the GCC cross compiler. See the following diagram.



- Run the `elftool` command-line utility to convert the compiled SEE machine to SXF for mat. See [Utilities](#) for additional information.
- If required, use the Trusted Code Tool (`tct2`) to sign the SEE machine with the code-signing keys. See [Utilities](#) for additional information.

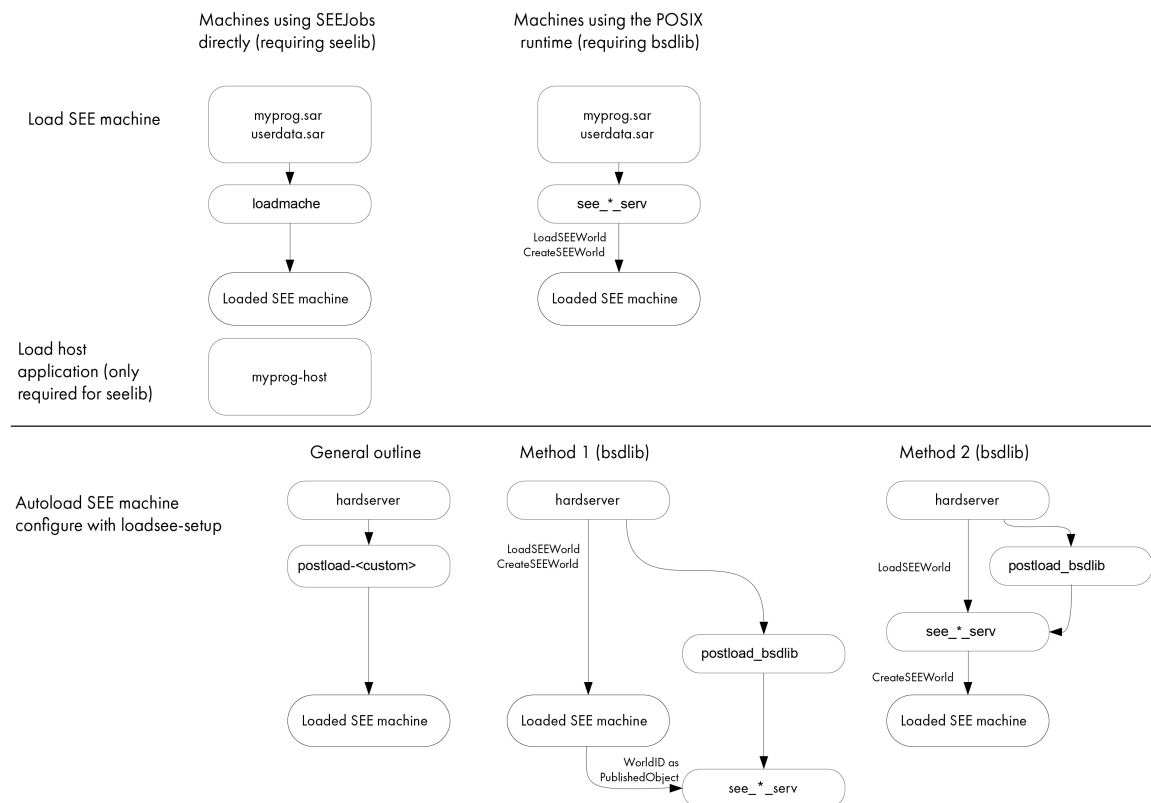
6. Use the Trusted Code Tool (`tct2`) to pack the HSM files and create a SAR file. See [Utilities](#) for additional information. You must pack the binary file even if signatures are not required.
7. Use the Trusted Code Tool (`tct2`) to pack (and, if required, sign with the code-signing keys) the `userdata` file and create a SAR file. You must pack the `userdata` file even if signatures are not required (unless you use one of the `see-*-serv` host utilities with the `--userdata-raw` option).



8. If required, use the Trusted Code Tool (`tct2`) to encrypt the `userdata` file, using the confidentiality key. See [Utilities](#) for additional information.
9. Place the `userdata` SAR file and the host application in an appropriate location to be used at runtime.
10. For SEE machines using the `SEELib` architecture, `userdata` file can either be either loaded automatically or can be loaded by running the `loadmache` command-line utility.

For SEE machines that require support from a host-side `see-*-serv` utility, the host utility loads the `userdata` file automatically.

The following diagram shows these different methods for loading an SEE machine.



For more information, see [Automatically loading an SEE machine](#).

4. Example SEE machines

This chapter documents the example SEE machines.

The supplied C examples consist of the source files and associated makefiles (**Linux**) and Cmake files (**Windows**) needed to compile and run the examples. To run the compiled examples correctly, you must have the latest version of the Security World for nShield. If you are using a Linux operating system, you must have version 2.22.34 or later of the HSM firmware. If you are using a Windows operating system, you must be on the latest version of the HSM firmware.



The latest versions of both the Security World for nShield and HSM firmware are supplied on the installation media.



Encrypted SEE machines are not currently supported for use with nShield Connects. When the SEEMachine binary is installed on the Connect itself for automated loading at boot, the SEE Confidentiality key is not available. However, when a client host loads a SEEMachine, it has access to the SEE Confidentiality key and can cause the binary to be decrypted. In this scenario, the Connect works fine with encrypted SEEMachine binaries.

4.1. Configure the Windows Build Environment

The Windows build environment requires that the following tools be already installed:

- CMake for Windows, minimum version 3.9.
- Visual Studio 2017 Build Tools.
- Ninja build system for Windows.

Each example is supplied with CMake files for each HSM architecture and Windows host environment.

The specifics of building the C code for the HSM architectures and the Windows host environment are described in the next sections.

In order to build the examples, you must use the Visual Studio Developer Command Prompt. This command prompt needs to be initialized to use the 64-bit compilation tools in the following manner:

1. Open a Windows command prompt, using **Run as Administrator**.
2. Navigate to the Visual Studio Build Tools installation directory. The default location for

this is `C:\Program Files (x86)\Microsoft Visual Studio\2017\BuildTools\VC\Auxiliary\Build`.

3. At the command prompt, execute the initialization batch file, `vcvars64.bat`. The batch file sets the required environment variables for using the 64-bit compilation tools.
4. At this point you may wish to enter the PowerShell environment. This can be done by executing the `powershell` command at the command prompt.



If you exit (close) the initialized Windows command prompt (or PowerShell), then these initialization steps must be repeated when you open a new command prompt in order to build the examples.



For information on the different library paths necessary to perform a 64-bit build of your own code, see the *nCore API Documentation* (supplied as HTML).



We strongly recommend that you familiarize yourself with the process of building the example programs supplied on the CodeSafe installation media before you attempt to adapt the makefiles to any other environments.

4.2. Examples for bsdlib library

This section is only relevant when using an **nShield Solo+** or an **nShield Connect+**. If you are using an **nShield Solo XC** or an **nShield Connect XC**, see [Examples for glibc library](#).

In default CodeSafe installations, the following C examples are supplied in directories under the path `/opt/nfast/c/csd/examples/` (**Linux**) or `%NFAST_HOME%\c\csd\examples` (**Windows**):

| Location | Description |
|-----------------------------------|---|
| <code>bsdsee/helloworld.c</code> | This example is a simple, introductory test program. |
| <code>bsdsee/see-random.c</code> | This example demonstrates basic usage of the generic stub within SEE. |
| <code>bsdsee/see-enquiry.c</code> | This example demonstrates host code running within SEE with no large modifications. |
| <code>bsdsee/tcp-proxy.c</code> | This example is a multithreaded TCP-TCP proxy that forwards all connections on port 8080 to 127.0.0.1:80. |

If the nShield Connect is configured to use `see-sock-serv` directly, any supplied **bsdlib** examples that use `see-sock-serv` can be run directly on the nShield Connect, rather than via a client machine.

The examples here show how to run a SEE machine from a command line. Alternatively, if you wish to run a SEE machine directly, please see [Deploying SEE Machines](#).



If you are running `see-sock-serv` directly on an nShield Connect, port numbers in the examples should be modified to bind to ports within the range 8000-8999.

All supplied examples for `bsdlib`, both standard and SSL-related, require one of the `see-*-serv` host-side utilities. For more information about these utilities, see [see-*-serv utilities](#).

4.2.1. Building the HSM-side code

1. Create a directory in your `Documents` location to contain the platform examples. For example, create a directory called `buildBSDmod`, and enter this directory:

Linux

```
cd ~
mkdir buildBSDmod
cd buildBSDmod
```

Windows

```
cd Documents
mkdir buildBSDmod
cd buildBSDmod
```

2. Configure the module examples build using the command:

Linux

```
cmake -DCMAKE_TOOLCHAIN_FILE=<path to BSD tool chain> <path to BSD SEE examples>
```

For example, using the default locations for the tool chain and the BSD SEE examples:

```
cmake -DCMAKE_TOOLCHAIN_FILE=/opt/nfast/c/csd/cmake/codesafe-linux-solo-bsdsee.cmake
/opt/nfast/c/csd/examples/
```

Windows

```
cmake -G "Ninja" -DCMAKE_TOOLCHAIN_FILE=<path to BSD tool chain> <path to BSD SEE examples>
```

For example, using the default locations for the tool chain and the BSD SEE examples:

```
cmake -G "Ninja" -DCMAKE_TOOLCHAIN_FILE="C:\Program Files\nCipher\nfast\c\csd\cmake\codesafe-linux-solo-bsdsee.cmake" "C:\Program Files\nCipher\nfast\c\csd\examples"
```

3. Build the module examples using the command:

Linux

```
cmake --build <build output location>
```

For example:

```
cmake --build .
```

Here, the `.` specifies the location where the build products should be placed, in this case to the current directory.

Windows

```
Ninja
```

This results in the creation of a directory, `bsdsee`, which contains all the compiled examples. The build process will create two files per example, one with a `.sxf` suffix and another with an `.elf` suffix.

4.2.2. Helloworld example

This example source code is a simple example of an SEE machine written in C. It is *not* intended to be the basis for any real world applications. It is intended only to demonstrate how to write SEE machines in C and the use of an appropriate host utility to handle output to `stdout` and `stderr`.

4.2.2.1. Packing the SEE machine

Use the `tct2` command-line utility to convert the SXF (Secure eXecution Format) file into a SAR (Secure or SEE ARchive) file as follows:

```
tct2 --pack --infile=helloworld.sxf --outfile=helloworld.sar
```

You can also choose to set options in this command that sign or encrypt the file. For more information, see [tct2](#).

4.2.2.2. Creating a userdata file



All SEE machines built with the **bsdlib** C library must be provided with a valid ASCII-format CPIO archive. This archive forms the base of the file system available to your SEE machine. You can use the **cpio** command-utility that we provide to create CPIO archives of the correct type.



Although the **helloworld** example does not use its file system, you must still create and supply it with dummy **userdata** as a place-holder.

Create a dummy **userdata** file as follows:

```
echo dummy > dummy
cpio userdata.cpio dummy
```

Output:

```
F dummy
Written 'userdata.cpio': 1 files, 0 directories, 0 errors
```

4.2.2.2.1. Running the example

To run the helloworld example on a PowerPC-based SEE machine, use the following commands:

```
see-stdoe-serv --machine helloworld.sar --userdata-raw userdata.cpio
```

Output:

```
nC SEE bsdlib entering main
Hello world!
```



If you are using an nShield Connect, you must also set the **--no-feature-check** option when running the **see-stdoe-serv** utility.

Before rerunning this example, run the following command to clear all HSMs:

```
nopclearfail --clear --all
```

4.2.3. SEE-Random example

This example shows basic usage of the generic stub from within SEE. It requests 128 bytes of random material from the HSM and prints the result in hexadecimal.

Before running or rerunning this example, run the following command to clear all HSMs:

```
nopclearfail --clear --all
```

The following assumes that the user is working in the directory that contains the compiled examples (both SXF and ELF files).

4.2.3.1. Packing the SEE machine

Use the **tct2** command-line utility to convert the SXF (Secure eXecution Format) file into a SAR (Secure or SEE ARchive) file:

Linux

```
tct2 --pack --infile=see-random.sxf --outfile=see-random.sar
```

Windows

```
tct2 --pack --machie-type=PowerPC ELF --infile=see-random.sxf --outfile=see-random.sar
```

For additional security, you can also set options in this command to sign or encrypt the file. For more information, see [tct2](#).

4.2.3.2. Running the example

To run the **SEE-Random** example on a PowerPC-based SEE machine, use the following commands:

```
see-stdoe-serv --machine see-random.sar --userdata-raw userdata.cpio
```

Output:

```
nC SEE bsdlib entering main
52 D1 C4 73 28 49 79 62 CD E6 64 14 1C 3B E1 B2 70 3D 6B D5 DF DE CE 7F 47 50 70 06 B6
C0 52 7F 19 3A 0A 7D E4 73 83 D8 EB F4 E5 82 F3 53 38 45 2A E3 08 49 1A 58 77 35 5F 5C
7C D9 7B 57 4A A9 C4 F4 67 C7 30 91 4A CA 0C 15 1F A7 F2 E1 2B 61 E2 3A CE EF BD FF ED
49 07 68 7B 76 D2 AC 8B 98 AA 02 FD 30 01 68 60 49 4C 0F 7E 23 7F AC EC B5 6A DE 0B CD
45 72 89 96 DD E2 96 C2 B8 7B 97 AA
```



If you are using an nShield Connect, you must also set the **--no-feature-check** option when running the **see-stdoe-serv** utility.

4.2.4. SEE-Enquiry example

This example shows how to cross-compile example code, originally written for use from the host environment, to be run within the SEE without any substantial modifications.

Before running or rerunning this example, run the following command to clear all HSMs:

```
nopclearfail --clear --all
```

The following assumes that the user is working in the directory that contains the compiled examples (both SXF and ELF files).



This example code is based on `enquiry.c` provided elsewhere in the software distribution.

4.2.4.1. Packing the SEE machine

Use the `tct2` command-line utility to convert the SXF (Secure eXecution Format) file into a SAR (Secure or SEE ARchive) file:

Linux

```
tct2 --pack --infile=see-enquiry.sxf --outfile=see-enquiry.sar
```

Windows

```
tct2 --pack --machine-type=PowerPC ELF --infile=see-enquiry.sxf --outfile=see-enquiry.sar
```

For additional security, you can also set options in this command to sign or encrypt the file. For more information, see [tct2](#).

4.2.4.2. Running the example

To run the **SEE-Enquiry** example on a PowerPC-based SEE machine, use the following command:

```
see-stdoe-serv --machine see-enquiry.sar --userdata-raw userdata.cpio
```

Output:

```
nC SEE bsdlib entering main
Server:
enquiry reply flags  none
enquiry reply level  Six
serial number        1BD7-DE7B-A370
```

```

mode           operational
version        2.38.7
speed index    4240
rec. queue     35..152
[etc]

```



If you are using an nShield Connect, you must also set the `--no-feature-check` option when running the `see-stdoe-serv` utility.

4.2.5. TCP proxy example

The TCP proxy example demonstrates how to set up a conduit between the local host and a destination IP address.

Before running or rerunning this example, run the following command to clear all HSMs:

```
nopclearfail --clear --all
```

The following assumes that the user is working in the directory that contains the compiled examples (both SXF and ELF files).

The default destination address is declared in the source code file `tcp-proxy.c` as follows:

```
#define BACKEND_ADDR "127.0.0.1"
```

For the TCP proxy example to work correctly, you must change this default destination address. You can replace the default address with the IP address of any valid website.

By default, the example TCP proxy code sets the front end port to 8080 and the back end port to 80. The remainder of this example assumes the use of these values, but you can change them as necessary.

4.2.5.1. Re-building the HSM-side code

If the file `tcp-proxy.c` has been modified as described in [TCP proxy example](#), then the example needs to be rebuilt in order for the changes to take effect. The example can be rebuilt by executing the cmake build command from within the appropriate directory as described in [Examples for bsdlib library](#) for example:

Linux

```
cd ~/buildBSDmod
cmake --build .
```

Windows

```
cd C:\Users\<USER-NAME>\Documents\buildBSDMod
Ninja
```



If the example has been rebuilt, before continuing ensure that you are working in the directory that contains the compiled examples. In this example, the directory path would be `~/buildBSDmod/bsdsee` (**Linux**) or `C:\Users\<USER-NAME>\Documents\buildBSDMod\bsdsee\` (**Windows**).

4.2.5.2. Packing the SEE machine

Use the `tct2` command-line utility to convert the SXF (Secure eXecution Format) file into a SAR (Secure or SEE ARchive) file:

Linux

```
tct2 --pack --infile=tcp-proxy.sxf --outfile=tcp-proxy.sar
```

Windows

```
tct2 --pack --machine-type=PowerPC ELF --infile=tcp-proxy.sxf --outfile=tcp-proxy.sar
```

For additional security, you can also set options in this command to sign or encrypt the file. For more information, see [tct2](#).

4.2.5.3. Running the example

Run the example on a PowerPC-based SEE machine as follows:

```
see-sock-serv --trace --machine tcp-proxy.sar --userdata-raw userdata.cpio
```

You can check that the example is working correctly by entering the URL `http://localhost:8080/` into any Web browser. If the example is working correctly, the browser displays the Web page at the address specified in the `tcp-proxy.c` file.

4.3. Examples for glibc library

This section is only relevant when using an **nShield Solo XC** or an **nShield Connect XC**. If you are using an **nShield Solo+** or an **nShield Connect+**, see [Examples for bsdlib library](#).

In default CodeSafe installations, the following C examples are supplied in directories under

the path `/opt/nfast/c/csd/examples/` (**Linux**) or `%NFAST_HOME%\c\csd\examples\` (**Windows**):

| Location | Description |
|------------------------------------|---|
| <code>glibsee/helloworld.c</code> | This example is a simple, introductory test program. |
| <code>glibsee/see-random.c</code> | This example demonstrates basic usage of the generic stub within SEE. |
| <code>glibsee/see-enquiry.c</code> | This example demonstrates host code running within SEE with no large modifications. |
| <code>glibsee/tcp-proxy.c</code> | This example is a multithreaded TCP-TCP proxy that forwards all connections on port 8080 to 127.0.0.1:80. |

If the nShield Connect is configured to use `see-sock-serv` directly, any supplied `glibc` examples that use `see-sock-serv` can be run directly on the nShield Connect, rather than via a client machine.

The examples here show how to run a SEE machine from a command line. Alternatively, if you wish to run a SEE machine directly, please see [Deploying SEE Machines](#).



If you are running `see-sock-serv` directly on an nShield Connect, port numbers in the examples should be modified to bind to ports within the range 8000-8999.

All supplied examples for `glibc`, both standard and SSL-related, require one of the `see-*-serv` host-side utilities. For more information about these utilities, see [see-*-serve utilities](#).



The SEE machine type must be specified as `--machine-type=PowerPCELF` when running the `tct2` tool.

4.3.1. Building the HSM-side code

1. Create a directory in your home (**Linux**) or **Documents** (**Windows**) location to contain the platform examples. For example, to create and enter a directory called `buildGLIBmod`:

Linux

```
cd ~
mkdir buildGLIBmod
cd buildGLIBmod
```

Windows

```
cd Documents
```

```
mkdir buildGLIBmod
cd buildGLIBmod
```

2. Configure the module examples build using the command:

Linux

```
cmake -DCMAKE_TOOLCHAIN_FILE=<path to GLIB tool chain> <path to GLIB SEE examples>
```

For example, using the default locations for the tool chain and the GLIB SEE examples:

```
cmake -DCMAKE_TOOLCHAIN_FILE=/opt/nfast/c/csd/cmake/codesafe-linux-xc-glibsee.cmake
/opt/nfast/c/csd/examples/
```

Windows

```
cmake -G "Ninja" -DCMAKE_TOOLCHAIN_FILE=<path to GLIB tool chain> <path to GLIB SEE examples>
```

For example, using the default locations for the tool chain and the GLIB SEE examples:

```
cmake -G "Ninja" -DCMAKE_TOOLCHAIN_FILE="C:\Program Files\nCipher\nfast\c\csd\cmake\codesafe-linux-xc-
glibsee.cmake" "C:\Program Files\nCipher\nfast\c\csd\examples"
```

3. Build the module examples using the command:

Linux

```
cmake --build <build output location>
```

For example:

```
cmake --build .
```

Here, the `.` specifies the location where the build products should be placed, in this case to the current directory.

Windows

```
Ninja
```

This results in the creation of a directory, `glibsee`, which contains all the compiled examples. The build process will create a file for each example, with an `.elf` suffix.

4.3.2. Helloworld example

This example source code is a simple example of an SEE machine written in C. It is *not* intended to be the basis for any real world applications. It is intended only to demonstrate how to write SEE machines in C and the use of an appropriate host utility to handle output to `stdout` and `stderr`.

4.3.2.1. Packing the SEE machine

Use the `tct2` command-line utility to convert the ELF (Executable and Linkable Format) file into a SAR (Secure or SEE ARchive) file as follows:

```
tct2 --pack --machine-type=PowerPC ELF --infile=helloworld.elf --outfile=helloworld.sar
```

For additional security, you can also choose to set options in this command that sign or encrypt the file. For more information, see [tct2](#).

4.3.2.2. Creating a userdata file



All SEE machines built with the `glibc` C library must be provided with a valid ASCII-format CPIO archive. This archive forms the base of the file system available to your SEE machine. You can use the `cpio` command-utility that we provide to create CPIO archives of the correct type.



Although the `helloworld` example does not use its file system, you must still create and supply it with dummy `userdata` as a place-holder.

Create a dummy `userdata` file as follows:

```
echo dummy > dummy  
cpio userdata.cpio dummy
```

Output:

```
F dummy  
Written 'userdata.cpio': 1 files, 0 directories, 0 errors
```

4.3.2.3. Running the example

To run the `helloworld` example on a PowerPC-based SEE machine, use the following com-

mands:

```
see-stdoe-serv --machine helloworld.sar --userdata-raw userdata.cpio
```

Output:

```
nC SEE glibc entering main
Hello world!
```



If you are using a nShield Connect, you must also set the `--no-feature-check` option when running the `see-stdoe-serv` utility.

Before rerunning this example, run the following command to clear all HSMs:

```
nopclearfail --clear --all
```

4.3.3. SEE-Random example

This example shows basic usage of the generic stub from within SEE. It requests 128 bytes of random material from the HSM and prints the result in hexadecimal.

Before running or rerunning this example, run the following command to clear all HSMs:

```
nopclearfail --clear --all
```

The following assumes that the user is working in the directory that contains the compiled examples (both SXF and ELF files).

4.3.3.1. Packing the SEE machine

Use the `tct2` command-line utility to convert the ELF (Executable and Linkable Format) file into a SAR (Secure or SEE ARchive) file:

```
tct2 --pack --machine-type=PowerPCELF --infile=see-random.elf --outfile=see-random.sar
```

For additional security, you can also set options in this command to sign or encrypt the file. For more information, see [tct2](#).

4.3.3.2. Running the example

To run the `SEE-Random` example on a PowerPC-based SEE machine, use the following com-

mands:

```
see-stdoe-serv --machine see-random.sar --userdata-raw userdata.cpio
```

Output:

```
nC SEE glibc entering main
52 D1 C4 73 28 49 79 62 CD E6 64 14 1C 3B E1 B2 70 3D 6B D5 DF DE CE 7F 47 50 70 06 B6
C0 52 7F 19 3A 0A 7D E4 73 83 D8 EB F4 E5 82 F3 53 38 45 2A E3 08 49 1A 58 77 35 5F 5C
7C D9 7B 57 4A A9 C4 F4 67 C7 30 91 4A CA 0C 15 1F A7 F2 E1 2B 61 E2 3A CE EF BD FF ED
49 07 68 7B 76 D2 AC 8B 98 AA 02 FD 30 01 68 60 49 4C 0F 7E 23 7F AC EC B5 6A DE 0B CD
45 72 89 96 DD E2 96 C2 B8 7B 97 AA
```



If you are using an nShield Connect, you must also set the `--no-feature-check` option when running the `see-stdoe-serv` utility.

4.3.4. SEE-Enquiry example

This example shows how to cross-compile example code, originally written for use from the host environment, to be run within the SEE without any substantial modifications.

Before running or rerunning this example, run the following command to clear all HSMs:

```
nopclearfail --clear --all
```

The following assumes that the user is working in the directory that contains the compiled examples (both SXF and ELF files).



This example code is based on `enquiry.c` provided elsewhere in the software distribution.

4.3.4.1. Packing the SEE machine

Use the `tct2` command-line utility to convert the ELF (Executable and Linkable Format) file into a SAR (Secure or SEE ARchive file):

```
tct2 --pack --machine-type=PowerPC ELF --infile=see-enquiry.elf --outfile=see-enquiry.sar
```

For additional security, you can also set options in this command to sign or encrypt the file. For more information, see [tct2](#).

4.3.4.2. Running the example

To run the **SEE-Enquiry** example on a PowerPC-based SEE machine, use the following commands:

```
see-stdoe-serv --machine see-enquiry.sar --userdata-raw userdata.cpio
```

Output:

```
nC SEE glibc entering main
Server:
enquiry reply flags  none
enquiry reply level  Six
serial number       1BD7-DE7B-A370
mode                operational
version             2.38.7
speed index         4240
rec.queue           35..152
[etc]
```



If you are using an nShield Connect, you must also set the **--no-feature-check** option when running the **see-stdoe-serv** utility.

4.3.5. TCP proxy example

The TCP proxy example demonstrates how to set up a conduit between the local host and a destination IP address.

Before running or rerunning this example, run the following command to clear all HSMs:

```
nopclearfail --clear --all
```

The following assumes that the user is working in the directory that contains the compiled examples (both SXF and ELF files).

The default destination address is declared in the source code file **tcp-proxy.c** as follows:

```
#define BACKEND_ADDR "127.0.0.1"
```

For the TCP proxy example to work correctly, you must change this default destination address. You can replace the default address with the IP address of any valid website.

By default, the example TCP proxy code sets the front end port to 8080 and the back end port to 80. The remainder of this example assumes the use of these values, but you can change them as necessary.

4.3.5.1. Re-building the HSM-side code

If the file `tcp-proxy.c` has been modified as described in section [TCP proxy example](#), then the example needs to be rebuilt in order for the changes to be effective. The example can be rebuilt by executing the cmake build command from within the appropriate directory as described in section [Examples for glibc library](#) for example:

Linux

```
cd ~/buildGLIBmod  
cmake --build .
```

In this example the directory path would be `~/buildGLIBmod/glibsee`.

Windows

```
cd C:\Users\<USER-NAME>\Documents\buildGLIBmod  
Ninja
```

In this example the directory path would be `C:\Users\<USER-NAME>\Documents\buildGLIBmod\glibsee\`.



If the example has been rebuilt, before continuing ensure that you are working in the directory that contains the compiled examples.

4.3.5.2. Packing the SEE machine

Use the `tct2` command-line utility to convert the ELF (Executable and Linkable Format) file into a SAR (Secure or SEE ARchive) file:

```
tct2 --pack --machine-type=PowerPC ELF --infile=tcp-proxy.elf --outfile=tcp-proxy.sar
```

You can also set options in this command to sign or encrypt the file. For more information, see [tct2](#).

4.3.5.3. Running the example

Run the example on a PowerPC-based SEE machine as follows:

```
see-sock-serv --trace --machine tcp-proxy.sar --userdata-raw userdata.cpio
```

You can check that the example is working correctly by entering the URL <http://localhost:8080/> into any browser. If the example is working correctly, the browser

displays the website at the address specified in the `tcp-proxy.c` file.

4.4. Examples for SEELib

In default CodeSafe installations, the following C examples are supplied in directories under the path `/opt/nfast/c/csd/examples/csee` (**Linux**) or `%NFAST_HOME%\c\csd\examples\csee` (**Windows**).

| Location | Description |
|------------------------------|--|
| <code>csee/hello/</code> | This example source code demonstrates a simple SEE machine in C and how you can use it from a C program on the host. |
| <code>csee/a3a8/</code> | This example code demonstrates how to write an SEE machine in C code and how to use it from a C program on the host. |
| <code>csee/nvram/</code> | This example shows the simple use of NVRAM in an SEE machine written in C. |
| <code>csee/rtc/</code> | This example demonstrates the use of an SEE machine written in C that implements a very simple timestamp service. |
| <code>csee/tickets/</code> | This example provides an API demonstration showing how an SEE machine can be written in C. |
| <code>csee/benchmark/</code> | This example implements a very simple utility that uses an SEE machine written in C to time stamp requests to benchmark the speed of response to requests. |

We also supply a Java version of the `HelloWorld` example. This consists of the source files for host-side applications that you can run with the example SEE machines written in C (or any other SEE machines written in any language) in order to understand how simple SEE machines work, see [About the Java example](#).

The `nvram`, `rtc`, and `benchmark` C examples can extract debugging information from the SEE trace buffer in all Security Worlds. If the Security World has restricted or authorized-only access to SEE debugging, the example prompts the user for the number of Administrator Cards required to gain authorization. Therefore, to avoid unnecessary exposure of the Administrator Cards, do not try to run these examples on an HSM in a production Security World. Debugging information from the trace buffer is not available for the `A3A8` or `tickets` C examples.

4.4.1. Building Linux host examples

1. Create a directory in your home location to contain the host platform examples. For example, create a directory called `buildhost`, and enter this directory:


```
mkdir ~/buildhost  
cd ~/buildhost
```

2. Configure the host platform examples using the command:

```
cmake <path to SEELib examples>
```

For example:

```
cmake /opt/nfast/c/csd/examples/
```

Here, the location of the examples is the default location, `/opt/nfast/c/csd/examples`.

3. Build the host platform examples using the command:

```
cmake --build <build output location>
```

For example

```
cmake --build .
```

Here, the `.` specifies the location where the build products should be placed, in this case to the current directory.

This results in the creation of a directory, `csee`, which contains a subdirectory for each of the examples. For example `~/buildhost/csee/a3a8`.

4.4.2. Building Windows host examples

1. Create a directory in your `Documents` location to contain the host examples. For example, create a directory called `host`, and enter this directory:

```
cd Documents  
mkdir host  
cd host
```

2. Configure the host platform examples using the command:

```
cmake -G "Ninja" -DCMAKE_C_COMPILER=cl -DCMAKE_CXX_COMPILER=cl "C:\Program  
Files\ncipher\nfast\c\csd\examples"
```

3. Build the host examples using the command:

```
ninja
```

This results in the creation of a directory, **csee**, which contains a subdirectory for each of the examples.

Each example's subdirectory contains a directory, **module**, which contains the compiled module code.

4.4.3. Building Solo SEE module examples

1. Create a directory in your home (**Linux**) or **Documents** (**Windows**) location to contain the module examples. For example, create a directory, **buildSoloMod**, and enter this directory.

Linux

```
cd ~
mkdir buildSoloMod
cd buildSoloMod
```

Windows

```
cd Documents
mkdir buildSoloMod
cd buildSoloMod
```

2. Configure the module examples build using the command:

Linux

```
cmake -DCMAKE_TOOLCHAIN_FILE=<path to Solo + module tool chain> <path to CSEE examples>
```

For example, using default locations for the Solo + module tool chain and the CSEE examples:

```
cmake -DCMAKE_TOOLCHAIN_FILE=/opt/nfast/c/csd/cmake/codesafe-linux-solo-csee.cmake
/opt/nfast/c/csd/examples/
```

Windows

```
cmake -G "Ninja" -DCMAKE_TOOLCHAIN_FILE="C:\Program Files\nCipher\nfast\c\csd\cmake\codesafe-linux-solo-csee.cmake" "C:\Program Files\nCipher\nfast\c\csd\examples"
```

3. Build the modules using the command:

Linux

```
cmake --build <build output location>
```

For example:

```
cmake --build .
```

Here the `.` specifies the location where the build products should be placed, in this case to current directory.

Windows

```
Ninja
```

This will result in the creation of a directory, `csee`, which contains a subdirectory for each of the examples. Each example's subdirectory contains a directory, `module`, which contains the compiled module code. For example, `~/buildSoloMod/csee/a3a8/module`. The compiled module executables have the suffix `sxf`.

4.4.4. Building Solo XC SEE module examples

1. Create a directory in your home (**Linux**) or **Documents** (**Windows**) location to contain the module platform examples. For example, create a directory, `buildXCmod`, and enter this directory:

Linux

```
cd ~
mkdir buildXCmod
cd buildXCmod
```

Windows

```
cd Documents
mkdir buildXCmod
cd buildXCmod
```

2. Configure the module examples build using the command:

Linux

```
cmake -DCMAKE_TOOLCHAIN_FILE=<path to Solo XC module tool chain> <path to SEELib examples>
```

For example, using the default locations for the Solo XC module tool chain and the

SEELib examples, the command would be:

```
cmake -DCMAKE_TOOLCHAIN_FILE=/opt/nfast/c/csd/cmake/codesafe-linux-xc-csee.cmake
/opt/nfast/c/csd/examples/
```

Windows

```
cmake -G "Ninja" -DCMAKE_TOOLCHAIN_FILE="C:\Program Files\nCipher\nfast\c\csd\cmake\codesafe-linux-xc-
csee.cmake" "C:\Program Files\nCipher\nfast\c\csd\examples"
```

3. Build the module examples using the command:

Linux

```
cmake --build <build output location>
```

For example:

```
cmake --build .
```

Here the `.` specifies the location where the build products should be placed, in this case to current directory.

Windows

```
Ninja
```

This will result in the creation of a directory, `csee`, which contains a subdirectory for each of the examples. Each example's subdirectory contains a directory, `module`, which contains the compiled module code. For example, `~/buildXCMod/csee/a3a8/module`. The compiled module executables have the suffix `.elf`.

4.4.5. Example: Hello-World

This example source code demonstrates a simple SEE machine in C and how you can use it from a C program on the host. The SEE machine examines the characters in the SEE job passed to it and replaces each lowercase alphabetic character with the corresponding uppercase character, returning the result as the SEE job reply. Additionally, if the SEE World is created with a `userdata` file, any characters found in the `userdata` file are replaced in the input SEE job with the character `X`.



The `Hello-World` example is *not* intended to be the basis for any real world applications. It is intended only to demonstrate how to write SEE machines in C and host-side use of an SEE machine by code written in

C.



There is also an example of the host-side code written in Java, supplied in the `nCipherKM-SEE-Examples.jar` found in `/opt/nfast/java/examples/` (**Linux**) or `%NFAST_HOME%\java\examples\` (**Windows**).

4.4.5.1. Signing, packing, and loading the SEE machine

1. Generate a key with which to sign the SEE machine:

```
generatekey -m 1 seeinteg
```

2. Complete the prompts as follows:

```
recovery: Key recovery? (yes/no) [yes] >
type: Key type? (RSA, DSA, ECDSA, KCDSA) [RSA] >
size: Key size? (bits, minimum 1024) [2048] >
OPTIONAL: pubexp: Public exponent for RSA key (hex)? []
>
plainname: Key name? [] > hellomachine
nvram: Blob in NVRAM (needs ACS)? (yes/no) [no] >
key generation parameters:
  operation      Operation to perform      generate
  application    Application                      seeinteg
  protect        Protected by                      token
  slot           Slot to read cards from    0
  recovery       Key recovery                yes
  verify         Verify security of key           yes
  type           Key type                  RSA
  size           Key size                  2048
  pubexp         Public exponent for RSA    key (hex)
  plainname      Key name                  hellomachine
  nvram          Blob in NVRAM (needs ACS)  no

Loading 'dev-ocs':
  Module 1: 0 cards of 1 read
  Module 1 slot 0: 'dev-ocs' #1
  Module 1 slot 0:- passphrase supplied - reading card
Card reading complete.
Key successfully generated.
Path to key: <path-to-key>
```

Where `<path-to-key>` is `/opt/nfast/kmdata/local/key_seeinteg_hellomachine` (**Linux**) or `C:\ProgramData\nCipher\Key Management Data\local\key_seeinteg_hellomachine` (**Windows**).

3. Change to the module directory.

For **nShield Solo**:

Linux

```
cd ~/buildSoloMod/csee/hello/module
```

Windows

```
cd C:\Users\<USER-NAME>\Documents\buildSoloMod\csee\hello\module
```

For **nShield Solo XC**:

Linux

```
cd ~/buildSoloXC/csee/hello/module
```

Windows

```
cd C:\Users\<USER-NAME>\Documents\buildXCMod\csee\hello\module
```

4. Use the **tct2** command line utility to convert the file into a SAR file.

For **nShield Solo**:

Convert the **hello.sxf** file to a SAR file:

Linux

```
tct2 --sign-and-pack --is-machine -i hello.sxf --machine-type=PowerPCSXF -o hello.sar -k hellomachine
```

Windows

```
tct2 -m 1 --sign-and-pack --is-machine -i .\hello.sxf --machine-type=PowerPCSXF -o hello.sar -k  
hellomachine
```

Output:

```
Signing machine as 'PowerPCSXF'.  
  
Loading 'dev-ocs':  
Module 1: 0 cards of 1 read  
Module 1 slot 0: 'dev-ocs' #1  
Module 1 slot 0:- passphrase supplied - reading card  
Card reading complete.
```

For **nShield Solo XC**:

Convert the **hello.elf** file to a SAR file:

Linux

```
tct2 --sign-and-pack --is-machine -i hello.elf --machine-type=PowerPCELF -o hello.sar -k hellomachine
```

Windows

```
tct2 --sign-and-pack --is-machine -i .\hello.elf --machine-type=PowerPC ELF -o hello.sar -k
hellomachine
```

Output:

```
Signing machine as 'PowerPC ELF'.

Loading 'dev-ocs':
Module 1: 0 cards of 1 read
Module 1 slot 0: 'dev-ocs' #1
Module 1 slot 0:- passphrase supplied - reading card
Card reading complete.
```



For more information about this command, see [tct2](#).

5. Load the SEE machine into the HSM by running the command:

```
loadmache -m 1 hello.sar
```



This example describes how to load the SEE machine by running the **loadmache** command-line utility. In a production environment, you can choose to configure the **load_seemachine** section of the host or client configuration file so that an SEE machine is loaded automatically. See [Automatically loading an SEE machine](#).

4.4.5.2. Preparing example userdata

You do not need to create real **userdata** for this example. Instead, you can simply pack a small text file with **tct2** and pass the packed file to the SEE machine to serve as **userdata**.

However, you can also choose to create and sign a real **userdata** file in the same way as for the **A3A8** example; see [A3A8 example](#)



When you run the **Hello-World** example, because the characters in the **userdata** you supply are converted from lower case to replaced by the character **X** in the output file, including a new line sequence in the **user-data** can produce unexpected results.

4.4.5.3. Running the example

To run the C example change to the host application directory by running the command:

Linux

```
cd ~/buildHost/csee/hello/hostside
```

Windows

```
cd C:\Users\<USER-NAME>\Documents\hostside\csee\hello\hostside
```

Pack the desired user data in the SAR file suitable for loading onto the HSM. Optionally, you could use the Trusted Code Tool (**tct2**) to create a signed and packed SAR file for this step.

4.4.5.4. Usage

The **hello** example program has the following arguments:

```
hello <FILENAME> [<USERDATA>.sar]
```

FILENAME

This parameter is the name of the input file that contains the source string.

USERDATA

This optional parameter is the name of a file that contains letters to be replaced by the ASCII character **X** in the output file.

4.4.5.4.1. What the code actually does

The host-side C code performs the following tasks:

1. It prompts the user to supply a file name and an optional *USERDATA* file.
2. It sends the string in the file, converted if necessary to standard output.

The HSM-side code awaits jobs from the host and performs the following:

1. It transforms the contents of the input file, capitalizing all input and replacing any characters that appear in the optional *USERDATA* file with an ASCII character **X**.
2. It sends the result as output.

4.4.6. A3A8 example

This example code demonstrates how to write an SEE machine in C code and how to use it from a C program on the host.



The **A3A8** example is *not* intended to be the basis for any real world applications. The algorithm used, known as ACOMP128, has been shown to be insecure and is not appropriate for production use. It is used here only to demonstrate the implementation of an algorithm in an SEE application, not to endorse it in any way.



This example does not support debugging when the SEE debug level is set to **Generate Authorization Key**.

The SEE machine is used to process data with the A3/A8 algorithm in conjunction with a Triple-DES key as follows:

1. Data comes in the form of a sequence of 16-byte input values.
2. These values are split into two 8-byte halves that are each Triple-DES ECB decrypted with the master key and reassembled to give a 16-byte key.
3. Then a 16-byte random value is generated and, along with the 16-byte key, is fed into the A3/A8 algorithm to produce a 12-byte output value.
4. The output from the HSM consists of a sequence of 28-byte blocks comprising the random value and the output value.



There is also an example of the host-side code written in Java, supplied in the **nCipherKM-SEE-Examples.jar** found in **opt/nfast/java/examples** (**Linux**) or **%NFAST_HOME%\java\examples** (**Windows**).

4.4.6.1. Signing, packing, and loading the SEE machine

To sign, pack, and load the SEE machine:

1. Generate a key with which to sign the SEE machine:

```
generatekey -m 1 seeinteg
```

2. Complete the prompts as follows:

```
recovery: Key recovery? (yes/no) [yes] >
type: Key type? (RSA, DSA, ECDSA, KCDSA) [RSA] >
size: Key size? (bits, minimum 1024) [2048] >
OPTIONAL: pubexp: Public exponent for RSA key (hex)? []
>
plainname: Key name? [] > a3a8machine
nvrn: Blob in NVRAM (needs ACS)? (yes/no) [no] >
key generation parameters:
operation      Operation to perform      generate
application    Application                seeinteg
protect        Protected by               token
slot           Slot to read cards from    0
```

```

recovery    Key recovery          yes
verify     Verify security of key yes
type       Key type             RSA
size       Key size             2048
pubexp     Public exponent for RSA key (hex)
plainname  Key name             a3a8machine
nvram      Blob in NVRAM (needs ACS) no

```

```

Loading `dev-ocs':
Module 1: 0 cards of 1 read
Module 1 slot 0: `dev-ocs' #1
Module 1 slot 0:- passphrase supplied - reading card
Card reading complete.

```

```

Key successfully generated.
Path to key: <path-to-key>

```

<path-to-key> is `/opt/nfast/kmdata/local/key_seeinteg_a3a8machine` (**Linux**) or `C:\ProgramData\nCipher\Key Management Data\local\key_seeinteg_a3a8machine` (**Windows**).

3. Change to the directory by running the command:

For nShield Solo

Linux

```
cd ~/buildSoloMod/csee/a3a8/module
```

Windows

```
cd C:\Users\<USER-NAME>\Documents\buildSoloMod\csee\A3A8\module
```

For nShield Solo XC

Linux

```
cd ~/buildXCMod/csee/a3a8/module
```

Windows

```
cd C:\Users\<USER-NAME>\Documents\buildXCMod\csee\A3A8\module
```

4. Use the `tct2` command line utility to convert the file into a SAR file.

```

$ generatekey -m 1 seeinteg
recovery: Key recovery? (yes/no) [yes] >
type: Key type? (RSA, DSA, ECDSA, KCDSA) [RSA] >
size: Key size? (bits, minimum 1024) [2048] >
OPTIONAL: pubexp: Public exponent for RSA key (hex)? []
>
plainname: Key name? [] > a3a8machine
nvram: Blob in NVRAM (needs ACS)? (yes/no) [no] >

```

```

key generation parameters:
operation  Operation to perform          generate
application Application                    seeinteg
protect    Protected by                  token
slot       Slot to read cards from       0
recovery   Key recovery                  yes
verify     Verify security of key        yes
type       Key type                      RSA
size       Key size                      2048
pubexp     Public exponent for RSA key (hex)
plainname  Key name                      a3a8machine
nvram      Blob in NVRAM (needs ACS) no

Loading 'ocs-dev':
Module 1: 0 cards of 1 read
Module 1 slot 0: 'ocs-dev' #1
Module 1 slot 0:- passphrase supplied - reading card
Card reading complete.

Key successfully generated.
Path to key: /opt/nfast/kmdata/local/key_seeinteg_a3a8machine

```

5. Change to the directory by running the command:

For nShield Solo

Convert the **a3a8mach.sxf** file into a SAR file.

```
tct2 -m 1 --sign-and-pack --is-machine -i a3a8mach.sxf --machine-type=PowerPCSXF -o a3a8mach.sar -k a3a8machine
```

Output:

```

Signing machine as 'PowerPCSXF'.

Loading 'ocs-dev':
Module 1: 0 cards of 1 read
Module 1 slot 0: 'ocs-dev' #1
Module 1 slot 0:- passphrase supplied - reading card
Card reading complete.

```

For nShield Solo XC

Convert the **a3a8mach.elf** file into a SAR file.

```
tct2 -m 1 --sign-and-pack --is-machine -i a3a8mach.elf --machine-type=PowerPCELF -o a3a8mach.sar -k a3a8machine
```

Output:

```

Signing machine as 'PowerPCELF'.

Loading 'ocs-dev':
Module 1: 0 cards of 1 read
Module 1 slot 0: 'ocs-dev' #1

```

```
Module 1 slot 0:- passphrase supplied - reading card
Card reading complete.
```

6. Load the SEE machine into the HSM by running the command:

```
loadmachine -m 1 a3a8mach.sar
```



This example describes how to load the SEE machine by running the **loadmachine** command-line utility. In a production environment, you can choose to configure the **load_seemachine** section of the host or client configuration file so that an SEE machine is loaded automatically. See [Automatically loading an SEE machine](#)

4.4.6.2. Creating and signing userdata

To create and sign the **userdata** file:

1. Change to the host-side code directory by running the command:

Linux

```
$ cd ~/buildhost/csee/a3a8/hostside
```

Windows

```
cd C:\Users\<USER-NAME>\Documents\hostside\csee\a3a8\hostside
```

2. Generate a key with which to sign a dummy **userdata** file for the example by running the command:

```
generatekey -m 1 seeinteg
```

3. Complete the prompts as follows:

```
recovery: Key recovery? (yes/no) [yes] >
type: Key type? (RSA, DSA, ECDSA, KCDSA) [RSA] >
size: Key size? (bits, minimum 1024) [2048] >
OPTIONAL: pubexp: Public exponent for RSA key (hex)? []
>
plainname: Key name? [] > a3a8userdata
nvrnm: Blob in NVRAM (needs ACS)? (yes/no) [no] >
key generation parameters:
operation      Operation to perform      generate
application    Application                seeinteg
protect        Protected by               token
slot           Slot to read cards from    0
recovery       Key recovery               yes
verify         Verify security of key     yes
type           Key type                   RSA
```

```

size      Key size      2048
pubexp    Public exponent for RSA key (hex)
plainname  Key name      a3a8userdata
nvram     Blob in NVRAM (needs ACS)  no

Loading 'dev-ocs':
Module 1: 0 cards of 1 read
Module 1 slot 0: 'dev-ocs' #1
Module 1 slot 0:- passphrase supplied - reading card
Card reading complete.

Key successfully generated.
Path to key: <path-to-key>

```

<path-to-key> is /opt/nfast/kmdata/local/key_seeinteg_a3a8userdata (**Linux**) or C:\ProgramData\ncipher\Key Management Data\local\key_seeinteg_a3a8userdata (**Windows**).

4. Create a dummy **userdata** file. Because the A3/A8 algorithm does not use the initialization data, the dummy **userdata** need contain only one arbitrary character to use as **userdata**.
5. Use the **tct2** command-line utility to sign and pack a dummy **userdata** file for the example:

For nShield Solo

Linux

```

tct2 --sign-and-pack --machine-type=PowerPCSF --infile a3a8userdata --outfile=a3a8userdata.sar
--machine-key-ident=a3a8machine -k a3a8userdata

```

Output:

```

Loading 'ocs-dev':
Module 1: 0 cards of 1 read
Module 1 slot 0: 'ocs-dev' #1
Module 1 slot 0:- passphrase supplied - reading card
Card reading complete.[sudo] password for XXX:

```

Windows

```

tct2 --sign-and-pack --machine-type=PowerPCSF --infile=a3a8userdata --outfile=a3a8userdata.sar
--machine-keyident=a3a8machine -k a3a8userdata

```

Output:

```

No module specified, using 1
Signing machine as 'PowerPCSF'.

```

For nShield Solo XC:

Linux

```
tct2 --sign-and-pack --machine-type=PowerPCELF --infile a3a8userdata --outfile a3a8userdata.sar
--machine-key-ident=a3a8machine -k a3a8userdata
```

Output:

```
Loading 'ocs-dev':
Module 1: 0 cards of 1 read
Module 1 slot 0: 'ocs-dev' #1
Module 1 slot 0:- passphrase supplied - reading card
Card reading complete.
```

Windows

```
tct2 --sign-and-pack --machine-type=PowerPCELF --infile=a3a8userdata --outfile=a3a8userdata.sar
--machine-keyident=a3a8machine -k a3a8userdata
```

Output:

```
No module specified, using 1
Signing machine as 'PowerPCELF'.
```



For more information about this command, see [tct2](#)

4.4.6.2.1. Running and testing the example

The **a3test** example application takes the following arguments:

```
a3test [-m <MODULEID>] <USERDATA>.sar
```

-m <MODULEID>

This option specifies the **ModuleID** of the HSM to use.

<USERDATA>.sar

This parameter specifies a **userdata** file (packed as a SAR) to use.

Thus, you can run the **a3test** program created in this example with a command of the form:

Linux

```
./a3test -m 1 a3a8userdata.sar
```

Windows

```
a3test -m 1 a3a8userdata.sar
```

The **a3test** example then processes data for approximately 20 seconds. If the example program runs successfully, its final output is of the form:

```
Getting Sarfile info (400 bytes)....
Creating world: init status was 0 (OK)
Making Master Key:
Get ticket.....
Sending ticket to SEWorld:
181000 triples, 21 sec
Releasing context
Thank you for watching. The end.
```

If the output from **a3test** takes any other form, this indicates an error. In case of an error, use the **enquiry** command-line utility to check:

- Whether the correct firmware is installed
- Whether the correct server is running
- Whether the HSM is in the operational state.

4.4.6.3. NVRAM example

The **NVRAM** example shows the simple use of NVRAM in an SEE machine written in C. It uses a file in NVRAM as a sort of postage meter. The contents of the file are interpreted as a little-endian integer that determines how many 'stamps' can be issued. Each time the host program is invoked, it requests one or more stamps from the machine, and the NVRAM counter is decreased accordingly.

The **NVRAM** example is *not* intended to be the basis for any real world applications. It is intended only to demonstrate how to write SEE machines in C that access the HSM's NVRAM.

4.4.6.3.1. Signing, packing, and loading the SEE machine

To sign, pack, and load the SEE machine:

1. Generate a key with which to sign the SEE machine:

```
generatekey seeinteg
```

2. Complete the prompts as follows:

```
module: Module to use? (1, 2) [1] >
recovery: Key recovery? (yes/no) [yes] >
type: Key type? (RSA, DSA) [RSA] >
size: Key size? (bits, minimum 1024) [1024] >
OPTIONAL: pubexp: Public exponent for RSA key (in hex)? []
```

```
>
plainname: Key name? [] > nvrammachine
key generation parameters:
operation      Operation to perform      generate
application    Application      seeinteg
module         Module to use          1
protect        Protected by          token
slot           Slot to read cards from      0
recovery       Key recovery          yes
verify         Verify security of key      yes
type           Key type            RSA
size           Key size            1024
pubexp         Public exponent for RSA key (in hex)
plainname      Key name            nvrammachine
Key successfully generated.
Path to key: <path-to-key>
```

<path-to-key> is `/opt/nfast/kmdata/local/key_seeinteg_nvrammachine` (**Linux**) or `%NFAST_KMDATA%\local\key_seeinteg_nvrammachine` (**Windows**).

3. Change to the directory by running the command:

For nShield Solo

Linux

```
cd ~/buildSoloMod/csee/nvram/module
```

Windows

```
cd C:\Users\<USER-NAME>\Documents\buildSoloMod\csee\nvram\module
```

For nShield Solo XC

Linux

```
cd ~/buildXCMod/csee/nvram/module
```

Windows

```
cd C:\Users\<USER-NAME>\Documents\buildXCMod\csee\nvram\module
```

4. Use the `tct2` command line utility to convert the file.

For nShield Solo

Convert the `nvram.sxf` file into a SAR file.

Linux

```
tct2 --sign-and-pack --is-machine -i nvram.sxf --machine-type=PowerPCSXF -o nvram.sar -k nvrammachine
```


Windows

```
tct2 -m 1 --sign-and-pack --is-machine -i nvram.sxf --machine-type=PowerPCSF -o nvram.sar -k
nvrammachine
```

Output:

```
Signing machine as 'PowerPCSF'.

Loading 'ocs-dev':
Module 1: 0 cards of 1 read
Module 1 slot 0: 'ocs-dev' #1
Module 1 slot 0:- passphrase supplied - reading card
Card reading complete.
```

For nShield Solo XC

Convert the **nvram.elf** file into a SAR file.

Linux

```
tct2 --sign-and-pack --is-machine -i nvram.elf --machine-type=PowerPCSELF -o nvram.sar -k nvrammachine
```

Windows

```
tct2 -m 1 --sign-and-pack --is-machine -i nvram.elf --machine-type=PowerPCSELF -o nvram.sar -k
nvrammachine
```

Output:

```
Signing machine as 'PowerPCSELF'.

Loading 'ocs-dev':
Module 1: 0 cards of 1 read
Module 1 slot 0: 'ocs-dev' #1
Module 1 slot 0:- passphrase supplied - reading card
Card reading complete.
```



For more information about this command, see [tct2](#).

5. Load the packed SEE machine into the HSM by running the command:

```
loadmachine nvram.sar
```



This example describes how to load the SEE machine by running the **loadmachine** command-line utility. In a production environment, you can choose to configure the **load_seemachine** section of the host or client configuration file so that an SEE machine is loaded automatically. For information about configuration files, see the *User Guide*.

4.4.6.3.2. Creating NVRAM and userdata files

You must now use the **setup** example application to create:

- An NVRAM file
- A **userdata** file that contains only the exact name of the specified NVRAM file.

1. Change to the host-side application directory by running the command:

Linux

```
cd ~/buildhost/csee/nvram/hostside
```

Windows

```
cd C:\Users\<USER-NAME>\Documents\hostside\csee\nvram\host
```

2. Create these files by running the setup command with 'root' (**Linux**) or Administrator (**Windows**) privileges:

Linux

```
./setup nvramfile 100 nvramuserdata
```

Windows

```
setup.exe nvramfile 100 nvramuserdata
```

3. Complete the on-screen instructions:

```
Please insert the next administrator card and press enter.
Please enter card passphrase:
allocated NVRAM file 'nvramfile'.
```

4.4.6.3.3. setup

The **setup** example application takes the following arguments:

```
setup [-k|--key <APPNAME>,<IDENT>] <nvram-filename> <stamp-count> <userdatafile>
```

-k|--key <APPNAME>,<IDENT>

This option specifies a signing key identified by *APPNAME* and *IDENT*. Specifying a signing key creates an NVRAM file that can only be accessed with authorization from that key (for example, by signing the **userdata** with the same key). A signing key is optional.

<nvr^{am}-filename>

This parameter specifies the name of an NVRAM file to create. The name must contain no more than 11 characters.

<tampcount>

This parameter specifies the number of stamps to issue.

<userdatafile>

This parameter specifies the name of the **userdata** SAR file created when the **setup** example application is run.

You can also use the **setup** example application to delete an existing NVRAM file. To delete a file, run **setup** with the **--delete** option, as follows:

```
setup --delete <nvram-filename>
```

In this case, **setup** deletes the NVRAM file specified by *nvr^{am}-filename*.

4.4.6.3.4. Signing and packing the userdata

Run the Trusted Code Tool (**tct2**) to sign and pack the created **userdata** file you created with the **setup** example application:

Linux

```
tct2 -m 1 --pack --infile nvramuserdata --outfile nvramuserdata.sar
```

Windows

```
tct2 --pack --infile nvramuserdata --outfile nvramuserdata.sar
```



If the NVRAM file created by the **setup** example application is bound to a key (that is, if you specified the **-k|--key** option when running **setup**), use that same key when signing the **userdata** file with **tct2**.

4.4.6.3.5. Running and testing the example

Run the **nvr^{am}** example application as follows:

Linux

```
./nvram ./nvramuserdata.sar 50
```

Windows

```
nvrnm.exe nvrnmuserdata.sar 50
```

Output:

```
SEESJob: read 1 bytes...
Stamp Request Accepted.
SEESJob: read 1 bytes...
Stamp Request Accepted.
SEESJob: read 1 bytes...
.
.
.
```

4.4.6.3.6. nvrnm

The **nvrnm** example application takes the following arguments:

```
nvrnm <userdatafile>.sar [<iterations>]
```

<userdatafile>.sar

This parameter specifies the name of the **userdata** SAR file to use. Normally, this file has been created by the **setup** example application (its name specified by that utility's *userdatafile* parameter).

<iterations>

This parameter specifies an integer that is the amount by which the **nvrnm** example application is to decrease its counter (as it issues virtual stamps).

4.4.6.3.7. What the code actually does

The host-side code performs the following tasks in order:

1. It allocates an NVRAM file with an access control list that requires the permission of a specified key for reading or writing.
2. It requests the name of a file to be loaded as a packed user data block and, optionally, the number of virtual stamps to request.

The HSM-side code awaits jobs from the host and returns a single byte to indicate whether or not a stamp has been issued.

4.4.7. Example: RTC

This source code provides an example of an SEE machine written in C that implements a very simple timestamp service.



Your SEE-Ready HSM must have an onboard real-time clock for this example to run correctly, and you must have set the clock using the `rtc` command-line utility.

The `rtc` example code is deficient in a number of ways and is *not* intended to be the basis for any real world applications. It is intended only to demonstrate some important concepts in writing SEE machines in C to perform time-stamping.

4.4.7.1. Signing, packing, and loading the SEE machine

To sign, pack, and load the SEE machine:

1. Generate a key with which to sign the SEE machine:

```
generatekey -m 1 seeinteg
```

2. Complete the prompts as follows:

```
recovery: Key recovery? (yes/no) [yes] >
type: Key type? (RSA, DSA, ECDSA, KCDSA) [RSA] >
size: Key size? (bits, minimum 1024) [2048] >
OPTIONAL: pubexp: Public exponent for RSA key (hex)? []
>
plainname: Key name? [] > rtccode
nvram: Blob in NVRAM (needs ACS)? (yes/no) [no] >
key generation parameters:
operation      Operation to perform      generate
application    Application          seeinteg
protect        Protected by          token
slot           Slot to read cards from  0
recovery       Key recovery          yes
verify         Verify security of key  yes
type           Key type              RSA
size           Key size              2048
pubexp         Public exponent for RSA key (hex)
plainname      Key name              rtccode
nvram          Blob in NVRAM (needs ACS)  no

Loading 'dev-ocs':
Module 1: 0 cards of 1 read
Module 1 slot 0: 'dev-ocs' #1
Module 1 slot 0:- passphrase supplied - reading card
Card reading complete.
Key successfully generated.
Path to key: <path-to-key>
```

`<path-to-key>` is `/opt/nfast/kmdata/local/key_seeinteg_rtccode` (**Linux**) or `C:\ProgramData\nCipher\Key Management Data\local\key_seeinteg_rtccode` (**Windows**).

3. Change to the directory by running the command:

For **nShield Solo**:

Linux

```
cd ~/buildSoloMod/csee/rtc/module
```

Windows

```
cd C:\Users\<USER-NAME>\Documents\buildSoloMod\csee\rtc\module
```

For **nShield Solo XC**:

Linux

```
cd ~/build-XC/csee/rtc/module
```

Windows

```
cd C:\Users\<USER-NAME>\Documents\buildXCMod\csee\rtc\module
```

4. Use the **tct2** command-line utility to convert the file into a SAR file.

For **nShield Solo**

```
tct2 -m 1 --sign-and-pack --is-machine -i rtc.sxf --machine-type=PowerPCSXF -o rtc.sar -k rtccode
```

Output:

```
Signing machine as 'PowerPCSXF'.

Loading 'ocs-dev':
Module 1: 0 cards of 1 read
Module 1 slot 0: 'ocs-dev' #1
Module 1 slot 0:- passphrase supplied - reading card

Card reading complete.
```

For **nShield Solo XC**:

```
tct2 -m 1 --sign-and-pack --is-machine -i rtc.elf --machine-type=PowerPCELF -o rtc.sar -k rtccode
```

Output:

```
Signing machine as 'PowerPCELF'.

Loading 'ocs-dev':
```

```
Module 1: 0 cards of 1 read
Module 1 slot 0: 'ocs-dev' #1
Module 1 slot 0:- passphrase supplied - reading card
```

Card reading complete.

5. Load the packed SEE machine into the HSM by running the command:

```
loadmache rtc.sar
```



This example describes how to load the SEE machine by running the **loadmache** command-line utility. In a production environment, you can choose to configure the **load_seemachine** section of the host or client configuration file so that an SEE machine is loaded automatically. For information about configuration files, see the *User Guide*.

4.4.7.1.1. rtc

The **rtc** example application takes the following arguments:

```
rtc [-y|--verify <file>] [-a|--userdata <SEEDATA>] <userdatafile> <APPNAME>,<IDENT>
```

-y|---verify

This option verifies the returned time-stamp for the file named *file*.

-a|---userdata <SEEDATA>

This option specifies use of the file *SEEDATA* for SEE **userdata**.

<userdatafile>

This parameter specifies a **userdata** file that contains at least one character.

<APPNAME>,<IDENT>

These parameters specify the *APPNAME* and *IDENT* of the key for the **rtc** example application to use.

4.4.7.1.2. Running the example

1. Enter the host-side application directory by running the command:

Linux

```
cd ~/buildhost/csee/rtc/hostside/
```

Windows

```
cd C:\Users\<USER-NAME>\Documents\host\csee\rtc\hostside
```

2. Create the test userdata file to be time-stamped by running the command:

Linux

```
cp /opt/nfast/c/csd/examples/csee/rtc/host/rtc.c ./mytestuserdata
```

Windows

```
copy "C:\Program Files\nCipher\nfast\c\csd\examples\csee\rtc\hostside\rtc.c" mytestuserdata
```

3. Generate an RSA key for the RTC example to use by running the command and completing the prompts in the output as follows:

Linux

```
generatekey simple
```

Output:

```
protect: Protected by? (token, module) [token] >
recovery: Key recovery? (yes/no) [yes] >
type: Key type? (AES, DES2, DES3, DH, DHEX, DSA, EC, ECDH, ECDSA, Ed25519, HMACRIPEMD160, HMACSHA1,
HMACSHA256, HMACSHA384, HMACSHA512, HMACTiger, KCDSA, Rijndael, RSA, X25519) [RSA] >
size: Key size? (bits, minimum 1024) [2048] >
OPTIONAL: pubexp: Public exponent for RSA key (hex)? []
>
ident: Key identifier? [] > rtctest
plainname: Key name? [] > rtctest
OPTIONAL: seeintegname: SEE integrity key?
(a3a8machine, nvrammachine, a3a8userdata, hellomachine, rtccode) []
>
nvram: Blob in NVRAM (needs ACS)? (yes/no) [no] >
key generation parameters:
operation      Operation to perform      generate
application    Application                          simple$ ./rtc mytestuserdata simple,rtctest >
mytestuserdata.stamp
Please insert the next operator card and press enter.
Please enter card passphrase:
rtc: timestamp issued.

protect      Protected by      token
slot         Slot to read cards from      0
recovery     Key recovery      yes
verify       Verify security of key      yes
type         Key type          RSA
size         Key size          2048
pubexp       Public exponent for RSA key (hex)
ident        Key identifier     rtctest
```



```

plainname      Key name                               rtctest
seeintegname   SEE integrity key
nvram          Blob in NVRAM (needs ACS)              no

Loading 'ocs-dev':
Module 1: 0 cards of 1 read
Module 1 slot 0: 'ocs-dev' #1
Module 1 slot 0:- passphrase supplied - reading card
Card reading complete.

Key successfully generated.
Path to key: /opt/nfast/kmdata/local/key_simple_rtctest

```

Windows

```
generatekey -m 1 simple
```

Output:

```

protect: Protected by? (token, module) [token] >
recovery: Key recovery? (yes/no) [yes] >
type: Key type? (AES, DES2, DES3, DH, DHEX, DSA, EC, ECDH, ECDSA, Ed25519,
        HMACRIPEMD160, HMACSHA1, HMACSHA256, HMACSHA384, HMACSHA512,
        HMACTiger, KCDSA, Rijndael, RSA, X25519) [RSA] >
size: Key size? (bits, minimum 1024) [2048] >
OPTIONAL: pubexp: Public exponent for RSA key (hex)? []
>
ident: Key identifier? [] > rtctest
plainname: Key name? [] > rtctest
OPTIONAL: seeintegname: SEE integrity key?
(a3a8machine, a3a8userdata, hellomachine, rtccode) [] >
nvram: Blob in NVRAM (needs ACS)? (yes/no) [no] >
key generation parameters:
operation      Operation to perform                generate
application    Application                                simple
protect        Protected by                                    token
slot           Slot to read cards from                        0
recovery       Key recovery                                    yes
verify        Verify security of key                        yes
type           Key type                                       RSA
size           Key size                                       2048
pubexp        Public exponent for RSA key (hex)
ident         Key identifier                               rtctest
plainname     Key name                                    rtctest
seeintegname  SEE integrity key
nvram         Blob in NVRAM (needs ACS)                  no

Loading 'dev-ocs':
Module 1: 0 cards of 1 read
Module 1 slot 0: 'dev-ocs' #1
Module 1 slot 0:- passphrase supplied - reading card
Card reading complete.

Key successfully generated.
Path to key: C:\ProgramData\nCipher\Key Management Data\local\key_simple_rtctest

```



The **rtc** example application only supports the use of RSA keys.

4. Run the RTC example by executing the following command:

Linux

```
./rtc mytestuserdata simple,rtctest > mytestuserdata.stamp
```

Windows

```
rtc.exe mytestuserdata simple,rtctest > mytestuserdata.stamp
```

5. Complete the on-screen instructions:

```
Please insert the next operator card annvramd press enter.  
Please enter card passphrase:  
rtc: timestamp issued.
```

4.4.7.1.3. What the code actually does

The host-side code performs the following tasks in order:

1. It sends a session key to the HSM.
2. When a time-stamped command is returned, it verifies the time-stamp using the session key.

The HSM-side code performs the following tasks in order:

1. It awaits a job from the host.
2. It time-stamps the contents of the job and signs the result with the session key.
3. It returns the job to the host.

4.4.8. Example: Tickets

This example source code is an API demonstration showing how an SEE machine can be written in C.

The **Tickets** example is *not* intended to be the basis for any real world applications. In particular, it does not support the loading of keys protected by card sets with the **-k** option. It is intended to demonstrate:

- How to write SEE machines in C
- Simple, custom-built marshalling and unmarshalling of jobs
- The use of tickets. See [Internals](#) for information about key tickets; also, for information about the consumption of single ticket, see [Loading stored keys](#).

Windows only

%NFAST_HOME%\c\csd\examples\csee\tickets\

The C code consists of the following parts:

- In the **module** directory, the source for the SEE machine:
 - **armtickets.c** (SEE machine start-up and job-processing threads)
 - **usrjobs.c** (job processing code)
- In the **host** directory, source for the host application:
 - **hosttickets.c** (starts the SEE machine, sends jobs and traces debug).
- The **common** directory contains a simple header file (**common.h**) for shared data structures between the HSM and the host code.

Sample makefiles are provided for building the HSM and host-side code (**Makefile-host**) and can be found in their respective directories.

4.4.8.1. Signing, packing, and loading the SEE machine

To sign, pack, and load the SEE machine:

1. Change to the module directory by running the command:

For **nShield Solo**

Linux

```
cd ~/buildSoloMod/csee/tickets/module
```

Windows

```
cd C:\Users\<USER-NAME>\Documents\buildSoloMod\csee\tickets\module
```

For **nShield Solo XC**

Linux

```
cd ~/buildXCMod/csee/tickets/module
```

Windows

```
cd C:\Users\<USER-NAME>\Documents\buildXCMod\csee\tickets\module
```

2. Use the **tct2** command line utility to convert the file into a SAR file.

For **nShield Solo**

Convert the `armtickets.sxf` file into a SAR file.

```
tct2 -m 1 --pack --infile armtickets.sxf --outfile armtickets.sar
```

For nShield Solo XC

Convert the `armtickets.elf` file into a SAR file.

```
tct2 -m 1 --pack --infile armtickets.elf --outfile armtickets.sar
```

3. Load the SEE machine into the HSM by running the command:

```
loadmachine armtickets.sar
```



This example describes how to load the SEE machine by running the `loadmachine` command-line utility. In a production environment, you can choose to configure the `load_seemachine` section of the host or client configuration file so that an SEE machine is loaded automatically. For information about configuration files, see the *User Guide*

4. Generate a key for the example to use by running the command and completing the prompts in the output as follows:

Linux

```
generatekey simple
```

Output:

```
protect: Protected by? (token, module) [token] >
recovery: Key recovery? (yes/no) [yes] >
type: Key type? (AES, DES2, DES3, DH, DHEX, DSA, EC, ECDH, ECDSA, Ed25519,
HMACRIPEMD160, HMACSHA1, HMACSHA256, HMACSHA384, HMACSHA512,
HMACTiger, KCDSA, Rijndael, RSA, X25519) [RSA] >
size: Key size? (bits, minimum 1024) [2048] >
OPTIONAL: pubexp: Public exponent for RSA key (hex)? []
>
ident: Key identifier? [] > ticketkey
plainname: Key name? [] > ticketkey
OPTIONAL: seeintegname: SEE integrity key?
(a3a8machine, nvrammachine, a3a8userdata, hellomachine, rtccode) []
>
nvram: Blob in NVRAM (needs ACS)? (yes/no) [no] >
key generation parameters:
operation      Operation to perform      generate
application    Application                simple
protect        Protected by                token
slot           Slot to read cards from    0
recovery       Key recovery                yes
```

```

verify      Verify security of key      yes
type        Key type                    RSA
size        Key size                    2048
pubexp      Public exponent for RSA key (hex)
ident       Key identifier              ticketkey
plainname   Key name                   ticketkey
seeintegname SEE integrity key
nvram       Blob in NVRAM (needs ACS)   no

Loading 'ocs-dev':
Module 1: 0 cards of 1 read
Module 1 slot 0: 'ocs-dev' #1
Module 1 slot 0:- passphrase supplied - reading card
Card reading complete.

Key successfully generated.
Path to key: /opt/nfast/kmdata/local/key_simple_ticketkey

```

Windows

```
generatekey -m 1 simple
```

Output:

```

protect: Protected by? (token, module) [token] >
recovery: Key recovery? (yes/no) [yes] >
type: Key type? (AES, DES2, DES3, DH, DHEX, DSA, EC, ECDH, ECDSA, Ed25519,
          HMACRIPEMD160, HMACSHA1, HMACSHA256, HMACSHA384, HMACSHA512,
          HMACTiger, KCDSA, Rijndael, RSA, X25519) [RSA] >
size: Key size? (bits, minimum 1024) [2048] >
OPTIONAL: pubexp: Public exponent for RSA key (hex)? []
>
ident: Key identifier? [] > ticketkey
plainname: Key name? [] > ticketkey
OPTIONAL: seeintegname: SEE integrity key?
(a3a8machine, a3a8userdata, hellomachine, rtccode) [] >
nvram: Blob in NVRAM (needs ACS)? (yes/no) [no] >
key generation parameters:
operation  Operation to perform          generate
application Application                          simple
protect    Protected by                    token
slot       Slot to read cards from        0
recovery   Key recovery                     yes
verify     Verify security of key          yes
type       Key type                       RSA
size       Key size                       2048
pubexp     Public exponent for RSA key (hex)
ident      Key identifier                  ticketkey
plainname  Key name                       ticketkey
seeintegname SEE integrity key
nvram      Blob in NVRAM (needs ACS)      no

Loading 'dev-ocs':
Module 1: 0 cards of 1 read
Module 1 slot 0: 'dev-ocs' #1
Module 1 slot 0:- passphrase supplied - reading card
Card reading complete.

Key successfully generated.
Path to key: C:\ProgramData\nCipher\Key Management Data\local\key_simple_ticketkey

```

4.4.8.2. hosttickets

The **hosttickets** example application takes the following arguments:

```
hosttickets [-f|--file <userdatafile>][-k|--key <APPNAME>,<IDENT>]
```

-k|--key <APPNAME>,<IDENT>

These options specify a Security World key.

For the public/private key pair, a Security World key can be specified with the **-k** option. The specified Security World key must be an RSA key of the type **simple** that is not tied to an SEE code-signing key. Otherwise, a fresh RSA key pair is generated automatically.

-f|--file <userdatafile>

These options specify a file for the **userdata** block.



The option to load a file for the **userdata** block is included only for example purposes.

4.4.8.3. Running the example application

1. Change to the host application directory by running the following command:

Linux

```
cd ~/buildhost/csee/tickets/hostside/
```

Windows

```
cd C:\Users\<USER-NAME>\Documents\hostside\csee\tickets\hostside
```

2. Run the hosttickets example application, specifying the simple key created earlier:

Linux

```
./hosttickets -k simple,ticketkey
```

Windows

```
hosttickets.exe -k simple,ticketkey
```

3. Complete the on-screen instructions:

```
Enter string to be encrypted (256 characters maximum): lskjfdljsdlfjsdlk
HostSide> Loading security world key (simple,ticketkey)
```

```
Please present the cardset protecting the key:
Module 1: 0 cards of 1 read
Module 1 slot 0: 'ocs-dev' #1
Module 1 slot 0:- passphrase supplied - reading card
Card reading complete.

HostSide> Creating World: init status was 0 (OK)
HostSide> Sending ticket for private RSA key to module
HostSide> Generating AES session key and creating blob under public RSA key
HostSide> Sending key blob to module
HostSide> Sending cipher-text to module
HostSide> decrypted cipher text received from SEE machine:
"lskjfdljsdlfjsdlk"
HostSide> Thank you for watching. The end.
```

4.4.8.4. What the code actually does

The host-side code performs the following tasks in order:

1. It prompts the user for a string.
2. It acquires an RSA key pair, either freshly created or loaded from the Security World (only HSM protected key pairs are supported).
3. It sends a ticket for the private half of the RSA key to the HSM-side code.
4. It generates a session key (DES3).
5. It encrypts the session key as a blob with the public half of the RSA key.
6. It sends the resulting blob to the HSM-side code.
7. It encrypts the string with the session key.
8. It sends the encrypted string to the HSM-side code.
9. It receives the decrypted string back from the HSM.

The HSM-side code awaits jobs from the host and performs the following tasks in order:

1. It receives and redeems the ticket for the private RSA key.
2. It receives the session key blob and decrypts it with the private RSA key.
3. It receives the encrypted string and decrypts it with the session key.
4. It sends the decrypted string back to the HSM.

4.4.9. Example: Benchmark

This example source code implements a very simple utility that uses an SEE machine written in C to time stamp requests to benchmark the speed of response to requests. You can use it for benchmarking during the development of other SEE machines or adapt it as required.



Your SEE-Ready HSM must have an onboard real-time clock for this example to run correctly, and you must have set the clock using the `rtc` command-line utility



This utility does not accept encrypted user data.

4.4.9.1. `bm-test`

The `bm-test` example application takes the following arguments:

```
bm-test [-l|--log <LOGFILE>][-a|--userdata <userdatafile>] <APPNAME>,<IDENT>
```

`-l|--log <LOGFILE>`

These options specify a file name to which to write time-stamps. If no log file is specified, no logging occurs.

`-a|--userdata <userdatafile>`

These options specify a file for an (optional) `userdata` block.

`<APPNAME>,<IDENT>`

These parameters specify the *APPNAME* and *IDENT* of a key that is to be into the SEE machine (and that SEE machine thereafter uses for signing purposes).

This utility does not have the `--slot` or `--debug` standard options.

4.4.9.2. `bm-verify`

The `bm-verify` example application takes the following arguments:

```
bm-verify <LOGFILE>
```

The *LOGFILE* parameter specifies the name of the log file created by the `bm-test` example application (specified by that application's `-l|--log` option).

4.4.9.3. Packing and loading the SEE machine

To pack and load the SEE machine:

1. Change to the module directory by running the command:

For **nShield Solo**

Linux

```
cd ~/buildSoloMod/csee/benchmark/module
```

Windows

```
cd C:\Users\<USER-NAME>\Documents\buildSoloMod\csee\benchmark\module
```

For nShield XC

Linux

```
cd ~/buildXCMod/csee/benchmark/module
```

Windows

```
cd C:\Users\<USER-NAME>\Documents\buildXCMod\csee\benchmark\module
```

2. Use the **tct2** command line utility to convert the file into a SAR file.

For nShield Solo

Convert the **bm-machine.sxf** file into a SAR file.

```
tct2 -m 1 --pack --infile bm-machine.sxf --outfile bm-machine.sar
```

For nShield XC

Convert the **bm-machine.elf** file into a SAR file.

```
tct2 -m 1 --pack --infile bm-machine.elf --outfile bm-machine.sar
```

3. Load the SEE machine into the HSM by running the command:

```
loadmache bm-machine.sar
```



This example describes how to load the SEE machine by running the **loadmache** command-line utility. In a production environment, you can choose to configure the **load_seemachine** section of the host or client configuration file so that an SEE machine is loaded automatically. For information about configuration files, see the *User Guide*.

4. Generate a key for the benchmark application to use by running the command and

completing the prompts in the output as follows:

Linux

```
generatekey simple
```

Output:

```
protect: Protected by? (token, module) [token] >
recovery: Key recovery? (yes/no) [yes] >
type: Key type? (AES, DES2, DES3, DH, DHEX, DSA, EC, ECDH, ECDSA, Ed25519,
HMACRIPEMD160, HMACSHA1, HMACSHA256, HMACSHA384, HMACSHA512,
HMACTiger, KCDSA, Rijndael, RSA, X25519) [RSA] >
size: Key size? (bits, minimum 1024) [2048] >
OPTIONAL: pubexp: Public exponent for RSA key (hex)? []
>
ident: Key identifier? [] > benchmark-test
plainname: Key name? [] > benchmark
OPTIONAL: seeintegname: SEE integrity key?
(a3a8machine, nvrammachine, a3a8userdata, hellomachine, rtccode) []
>
nvram: Blob in NVRAM (needs ACS)? (yes/no) [no] >
key generation parameters:
operation      Operation to perform      generate
application    Application                  simple
protect        Protected by                  token
slot           Slot to read cards from      0
recovery       Key recovery                  yes
verify         Verify security of key      yes
type           Key type                      RSA
size           Key size                      2048
pubexp         Public exponent for RSA key (hex)
ident          Key identifier                benchmark-test
plainname      Key name                      benchmark
seeintegname   SEE integrity key
nvram          Blob in NVRAM (needs ACS)     no

Loading 'ocs-dev':
Module 1: 0 cards of 1 read
Module 1 slot 0: 'ocs-dev' #1
Module 1 slot 0:- passphrase supplied - reading card
Card reading complete.

Key successfully generated.
Path to key: /opt/nfast/kmdata/local/key_simple_benchmark-test
```

Windows

```
generatekey -m 1 simple
```

Output:

```
protect: Protected by? (token, module) [token] >
recovery: Key recovery? (yes/no) [yes] >
type: Key type? (AES, DES2, DES3, DH, DHEX, DSA, EC, ECDH, ECDSA, Ed25519,
HMACRIPEMD160, HMACSHA1, HMACSHA256, HMACSHA384, HMACSHA512,
HMACTiger, KCDSA, Rijndael, RSA, X25519) [RSA] >
size: Key size? (bits, minimum 1024) [2048] >
OPTIONAL: pubexp: Public exponent for RSA key (hex)? []
```

```

>
ident: Key identifier? [] > benchmark-test
plainname: Key name? [] > benchmark-test
OPTIONAL: seeintegname: SEE integrity key?
(a3a8machine, a3a8userdata, hellomachine, rtccode) [] >
nvram: Blob in NVRAM (needs ACS)? (yes/no) [no] >
key generation parameters:
operation      Operation to perform      generate
application    Application                    simple
protect        Protected by                        token
slot           Slot to read cards from      0
recovery       Key recovery                      yes
verify         Verify security of key                yes
type           Key type                      RSA
size           Key size                   2048
pubexp         Public exponent for RSA key (hex)
ident          Key identifier              benchmark-test
plainname      Key name                  benchmark-test
seeintegname   SEE integrity key
nvram          Blob in NVRAM (needs ACS)  no

Loading 'dev-ocs':
Module 1: 0 cards of 1 read
Module 1 slot 0: 'dev-ocs' #1
Module 1 slot 0:- passphrase supplied - reading card
Card reading complete.

Key successfully generated.
Path to key: C:\ProgramData\nCipher\Key Management Data\local\key_simple_benchmark-test

```

4.4.9.4. Running the example application

To use the example change to the host application directory by running the command:

Linux

```
cd ~/buildhost/csee/benchmark/hostside/
```

Windows

```
cd C:\Users\<USER-NAME>\Documents\host\csee\benchmark\hostside
```

Run the bm-test example application as follows, completing any on-screen instructions in the output:

Linux

```
./bm-test -l bmttest.log simple benchmark-test
```

Windows

```
bm-test.exe -l bmttest.log simple benchmark-test
```

Output:

```
Please insert the next operator card and press enter.  
Please enter card passphrase:  
1 878 878.00  
2 1758 879.00  
3 2639 879.67  
4 3522 880.50  
5 4406 881.20  
6 5284 880.67  
.  
.  
.
```



The application will run indefinitely, the user must terminate the application manually by using **Ctrl-C**.

Run the `bm-verify` example application, specifying the log file, `bm-test.log`, created in the previous step by the `bm-test` application.

Linux

```
./bm-verify bctest.log
```

Windows

```
bm-verify.exe bctest.log
```

Output:

```
Verified timestamp #1.  
Verified timestamp #2.  
Verified timestamp #3.  
Verified timestamp #4.  
Verified timestamp #5.  
Verified timestamp #6.  
.  
.  
.
```

4.4.9.5. What the code actually does

The host program performs the following tasks in order:

1. It tickets a generated key into the SEE machine.
2. The SEE machine uses that key for signing purposes.
3. Each request is concatenated with the current time and then signed.
4. The signature is concatenated with the time and then returned to the host side.

On the host side, two programs are generated:

- `bm-test`
- `bm-verify`.

The `bm-test` command is used to generate pseudo-random values that are sent to the HSM-side code to be signed. Every second, the total number of completed time-stamp requests is printed, along with the average number completed each second.

The `bm-verify` command looks for the file specified as *LOGFILE* on the host. From this file, `bm-verify` extracts the public key and verifies the time-stamp requests until it finds an invalid request or reaches the end of the file.

4.4.9.6. About the Java example

We supply a Java version of the `HelloWorld` example. This consists of the source files for host-side applications that you can run with the example SEE machines written in C (or any other SEE machines written in any language) in order to understand how simple SEE machines work.



For information about the C examples for SEElib, see [Examples for SEElib](#)

The Java SEE example files can be found within the `nCipherKM-SEE-Examples.jar` located in `/opt/nfast/java/examples` (**Linux**) or `%NFAST_HOME%\java\examples` (**Windows**). A common directory is also supplied which contains files that are used by more than one of the examples.

The Java examples have the same options as their equivalent, similarly named C examples.

4.4.9.6.1. Supported versions of Java

The following versions of Java have been tested to work with, and are supported by, your nShield Security World Software:

- Java7 (or Java 1.7x)
- Java8 (or Java 1.8x)
- Java11

We recommend that you ensure Java is installed before you install the Security World Software. The Java executable must be on your system path.

If you can do so, please use the latest Java version currently supported by Entrust that is compatible with your requirements. Java versions before those shown are no longer supported. If you are maintaining older Java versions for legacy reasons, and need compatibil-

ity with current software, please contact <https://www.oracle.com/java/technologies/javase-jdk11-downloads.html> for Java downloads.

4.4.9.6.2. HelloWorld.java



The **HelloWorld.java** example is *not* intended to be the basis for any real world applications. It is intended only to demonstrate host-side use of an SEE machine by code written in Java.

First, ensure you have already built the file **hello.sxf** as described in [Examples for SEELib](#) converted this into the file **hello.sar** and loaded it into the HSM as described in [Signing, packing, and loading the SEE machine](#).

To build the example:

1. Change to the example directory by running the command:

Linux

```
cd /opt/nfast/java/examples
```

Windows

```
cd %NFAST_HOME%\java\examples
```

2. Extract the example files by running the command:

Linux

```
jar xf nCipherKM-SEE-Examples.jar  
jar xf ../classes/nCipherKM-jhsee.jar
```

Windows

```
jar xf nCipherKM-SEE-Examples.jar  
jar xf ../classes/nCipherKM-jhsee.jar
```

3. Compile the example using this command:

Linux

```
javac -cp /opt/nfast/java/classes/nCipherKM.jar com/ncipher/see/hostside/*.java  
javac -cp  
../opt/nfast/java/classes/nCipherKM.jar com/ncipher/see/hostside/examples/helloworld/HelloWorld.java
```

Windows

```
javac -cp "%NFAST_HOME%\java\classes\nCipherKM.jar com\ncipher\see\hostside\*.java"
javac -cp "%NFAST_HOME%\java\classes\nCipherKM.jar ^
com\ncipher\see\hostside\examples\helloworld\HelloWorld.java"
```

To run the **helloworld** example:

1. Ensure you are in the example's directory by running the command:

Linux

```
cd /opt/nfast/java/examples
```

Windows

```
cd %NFAST_HOME%\java\examples
```

2. Run the example:

Linux

```
java -cp ./opt/nfast/java/classes/nCipherKM.jar
com/ncipher/see/hostside/examples/helloworld/HelloWorld <FILENAME> [<USERDATA>]
```

Windows

```
java -cp "%NFAST_HOME%\java\classes\nCipherKM.jar ^
com\ncipher\see\hostside\examples\helloworld\HelloWorld <FILENAME> [<USERDATA>]"
```

In this example, **<FILENAME>** is the name of an input file to pass to the SEE machine as an SEE job, and **<USERDATA>** the name of an (optional) userdata file. The SEE machine transforms the input by replacing all lowercase alphabetic characters in **<FILENAME>** with their uppercase equivalents and replacing any characters in **<FILENAME>** that are also found in **<USERDATA>** (if supplied) with the character X.

5. Debugging SEE machines

This chapter provides some guidance on debugging an SEE machine.

5.1. Debugging settings and output

To debug an SEE application effectively, you must have:

- Enabled SEE debugging when creating the Security World in which the application is to run.



SEE debugging is enabled when creating a Security World by specifying the new-world command-line utility's `dsee` or `dseeall` features; for more information, see the *User Guide*. We do not recommend specifying the `dseeall` feature for Security Worlds in a production system.

- Set `Cmd_CreateSEEWorlD_Args_flags_EnableDebug` when creating the SEE World.



If you try to set the `Cmd_CreateSEEWorlD_Args_flags_EnableDebug` flag in a Security World that does not allow SEE debugging, the `CreateSEEWorlD` command returns `AccessDenied`. This also occurs if you call `CreateSEEWorlD` in a Security World where SEE debugging is restricted and an appropriate certifier is not present.

5.1.1. Debugging authorization

Access to the SEE trace buffer is controlled by the Security World in which the SEE machine runs. Every Security World has exactly one of the following properties:

- Restricted SEE debugging

This is the default setting. When SEE debugging is restricted, there is no delegation key from K_{NSO} for accessing the SEE trace buffer. All Security Worlds created by software released before the introduction of SEE have restricted SEE debugging. A full quorum of Administrator Cards is required to access the SEE trace buffer in such Security Worlds.

- Authorized SEE debugging

In this case, a delegation key from K_{NSO} exists to allow access to the SEE trace buffer. A subset of a full quorum of the Administrator Cards is required to access the SEE trace

buffer in such Security Worlds. This delegation key must have been created and the number of cards required to authorize access to the SEE trace buffer must have been specified when the Security World was created.

- No access-control SEE debugging

In this case, no authorization of any kind is required for accessing the SEE trace buffer. No cards are required to access the SEE trace buffer in such Security Worlds. This property must have been specified when the Security World was created.

5.1.2. Obtaining debugging output

For SEE machines that require support from a host-side `see-*-serv` utility, you can run the `see-*-serv` utilities with the `--trace` or `--plain-trace` option to perform tracing automatically.

For SEE machines using the `SEELib` architecture, the `TraceSEWorld()` command can be used to return debugging information. An example of this is provided in the `a3a8` host-side example code. See [A3A8 example](#).

Data written to standard output and standard error on the HSM is written to the SEE World's Trace Buffer. The Trace Buffer is a 3000 character circular buffer: if more than 3000 characters are written to it without being retrieved, information is lost on a first-in/first-out basis. The `TraceSEWorld` command retrieves the contents of the buffer so that the host can analyze or display them.

If the SEE machine crashes, a SEE register dump is printed to the SEE Trace Buffer for the nShield Solo, but not for the nShield Solo XC.

For example, assume that the HSM code calls the following command:

```
printf("Hello World!\n");
```

The string `Hello World!\n` is pushed into the Trace Buffer. A host-side call to `TraceSEWorld` would then return this string and empty the buffer.

If a SEE World is terminated by the HSM (for instance, if its last remaining thread exits or it causes a fatal signal to be raised), a diagnostic message is usually sent to the Trace Buffer to help debug the problem.

5.1.2.1. Example Debug

If an illegal access violation (segmentation fault) occurs, the tail of the Trace Buffer looks

similar to this:

```
*** World exits: thread 28 caused CPU exception
DSI exception:
Exception vector 00300h
r0 =001D9E40h r1 =001D9F38h r2 =00C4E090h r3 =00000008h
r4 =00000000h r5 =00C00444h r6 =00000000h r7 =001C21B1h
r8 =00C39CB8h r9 =00000019h r10=40000000h r11=00002000h
r12=00000000h r13=00D08048h r14=00000000h r15=00000000h
r16=00000000h r17=00000000h r18=00000000h r19=00000000h
r20=00000000h r21=00000000h r22=00000000h r23=00C40000h
r24=FFFC5CD0h r25=00C3A750h r26=00C40000h r27=00C40000h
r28=00000000h r29=00000000h r30=00000000h r31=00D00000h
XER=20000000h CR =20000000h LR =00C00444h CTR=00C39B9Ch
PC =00C00448h MSR=0000F030h
f0 =0000000000000000h f1 =0000000000000000h
f2 =0000000000000000h f3 =0000000000000000h
f4 =0000000000000000h f5 =0000000000000000h
f6 =0000000000000000h f7 =0000000000000000h
f8 =0000000000000000h f9 =0000000000000000h
f10 =0000000000000000h f11 =0000000000000000h
f12 =0000000000000000h f13 =0000000000000000h
f14 =0000000000000000h f15 =0000000000000000h
f16 =0000000000000000h f17 =0000000000000000h
f18 =0000000000000000h f19 =0000000000000000h
f20 =0000000000000000h f21 =0000000000000000h
f22 =0000000000000000h f23 =0000000000000000h
f24 =0000000000000000h f25 =0000000000000000h
f26 =0000000000000000h f27 =0000000000000000h
f28 =0000000000000000h f29 =0000000000000000h
f30 =0000000000000000h f31 =0000000000000000h
FPSCR=00000000h
```

The program counter, which is currently at position **00C00448h** in the PowerPC-based compilation shows where this access occurs.

The following excerpt from the PowerPC based map file created at application link time (by specifying the **-map** option to the linker) indicates that the problem address is in **main.o**:

```
.text 0x00c00000          0x3a0ac
*(.text.stub.text.*.gnu.linkonce.t.*)
.text 0x00c00000          0xa5c usermain.o
      0x00c00160          main
.text 0x00c00a5c          0x544 .\lib-ppc-gcc\seelib.a(nfsterr.o)
      0x00c00a5c          NFast_StrError
```

To find out which instruction is causing the segmentation fault, calculate the offset into **main.o**. The formula is:

$$\text{program_counter} - \text{object_base_address}$$

The calculation is as follows:

```
00C00448h -
00C00000
```

```
-----
0x00448h
```

Once the location of the problem is located in this way, investigate it as follows:

1. Recompile the source with the `-g` option and no optimization (if you did not originally compile it with these options).
2. Run an object dump utility on the object files `powerpc-codesafe-linux-gnu-objcopy`.

The head of the generated object is now similar to the following for PowerPC based objects:

```
434: 38 7a 03 34  addi  r3,r26,820
438: 38 80 00 08  li    r4,8
43c: 4c c6 31 82  crclr 4*cr1+eq
440: 48 00 00 01  bl    440 <main+0x2e0>
444: 38 60 00 08  li    r3,8
448: 80 03 00 00  lwz   r0,0(r3)
44c: 4b ff fe 74  b     2c0 <main+0x160>
450: 3c 80 00 00  lis   r4,0
```

From this output it is possible to see that the segmentation fault is caused by an illegal access to the pointer held in `R4` (which the register dump showed to be `80000004h`, an obviously invalid user mode memory address). The source shows plainly that the instruction at offset `0458h` in `usermain.o` is trying to assign to `*i`, but `i` has not been allocated. The bug can now be fixed and the program rebuilt.

5.2. Finding memory leaks with stattree

You can use the `stattree` command-line utility to find memory leaks. Run the command:

Linux

```
stattree | grep Mem
```

Windows

```
stattree | find "Mem"
```

For each HSM in the Security World, this command produces output that reports values for the total memory (`MemTotal`), the memory currently allocated to the kernel (`MemAllocKernel`), and the memory currently allocated to the loaded SEE machine (`MemAllocUser`).

If no SEE machine is loaded, the output from this `stattree` command (if there is only one HSM) looks similar to the following:

```
-MemTotal      128921600
-MemAllocKernel 1355776
-MemAllocUser   0
```

If an SEE machine is loaded, the output from this **stattree** command (if there is only one HSM) looks similar to the following:

```
-MemTotal      128921600
-MemAllocKernel 1355776
-MemAllocUser  1032192
```

You can monitor a loaded SEE machine's memory usage by either repeatedly running and checking output from **stattree** or by writing code to call the nCore statistics APIs directly. In any case, if any reported memory value appears to be growing continuously over time, this probably indicates some kind of memory leak.

5.3. Segment addresses for Solo

SEE executables are non-relocatable; that is, they are loaded in memory at the addresses specified in the image. Ensure that you choose these addresses carefully so that they map onto usable RAM and do not overlap with memory being used by the kernel. Typically, this means you must choose an address at the high end of RAM.

Different HSM types have different mappable memory ranges.

- The CodeSafe compiler sets all values for Solo XC and later HSM models.
- You have to set the ranges in the CodeSafe application code if you are developing for Solo +.

The rest of this section describes guidelines for Solo +.

To determine your HSM type, run the **enquiry** command-line utility and check the **SEE Machine Type** output. You can then determine where the mappable memory range starts from this table:

| SEE Machine Type | Start of mappable range |
|------------------|-------------------------|
| PowerPCSXF | 0x00400000 |

These ranges follow the approximately 4MB of RAM reserved for use by the kernel.

You can use the **stattree** command-line utility to find the total length of the mappable range. Run the command:

Linux

```
stattree | grep MemTotal
```

Windows

```
stattree | find "MemTotal"
```

This command produces output that reports values for the total memory (**MemTotal**) for each HSM in the Security World.

For Solo +, we recommend the following segment addresses as starting points:

| | |
|---------------------------|--|
| SEE Machine Type | PowerPCSXF |
| text segment start | 0xa00000 |
| data segment start | 0x00d00000 |
| Arguments to the linker | -Ttext 0xa00000 -Tdata 0xd00000 |

For large SEE machines more space may be needed in the text segment, causing a linker error of the following form:

```
powerpc-codesafe-linux-gnu-ld: section .data [00d00000 -> 00d0327f] overlaps section .text [00c00000 -> 00d7bd8b]
powerpc-codesafe-linux-gnu-ld: section .sdata [00d03280 -> 00d035ef] overlaps section .text [00c00000 -> 00d7bd8b]
powerpc-codesafe-linux-gnu-ld: section .sbss [00d035f0 -> 00d036ab] overlaps section .text [00c00000 -> 00d7bd8b]
powerpc-codesafe-linux-gnu-ld: section .bss [00d036b0 -> 00d0854f] overlaps section .text [00c00000 -> 00d7bd8b]
```

To resolve this example error, you could move the data segment start point upward (for example, to **0x00e00000**) as necessary to prevent the overlap. Alternatively (or additionally), you could move the text segment start point downward.

5.4. Vulnerability test harness

We supply a test harness called **vulnerability.o** that can be used for debugging SEE machines. It supplies a standard set of command-line arguments and environment variables to the SEE environment, as well as providing the standard **stdio** and socket support.



Because the **vulnerability.o** test harness is insecure, we recommend that you *not* link **vulnerability.o** into a production SEE machine.

5.5. Troubleshooting guide

| Symptom | Possible problems | Solution |
|---|--|--|
| <code>SEEJob</code> takes a long time then fails with <code>HardwareFailed</code> | The SEE machine has deadlocked or entered an infinite loop which prevents the job from returning and causes the <code>SEEJob</code> to trigger the command time-out. | Check the code for possible deadlocks or infinite loops. Non-obvious problems can be debugged by writing progress reports to the Trace Buffer and calling <code>TraceSEEWORLD</code> after the job returns <code>HardwareFailed</code> . |
| <code>CreateSEEWORLD</code> fails with <code>BadMachineImage</code> | No SEE machine is loaded. | Load an SEE machine |
| SEE machine loading fails with <code>BadMachineImage</code> | The file being loaded is not a correctly formatted SAR file. | Ensure that the correct SEE machine file is being loaded. Ensure that the SEE machine has been properly processed by the Trusted Code Tool into a SAR file. |
| | The SEE machine file is corrupted. | Rebuild the SEE machine, or revert to a known good back-up. |
| | The SEE machine has been compiled or linked with the wrong options. | SEE machines must be nonexecutable, uncompressed, non-relocatable AIFs or SXFs, packaged as SAR files. |
| <code>CreateSEEWORLD</code> fails with <code>InvalidCertificate</code> | The machine signing hash on <code>user-data</code> signatures does not match any signature hash on the currently loaded machine. | <p>Ensure the correct SEE machine with the correct signatures is loaded.</p> <p>Ensure the correct user data is being passed to <code>CreateSEEWORLD</code>.</p> <p>Ensure the user data signatures are correct.</p> |
| SEE machine loading fails with <code>InvalidCertificate</code> . | The SEE machine signatures were created incorrectly. | SEE machine signatures must be created with the machine key specification <code>--is-machine</code> . Recreate the SEE machine SAR with correct signatures. |
| The SEE machine crashes, and Trace Buffer output shows raised signal. | Dependent on signal number. | Check <code>stdh.h</code> and <code>signal.h</code> for signal descriptions then check the code to see how that signal could be raised. |

| Symptom | Possible problems | Solution |
|--|---|--|
| AccessDenied from CreateSEWorld. | SEE World debugging is not available in Security World. | Check the Security World's SEE debugging policy. |
| | SEE machine is returning AccessDenied in SEELib_initComplete. | Check the SEE machine set-up code to see where it might be passing AccessDenied to SEELib_initComplete, and fix the cause of that, if necessary. |
| All SEEJobs return with Status_Canceled. | SEELib transaction listener is not running. | If you are using SEELib_Transact you must call SEELib_StartTransactListener before making use of SEELib_Transact. |
| NoModuleMemory is returned from the CreateSEWorld command. | Segment addresses clash with kernel pages. | Adjust segment positions away from kernel RAM; see Segment addresses for Solo . . |
| | Segment addresses overlap. | Adjust segment away from each other; see Segment addresses for Solo . . |
| | Segment addresses are not usable RAM. | Adjust segment positions to usable RAM; see Segment addresses for Solo . . |
| NoModuleMemory is returned when loading a SEE machine. | Userdata has been specified but is not expected. | Exclude the userdata. |
| | The previous SEE machine has not been cleared | Clear the previous SEE machine; see clearing a SEE machine from the front panel or clearing a SEE machine remotely |
| Error from link: section .data [hhh hhhh → hhhhhhhh] overlaps section .text [hhhhhhh → hhhh-hhh] | Segment addresses overlap. | Adjust segment away from each other; see Segment addresses for Solo . . |

6. Deploying SEE Machines

This chapter discusses the deployment of SEE machines after their development is complete. It includes information about Feature Enabling as this applies to SEE.

Deploying a SEE machine involves the following steps:

1. Sign and encrypt the SEE machine. See [Signing methods](#) and [Encryption](#).
2. Obtain an export certificate for the SEE machine from Entrust and incorporate the certificate in the distribution. See [Obtaining and using export certificates](#).
3. Distribute the SEE machine to customers.

6.1. About the Feature Enabling Mechanism (FEM)

Entrust provides a Feature Enabling Mechanism (FEM) that controls the software that any given HSM can use. This is used to control access to the `SetSEEMachine` command that loads the SEE machines.

The `SetSEEMachine` command can be authorized in either of the following ways:

- The `GeneralSEE` static feature is set with a bit in the EEPROM. If this bit is set, the command can load any SEE machine without further certificates or authorization.
- If the `GeneralSEE` static feature is not applied, the command requires a dynamic Feature Enabling certificate chain to load a SEE machine.

All CodeSafe *development* environments have the `GeneralSEE` static feature. However, to deploy an already-developed SEE machine, you require the dynamic Feature Enabling certificate chain.

Customers who require the dynamic certificate chain can load a SEE machine only when the key used to sign the SEE machine is export approved by Entrust through the provision of a signing certificate (an ADDER certificate). See [Obtaining and using export certificates](#).

The SEE machine signing (ADDER) certificate authorizes `SetSEEMachine` on any HSM, but the dynamic Feature Enabling certificate chain is valid only on the specified HSM.

6.2. Obtaining and using export certificates



You must understand and agree to the conditions for exporting SEE machines. Contact Entrust for full details of these conditions.

To obtain an export certificate for a SEE machine:



Users with a Restricted SEE, [SEE(R)], enabled Connect will need to run `update world files` to pull the ADDER cert onto the Connect file system to load a SEE machine.

1. Generate a signing key and send the hash to Entrust together with a description of the SEE machine.

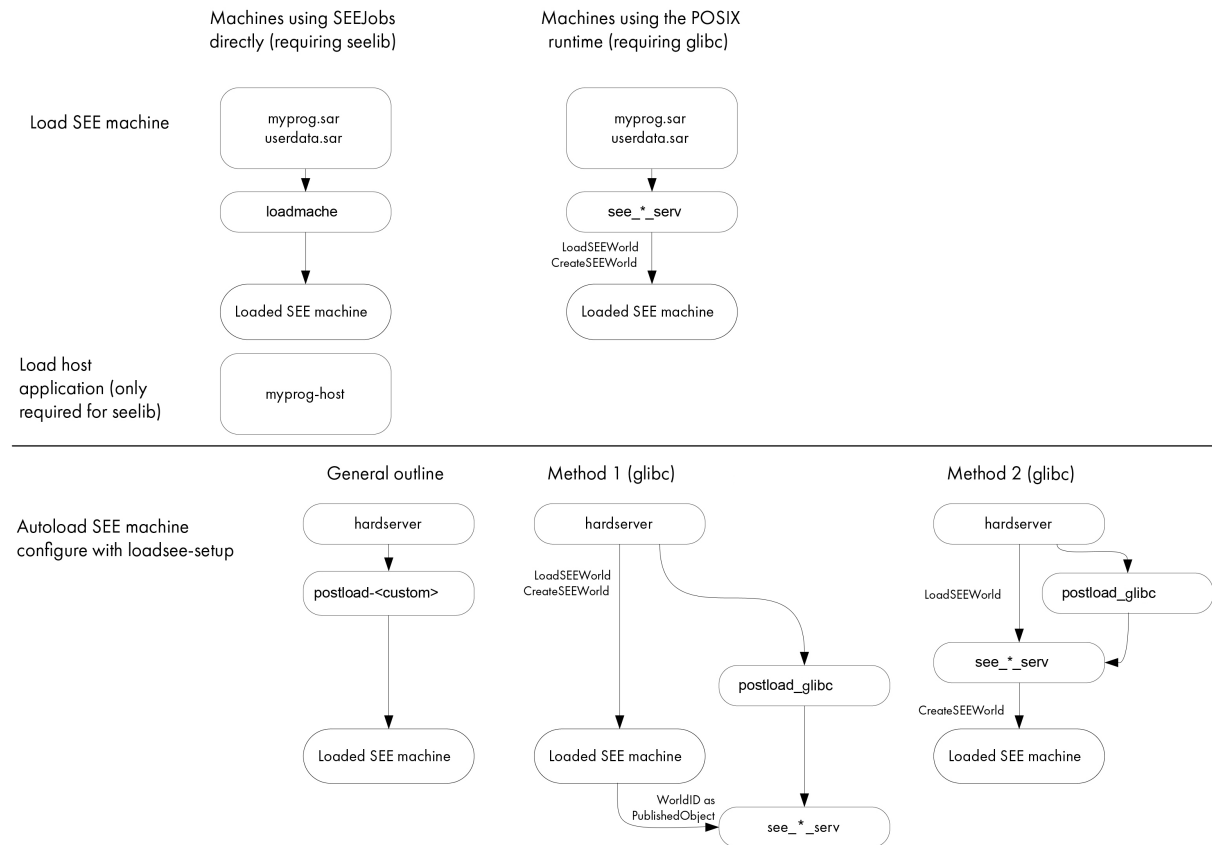
Entrust approves the SEE machine for export and sends you an ADDER certificate to allow the SEE machine signed by the specified key to run.

2. Sign the SEE machine with the signing key supplied to Entrust and, optionally, encrypt it.
3. Develop an installation process that places the certificate in the `/opt/nfast/femcerts` (Linux systems) or `%NFAST_CERTDIR%` (Windows) directory.
4. Distribute the signed SEE machine and the certificate to end-users with the appropriate installation instructions.

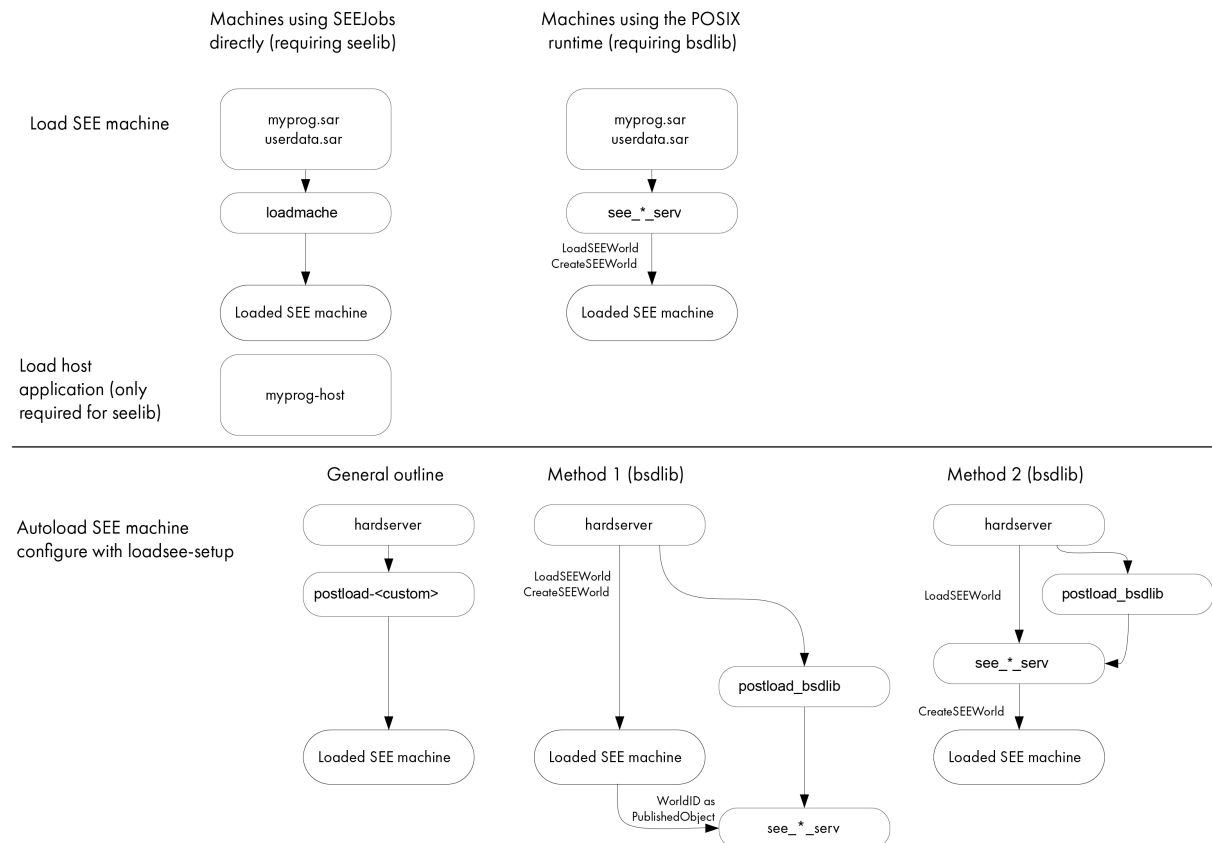
6.3. Automatically loading a SEE machine

The figures below outline different methods for loading a SEE machine.

Loading SEE machines for Solo XC:



Loading SEE machines for Solo PCIe:



You can load SEE machines manually by running the `loadmache` command-line utility or, optionally, you can load SEE machines that require support from a host-side `see-*-serv` utility by specifying the `-M` option when you run the utility.

However, you can also configure the hardserver to load SEE machines automatically whenever the HSM is initialized (that is, when the hardserver starts, or restarts, or after the HSM receives a `ClearUnit` command).

To configure the hardserver to load a SEE machine automatically, you must edit the settings in the host systems hardserver configuration file. Entrust provides the `loadsee-setup` command-line utility to help you set up, display, and remove settings in the hardserver configuration file that control the automatic loading of SEE machines.



For a usage description of the `loadsee-setup` command-line utility, see [Loadsee setup](#). For more information about the configuration files, see the *User Guide*.

The `loadsee-setup` utility configures the hardserver settings that specify:

- The name of the SEE machine file to be automatically loaded
- If appropriate, the name of an accompanying `userdata` file.
- If appropriate (if `userdata` is specified), the published-object name for the SEE machine
- The name of an appropriate post-load program (to perform setup and initialization tasks for the SEE machine) and any necessary arguments for it (a `-m` option to specify an HSM is automatically added)

For SEE machines that require support from a host-side `see-*-serv` utility, Entrust provides the `postload-bsdlib` post-load program, which runs the appropriate host utility, in restricted mode, while returning control back to the hardserver. The `postload-bsdlib` program takes the same arguments as the `see-*-serv` host utilities (see [see-*-serv utilities](#)), together with a `--provision` argument that takes one of the following parameters to specify which utility to run:

- `stdoe`
- `stdioe`
- `sock`
- `stdioesock`

For SEE machines using the `SEELib` architecture, it is usually necessary to write a custom post-load program.

6.3.1. Automatically loading a glibc/bsdlib SEE machine with userdata

To configure the hardserver configuration file to automatically load a **glibc/bsdlib** SEE machine and its accompanying **userdata** file, run a command similar to the following example:

Linux

```
loadsee-setup -m1 -M /tmp/MySEEMachine.sar -U /tmp/MyUserdata.sar -p MyPublishedObjectName -P glibc -A "--provision sock -p MyPublishedObjectName"
```

Windows

```
loadsee-setup -m1 -M C:\MySEEMachine.sar -U C:\MyUserdata.sar -p MyPublishedObjectName -P glibc -A "--provision sock -p MyPublishedObjectName"
```

In this example, **MySEEMachine.sar** is the SEE Machine (packed as a SAR file), **MyUserdata.sar** is the **userdata** (packed as a SAR file), **MyPublishedObjectName** is the name to use for publishing the **KeyID** of the started SEE machine, and the **glibc/bsdlib** parameter specifies use of the **postload-bsdlib** post-load program.

The **sock** parameter in this example tells **postload-bsdlib** to run the **see-sock-serv** host utility. If a different host utility were necessary, you would specify the appropriate parameter for the appropriate utility (**stdoe**, **stdioe**, or **stdioesock**).



When running a command of this form, ensure that the parameters specifying name of the published object (in this example, **MyPublishedObjectName**) are the same for both the **loadsee-setup** utility and the **postload-bsdlib** program.

For more information about the **loadsee-setup** command-line utility, see [Loadsee setup](#).

6.3.2. Automatically loading a glibc/bsdlib SEE machine without userdata

To configure the hardserver configuration file to automatically load a **glibc/bsdlib** SEE machine without its accompanying **userdata** file (which instead is to be loaded by the host utility), run a command similar to the following example:

Linux

```
loadsee-setup -m1 -M /tmp/MySEEMachine.sar -P glibc -A "--provision sock --userdata-sar /opt/nfast/nc-seemachines/MyUserdata.sar"
```

Windows

```
loadsee-setup -m1 -M C:\MySEEMachine.sar -P glibc -A "--provision sock --userdata-sar C:\MyUserdata.sar"
```

In this example, **MySEEMachine.sar** is the SEE Machine (packed as a SAR file) and the **glibc/bsdlib** parameter specifies use of the **postload-bsdlib** post-load program.

The **sock** parameter in this example tells **postload-bsdlib** to run the **see-sock-serv** host utility. If a different host utility were necessary, you would specify the appropriate parameter for the appropriate utility (**stdoe**, **stdioe**, or **stdioesock**).

The **MyUserdata.sar** parameter in this example, passed to the **postload-glibc/postload-bsdlib** program, specifies a **userdata** file (packed as a SAR) that is to be loaded by the host utility.



To specify **userdata** that has not been packed as a SAR file, use the **--userdata-raw** option instead of **--userdata-sar**.



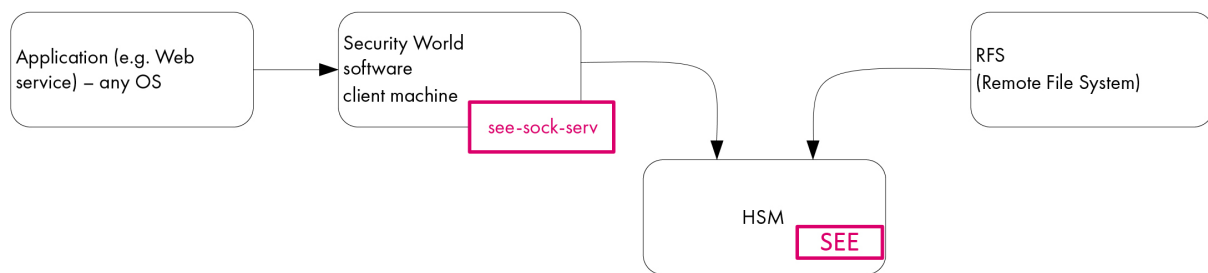
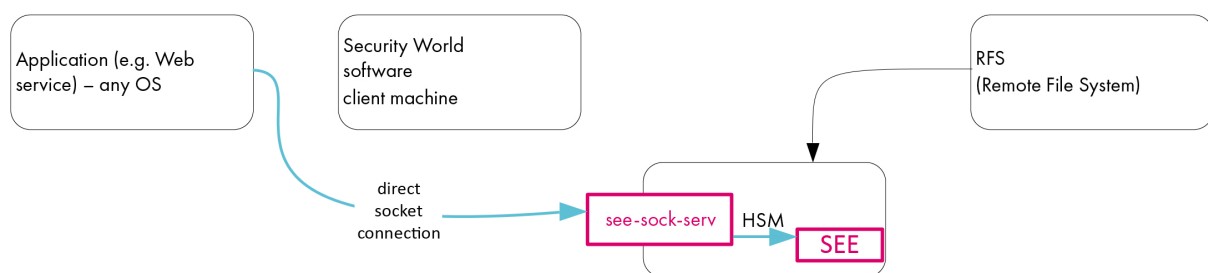
To turn on SEE debugging, pass one of the options **--trace** or **--plain-trace** as an argument for the post-load program. See also [Debugging SEE machines](#).



The host utility will be run in restricted mode, using the **-r** option.

6.4. Configuring the nShield Connect to use CodeSafe Direct

The CodeSafe client can be any OS platform (including mainframe, Non-Stop or embedded device). The use of CodeSafe Direct eliminates proxy devices, complexity and points of failure.

Implementation without CodeSafe DirectCodeSafe Direct implementation

The nShield Connect can be configured to receive direct socket connections from the SEE machine via `see-sock-serv`, removing the need for a client machine. You do this by specifying `postload_prog` and `postload_args` in the `load_seemachine` section of the nShield Connect hardserver configuration file, located in `NFAST_KMDATA/hsm-<ESN>`, where `<ESN>` is the Electronic Serial Number of the HSM. (For more information about this section of the configuration file, see the *User Guide*.)



CodeSafe Direct is supported on bsdlib-based/glibc-based SEE machines only: the functionality is not available on SEELib-based machines.

The configuration file can be managed in two ways: via the front panel of the nShield Connect (see [Configuring a SEE machine using the front panel](#)), and by using the remote configuration functions to push a `config.new` file, containing the `postload_prog` and `postload_args` settings, to the HSM.



For more information, see *Configuring the HSM with configuration files and HSM and client configuration files* in the *User Guide*.

6.5. Configuring a SEE machine using the front panel

To use `see-sock-serv` directly, you must create a bsdlib/glibc SEE machine.

Ensure that the SEE machine for the application is in the `/opt/nfast/custom-seemachines` (**Linux**) or `%NFAST_HOME%\custom-seemachines` (**Windows**) directory on the remote file system.

If a SEE machine has previously been loaded on a network-attached HSM with a front panel, such as an nShield Connect, clear the current SEE machine from memory in one of the following ways:

- Press the **Clear** button on the front of the HSM.
- Log in to a host machine as a user in the `nfast` group and run the following command (`m1` is the Security World's module number for the HSM whose front panel you used in the previous steps):

```
sudo /opt/nfast/bin/nopclearfail -c -w -m1
```

6.5.1. Configuring a glibc/bsdlib SEE machine

Select the CodeSafe menu option, and enter the following information when prompted:

1. The name of the SEE machine file.
2. The name of the userdata file.



For CodeSafe Direct, the `userdata` file must be packed as a SAR file.

3. The type of custom SEE machine you are using (`glibc/bsdlib sockserv`). `worldid_pubname`, `postload_prog`, and `postload_args` will be passed to `load_seemachine`. For detailed descriptions of the options in this section, see the *User Guide*.

6.5.2. Configuring a SEElib SEE machine

Select the CodeSafe menu option, and enter the following information when prompted:

1. The name of the SEE machine file.
2. The name of the userdata file, if required.

The `userdata` file must be packed as a SAR file.

3. The type of custom SEE machine you are using (`SEElib`).
4. The ID of the SEE World to create.

6.6. Remotely loading and updating SEE machines

The SEE remote push facility allows the remote deployment of CodeSafe SEE machines to an nShield Connect, negating the need to physically visit the HSM to load or update the SEE machine. This is achieved by editing the configuration file on the RFS for a specific nShield Connect to specify the new SEE machine, then setting a configuration flag in the config file to **true**.

Before configuring an HSM to autonomously run a SEE machine and accept updates using the RFS, that HSM must first be set up to accept remotely-pushed configurations; see *Pushing configuration files to the nShield Connect* in the *nShield Connect User Guide*.

For more information about configuring log file storage options, see *Configuring the HSM with configuration files* in the *nShield Connect User Guide*.

Both **SEELib** and **glibc/bsdlib sockserv** SEE machines are supported on the nShield Connect.

To configure an nShield Connect to autonomously run a SEE machine and accept updates using the RFS:

1. Copy the existing config file to a new file called **config.new**.
2. In the **load_seemachine** section of the **config.new** file for the remote HSM, add or amend the following settings:

```
pull_rfs=true
machine_file=mymachinename.sar
userdata=myuserdata.sar
worldid_pubname=publ_name
```



These settings specify the type, name and user data of the SEE machine you wish to load. For more information about each setting, see **load_seemachine** in *Hardserver configuration files*, in the *nShield Connect User Guide*.



For CodeSafe Direct, the **userdata** file must be packed as a SAR file.



The remote HSM will load the new SEE machine in place of any existing SEE machine. If no **machine_file** value is set, then pushing the config file will remove any existing machines on the HSM.

3. In the **sys_log** section of the **config.new** file for the remote HSM, add or amend the following settings:


```
behaviour=push  
push_interval=1
```



These settings control how and where log messages are written. Using the example above, messages will be written to the `system.log` and `hardserver.log` files of the HSM, which are accessible using the remote file system. You may wish to revise the `push_interval` to a higher value once the nShield Connect has successfully loaded the new SEE machine.

1. Run `nopclearfail` to clear the HSM, followed by `enquiry` to check that the HSM is ready.
2. Run `cfg-pushnethsm` to push the new config file to the HSM.
3. Run `nopclearfail -c -w`.

For more information about the `cfg-pushnethsm` utility, see the *User Guide*.

To load a new SEE machine to multiple nShield Connects, we recommend scheduling down time for each HSM, upgrading them on a per HSM basis. Each nShield Connect configuration file is specific to an individual HSM and each configuration file should be updated separately to load the new SEE machine.

7. Utilities

Entrust supplies the following SEE-specific nShield command-line utilities, described in this appendix:

- `elftool`.
- `loadmache`.
- `loadsee-setup`.
- `hsc_loadseemachine`
- The `see-*-serv` host-side utilities:
 - `see-sock-serv`.
 - `see-stdoe-serv`.
 - `see-stdioe-serv`.
 - `see-stdioesock-serv`.
- `seessl-migrate.py`.
- `tct2` (the Trusted Code Tool)

This appendix also describes the following general nShield command-line utilities:

- `nfmverify`
- `stattree`

For a list of all supplied nShield utilities, see the *User Guide*.

7.1. cpio

The `cpio` command-line utility takes a collection of files and packs them up into a `userdata` archive file that the SEE machine can use.

7.1.1. Usage

```
cpio userdata.cpio <MyFile1> <MyFile2> <MyFile3> <[...]>
```

In this command, `<MyFile1>`, `<MyFile2>`, and `<MyFile3>` represent the files being packed into the `userdata.cpio` file that is generated by the command. You can specify as many files as appropriate.

You can also specify one or more directories; the command automatically packs their contents (including any subdirectories) into the generated `userdata.cpio` file.

7.2. elftool

The **elftool** command-line utility lets you convert ELF format executables into a format suitable for loading as an SEE machine.

7.2.1. Usage

```
elftool [<options>] <infile> [<outfile>]
```

This utility has the following options:

-d|--dump-fields

These options dumps (display) all fields in the input file *infile* as they are read.

-q|--quiet

These options suppresses informative messages.

--single-section

This option checks that exactly one of each section type is present in the input file *infile*. If more than one section of a type is present, an error is displayed.

--aif

This option generates an output file *outfile* in nonexecutable AIF output (ARM only, deprecated).

--bin

This option generates an output file *outfile* in raw binary format.

--sxf

This option generates an output file *outfile* in nShield SEE Executable Format (SXF).

-n|--no-output

These options check the input file *infile* without generating any output.

To view the loadable sections of an ELF file, use the following command:

```
elftool --dump-fields <infile>
```

This command displays details of the sections of the file under one of the following categories:

Read Only

This category includes program code and constant data (either **Read** or **Read+Execute** permissions).

Read/Write

This category includes non-constant data initialized to particular values (**Read+Write** permissions).

Zero Init

This category includes non-constant data initialized to zero.

To generate an AIF or SXF format output file correctly, the ELF input file must have the following characteristics:

- The address range for one category of data (for example, **Read Only**) must not overlap with the address range for another (for example, **Read/Write**).
- All **Zero Init** data must come after all **Read/Write** data in memory (that is, **Zero Init** data must occupy a higher memory address).

The default options for most linkers ensure that ELF files meet these requirements.

To convert a ELF file into SXF, a format specifically for SEE machines, use the following command:

```
elftool --sxf <infile> <outfile>
```

SXF format files can be loaded on all existing SEE-enabled HSMs. This is the preferred format.

To convert a ELF file into binary format, use the following command:

```
elftool --bin <infile> <outfile>
```

The output file consists of the **Read Only** data immediately followed by the **Read/Write** data, without a header. This may be useful in applications other than SEE Machine images.

7.3. loadmache

The **loadmache** command-line utility supplied with the Secure Execution Engine (SEE) loads an SEE machine into an SEE-enabled HSM. The hardserver can automatically use this utility to load an SEE machines.

To use this command, you must be logged in to the host computer as a user in the group **nfast (Linux)** or as a user who is permitted to create privileged connections (**Windows**).



SEE machines that require support from a host-side **see-*-serv** utility



If your SEE machine requires support from a host-side **see-*-serv** utility, you must run one of those utilities as appropriate to serve the SEE machine before its networking or **stdioe** provisions can work.

7.3.1. Usage

```
loadmache [-m|--module=<MODULE>] [-s|--slot=<SLOT>] [-U|--unencrypted] [-e|--encryptionkey=<IDENT>] [-a|--sighash=<HASH>] [-n|--noprompt] <machine-filename>
```

In this command, the *machine-filename* parameter specifies the path of the SEE machine. If *machine-filename* is not specified, **loadmache** tries to select a machine from the location specified by the ``NFAST_SEE_MACHINEIMAGE_`*` environment variables. See the *User Guide* for more information about environment variables.

7.3.1.1. HSM options

-m|--module=<MODULE>

These options specify the hardware security module to use.

-s|--slot=<SLOT>

These options specify the slot from which to load cards.

7.3.1.2. SEE machine loading options

-a|--sighash=<HASH>

These options specify that the SEE machine is to be signed with a key whose hash is *HASH*.

-n|--noprompt

These options specify that you are never prompted for missing smart cards.

-U|--unencrypted

These options specify that the SEE machine is to be unencrypted. This is the default. If set, these options override any previously specified ``NFAST_SEE_MACHINEENCKEY_`*` variable. See the *User Guide* for more information about environment variables.

-e|--encryptionkey=<IDENT>

These options specify that the SEE machine is to be encrypted with the key identified by *IDENT*. If set, these options override the **-U|--unencrypted** options.



If neither the **-e|--encryptionkey** nor the **-U|--unencrypted** options are specified, a decryption key is used only if the name of a suitable one is found in the location specified by the **NFAST_SEE_MACHINEENCKEY_DEFAULT** environment variable. See the *User Guide* for more information about environment variables.

7.4. loadsee-setup

The **loadsee-setup** command-line utility helps you set up, display, or remove settings in the hardserver configuration file that control the automatic loading of SEE machines.



For details about the configuration files, see the *User Guide*.

You can use **loadsee-setup** for one of three types of action by specifying the appropriate option:

- Specifying the **--setup** option selects the **setup** action, used to add a new configuration or replace an existing configuration
- Specifying the **--remove** option selects the **remove** action, used to remove an existing configuration (without replacing it)
- Specifying the **--display** option selects the **display** action, used to display the configuration of one or all HSMs

7.4.1. Usage

```
loadsee-setup -s|--setup -m <MODULE>
loadsee-setup -r|--remove -m <MODULE>
loadsee-setup -d|--display [-m <MODULE>]
```

7.4.1.1. Action selection

-s|--setup

This option selects the **setup** action, enabling you to set up the hardware configuration file for the HSM specified by **-m|--module=<MODULE>** to provide automatic loading for the SEE machine specified by **-M|--machine=<MACHINE>.sar**.



You must always specify the `-m|--module=<MODULE>` and `-M|--machine=<MACHINE>.sar` options when using the `--setup` option. See the comments in the hardware configuration file for information about the effects of specifying or omitting other options.

`-r|--remove`

This option selects the `remove` action, enabling you to remove settings that control automatic SEE machine loading from the hardware configuration file for the HSM specified by `-m|--module=<MODULE>`

`-d|--display`

This option selects the `display` action, enabling you to display the current configuration of automatic SEE machine loading for the HSM specified by `-m|--module=<MODULE>` or, if no HSM is specified, all HSMs in the Security World.

7.4.1.2. Setup options

`-M|--machine=<MACHINE>.sar`

This option specifies the SEE machine file (packed as a SAR). You must supply a value for this option when using setup mode.

`-U|--userdata=<USERDATA>.sar`

This option specifies the name of the `userdata` file (packed as a SAR) to be passed to SEE machine.

`-k|--key=<IDENT>`

This option identifies the `seeconf` key protecting the SEE machine. You must supply this option if the SEE machine is encrypted. Only HSM-protected keys are supported.

`-S|--sighash=<HASH>`

This option identifies the hash of the key that the SEE machine is signed with. You only need to supply this option if the SEE machine is encrypted and you are using a dynamic SEE feature. This option is not required if the SEE machine is not encrypted or if you have the `GeneralSEE` static feature.

`-p|--published-object=<NAME>`

This option specifies the `PublishedObject` name to use for publishing the `KeyID` of the started SEE machine.

`-P|--postload-prog=<PROGRAM>`

This option specifies the post-load program to be run after the SEE machine is loaded.



In most cases, SEE machines using the `bsdlib/glibc` architecture should supply the value `bsdlib/glibc` to specify use of the provided `postload-bsdlib` program.

-A|--postload-args=<ARGUMENTS>

This option specifies an argument string to pass to the post-load program specified by the `--postload-prog` option. Supply the individual arguments within the double quotation marks, each argument separated from the next by a single space.

7.4.1.3. General options

-m|--module=<MODULE>

This option specifies the HSM with the hardware configuration file that is to be acted upon by the command. You must supply a value for this option in either setup or remove mode.

-c|--configfile=<FILENAME>

This option specifies name of (or path to) the hardserver configuration file to be acted upon by the command. The default is `/opt/nfast/kmdata/config/config` (**Linux**) or `%NFAST_KMDATA%\config\config` (**Windows**).

-f|--force

Setting this option allows the command to make configuration changes without prompting you.

--no-reset

This option prevents resetting HSMs with changed configurations.

7.4.2. Output

7.4.2.1. `loadsee-setup --setup`

This section provides an example of `loadsee-setup` used in `--setup` mode.

When `--setup` mode is specified, the only other required options are `-m|--module=<MODULE>` and `-M|--machine=<MACHINE>.sar`. However, if you supply the `-A|--postload-args=<ARGUMENTS>` option, you must also supply the `-P|--postload-prog=<PROGRAM>` option.

To set up a hardware configuration file to provide automatic loading for an SEE machine, run a command similar to the following Solo XC example:


```
loadsee-setup --setup -m1 --machine /tmp/test.sar --postload-prog=glibc --postload-args="--provision stdoe
--userdata-sar /tmp/userdata.sar --trace"
```

If automatic SEE machine loading has already been configured for the specified HSM, **loadsee-setup** warns you before it is overwritten:

```
Module #1 new SEE configuration saved, new configuration follows:
Module #1:
  Machine file:           /tmp/test-helloworld.sar
  Userdata file:
  WorldID published object:
  Postload helper:       libc
  Postload args:         --provision stdoe --userdata-sar /tmp/test.cpio.sar
--trace
Clear modules now to reload new configuration? (yes/no): yes
```

You can use the **-f|--force** option to bypass this warning and overwrite the existing configuration.

After setting up the configuration, **loadsee-setup** resets the affected HSM (unless you specified the **--no-reset** option).

7.4.2.2. loadsee-setup --remove

This section provides an example of **loadsee-setup** used in **--remove** mode.

When **--remove** mode is specified, the only other required option is **-m|--module=<MODULE>**. This specifies the HSM with the hardware configuration file that needs the settings for automatic SEE machine loading removed.

To remove settings for automatic SEE machine loading from an HSM's hardware configuration file, run a command similar to the following example:

```
loadsee-setup --remove -m1
```

If the HSM specified by **-m|--module=<MODULE>** does not exist or is not currently configured to automatic SEE machine loading configured, an error is displayed. Otherwise, the current configuration is displayed and **loadsee-setup** prompts you to continue:

```
Module #1:
  Machine file:           /tmp/test-helloworld.sar
  Userdata file:
  WorldID published object:
  Postload helper:       libc
  Postload args:         --provision stdoe --userdata-sar /tmp/test.cpio.sar
--trace
Erase this configuration? (yes/no): yes
Module #1 SEE auto-loading configuration removed.
```

```
Clear modules now to reload new configuration? (yes/no): yes
```

You can use the `-f|--force` option to bypass warnings and remove the existing configuration without being prompted.

After removing the configuration, `loadsee-setup` resets any HSM with a configuration that has changed (unless you specified the `--no-reset` option). After running `loadsee-setup` command in `--remove` mode, no SEE machines are automatically loaded onto the specified HSM.

7.4.3. loadsee-setup --display

This section provides an example of `loadsee-setup` used in `--display` mode.

You are not required to specify any additional options with `--remove` mode. You can specify the `-m|--module=<MODULE>` option to display the settings for automatic SEE machine loading in a particular HSM's hardserver configuration file; without specifying this option, `loadsee-setup` displays the settings for automatic SEE machine loading in the hardserver configuration files for any HSM in the Security World for which these settings exist.

To display settings for automatic SEE machine loading for all HSMs, run a command similar to the following example:

```
$ loadsee-setup --display
```

This command produces output similar to the following:

```
Module #1:
Machine file:          /tmp/test-helloworld.sar
Userdata file:
WorldID published object:
Postload helper:       glibc
Postload args:         --provision stdoe --userdata-sar /tmp/test
```

7.5. hsc_loadseemachine

The `hsc_loadseemachine` utility enables you to publish an SEE machine. The utility:

1. Loads an SEE machine into each HSM configured.
2. Publishes a newly created SEE world, if appropriate.

7.5.1. Usage

```
hsc_loadseemachine [<options>]
```

7.5.1.1. Options

-m|--module

This option specifies the HSM number into which the configuration data must be read. The default value is **0**.

The SEE machine can be loaded only if you specify this option. If you do not specify this option, the utility examines the configuration file to check the changes that are made to the **load_seemachine** section and then reset any HSM that has had its entry modified.

The hardserver loading script then calls **hsc_loadseemachine -m MODULE** for each HSM that has been reset.

-c|--configfile=<FILENAME>

This option specifies the name of the configuration file that must be read.

7.6. nfkmverify

The **nfkmverify** command-line utility verifies key generation certificates. You can use **nfkmverify** to confirm how a particular Security World and key are protected. It also returns some information about the Security World and key.

The **nfkmverify** utility compares the details in the ACL of the key and those of the card set that currently protects the key.

A key that has been recovered to a different card set shows a discrepancy for every respect that the new card set differs from the old one. For example, a key recovered from a 2-of-1 card set to a 1-of-1 card set has a different card-set hash and a different number of cards, so two discrepancies are reported. The discrepancy is between the card set mentioned in the ACL of the key and the card set by which the key is currently protected (that is, the card set mentioned in the key blobs).



A key that has been transferred from another Security World shows discrepancies and fails to be verified. We recommend that you verify keys in their original Security World at their time of generation.

If you must replace your Security World or card set, we recommend that you generate new keys whenever possible. If you must transfer a key, perform key verification immediately before transferring the key; it is not always possible to verify a key after transferring it to a new Security World or changing the card set that protects it.

7.6.1. Usage

```
nfkmverify [-f|--force] [-v|--verbose] [-U|--unverifiable] [-m|--module=<MODULE>] [apname ident [apname ident [...]]]
```

7.6.1.1. Help options

-h|--help

This option displays help for **nfkmverify**.

-V|--version

This option displays the version number for **nfkmverify**.

-u|--usage

This option displays a brief usage summary for **nfkmverify**.

7.6.1.2. Program options

-m|--module=<MODULE>

This option performs checks with module *MODULE*.

-f|--force

This option forces display of an output report that might be wrong.

-U|--unverifiable

This option permits operations to proceed even if the Security World is unverifiable.



If you need the **-U|--unverifiable** option, there may be some serious problems with your Security World.

-v|--verbose

This option prints full public keys and generation parameters.

-C|--certificate

This option checks the original ACL for the key using the key generation certificate. This is the default.

-L|--loaded

These options check the ACL of a loaded key instead of the generation certificate.

-R|--recov

This option checks the ACL of the key loaded from the recovery blob.

--allow-dh-unknown-sg-group

This option allows an operation to proceed even if a Diffie-Hellman key is using an unrecognized Sophie-Germain group.

7.6.2. Output

Output returned from `nfmverify` can take a variety of forms, depending on the parameters of the given key generation certificate, Security World, and key concerned. Examples of possible output resulting from several different situations are provided below.

Under normal circumstances, issuing a command of the form:

```
nfmverify --verbose --unverifiable myapp 020010621a13h25m02
```

returns output of the form:

```
** [Security world] **
 1 Administrator Cards
   (Currently in Module #1 Slot #0: Card #1)
   Cardset recovery ENABLED
   Passphrase recovery disabled
   Strict FIPS 140 level 3 (does not improve security) disabled
   SEE application nonvolatile storage disabled
   real time clock setting disabled
   SEE debugging disabled
   Generating module ESN 0A42-E645-7A75 currently #1 (in same incarnation)
** [Application key myapp 020010621a13h25m02] **
   [Named 'test Thu, 21 Jun 2001 13:25:02 +0100']
   Useable by HOST applications.
   Recovery ENABLED.
   MODULE-ONLY protection
   Type RSAPrivate 1024 bits keygenparams.type= RSAPrivate 2
     .params.rsaprivate.flags= none 0x00000000
                                   .lenbits= 0x00000400 1024
                                   .given_e absent
                                   .nchecks absent

   Generating module ESN 0A42-E645-7A75 currently #1 (in same incarnation)
   nCore hash 23a901f3329aa9e29cd79d3bb7b32d549b725fc3
   public_half.type= RSAPublic 1
     .data.rsapublic.e= 4 bytes
                                   00010001

                                   .n= 128 bytes
8a6ab219 183de558 48c8379e 840895ff 0ba64bae 392848c6 c0aeb7f9 d10b046d
4a214b70 4878b518 8e599c69 1cd61db0 bab4f852 425c70f5 b9c000e5 4ceda15f
c062b5dd 01852380 f70275a1 870a6947 68ef59f0 db5d2e84 d6ae8dc1 7542e94d
adedece8 cb3c9fb6 98fab8af 52c94137 a76ab7dd 38648134 0df55ca8 2f45e8b7

Verification successful, check details above.
```

Output of the form shown above indicates successful verification of the relevant key generation certificate.

The following examples indicate forms of output that could be returned if you try to verify the generation certificate of a key generated in a Security World that was created with an insufficiently up-to-date version of Security World for nShield.

In such a case, issuing a command of the form:

```
nfmverify --verbose myapp spong
```

returns output of the form:

```
PROBLEM: no world generation certificates
PROBLEM: application key myapp spong: no key generation signature
2 issues found, NOT VERIFIED
```

Adding the **--unverifiable** option to the same command:

```
nfmverify --verbose --unverifiable myapp spong
```

returns output of the form:

```
PROBLEM: application key myapp spong: no key generation signature
1 issues found, NOT VERIFIED
```

Then, also adding the **--force** option to this same command:

```
nfmverify --force --verbose --unverifiable myapp spong
```

returns output of the form:

```
PROBLEM: application key myapp spong: no key generation signature
PROBLEMS BUT FORCING POSSIBLY-WRONG OUTPUT
** [Security world] **
  UNVERIFIED SECURITY WORLD !
    proceeding anyway as requested
** [Application key myapp spong] **
  [Not named]
    Useable by HOST applications.
    Recovery ENABLED.
    MODULE-ONLY protection

1 issues found, NOT VERIFIED
```

7.7. see-*--serv utilities

This section describes the usage and available options for the host-side utilities that Entrust supplies to enable standard IO and socket connections for SEE machines using the **bsdlib** /**glibc** architecture:

- **see-sock-serv**, for SEE machines that require only sockets.
- **see-stdoe-serv**, for SEE machines that require only standard output and error streams.
- **see-stdioe-serv**, for SEE machines that require standard input, output, and error streams.



If you are using a nShield Connect, you must set the **--no-feature-check** option when running the **see-stdoe-serv** utility.

- **see-stdioesock-serv**, for SEE machines that require sockets in addition to standard input, output, and error streams.

Each of the 4 supplied utilities has the capability to:

- Load the SAR file for the SEE machine
- Load the mandatory **userdata** file
- Provide a selection of socket and I/O streams

SEE machines that require the standard I/O streams or INET domain sockets must be serviced by one of the described host-side utilities. Without an appropriate host-side utility, SEE machine operations requiring any of these streams are blocked until the appropriate service becomes available.



Ensure that you select the appropriate utility for your SEE machine, because running a host-side utility with more provisions than the SEE machine was linked against causes the SEE machine to abort.

7.7.1. Usage

All the **see-*-serv** host-side utilities take the same arguments:

```
see-sock-serv -p <PUBL-NAME> | -o <KEYID> | -M <MACHINE>.sar
see-stdoe-serv -p <PUBL-NAME> | -o <KEYID> | -M <MACHINE>.sar
see-stdioe-serv -p <PUBL-NAME> | -o <KEYID> | -M <MACHINE>.sar
see-stdioesock-serv -p <PUBL-NAME> | -o <KEYID> | -M <MACHINE>.sar
```

-M|--machine=<MACHINE>.sar

This option specifies SEE machine file (packed as a SAR). If you do not specify this option, the SEE machine must have been loaded previously by, for example, running the **loadmache** command-line utility. (See [loadmache](#).)

--userdata-sar <USERDATA>.sar

This option specifies the name of the **userdata** file (packed as a SAR) to be passed to SEE machine.

--userdata-raw <USERDATAFILE>

This option specifies the name of an unpacked **userdata** file to be passed to SEE machine.



The raw file is internally made into an unsigned SAR file.

-p|--published-object=<NAME>

This option specifies the **PublishedObject** name to use for publishing the **KeyID** of the started SEE machine.

-o|--object-id=<NAME>

This option specifies the **KeyID** of the started SEE machine.

-m|--module=<MODULE>

This option specifies an HSM onto which the SEE machine is to be loaded.



Use the **enquiry** command-line utility to get information about an HSM. For more information, see the *User Guide*.

--job-prefix <PREFIX>

This option is for debugging. For the host-side utilities that provide a single service (that is, **see-sock-serv**, **see-stdoe-serv**, and **see-stdioe-serv**), specifying this option forces the service to use the job prefix specified by **<PREFIX>**.

--trace

Specifying this option polls the Security World's trace buffer. The contents are printed to **stderr** in dark red.



If the configuration of the Security World requires it, you must supply authorization to poll the trace buffer when specifying this option. The **see-*-serv** host-utility prompts you to supply authorization if it is required.

--plain-trace

This option functions like the **--trace** option to poll the Security World's trace buffer, but the output from **--plain-trace** is not surrounded by terminal escape codes.

-f|--no-feature-check

Specifying this option suppresses the default behavior of the `see-*-serv` host-side utilities to ensure that the HSM specified by the `-m|--module=<MODULE>` option has the `Has-SEE` flag and the `GeneralSEE` feature before the utility tries to load an SEE machine.



If you are using a nShield Connect, you must set the `--no-feature-check` option when running the `see-stdoe-serv` utility.

-r|--restrict

This option only permits userdata and machine-image files from the `nc-seemachines` or the `custom-seemachines` subdirectories of the `/opt/nfast` (**Linux**) or `%NFAST_HOME%` (**Windows**) directory to be loaded. When userdata is loaded automatically by a privileged account, this option should be specified, for extra security.

7.7.2. Error output from SEE machine with SEElib architecture

You cannot use the `see-*-serv` host-side utilities to load SEE machines built with the `SEElib` architecture. If you try to do so, the utility returns a message similar to

```
FATAL: SeeHostCallProvision_Init (prefix 'nC/HC/sock/INET ') failed:
SeeHostcallProvisionFailed
```

This is the expected behavior caused by the host utility sending `SEEJobs` that the SEE machine cannot understand or to which it cannot respond correctly.

You can use the `loadmache` command-line utility to manually load SEE machines built with the `SEElib` architecture.

7.8. stattree

The `stattree` utility returns the statistics gathered by the hardserver and HSMs.

7.8.1. Usage

```
stattree [<node> [<node> [...]]]
```

7.8.2. Output

Running the `stattree` utility displays a snapshot of statistics currently available on the host

machine. Statistics are gathered both by the hardserver (relating to the server itself, and its current clients) and by each attached HSM.

Times are listed in seconds. Other numbers are integers, which are either real numbers, IP addresses, or counters. For example, a result `-CmdCount 74897` means that there have been 74,897 commands submitted.

A typical fragment of output from `stattree` looks like this:

```
+PerModule:
  +#1:
    +ModuleObjStats:
      -ObjectCount      5
      -ObjectsCreated   5
      -ObjectsDestroyed  0
    +ModuleEnvStats:
      -MemTotal          15327232
      -MemAllocKernel    126976
      -MemAllocUser      0
    +ModuleJobStats:
      -CmdCount          169780
      -ReplyCount        169778
      -CmdBytes          3538812
      -ReplyBytes        4492764
      -HostWriteCount     169772
      -HostWriteErrors    0
      -HostReadCount      437472
      -HostReadErrors     0
      -HostReadEmpty      100128
      -HostReadDeferred   167578
      -HostReadTerminated 0
      -PFNIssued          102578
      -PFNRejected        1
      -PFNCompleted       102577
      -ANIssued           1
      -CPULoadPercent     0
    +ModuleSerialStats:
      -HostReadCount      437476
      -HostReadDeferred   167580
      -HostReadReconnect  167579
      -HostReadErrors     0
      -HostWriteCount     169774
      -HostWriteErrors    0
```

`PerModule`, `ModuleObjStats`, and `ModuleEnvStats` are node tags that identify classes of statistics. `1` identifies an instance node.

`ObjectCount`, `MemTotal`, and the remaining items at the same level are statistics IDs. Each has a corresponding value.

If `<node>` is provided, `stattree` uses the value given as the starting point of the tree and displays only information at or below that node in the tree. Values for `<node>` can be numeric or textual. For example, to view the object counts for local HSM number 3:

```
$ stattree PerModule 3 ModuleObjStats
+PerModule:
```

```

+#3:
  ++ModuleObjStats:
    -ObjectCount      6
    -ObjectsCreated    334
    -ObjectsDestroyed  328

```

The value of `<node>` must be a node tag; it must identify a node in the tree and not an individual statistic. Thus, the following command does not work:

```

$ stattree PerModule 3 ModuleObjStats ObjectCount
+#PerModule:
  +#3:
    ++ModuleObjStats:
      Unable to convert 'ObjectCount' to number or tag name.

```

7.8.2.1. Node tags

These hold statistics for each HSM:

| Category | Contains |
|--------------------------|--|
| ModuleJobStats | This tag holds statistics for the Security World Software commands (jobs) processed by this HSM. |
| ModulePCISStats | This tag holds statistics for the PCI connection between the HSM and the host computer. It does not apply to nShield Edge HSMs. |
| ModuleSerialStats | This tag is for nShield Edge HSMs only. It holds statistics for the serial connection between the HSM and the host computer. |
| ServerGlobals | Aggregate statistics for all commands processed by the hardserver since it started. The standard statistics (as described below) apply to the commands sent from the hardserver to HSMs. Commands processed internally by the server are not included here. The Uptime statistic gives the total running time of the server so far. |
| Connections | Statistics for connections between clients and the hardserver. There is one node for each currently active connection. Each node has an instance number that matches the log message generated by the server when that client connected. For example, when the hardserver message is Information: New client #24 connected , the client's statistics appear under node #24 in the stattree output. |
| PerModule | Statistics kept by the HSMs. There is one instance node for each HSM, numbered using the standard HSM numbering. The statistics provided by each HSM depend on the HSM type and firmware version. |
| ModuleObjStats | Statistics for the HSM's Object Store, which contains keys and other resources. These statistics may be useful in debugging applications that leak key handles, for example. |

| Category | Contains |
|----------------|---|
| ModuleEnvStats | General statistics for the HSM's operating environment. |
| HostEnvStats | Environmental statistics for the HSM. |
| HostSysInfo | Further statistics for the HSM. |

7.8.2.2. Statistics IDs

| ID | Value |
|--------------------|---|
| Uptime | The length of time (in seconds) since an HSM was last reset, the hardserver was started, or a client connection was made. |
| CmdCount | The total number of commands sent for processing from a client to the server, or from the server to an HSM. Contains the number of commands currently being processed. |
| ReplyCount | The total number of replies returned from server to client, or from HSM to server. |
| CmdBytes | The total length of all the command blocks sent for processing. |
| ReplyBytes | The total length of all the reply blocks received after completion. |
| CmdMarshalErrors | The number of times a command block was not understood when it was received. A nonzero value indicates either that the parties at each end of a connection have mismatched version numbers (for example, a more recent hardserver has sent a command to a less recent HSM that the HSM does not understand), or that the data transfer mechanism is faulty. |
| ReplyMarshalErrors | The number of times a reply was not understood when it was received. A nonzero value indicates either that the parties at each end of a connection have mismatched version numbers (for example, a more recent hardserver has sent a command to a less recent HSM that the HSM does not understand), or that the data transfer mechanism is faulty. |
| ClientCount | The number of client connections currently made to the server. This appears in the hardserver statistics. |
| MaxClients | The maximum number of client connections ever in use simultaneously to the hard server. This gives an indication of the peak load experienced so far by the server. |
| DeviceFails | The number of times the hardserver has declared a device to have failed. The hardserver provides a diagnostic message when this occurs. |
| DeviceRestarts | The number of times the hardserver has attempted to restart an HSM after it has failed. The hardserver provides a Notice message when this occurs. The message does not indicate that the attempt was successful. |

| ID | Value |
|--------------------------|--|
| QOutstanding | The number of commands waiting for an HSM to become available on the specified client connection. When an HSM accepts a command from a client, this number decreases by 1 and DevOutstanding increases by 1. Commands that are processed purely by the server are never included in this count. |
| DevOutstanding | The number of commands sent by the specified client that are currently executing on one or more HSMs. When an HSM accepts a command from a client, this number decreases by 1 and QOutstanding increases by 1. Commands that are processed purely by the server are never included in this count. |
| LongOutstanding | The number of LongJobs sent by the specified client that are currently executing on one or more HSMs. When an HSM accepts a LongJobs command from a client, this number increases by 1 and QOutstanding decreases by 1. Commands that are processed purely by the server are never included in this count. |
| RemoteIPAddress | The remote IP address of a client who has this connection. A local client has the address 0.0.0.0. |
| HostWriteCount | The number of write operations (used to submit new commands) that have been received by the HSM from the host machine. One write operation may contain more than one command block. The operation is most efficient when this is the case. |
| HostWriteErrors | The number of times the HSM rejected the write data from the host. A nonzero value may indicate that data is being corrupted in transfer, or that the hard-server/device driver has got out of sync with the HSM's interface. |
| HostWriteBadData | Not currently reported by the HSM. Attempts to write bad data to the HSM are reflected in HostWriteErrors . |
| HostWriteOverruns | Not currently reported by the HSM. Write overruns are reflected in HostWriteErrors . |
| HostWriteNoMemory | Not currently reported by the HSM. Write failures due to a lack of memory are reflected in HostWriteErrors . |
| HostReadCount | The number of times a read operation to the HSM was attempted. The HSM can defer a read if it has no replies at the time, but expects some to be available later. Typically the HSM reports HostReadCount in two places: the number under ModuleJobStats counts a deferred read twice, once when it is initially deferred, and once when it finally returns some data. The number under ModulePCISStats counts this as one operation. |
| HostReadErrors | The number of times a read to an HSM failed because the parameters supplied with the read were incorrect. A nonzero value here typically indicates some problem with the host interface or device driver. |
| HostReadEmpty | The number of times a read from the HSM returned no data because there were no commands waiting for completion. In general, this only happens infrequently during HSM startup or reset. It can also happen if PauseForNotifications is disabled. |

| ID | Value |
|--------------------|---|
| HostReadUnderruns | Not currently reported by the HSM. |
| HostReadDeferred | The number of times a read operation to the HSM was suspended because it was waiting for more replies to become available. When the HSM is working at full capacity, a sizeable proportion of the total reads are likely to be deferred. |
| HostReadTerminated | The number of times an HSM had to cancel a read operation which has been deferred. This normally happens only if the clear key is pressed while the HSM is executing commands. Otherwise it might indicate a device driver, interface, or firmware problem. |
| PFNIssued | The number of PauseForNotifications commands accepted by the HSM from the hardserver. This normally increases at a rate of roughly one every two seconds. If the hardserver has this facility disabled (or a very early version), this does not occur. |
| PFNRejected | The number of PauseForNotifications commands rejected by the HSM when received from the hardserver. This can happen during HSM startup or reset, but not in normal use. It indicates a hardserver bug or configuration problem. |
| PFNCompleted | The number of PauseForNotifications commands that have been completed by the HSM. Normally, this is one less than the PFNIssued figure because there is normally one such command outstanding. |
| ANIssued | The number of Asynchronous Notification messages issued by the HSM to the hardserver. These messages indicate such things as the clear key being pressed and the HSM being reset. In later firmware revisions inserting or removing the smartcard or changing the non-volatile memory also generate asynchronous notifications. |
| ChanJobsIssued | The number of fast channel jobs issued to the HSM. The fast channel facility is unsupported on current HSMs. This number should always be 0. |
| ChanJobsCompleted | The number of fast channel jobs completed by the HSM. The fast channel facility is unsupported on current HSMs. This number should always be 0. |
| CPUloadPercent | The current processing load on the HSM, represented as a number between 0 and 100. Because an HSM typically contains a number of different types of processing resources (for example, main CPU, and RSA acceleration), this figure is hard to interpret precisely. In general, HSMs report 100% CPU load when all RSA processing capacity is occupied; when performing non-RSA tasks the main CPU or another resource (such as the random number generator) can be saturated without this statistic reaching 100%. |
| HostIRQs | On PCI HSMs, the total number of interrupts received from the host. On current HSMs, approximately equal to the total of HostReadCount and HostWriteCount . |
| ChanJobErrors | The number of low-level (principally data transport) errors encountered while processing fast channel jobs. Should always be 0 on current HSMs. |

| ID | Value |
|--------------------------------|---|
| <code>HostDebugIRQs</code> | On PCI HSMs, the number of debug interrupts received. This is used only for driver testing, and should be 0 in any production environment. |
| <code>HostUnhandledIRQs</code> | On PCI HSMs, the number of unidentified interrupts from the host. If this is nonzero, a driver or PCI bus problem is likely. |
| <code>HostReadReconnect</code> | On PCI HSMs, the number of deferred reads that have now completed. This should be the same as <code>HostReadDeferred</code> , or one less if a read is currently deferred. |
| <code>ObjectsCreated</code> | The number of times a new object has been put into the object store. This appears under the HSM's <code>ModuleObjStats</code> node. |
| <code>ObjectsDestroyed</code> | The number of items in the HSM's object store that have been deleted and their corresponding memory released. |
| <code>ObjectCount</code> | The current number of objects (keys, logical tokens, buffers, SEE Worlds) in the object store. This is equal to <code>ObjectsCreated</code> minus <code>ObjectsDestroyed</code> . An empty HSM contains a small number of objects that are always present. |
| <code>CurrentTempC</code> | The current temperature (in degrees Celsius) of the HSM main circuit board. First-generation HSMs do not have a temperature sensor and do not return temperature statistics. |
| <code>MaxTempC</code> | The maximum temperature recorded by the HSM's temperature sensor. This is stored in non-volatile memory, which is cleared only when the HSM is initialized. First-generation HSMs do not have a temperature sensor and do not return temperature statistics. |
| <code>MinTempC</code> | The minimum temperature recorded by the HSM's temperature sensor. This is stored in non-volatile memory, which is cleared only when the HSM is initialized. First-generation HSMs do not have a temperature sensor and do not return temperature statistics. |
| <code>MemTotal</code> | The total amount of RAM (both allocated and free) available to the HSM. This is the installed RAM size minus various fixed overheads. |
| <code>MemAllocKernel</code> | The total amount of RAM allocated for kernel (that is, non-SEE) use in an HSM. This is principally used for the object store (keys, logical tokens, and similar) and for big-number buffers. |
| <code>MemAllocUser</code> | The total amount of RAM allocated for user-mode processes in the HSM (0 for non-SEE use). This includes the size of the SEE Machine image, and the total heap space available to it. The HSM's kernel does not know (and does not report in the statistics) how much of the user-mode's heap is currently free, and how much is in use. |
| <code>SystemFans</code> | The fan speed (RPM) for each fan in the HSM. |

7.9. tct2

The **tct2** command-line utility (also referred to as the Trusted Code Tool) enables users to sign, pack, and encrypt file archives so that they can be loaded onto an SEE-Ready nShield HSM. **tct2** creates SAR files.

tct2 uses keys that are protected by a Security World or an OCS.



Examples of how **tct2** can be used are provided in [Example SEE machines](#).



Encrypted SEE machines are not currently supported for use with nShield Connect HSMs. When the **SEEMachine** binary is installed on the Connect itself for automated loading at boot, the SEE Confidentiality key is not available. However, when a client host loads a **SEEMachine**, it has access to the SEE Confidentiality key and can cause the binary to be decrypted. In this scenario, the Connect works fine with encrypted **SEEMachine** binaries.



Check the documentation supplied by the application vendor to see if you need to use **tct2** to set up and use the application.

7.9.1. Usage

```
tct2 [[-S|--sign] | [-P|--pack] | [-E|--encrypt] | [--add-sig] | [--sign-and-pack] | [--print-sigs] | [--unpack-skycert] | [--unpack-sar-payload]] [--sigfile=<NAME> ] [-k|--key=<IDENT>] [--is-machine] | [--machine-key=<HASH>]] [--machinekey-ident=<IDENT> ] [-T|--machine-type=<TYPE>]] [-m|--module=<MODULE> ] [-o|--outfile=<OUTFILE>] [--non-interactive] [--show-metadata] [-v|--verbose] [-q|--quiet] [[-i|--infile=<INFILE>]]
```

7.9.1.1. Help options

-h|--help

These options display help for **tct2**.

-V|--version

These options display the version number of **tct2**.

-u|--usage

These options display a brief usage summary for **tct2**.

7.9.1.2. Program options

-S|--sign

These options create a signature on the file specified by `--infile=<INFILE>`. You must specify `--key=<IDENT>` and one of `--is-machine`, `--machine-key=<HASH>`, `--machine-key-ident=<IDENT>`.

-P|--pack

These options pack the file specified by `--infile=<INFILE>` and any signatures specified by `--sigfile=<NAME>` into a SAR file specified by `--outfile=<OUTFILE>`. When creating an SEE machine image, the input file is a `.SXF` file produced by the `elftool` utility. When creating a SEE user data file, the input format is determined by the SEE machine type.

-E|--encrypt

These options encrypt the packed SAR file specified by `--infile=<INFILE>`. `--key=<IDENT>` must be specified.



Encrypted SEE machines are not currently supported for use with nShield Connects. When the `SEEMachine` binary is installed on the Connect itself for automated loading at boot, the SEE Confidentiality key is not available. However, when a client host loads a `SEEMachine`, it has access to the SEE Confidentiality key and can cause the binary to be decrypted. In this scenario, the Connect works fine with encrypted `SEEMachine` binaries.

--add-sig

This option creates a signed SAR file specified by `--outfile=<OUTFILE>` from the unsigned SAR file specified by `--infile=<INFILE>` and the key specified by `--key=<IDENT>`.

--sign-and-pack

This option creates a signature on the file specified by `--infile=<INFILE>` using `--key=<IDENT>` and one of `--is-machine`, `--machine-key=<HASH>`, or `--machine-key-ident=<IDENT>`, then to pack it in the file specified by `--outfile=<OUTFILE>`.

--print-sigs

This option displays the key hashes used to sign the SAR file specified by `--infile=<INFILE>`.

--unpack-sar-payload

This option retrieves the payload of the SAR file specified by `--infile=<INFILE>`.

7.9.1.3. Packing and signing options

--sigfile=<NAME>

This option specifies the file that contains the signature. This option can be repeated to specify multiple signatures.

7.9.1.4. Machine key specification options for signing operations

--is-machine

This option specifies SEE machine signing mode.

--machine-key=<HASH>

This option specifies the key hash of the SEE machine for which this signature is good.

--machine-key-ident=<IDENT>

This option retrieves the hash of key **<IDENT>** then behaves like **--machine-key=<HASH>**. Only one machine key specification option can be specified.

-T|--machine-type=<TYPE>

These options specify the SEE machine type. You can specify the appropriate machine type parameter (**<TYPE>**) for **tct2** as a string or a number:

| SEE Machine Type | tct2 machine type parameter |
|------------------|-----------------------------|
| PowerPCSXF | PowerPCSXF or 2 |
| PowerPCELF | PowerPCELF or 5 |

If you are not sure which SEE machine type is appropriate for your HSM, run the enquiry command-line utility, and check the **SEE Machine Type** output.

If you do not specify an SEE machine type with this option, **tct2** tries to determine the appropriate type by reading the format of the code to be signed. If **tct2** cannot determine the appropriate SEE machine type, it returns an error message. In such a case, run **tct2** again, explicitly setting the SEE machine type with this option.

7.9.1.5. Other options

-m|--module=<MODULE>

These options specify the HSM to use (where *MODULE* is an HSM number). The default is **1**.

-i|--infile=<INFILE>.

These options specify the name of the input **.sxf** file. You can also specify the input file without the using **--infile** option by including the file name at the end of the command.

-o|--outfile=<OUTFILE>

These options specify the name of the output **.sar** file to create. This option is valid only with the program options that create an output file, as described in [Program options](#).

--non-interactive

This option sets non-interactive mode. This means that, if you have not already loaded any required card sets, **tct2** fails (instead of prompting you to load any required card sets).

--show-metadata

This option shows image metadata before signing.

-v|--verbose

These options increase the verbosity level. These options can be repeated.

-q|--quiet

These options decrease the verbosity level. These options can be repeated.

7.9.2. Signing

Use one of the following methods to create a signing key:

- During the KeySafe key-generation process, ensure you select the **SEE Code Integrity** option.
- When generating the key with the **generatekey** command-line utility, ensure you select the application type **seeinteg**.

Signing keys can be DSA or RSA. You can sign a file any number of times using different signing keys.



For information about key application types, see [Key application type \(APPNAME\)](#).



For information about generating keys, see the *User Guide*.

To create a signature, give a command of the form:

```
tct2 -S|--sign [-m|--module=<MODULE>] -k|--key=<IDENT> [--machine-key=<HASH>| --machine-key-ident=<IDENT> | --is-machine] -o|--outfile=<OUTFILE> [-i|--infile=<INFILE>]
```

If the signing key is protected by an OCS, **tct2** prompts you for the passphrase for the inserted card.

7.9.3. Packing

All files must be packed even if you are not adding signatures. The packing operation must be performed once and only once. Your application vendor may have supplied a pre-packed SAR file.

Packing a file creates a new SAR file. The packed file contains:

- The original file
- Specified signatures, if any.

To pack a file and any signatures, give a command of the form:

```
tct2 -P|--pack -o|--outfile=<OUTFILE> [-i|--infile=<INFILE>] [sigfile...]
```

7.9.4. Encryption



Encrypted SEE machines are not currently supported for use with nShield Connects. When the **SEEMachine** binary is installed on the Connect itself for automated loading at boot, the SEE Confidentiality key is not available. However, when a client host loads a **SEEMachine**, it has access to the SEE Confidentiality key and can cause the binary to be decrypted. In this scenario, the Connect works fine with encrypted **SEEMachine** binaries.

Use one of the following methods to create an encryption key:

- During the KeySafe key-generation process, ensure you select the **SEE Code Confidentiality** option.
- When generating the key with the **generatekey** command-line utility, ensure you select the application type **seeconf**.

Encryption keys can be either Triple DES or AES keys. Encryption keys can be protected by the Security World or by a 1/N OCS.



For information about key application types, see [Key application type](#)

(APPNAME).



For information about generating keys, see the *User Guide*.

A **.sar** file can be encrypted only once. To encrypt a **.sar** file, use the command:

```
tct2 -E|--encrypt -k|--key=<IDENT> [-m|--module=<MODULE>] -o|--outfile=<OUTFILE> [-i|--infile=<INFILE>]
```

8. Environment variables

This appendix describes the environmental variables used by Security World Software to control SEE functionality:

| Variable | Description |
|---|---|
| <code>NFAST_SEE_MACHINEENCKEY_DEFAULT</code> | This variable is the name of the <code>SEEConf</code> key needed to decrypt SEE-machine images. Running the command <code>loadmache --encryptionkey=<IDENT></code> (or <code>loadmache --unencrypted</code>) overrides any value set by this variable. |
| <code>NFAST_SEE_MACHINEENCKEY_<module></code> | This variable is the name of the <code>SEEConf</code> key needed to decrypt the SEE-machine image targeted for the specified HSM. It overrides <code>NFAST_SEE_MACHINEENCKEY_DEFAULT</code> for the specified HSM. Running the command <code>loadmache --encryptionkey=<IDENT></code> (or <code>loadmache --unencrypted</code>) overrides any value set by this variable. |
| <code>NFAST_SEE_MACHINEIMAGE_DEFAULT</code> | This variable is the path of the SEE machine image to load on to any HSM for which a specific image is not defined. Supplying the <i>machine-filename</i> parameter when running the <code>loadmache</code> command-line utility overrides this variable. This variable is not affected when running the <code>loadsee-setup</code> or <code>hsc_loadseemachine</code> utilities. |
| <code>NFAST_SEE_MACHINEIMAGE_<module></code> | This variable is the path of the SEE machine image to load on to the specified HSM. If set, this variable overrides the use of <code>NFAST_SEE_MACHINEIMAGE_DEFAULT</code> for the specified HSM. Supplying the <i>machine-filename</i> parameter when running the <code>loadmache</code> command-line utility overrides the <code>NFAST_SEE_MACHINEIMAGE_<module></code> variable. This variable is not affected when running the <code>loadsee-setup</code> or <code>hsc_loadseemachine</code> utilities. |
| <code>NFAST_SEE_MACHINESIGHASH_DEFAULT</code> | This variable is the default key hash of the vendor signing key (<code>seeinteg</code>) that signs SEE machine images. This variable is only required if you are using a dynamic SEE feature with an encrypted SEE machine. Running the command <code>loadmache --sighash=<HASH></code> any value set in this variable. |

| Variable | Description |
|--|---|
| <code>NFAST_SEE_MACHINESIGHASH_<module></code> | This variable is the key hash of the vendor signing key (<code>seeinteg</code>) that signs SEE machine images for the specified HSM. It overrides <code>NFAST_SEE_MACHINESIGHASH_DEFAULT</code> for the specified HSM. This variable is only required if you are using a dynamic SEE feature with an encrypted SEE machine. Running the command <code>loadmache --sighash=<HASH></code> any value set in this variable. |



Windows-only

When the hardserver is running normally as a service, these are System variables only; not the User Variables. The hardserver checks first for these variables, but if any given value is not set in the environment, the hardserver next searches for a string value in the Registry under `HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\nFast Server\Environment`.

For information on additional (non-SEE) environment variables used by Security World Software, see the *User Guide*.

9. Key generation options and parameters

This appendix describes the various options and parameters that you can set when running the `generatekey` utility to control the application type and other properties of a key being generated.



For information about generating keys with the `generatekey` utility, see the *User Guide*.

9.1. Key application type (<APPNAME>)

The <APPNAME> parameter specifies the name of the application for which `generatekey` can generate keys. Specifying an application can restrict your choice of key type. A value for <APPNAME> must follow any <OPTIONS> and must precede any parameters specified for the key:

| Parameter | Description |
|---------------------|---|
| <code>simple</code> | Specifying the <code>simple</code> application type generates an nShield-native key. No special action is taken after the key is generated. |
| <code>custom</code> | <p>Specifying the <code>custom</code> application type generates a key for custom applications that require the key blob to be saved in a separate file.</p> <p>Specifying <code>custom</code> also causes the generation of a certificate request and self-signed certificate. However, we recommend that you specify the <code>simple</code> (instead of <code>custom</code>) application type whenever possible.</p> |
| <code>pkcs11</code> | <p>Specifying the <code>pkcs11</code> application type generates keys that are formatted for use with PKCS #11 applications and are given a suitable identifier. The set of possible supported key types is currently limited to:</p> <ul style="list-style-type: none"> • <code>DES3</code> • <code>DH</code> • <code>DSA</code> • <code>ECDH</code> • <code>ECDSA</code> • <code>HMACSHA1</code> • <code>RSA</code> • <code>Rijndael (AES)</code> <p>Some key types are only available if the features that support them have been enabled for the HSM, if the Security World is not compliant with FIPS 140 Level 3, or if you do not set the <code>--no-verify</code> option.</p> |

| Parameter | Description |
|-----------------------|--|
| <code>embed</code> | <p>Specifying the <code>embed</code> application type generates a key for use with CHIL applications that:</p> <ul style="list-style-type: none"> • Do not support <code>hwcrhk</code> key storage • Have a key importation facility capable of reading PEM-format RSA key files. <p>Specify the <code>hwcrhk</code> application type for CHIL applications that support <code>hwcrhk</code> key storage.</p> <p>You can use a key of the <code>embed</code> application type like a PEM-format RSA/DSA key file, even though it is really a specially encoded reference to a key stored in <code>opt/nfast/kmdata/local</code> (Linux) or <code>%NFAST_KMDATA%\local</code> (Windows). This allows you to use an <code>embed</code> key when integrating with applications that normally require software RSA keys. For example, you can supply an <code>embed</code> key to the patched version of OpenSSL we have provided so that it uses the HSM to access the key rather than using its own built-in RSA operations.</p> |
| <code>hwcrhk</code> | Specifying the <code>hwcrhk</code> application type generates a key for Cryptographic Hardware Interface Library (CHIL) applications that do not require <code>embed</code> keys. Only <code>RSA</code> , <code>DSA</code> , and <code>DH</code> key types are supported |
| <code>kpm</code> | Specifying the <code>kpm</code> application type generates a key for delivery by an nForce Ultra key server. The <code>generatekey</code> utility automatically creates a special ACL entry that permits a <code>kpm</code> to be delivered to an nForce Ultra's enrolled internal hardware security module. |
| <code>seeinteg</code> | Specifying the <code>seeinteg</code> application type generates an SEE integrity key. The DSA, RSA, ECDSA and KCDSA algorithms are supported. SEE integrity keys are always protected by an OCS and cannot be imported. You cannot retarget an existing key as an SEE integrity key. |
| <code>seeconf</code> | Specifying the <code>seeconf</code> application type generates an SEE confidentiality key. Both the Triple DES and AES algorithms are supported for this key type. SEE confidentiality keys are HSM-protected by default and cannot be imported. You cannot retarget an existing key as an SEE confidentiality key. |

9.2. Key properties (<NAME> = <VALUE>)


The <NAME> = <VALUE> syntax is used to specify the properties of the key being generated.



If a parameter's argument contains spaces, you must enclose the argument within quotation marks (" ").

You can supply an appropriate <VALUE> for the following *NAME* options:

| Option | Description |
|----------------------------|---|
| <code>alias</code> | The <code><VALUE></code> for <code>alias</code> specifies an alias to assign to the key. |
| <code>blobsavefile</code> | When using the <code>custom</code> application type, the <code><VALUE></code> for <code>blobsavefile</code> specifies a file name of the form <code><FILENAME>.ext</code> to which the key blob is saved. Additionally, a text file containing information about the key is saved to a file whose name has the form <code><ROOT>_inf.txt</code> ; for asymmetric key types, the public key blob is also saved to a file whose name has the form <code><ROOT>_pub.ext</code> . |
| <code>cardset</code> | The <code><VALUE></code> for <code>cardset</code> specifies an OCS that is to protect the key (if <code>protect</code> is set to <code>token</code>). In interactive mode, if you do not specify an OCS, you are prompted to select one at card-loading time. The default is the OCS to which the card currently inserted in the slot belongs (or the first one returned by <code>nfkminfo</code>). |
| <code>certreq</code> | <p>Setting <code>certreq</code> enables you to generate a certificate request when generating a PKCS #11 key (RSA keys only). The default behavior is to not generate a certificate request.</p> <p>To generate a certificate request you must set the <code><VALUE></code> for <code>certreq</code> to <code>yes</code>, which makes <code>generatekey</code> prompt you to fill in the extra fields required to generate a key with a certificate request. The resultant certificate request is saved to the current working directory with a file name of the form <code><FILENAME>_req.ext</code> (where <code>FILENAME</code> is a name of your choice).</p> <p>An extra file with a name of the form <code><FILENAME>.ext</code> is also generated for use as a pseudo-key-header. This file can be removed after the certificate request has been generated. You can use <code>certreq</code> with the <code>--retarget</code> option to generate a self-signed certificate for an existing key.</p> |
| <code>checks</code> | For RSA key generation only, this specifies the number of checks to be performed. Normally, you should leave <code><VALUE></code> empty to let the HSM pick an appropriate default. |
| <code>curve</code> | For ECDH and ECDSA key generation only, the <code><VALUE></code> for <code>curve</code> specifies which curves from the supported range to use. Supported curves are: NISTP192, NISTP224, NISTP256, NISTP384, NISTP521, NISTB163, NISTB233, NISTB283, NISTB409, NISTB571, NISTK163, NISTK233, NISTK283, NISTK409, NISTK571, ANSIB163v1, ANSIB191v1, SECP160r1 and SECP256k1. |
| <code>embedconvfile</code> | The <code><VALUE></code> for <code>embedconvfile</code> specifies the name of the PEM file that contains the RSA key to be converted. |
| <code>embedsavefile</code> | <p>When using the <code>embed</code> application type, the <code><VALUE></code> for <code>embedsavefile</code> specifies the name for the file where the fake RSA private key is to be saved. The file has the same syntax as an RSA private key file, but actually contains the key identifier rather than the key itself, which remains protected.</p> <p>A certificate request and a self-signed certificate are also written. If the filename is <code><ROOT>.ext</code> then the request is saved to <code><ROOT>_req.ext</code> and the self-signed certificate is saved to <code><ROOT>_selfcert.ext</code>.</p> |

| Option | Description |
|-------------------------------|---|
| <code>from-application</code> | When retargeting a key, the <code><VALUE></code> for <code>from-application</code> specifies the application name of the key to be retargeted. Only applications for which at least one key exists are acceptable. |
| <code>from-ident</code> | When retargeting a key, the <code><VALUE></code> for <code>from-ident</code> specifies the identifier of the key to be retargeted (as displayed by the <code>nfkminfo</code> command-line utility). |
| <code>hexdata</code> | The <code><VALUE></code> for <code>hexdata</code> specifies the hex value of DES or Triple DES key to import. The hex digits are echoed to the screen and can appear in process listings if this parameter is specified on the command line. |
| <code>ident</code> | The <code><VALUE></code> for <code>ident</code> specifies a unique identifier for the key in the Security World. For applications of types <code>simple</code> or <code>hwcrhk</code> , this is the key identifier to use (the exact identifier for <code>simple</code> , for <code>hwcrhk</code> the key type is implicitly included). For other application types, keys are assigned an automatically generated identifier and accessed by means of some application-specific name. |
| <code>keystore</code> | The <code><VALUE></code> for <code>keystore</code> specifies the file name of the key store to use. This must be an nShield key store. |
| <code>keystorepass</code> | The <code><VALUE></code> for <code>keystorepass</code> specifies the password to the key store to use. |
| <code>module</code> | <p>The <code><VALUE></code> for <code>module</code> specifies an HSM to use when generating the key. If there is more than one usable HSM, you are prompted to supply a value for one of them. The default is the first usable HSM (one in the current Security World and in the operational state).</p> <div>  <p>You can also specify an HSM by setting the <code>--module</code> option.</p> </div> |
| <code>paramsreadfile</code> | The <code><VALUE></code> for <code>paramsreadfile</code> specifies the name of the group parameters file that contains the discrete log group parameters for Diffie-Hellman keys only. This should be a PEM-formatted PKCS#3 file. If a <code><VALUE></code> for <code>paramsreadfile</code> is not specified, the HSM uses a default file. |
| <code>pemreadfile</code> | The <code><VALUE></code> for <code>pemreadfile</code> specifies the name of the PEM file that contains the key to be imported. When importing an RSA key, this is the name of the PEM-encoded PKCS #1 file to read it from. Password-protected PEM files are not supported. |
| <code>plainname</code> | The <code><VALUE></code> for <code>plainname</code> specifies the key name within the Security World. For some applications, the key identifier is derived from the name, but for others the name is just recorded in <code>kmdata</code> (Linux) or <code>%NFAST_KMDATA%</code> (Windows) and not used otherwise. |
| <code>protect</code> | The <code><VALUE></code> for <code>protect</code> specifies the protection method, which can be <code>module</code> for Security World protection, <code>softcard</code> for softcard protection or <code>token</code> for Operator Card Set protection. The default is <code>token</code> , except for <code>seeconf</code> keys, where the default is <code>module</code> . <code>seeinteg</code> keys are always token-protected. The <code>softcard</code> option is only available when your system has at least one softcard present. |

| Option | Description |
|----------------------------|--|
| <code>pubexp</code> | For RSA key generation only, the <code><VALUE></code> for <code>pubexp</code> specifies (in hexadecimal for <code>mat</code>) the public exponent to use when generating RSA keys. We recommend leaving this parameter blank unless advised to supply a particular value by Support. |
| <code>recovery</code> | The <code><VALUE></code> for <code>recovery</code> enables recovery for this key and is only available for card-set protected keys in a recovery-enabled world. If set to <code>yes</code> , the key is recoverable. If set to <code>no</code> , key is not recoverable. The default is <code>yes</code> . Non-recoverable HSM-protected keys are not supported. |
| <code>seeintegname</code> | If present, the <code><VALUE></code> for <code>seeintegname</code> identifies a <code>seeinteg</code> key. The ACL of the newly generated private key is modified to require a certificate from the <code>seeinteg</code> key for its main operational permissions, such <code>Decrypt</code> and <code>Sign</code> (<code>DuplicateHandle</code> , <code>ReduceACL</code> , and <code>GetACL</code> are still permitted without certification.) |
| <code>selfcert</code> | The <code><VALUE></code> for <code>selfcert</code> enables you to generate a self-signed certificate when generating a PKCS #11 key (RSA keys only). To generate a self-signed certificate request you must set <code>selfcert</code> to <code>yes</code> , which makes <code>generatekey</code> prompt you to fill in the extra fields required to generate a key with a self-signed certificate. The resultant certificate is saved to the current working directory with a file name of the form <code><FILENAME>.ext</code> . You can use this parameter with the <code>--retarget</code> option to generated a self-signed certificate for an existing key. |
| <code>size</code> | For key types with variable-sized keys, the <code><VALUE></code> for <code>size</code> specifies the key size in bits. The range of allowable sizes depends on the key type and whether the <code>--no-verify</code> option is used. The default depends on the key type; for information on available key types and sizes, see the <i>User Guide</i> . This parameter does not exist for fixed-size keys, nor for ECDH and ECDSA keys which are specified using <code>curve</code> . |
| <code>strict</code> | For DSA key generation only, setting the <code><VALUE></code> for <code>strict</code> to <code>yes</code> enables strict verification, which also limits the size to exactly 1024 bits. The default is <code>no</code> . |
| <code>type</code> | The <code><VALUE></code> for <code>type</code> specifies the type of key. You must usually specify the key type for generation and import (though some applications only support one key type, in which case you are not asked to choose). Sometimes the type must also be specified for retargeting; for information on available key types and sizes, see the <i>User Guide</i> . The <code>--verify</code> option limits the available key types. |
| <code>x509country</code> | The <code><VALUE></code> for <code>x509country</code> specifies a country code, which must be a valid 2-letter code, for the certificate request. |
| <code>x509dnscommon</code> | The <code><VALUE></code> for <code>x509dnscommon</code> specifies a site domain name, which can be any valid domain name, for the certificate request. |
| <code>x509email</code> | The <code><VALUE></code> for <code>x509email</code> specifies an email address for the certificate request. |
| <code>x509locality</code> | The <code><VALUE></code> for <code>x509locality</code> specifies a city or locality for the certificate request. |
| <code>x509org</code> | The <code><VALUE></code> for <code>x509org</code> specifies an organization for the certificate request. |

| Option | Description |
|---------------------------|---|
| <code>x509orgunit</code> | The <VALUE> for <code>x509orgunit</code> specifies an organizational unit for the certificate request. |
| <code>x509province</code> | The <VALUE> for <code>x509province</code> specifies a province for the certificate request. |
| <code>xsize</code> | The <VALUE> for <code>xsize</code> specifies the private key size in bits when generating Diffie-Hellman keys. The defaults are 256 bits for a key size of 1500 bits or more or 160 bits for other key sizes. |

9.3. Available key properties by action

The following table shows which actions are applicable to the different *NAME* options:

| Property | generate | import | retarget |
|-------------------------------|----------|--------|----------|
| <code>alias</code> | X | X | X |
| <code>blobsavefile</code> | X | X | X |
| <code>cardset</code> | X | X | |
| <code>certreq</code> | | | |
| <code>checks</code> | X | | |
| <code>curve</code> | X | | |
| <code>embedconvfile</code> | | X | |
| <code>embedsavefile</code> | X | X | X |
| <code>from-application</code> | | | X |
| <code>from-ident</code> | | | X |
| <code>hexdata</code> | | X | |
| <code>ident</code> | X | X | |
| <code>keysavefile</code> | | | |
| <code>keystore</code> | X | X | X |
| <code>keystorepass</code> | X | X | X |
| <code>module</code> | X | X | |
| <code>nvrnm</code> | X | X | |
| <code>paramsreadfile</code> | X | | |
| <code>pemreadfile</code> | | X | |

| Property | generate | import | retarget |
|---------------|----------|--------|----------|
| plainname | X | X | X |
| protect | X | X | |
| pubexp | X | | |
| qsize | X | | |
| recovery | X | X | |
| seeintegname | | | |
| selfcert | | | |
| size | X | | |
| strict | X | | |
| type | X | | |
| x509country | X | X | X |
| x509dnscommon | X | X | X |
| x509email | X | X | X |
| x509locality | X | X | X |
| x509org | X | X | X |
| x509orgunit | X | X | X |
| x509province | X | X | X |
| xsize | X | | |

9.4. Available key properties by application

The following table shows which applications are applicable to the different *NAME* options:

| Property | custom | embed | hwcrhk | pkcs 11 | seeconf | seeinteg | seessl | simple | kpm |
|--------------|--------|-------|--------|---------|---------|----------|--------|--------|-----|
| alias | | | | | | | | | |
| blobsavefile | X | | | | | | | | |
| cardset | X | X | X | X | | | | X | X |
| certreq | | | | X | | | | | |
| checks | X | X | X | X | | | | X | X |
| curve | X | X | X | X | X | X | | X | |

| Property | custom | embed | hwcrhk | pkcs 11 | seeconf | seeinteg | seessl | simple | kpm |
|------------------|--------|-------|--------|---------|---------|----------|--------|--------|-----|
| embedconvfile | | X | | | | | | | |
| embedsavefile | | X | | X | | | | | |
| from-application | X | X | X | X | | | | X | X |
| from-ident | X | X | X | X | | | | X | X |
| hexdata | X | X | X | X | | | | X | |
| ident | | | X | | | | | X | X |
| keysavefile | | X | | | | | X | | |
| keystore | | | | | | | | | |
| keystorepass | | | | | | | | | |
| module | X | X | X | X | | | X | X | X |
| nvram | X | X | X | X | | | | X | |
| paramsreadfile | X | X | X | X | X | X | | X | |
| pemreadfile | X | | X | | | | | X | X |
| plainname | X | X | | X | X | X | X | X | X |
| protect | X | X | X | X | X | X | X | X | X |
| pubexp | X | X | X | X | | | | X | X |
| qsize | X | X | X | X | | | | X | X |
| recovery | X | X | X | X | X | X | | X | X |
| seeintegname | X | | | | | | | X | |
| selfcert | | | | X | | | | | |
| size | X | X | X | X | X | X | X | X | X |
| strict | X | X | X | X | | | | X | |
| type | X | X | X | X | X | X | X | X | X |
| x509country | | X | | | | | | | X |
| x509dnscommon | | X | | | | | | | X |
| x509email | | X | | | | | | | X |
| x509locality | | X | | | | | | | X |
| x509org | | X | | | | | | | X |
| x509orgunit | | X | | | | | | | X |

| Property | custom | embed | hwcrhk | pkcs 11 | seeconf | seeinteg | seessl | simple | kpm |
|--------------|--------|-------|--------|---------|---------|----------|--------|--------|-----|
| x509province | | X | | | | | | | X |
| xsize | X | X | X | X | | | | X | |

10. SEELib functions

The file `seelib.h` contains wrapper functions for the software interrupts.

10.1. SEELib_init

```
extern void SEELib_init(void);
```

This function initializes the `SEELib` library.

It also checks that the SWI interface that was implemented by the nShield core matches the version that the SEE machine implements.



This function does not return on error.

10.2. SEELib_RecProcessThreads

```
int  
SEELib_RecProcessThreads(void);
```

This function returns the recommended number of processing threads on this system.

10.3. SEELib_StartProcessorThreads

```
struct ProcessThreadCtx; /* User-defined */  
typedef struct SEELib_ProcessContext  
{  
    struct ProcessThreadCtx *uc;  
  
    unsigned char *iobuf;  
    int iobuf_maxlen;  
}  
SEELib_ProcessContext;  
  
typedef struct ProcessThreadCtx * (*SEELib_InitFn) (SEELib_ProcessContext *pC);  
/* Function called during thread initialisation */  
typedef int (*SEELib_ProcessFn) ( SEELib_ProcessContext *pC, M_Word tag, int in_len );  
/* Function to process an SEELib job; data is sent in & out via pC->iobuf.  
Returns length being returned.  
*/  
extern int SEELib_StartProcessorThreads(int nthreads, int stacksize, SEELib_InitFn  
pfnInit, SEELib_ProcessFn pfnProcess);
```

This function causes the SEE library to start a number of processing threads. Each thread has its own `SEELib_ProcessContext` allocated, which remains constant throughout the life

of the thread.

A working buffer for a given thread is allocated; the `iobuf` member points to this buffer and `iobuf_maxlen` is set to the size. Data for the `SEEJob` is passed in and out through this buffer.

For each thread, the supplied `SEEJobInitFn` is called first, and the `ProcessThreadCtx` pointer it returns is stored in the `SEELib_ProcessContext` structure. This structure is typically some convenient thread-local storage. The pointer may be NULL if it is not required.

When a job arrives for the given thread, the supplied `SEEJobFn` is called. It is passed the `SEELib_ProcessContext` pointer `pC`, a tag, and a length (`in_len`). The `SEEJob` data is at `pC→iobuf`, length `in_len`. The tag is merely for information. The function should process the data and leave a reply at `pC→iobuf`. The return value from the function indicates the number of bytes to be returned from this buffer.

10.4. SEELib_GetUserDataLen

```
extern M_Word SEELib_GetUserDataLen (void);
```

This function gets the length in bytes of the `UserData` block that was passed in to create this SEE World. The function returns 0 if the `UserData` block has been freed with `SEELib_ReleaseUserData()`.

10.5. SEELib_ReadUserData

```
extern int SEELib_ReadUserData ( M_Word offset, unsigned char *buf, M_Word len );
```

This function reads selected bytes from the `UserData` block, starting at *offset* bytes in and continuing for *len* bytes. It returns an `M_Status` value.

10.6. SEELib_ReleaseUserData

```
extern void SEELib_ReleaseUserData(void);
```

This function frees the resources associated with the `UserData` block. Typically, if an SEE machine copies the `UserData` block into some internal format on initialization, it should call this function on completion to avoid having two copies of the data in memory.

10.7. SEELib_InitComplete

```
extern void SEELib_InitComplete( M_Word status );
```

This function must be called as soon as the SEE World has been initialized. This call must be made as soon as the SEE World is ready to accept jobs or has decided that it cannot accept jobs.

The **status** value forms the **initstatus** value in the reply to the **CreateSEWorld** nCore API command.

10.8. SEELib_AwaitJob

```
extern int SEELib_AwaitJob( M_Word *tag_out, , unsigned char *buf, M_Word *len_io );
```

This function blocks and waits for the next **SEEJob** in from the nShield core. On entry, ***buf** and ***len_io** give the base and length of a buffer area to receive the job. On return, ***len_io** is set to the length delivered (if the job is received successfully). This buffer is a copy of the **seargs** field that was sent in to the **SEEJob** command.

The ***tag_out** value is the tag for this command. It must be returned in the **SEELib_ReturnJob** so that the nShield core associates the reply with this command.

The **SEELib_AwaitJob** function returns an **M_Status**, which is only likely to be **OK** or **Buffer-Full**.



If you use **SEELib_StartProcessorThreads()**, it calls this function automatically, and you should not call this function yourself.

10.9. SEELib_StartTransactListener

```
extern void SEELib_StartTransactListener(void);
```

This function starts the thread that listens for **SEELib_Transact** calls and dispatches them. This function must be called before any use is made of **SEELib_Transact**.

10.10. SEELib_Transact

```
extern int SEELib_Transact(struct M_Command *cmd, struct M_Reply *buf);
```

This function marshals a command, submits it, waits for the response, and unmarshals it into a reply structure.

10.11. SEELib_MarshalSendCommand

```
extern int SEELib_MarshalSendCommand(M_Command *cmd);
```

This function marshals a command and places it on the input queue for processing by the nShield core.

The command takes a reference to an **M_Command** structure, as described in the *nCore Code-Safe API Documentation*.

The SEE machine can submit any of the nCore API commands listed in the Basic commands and Key-Management commands sections of the *nCore CodeSafe API Documentation* except:

- **RetryFailedModule**
- **GetWhichModule**
- **MergeKeyIDs**.

If the SEE machine attempts to submit one of these commands, the nShield core returns a response with the status code **NotAvailable**.

The **SEELib_MarshalSendCommand** function returns an **M_Status** value. This value is **OK** if the command was marshalled and transferred to the nShield core correctly.



Do not mix calls to **SEE_Transact()** and **SEELib_MarshalSendCommand()** and **SEELib_GetUnmarshalResponse()**, because the replies may be misdirected.

10.12. SEELib_GetUnmarshalResponse

```
extern int SEELib_GetUnmarshalResponse(M_Reply *buf);
```

If there is a reply in the input queue for this SEE World, this function returns the first job in the queue. Otherwise, it blocks and waits for the nShield core to return a job.

On return, **M_Reply** contains the unmarshalled reply.

The **SEELib_GetUnmarshalResponse** function returns an **M_Status** value. This value is **OK** if the

reply was unmarshalled successfully. The return of this value does not necessarily mean that the command was completed successfully, only that the reply was unmarshalled. You must also check the `M_Status` within the reply.

10.13. SEELib_FreeCommand

```
extern int SEELib_FreeCommand(struct M_Command *cmd);
```

This function frees a command structure and is equivalent to the generic stub function `NFastApp_FreeCommand` (described in the *nCore CodeSafe API Documentation*).

10.14. SEELib_FreeReply

```
extern int  
SEELib_FreeReply(struct M_Reply *reply);
```

This function frees a reply structure and is equivalent to the generic stub function `NFastApp_FreeReply` (described in the *nCore CodeSafe API Documentation*).

10.15. SEELib_ReturnJob

```
extern void SEELib_ReturnJob( M_Word tag, const unsigned char *data, unsigned int len );
```

This function returns an `SEELib_ReturnJob` reply to the nShield core so that the core can pass it to the calling application.



If you use the `SEELib_StartProcessorThreads()` function, it calls `SEELib_ReturnJob()` for you.

The tag field must match the tag supplied in the `SEELib_AwaitJob()` call that created the job.

The given data is copied away and forms the `seereply` field of the `SEELib_ReturnJob` reply (see the description of the `SEELib_ReturnJob` command in the *nCore CodeSafe API Documentation*).

10.16. SEELib_SubmitCoreJob

```
extern int SEELib_SubmitCoreJob( const unsigned char *data, unsigned int len );
```

This function puts a job on the input queue for processing by the core. The byte block is passed in **data** and **len**. It should be a full marshalled **M_Command** with a valid tag at the start.

This function returns an **M_Status**, which is typically **OK** or **BufferFull** (if **len** is too big).

10.17. SEELib_GetCoreJob

```
extern int SEELib_GetCoreJob ( unsigned char *buf, M_Word *len_io );
```

This function blocks and waits for a job submitted to the core to be returned. On entry, **buf** points to a buffer of length **(*len_io) max**. On exit, if successful, ***len_io** is the length of bytes returned.

This function returns an **M_Status**, which is typically **OK** or **BufferFull** (if **len_io** is too big).

10.18. SEELib_GetUserDataLen

```
extern M_Word SEELib_GetUserDataLen ( void );
```

This function gets the length in bytes of the UserData block passed in to create this SEE World.

If this data has been discarded because **SEELib_ReleaseUserData()** has been called, this function returns **0**.

10.19. SEELib_Submit

```
extern int SEELib_Submit(M_Command *cmd, M_Reply *reply, PEVENT ev, SEELib_ContextHandle tctx);
```

This function submits the command specified in **cmd**. The transaction listener thread calls EventSet **ev**, if **ev** is non-NULL, when the reply returns for this command. The reply is unmarshalled into **reply** and **tctx** is returned to the caller in **SEELib_Query**.

Unlike **SEELib_SubmitCoreJob** this function can be called at the same time as another thread is blocking in **SEELib_Transact**.

SEELib_StartTransactListener must have been called before this function is called.

10.20. SEELib_Query

```
extern int SEELib_Query(M_Reply **reply, SEELib_ContextHandle *tctx_r);
```

This function is called to receive a reply that is being held by the transaction listener thread. It is typically called after having been woken from `EventWait` as a result of the transaction listener thread posting to the event passed in to `SEELib_Submit`.

If `*reply` is NULL, `SEELib_Query` accepts any returned reply, and `*reply` is changed to point to that reply. If `*reply` is not NULL, the function accepts the reply specified; other replies are queued internally.

`tctx_r` may be NULL. If it is not, the `tctx` used when submitting the reply is stored in `*tctx_r`. `SEELib_Query` can return, in addition to the usual return values, `TransactionNotYetComplete` if the reply (or any reply if `*reply` was NULL) has not come back from the core yet.

`SEELib_StartTransactListener` must have been called before this function is called.

10.21. SEELib_StartSEESJobListener

```
extern int SEELib_StartSEESJobListener(PEVENT ev);
```

This function starts the `SEESJob` listener thread which blocks calling `SEELib_AwaitJob`, caches the new job and then sets the event `ev` if `ev` is non-NULL.

Use `SEELib_QuerySEESJob` to receive any `SEESJobs` that have been cached by this listener thread, followed by `SEELib_ReturnJob` to reply to the `SEESJob`, then followed by `SEELib_ReleaseSEESJob` to free the buffer.

It is safe to call this function multiple times. Calls after the first call will have no effect.

10.22. SEELib_QuerySEESJob

```
extern M_Status SEELib_QuerySEESJob( M_Word *tag_out, unsigned char **buf, M_Word *len );
```

This function is called to receive a `SEESJob` that is being held by the `SEESJob` listener thread. It is typically called after having been woken from `EventWait` as a result of the `SEESJob` listener thread setting the event passed in to `SEELib_StartSEESJobListener`.

`buf` is set to the buffer containing the `SEESJob`, `len` is set to the length of the data contained in `buf`.

This function returns `TransactionNotYetComplete` if there were no outstanding `SEETasks`.

10.23. SEELib_ReleaseSEETask

```
extern void SEELib_ReleaseSEETask( unsigned char **buf );
```

This function is called to release a buffer which was returned from `SEELib_QuerySEETask`. This function must be called after the buffer specified by `buf` in a call to `SEELib_QuerySEETask` has been finished with. This function is safe to call even if `*buf` is NULL. In addition, this function sets `*buf` to NULL on completion.

11. Differences between glibc and bsdlib (SoloXC only)

In order to provide CodeSafe developers the ability to write standard POSIX calls and be able to run in the SEE environments, gcc wrappers have been used to override certain standard functions. For example, both CodeSafe and Libc, have a definition for the function `socket`:

```
socket(int __domain, int __type, int __protocol)
```

At link time, the function call is overridden and resolved to the CodeSafe implementation. A linker options is used to accomplish that.

```
-Wl,-wrap=socket
```

The standard POSIX `socket()` function can still be used calling `real_socket()`. The applicability of the standard (`real_*`) familiarity of functions is limited in the SEE environment due to embedded system constraints.

All the wrapped functions were replaced by equivalent ones with the underlying IPC support to communicate with nShield core and provide the same functionality as in legacy systems.

List functions that were wrapped and redefined:

- `socket()`
- `bind()`
- `listen()`
- `accept()`
- `connect()`
- `read()`
- `write()`
- `send()`
- `setsockopt()`
- `poll()`
- `select()`

11.1. glibc Compatibility exceptions

As a consequence of some function redefinitions and the underlying differences, some standard C functions may not work as expected in CodeSafe.

`FILE *fdopen(int fd, const char *mode)`: associates a stream with an existing file descriptor, `fd`. In the case of a socket `fd` (returned by CodeSafe `socket()` implementation) the association result may fail or cause unexpected errors in subsequent calls. Developers should avoid using `fdopen` with non-standard Unix file descriptors.

12. SEE Machines Whitelist

Classic and GLIBC SEE machines are restricted to a subset of Linux system calls they can execute.

An SEE machine that attempts to execute a system call that is not allowed will be immediately terminated by a safeguarding process.

The whitelisted system calls are given in the following table, with their number and name.

| Whitelisted System Calls | |
|--------------------------|----------------------|
| 1 __NR_exit | 2 __NR_fork |
| 3 __NR_read | 4 __NR_write |
| 5 __NR_open | 6 __NR_close |
| 7 __NR_waitpid | 8 __NR_creat |
| 9 __NR_link | 10 __NR_unlink |
| 11 __NR_execve | 12 __NR_chdir |
| 13 __NR_time | 15 __NR_chmod |
| 19 __NR_lseek | 21 __NR_mount |
| 22 __NR_umount | 24 __NR_getuid |
| 29 __NR_pause | 33 __NR_access |
| 37 __NR_kill | 38 __NR_rename |
| 39 __NR_mkdir | 40 __NR_rmdir |
| 41 __NR_dup | 42 __NR_pipe |
| 45 __NR_brk | 49 __NR_geteuid |
| 54 __NR_ioctl | 60 __NR_umask |
| 63 __NR_dup2 | 64 __NR_getppid |
| 65 __NR_getpgrp | 78 __NR_gettimeofday |
| 83 __NR_symlink | 85 __NR_readlink |
| 90 __NR_mmap | 91 __NR_munmap |
| 94 __NR_fchmod | 99 __NR_statfs |
| 102 __NR_socketcall | 106 __NR_stat |
| 107 __NR_lstat | 108 __NR_fstat |

| Whitelisted System Calls | |
|---------------------------------|--------------------------|
| 114 __NR_wait4 | 119 __NR_sigreturn |
| 120 __NR_clone | 125 __NR_mprotect |
| 140 __NR_llseek | 141 __NR_getdents |
| 145 __NR_readv | 146 __NR_writev |
| 160 __NR_sched_get_priority_min | 162 __NR_nanosleep |
| 163 __NR_mremap | 172 __NR_rt_sigreturn |
| 173 __NR_rt_sigaction | 174 __NR_rt_sigprocmask |
| 175 __NR_rt_sigsuspend | 176 __NR_rt_sigtimedwait |
| 177 __NR_rt_sigqueueinfo | 178 __NR_rt_sigsuspend |
| 179 __NR_pread64 | 181 __NR_chown |
| 182 __NR_getcwd | 190 __NR_ugetrlimit |
| 195 __NR_stat64 | 196 __NR_lstat64 |
| 197 __NR_fstat64 | 202 __NR_getdents64 |
| 204 __NR_fcntl64 | 205 __NR_madvise |
| 207 __NR_gettid | 221 __NR_futex |
| 232 __NR_set_tid_address | 234 __NR_exit_group |
| 250 __NR_tgkill | 252 __NR_statfs64 |
| 286 __NR_openat | 300 __NR_set_robust_list |
| 326 __NR_socket | 327 __NR_bind |
| 328 __NR_connect | 329 __NR_listen |
| 330 __NR_accept | 331 __NR_getsockname |
| 332 __NR_getpeername | 333 __NR_socketpair |
| 334 __NR_send | 335 __NR_sendto |
| 336 __NR_recv | 337 __NR_recvfrom |
| 338 __NR_shutdown | 339 __NR_setsockopt |
| 340 __NR_getsockopt | |