nShield Post-Quantum Software Development Kit

# PQSDK v1.1.0 User Guide

10 April 2024

# Table of Contents

# 1. Introduction

The nShield Post-Quantum Software Development Kit (PQSDK) provides users of Security World Software with the ability to generate and use keys with public-key cryptographic algorithms selected by NIST as part of the Post-Quantum Cryptography standardisation process.

PQSDK is installed on top of your Security World Software, allowing you to use your existing keys and algorithms alongside post-quantum algorithms.

The PQSDK provides the user with the opportunity to experiment with the use of PQC digital signature algorithms and signatures but at this moment the underlying Security World protection mechanisms still use classical (non Post-Quantum) crypto. It should not be used in an environment where a full post-quantum resistance security solution is required.

# 2. Software Prerequisites

Before you install PQSDK:

- Refer to the latest Release Notes at https://nshieldsupport.entrust.com/hc/en-us/sections/360001115837-Release-Notes for hardware and software compatibility, and known and fixed issues.
- Check you have the Security World software installed, and a working Security World configured. See Security World software.
- Check you have the CodeSafe software installed. See CodeSafe.
- Check that you have a suitable firmware version on your nShield HSM. See HSM Firmware.
- Remove any previous installations of PQSDK. See Remove existing nShield Post-Quantum Software Development Kit.
- Check that you have a usable OCS, and that it is present.
- Check that you have the required third party software installed. See Third party software.

This release of PQSDK is compatible with Linux only. See the *PQSDK Release Notes* for the list of compatible operating systems and versions.

## 2.1. Security World software

PQSDK requires nShield Security World software to be installed, and a working Security World to be configured. To confirm that there is a usable Security World, use the `nfkminfo` command:

```
nfkminfo
```

If the Security World is usable then the state line in the `nfkminfo` output shows `Usable`.

```
World
    generation 2
    state 0x37270008 Initialised Usable Recovery !PINRecovery !ExistingClient RTC NVRAM FTO AlwaysUseStrongPrimes
!DisablePKCS1Padding !PpStrengthCheck !AuditLogging SEEDebug
...
```

Additionally, your hardserver should have appropriately configured `priv_port` and `nonpriv_port` settings.

```
[server_startup]
nonpriv_port=9000
```

```
priv_port=9001
```

For further information on installing Security World software and creating a Security World, see the *User Guide* shipped with your nShield Security World software.

See the *PQSDK Release Notes* for supported Security World Software versions.

## 2.2. CodeSafe

The requirements for PQSDK remote and local HSM installations are different.

- PQSDK remote installations require only Security World software.
- Local HSM installations require nShield CodeSafe software to be installed for building examples with the PQSDK. To confirm that CodeSafe is installed, use the `elftool` command:

```
elftool --version
```

If CodeSafe is installed, a message similar to the following will be printed in your terminal:

```
elftool, nshield (12.70.4-265-4efba9d)
```

See the *PQSDK Release Notes* for supported CodeSafe versions.

## 2.3. HSM Firmware

PQSDK requires a supported version of the nShield HSM firmware to be installed. To confirm the installed version, use the `enquiry` command.

```
Module #1:
...
 version             13.4.3
 speed index         20000
 rec. queue          120..250
 level one flags     Hardware HasTokens SupportsCommandState SupportsHotReset
 version string      13.4.3-338-6c66aa0d
 checked in          00000000649dc17c Thu Jun 29 13:38:04 2023
 level two flags     none
...
```

In this example, the installed firmware version is `13.4.3`. See the *PQSDK Release Notes* for supported firmware versions.

In addition, for nShield XC, you must enable the Unrestricted SEE feature. This is indicated

by the presence of `SEE Activation (EU+10)` in the enabled features seen in FET.

For nShield 5, you must enable the SEE Activation feature. This is indicated by the presence of `SEE Activation, Codesafe 5` in the enabled features seen in FET.

## 2.4. Third party software

PQSDK requires following third party software to be installed:

- CMake 3.13.0 (or higher).
- GCC version 4.8.5 (or higher).
- GNU Make version 3.82 (or higher).
- Java Development Kit (Java 8) version 1.8.0_362 (or higher).
- Apache Ant version 1.9.4 (or higher).

## 2.5. Remove existing nShield Post-Quantum Software Development Kit

Please see Uninstallation for uninstallation instructions.

# 3. Installation

The nShield Post-Quantum Software Development Kit (PQSDK) requires that an OCS is present and usable. Please refer to the appropriate user guide for your product for further information.

To install the PQSDK:

1. Sign in as a user with root privileges.
2. Open a terminal window and create a temporary directory to mount the PQSDK ISO to:

```
sudo mkdir /mnt/pqsdk
```

3. Mount the PQSDK ISO to the temporary directory created above:

```
sudo mount -o loop pqsdk-1.1.0.iso /mnt/pqsdk
```

4. Change to the root directory and extract the appropriate `.tar.gz` file in the mounted PQSDK ISO.

The following three installation files are provided in the PQSDK ISO:

- pqsdk-xc-1.1.0.tar.gz : nShield XC local HSM installation with SDK sources and builder, no pre-built binaries.
- pqsdk-n5-hsm-1.1.0.tar.gz : nShield 5 local HSM installation with SDK sources, builder and pre-built examples.
- pqsdk-n5-client-1.1.0.tar.gz : nShield 5 remote client installation (without a local HSM installed) with pre-built examples and sources.

An installation file can be extracted as follows:

This installs all files required by PQSDK to `/opt/nfast`.

```
cd /
sudo tar -xzf /mnt/pqsdk/pqsdk-<VERSION>.tar.gz -C /
```

Only install one of the PQSDK installation files at a time.

## 3.1. nShield XC installation

In the case of a Solo XC or a Connect XC installation, the PQSDK can now be installed using the following commands:

```
/opt/nfast/pqsdk/sbin/install_pqsdk_java_pkg
/opt/nfast/pqsdk/sbin/install_pqsdk_see_xc
```

The installation process can be customised for your needs. Use `--help` for more information.

PQSDK is built from source during the installation. This may take a short while.

PQSDK is provided as a source-code release so that you may experiment with it. Changes to the code require re-installation of PQSDK. Repeat the last step to rebuild and reinstall the product.

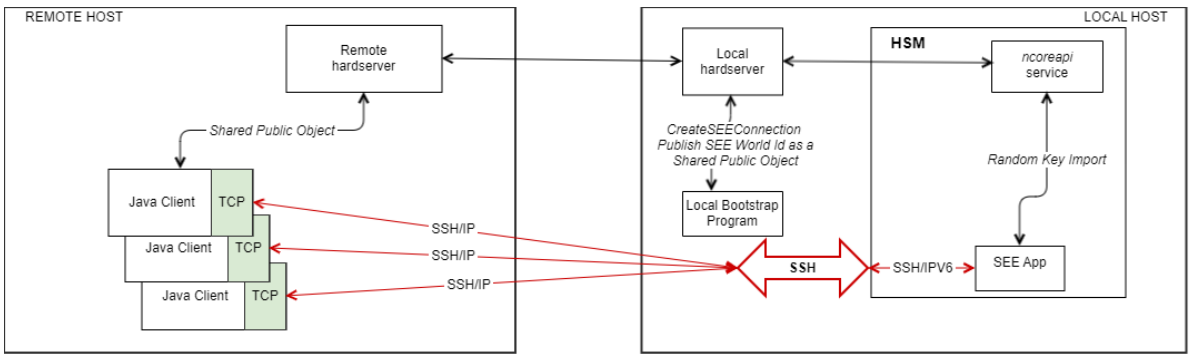
## 3.2. nShield 5 installation

There are two possible nShield 5 installations, the nShield 5 HSM installation and the nShield 5 remote installation. Each is described in detail in the following sections.

### 3.2.1. nShield 5 HSM installation

In this deployment, administration of the HSM is performed by the customer (for example, initializing the Security World on the HSM). The CodeSafe container is started from a local host and a local bootstrap program sends the `CreateSEEConnection` command and publishes the obtained worldid as an HSM object. After this, the client applications retrieves the published worldid and connects to the SEE machine using the IP address.

For more information about the `CreateSEEConnection` command, see the Codesafe Developer Guide.




Loading and running the SEE Machine uses HSM Keys with Combined Certs. In the case of the nShield 5 HSM installation, the PQSDK can now sign the SEE Machine image, install and run it using the following command:

```
sudo /opt/nfast/pqsdk/sbin/install_pqsdk_see_n5 --install local --askeyname codesafe-ask --devkeyname
testdeveloperkey --devintcert devinter_certs.pem --bin /opt/nfast/pqsdk/bin/see/pqsdk-1.1.0.bin --sign true
```

The signing process will always look for the required certificates under: `/opt/nfast/pqsdk/n5_signing_certs/*`

A signed PQSDK cs5 image can only be run on the same machine it was generated and signed on.

As seen in the example above, in `/opt/nfast/pqsdk/n5_signing_certs/*` the intermediate and development certificates can be combined as a single file. For example, `devinter_certs.pem`. Use the `--devintcert` option to specify the combined cert. `/opt/nfast/pqsdk/n5_signing_certs/devinter_certs.pem`

The `--cs5` flag allows the re-running of a signed cs5 image again:

```
sudo /opt/nfast/pqsdk/sbin/install_pqsdk_see_n5 --install local --devintcert devinter_certs.pem --cs5
/opt/nfast/pqsdk/bin/see/pqsdk-1.1.0-signed.cs5
```

The HSM Keys created and used for signing can be specified using `--askeyname` and `--devkeyname`

```
/opt/nfast/pqsdk/n5_signing_certs$ nfkminfo -k
Key list - 2 keys
 AppName simple              Ident codesafe-ask
 AppName simple              Ident testdeveloperkey
```

If the default names for certificates and key files are different, then they can be specified with the following option flags when executing install_pqsdk_see_n5:

- `-askeyname`, `--askeyname [string]` : The ask key name for signing the image.
- `-askeyfile`, `--askeyfile [string]` : The ask key file for signing the image.
- `-devkeyfile`, `--devkeyfile [string]` : The developer signing key File used for signing.
- `-devcert`, `--devcert [string]` : The signed developer certificate PEM file, used for loading or signing.
- `-intcert`, `--intcert [string]` : The signed intermediate certificate PEM file, used for loading image.

Bootstrap is automatically started by the script (ie. `/opt/nfast/python3/bin/python3 ./src/pqsdk/source/python/n5/bootstrap.py --cs5file /opt/nfast/pqsdk/bin/see/<pqsdk.cs5> --uuid <uuid>`)

### 3.2.2. nShield 5 client installation

In this scenario, administration of the HSM and the CodeSafe container is performed by Entrust. The remote client application will need to have a Hardserver that is remotely connected to the Hardserver at the HSM location. The client installation will retrieve the published worldid via a shared public object and connect to the SEE Machine using the remote IP address to the SEE machine container.

For reference, the java examples could be run using the following command:

```
java -cp .:/opt/nfast/pqsdk/bin/java/pqsdk.jar com.entrust.pqsdk.examples.<example> <IP_ADDRESS> <PORT>
```

### 3.2.3. nShield 5 client SSH configuration

For security, an SSH tunnel is to be configured between the Java Client and the CodeSafe container running the SEE Machine. The container SSHD will only start when the state for that container has been set to enabled. By default, it is disabled. It can be enabled with the csadmin SSHD state enable subcommand. The enable subcommand will also return the port and address on which the SSHD is listening on. Example output is shown below:

```
csadmin sshd state enable -u 81c4f72f-586d-48c8-8020-7a6975159b37
F973-CCA4-370B        SUCCESS
SSHD PORT: 3006
LISTENING ADDRESS: fe80::53:89ff:fe92:3260
```

Once the container SSHD is enabled, started, and its keys are set, to forward connections to the container SSHD, the user will establish port forwarding on the host machine. Use of a secure tunnel over an open TCP connection to communicate with the container is recommended and so we use local port forwarding to enable SSH tunneling. This is done with the SSH local port forward command (can be IPv4 or IPv6 depending on the required network configuration). The basic usage is as follows:

```
ssh -i [PATH_TO_PRIV_KEY] -L [LOCAL_IP]:[LOCAL_PORT]:[CONTAINER_IP_ADDR%lxcbr0]:[CONTAINER_PORT] -f -N -p
[SSHD_PORT] launcher@[LISTENING_ADDRESS]%nshield0
```

Where:

- PRIV_KEY is the private key to the public client key that was set with the `setclient` command.
- LOCAL_PORT is the port on the local client where traffic to be forwarded will be sent.
- CONTAINER_IP_ADDR is the ip address of the container. This is the address returned when the container is started.

- CONTAINER_PORT is the port on the container that is listening for forwarded traffic which is set in the network-conf.json file as "ssh_tunnel" (note valid range 1024-65535).
- SSHD_PORT is the port the SSH daemon is listening on. This port is returned when SSHD is enabled and can also be found with the `csadmin sshd state get` command.
- LISTENING_ADDRESS is the address the host clients use to communicate with the HSM (on the hsm side). This address is returned when SSHD is enabled and can also be found with the `csadmin sshd state get` command.

As an example, in the local host, using an IPv4 LOCAL_IP and LOCAL_PORT:

```
ssh -i /home/.../test_key -L [10.194.147.71]:6000:[fe80::216:3eff:fe41:995%lxcbr0]:8888 -f -N -p 3000
launcher@fe80::53:89ff:fe92:3260%nshield0
```

And in the remote host:

```
java -cp /opt/nfast/pqsdk/bin/java/pqsdk-examples.jar com.entrust.pqsdk.examples.KEM 10.194.147.71 6000
```

Further information on enabling SSH port forwarding is available in the CodeSafe 5 Developer Guide.

# 4. Uninstallation

Before uninstalling the nShield Post-Quantum Software Development Kit (PQSDK), Entrust advises that you create a full back up of `/opt/nfast/pqsdk`. Removing the PQSDK will not affect your existing Security World, or your Security World Software installation. Once the PQSDK is removed, you will no longer be able to use keys created with PQSDK.

To uninstall the PQSDK, run the following command:

```
/opt/nfast/pqsdk/sbin/uninstall
```

The following options are available for the uninstall command (the full list is available with `--help`):

- `-p`, `--product [string]` : Use to specify "xc" or "n5" (default "xc")
- `-i`, `--install_type [string]` : The type of install to uninstall for n5 only. "local" or "remote" (default "remote").

Uninstall by default runs for the nShield Solo XC. Use `n5` with the `-p` option as well as the appropriate `-i` option when you are uninstalling for that platform.

# 5. Supported Post-Quantum Algorithms

## 5.1. Digital Signature Algorithms

This version of PQSDK supports the following signing algorithms:

| Algorithm | Variants |
| --- | --- |
| Falcon | • Falcon-512<br>• Falcon-1204 |
| CRYSTALS-Dilithium | • Dilithium2<br>• Dilithium2-AES<br>• Dilithium3<br>• Dilithium3-AES<br>• Dilithium5<br>• Dilithium5-AES |
| SPHINCS+-Haraka | • SPHINCS+-Haraka-128f-robust<br>• SPHINCS+-Haraka-128f-simple<br>• SPHINCS+-Haraka-128s-robust<br>• SPHINCS+-Haraka-128s-simple<br>• SPHINCS+-Haraka-192f-robust<br>• SPHINCS+-Haraka-192f-simple<br>• SPHINCS+-Haraka-192s-robust<br>• SPHINCS+-Haraka-192s-simple<br>• SPHINCS+-Haraka-256f-robust<br>• SPHINCS+-Haraka-256f-simple<br>• SPHINCS+-Haraka-256s-robust<br>• SPHINCS+-Haraka-256s-simple |

| Algorithm | Variants |
| --- | --- |
| SPHINCS+-SHA256 | • SPHINCS+-SHA256-128f-robust<br>• SPHINCS+-SHA256-128f-simple<br>• SPHINCS+-SHA256-128s-robust<br>• SPHINCS+-SHA256-128s-simple<br>• SPHINCS+-SHA256-192f-robust<br>• SPHINCS+-SHA256-192f-simple<br>• SPHINCS+-SHA256-192s-robust<br>• SPHINCS+-SHA256-192s-simple<br>• SPHINCS+-SHA256-256f-robust<br>• SPHINCS+-SHA256-256f-simple<br>• SPHINCS+-SHA256-256s-robust<br>• SPHINCS+-SHA256-256s-simple |
| SPHINCS+-SHAKE256 | • SPHINCS+-SHAKE256-128f-robust<br>• SPHINCS+-SHAKE256-128f-simple<br>• SPHINCS+-SHAKE256-128s-robust<br>• SPHINCS+-SHAKE256-128s-simple<br>• SPHINCS+-SHAKE256-192f-robust<br>• SPHINCS+-SHAKE256-192f-simple<br>• SPHINCS+-SHAKE256-192s-robust<br>• SPHINCS+-SHAKE256-192s-simple<br>• SPHINCS+-SHAKE256-256f-robust<br>• SPHINCS+-SHAKE256-256f-simple<br>• SPHINCS+-SHAKE256-256s-robust<br>• SPHINCS+-SHAKE256-256s-simple |

## 5.2. Key Encapsulation Mechanisms

| Algorithm | Variants |
| --- | --- |
| CRYSTALS-Kyber | • Kyber512<br>• Kyber512-90s<br>• Kyber768<br>• Kyber768-90s<br>• Kyber1024<br>• Kyber1024-90s |

# 6. Application Programming Interface

The nShield Post-Quantum Software Development Kit (PQSDK) can build and load a CodeSafe SEE machines onto nShield HSMs:

- Legacy CodeSafe SEE machines for nShield Solo XC HSMs
- CodeSafe 5 SEE machines for nShield 5s HSMs.

During this process, a Java binary is produced that enables you to interface with the SEE machine.

See Examples for example programs that show how to use the PQSDK API.

## 6.1. Integration

To integrate the PQSDK within your own Java code, please include `/opt/nfast/pqsdk/bin/java/pqsdk.jar` in your classpath. `pqsdk.jar` exposes a Java API for you to integrate with. The source files describing the API exist at `/opt/nfast/pqsdk/src/pqsdk/source/java`.

You should also ensure that the `nCipherKM.jar` is installed.

## 6.2. HostCommands

The `HostCommands` class provides you with a Java interface into the SEE machine. You may then use the exposed API to perform key generation, signing, and verification activities.

```
HostCommands hc = new HostCommands();
```

### 6.2.1. Constants

| Modifier and Type | Name | Value |
|---|---|---|
| public static final int | algorithm_dilithium_2 | 1 |
| public static final int | algorithm_dilithium_3 | 2 |
| public static final int | algorithm_dilithium_4 | 3 |
| public static final int | algorithm_falcon_512 | 4 |
| public static final int | algorithm_falcon_1024 | 5 |

| Modifier and Type | Name | Value |
|---|---|---|
| public static final int | algorithm_sphincs_haraka_128f_robust | 6 |
| public static final int | algorithm_sphincs_haraka_128f_simple | 7 |
| public static final int | algorithm_sphincs_haraka_128s_robust | 8 |
| public static final int | algorithm_sphincs_haraka_128s_simple | 9 |
| public static final int | algorithm_sphincs_haraka_192f_robust | 10 |
| public static final int | algorithm_sphincs_haraka_192f_robust | 11 |
| public static final int | algorithm_sphincs_haraka_192s_robust | 12 |
| public static final int | algorithm_sphincs_haraka_192s_simple | 13 |
| public static final int | algorithm_sphincs_haraka_256f_robust | 14 |
| public static final int | algorithm_sphincs_haraka_256f_simple | 15 |
| public static final int | algorithm_sphincs_haraka_256s_robust | 16 |
| public static final int | algorithm_sphincs_haraka_256s_simple | 17 |
| public static final int | algorithm_sphincs_sha256_128f_robust | 18 |
| public static final int | algorithm_sphincs_sha256_128f_simple | 19 |
| public static final int | algorithm_sphincs_sha256_128s_robust | 20 |
| public static final int | algorithm_sphincs_sha256_128s_simple | 21 |
| public static final int | algorithm_sphincs_sha256_192f_robust | 22 |
| public static final int | algorithm_sphincs_sha256_192f_simple | 23 |

| Modifier and Type | Name | Value |
|---|---|---|
| public static final int | algorithm_sphincs_sha256_192s_robust | 24 |
| public static final int | algorithm_sphincs_sha256_192s_simple | 25 |
| public static final int | algorithm_sphincs_sha256_256f_robust | 26 |
| public static final int | algorithm_sphincs_sha256_256f_simple | 27 |
| public static final int | algorithm_sphincs_sha256_256s_robust | 28 |
| public static final int | algorithm_sphincs_sha256_256s_simple | 29 |
| public static final int | algorithm_sphincs_shake256_128f_robust | 30 |
| public static final int | algorithm_sphincs_shake256_128f_simple | 31 |
| public static final int | algorithm_sphincs_shake256_128s_robust | 32 |
| public static final int | algorithm_sphincs_shake256_128s_simple | 33 |
| public static final int | algorithm_sphincs_shake256_192f_robust | 34 |
| public static final int | algorithm_sphincs_shake256_192f_simple | 35 |
| public static final int | algorithm_sphincs_shake256_192s_robust | 36 |
| public static final int | algorithm_sphincs_shake256_192s_simple | 37 |
| public static final int | algorithm_sphincs_shake256_256f_robust | 38 |
| public static final int | algorithm_sphincs_shake256_256f_simple | 39 |
| public static final int | algorithm_sphincs_shake256_256s_robust | 40 |
| public static final int | algorithm_sphincs_shake256_256s_simple | 41 |

| Modifier and Type | Name | Value |
|---|---|---|
| public static final int | algorithm_dilithium_5 | 42 |
| public static final int | algorithm_dilithium_2_aes | 43 |
| public static final int | algorithm_dilithium_3_aes | 44 |
| public static final int | algorithm_dilithium_5_aes | 45 |
| public static final int | algorithm_kyber_512 | 46 |
| public static final int | algorithm_kyber_768 | 47 |
| public static final int | algorithm_kyber_1024 | 48 |
| public static final int | algorithm_kyber_512_90s | 49 |
| public static final int | algorithm_kyber_768_90s | 50 |
| public static final int | algorithm_kyber_1024_90s | 51 |

## 6.2.2. Methods

### 6.2.2.1. init(String)

```
protected void init (String published)
```

Initialises the HostCommands object.

**Throws**

`RuntimeException` - if one of the following conditions is met:

- The PQSDK SEE machine is not installed, published, or running.
- The Security World is not usable.

### 6.2.2.2. algorithm_toString(long)

```
public static String algorithm_toString(long value)
```

Gets the name of an algorithm, given a constant value.

**Parameters**

`value` - an algorithm id constant.

**Returns**

A `String` value describing the algorithm, or `UNKNOWN`.

#### 6.2.2.3. getVersion()

```
public getVersionResponse getVersion()
```

Gets the version of the SEE machine interface.

**Returns**

A `getVersionResponse` object encapsulating the SEE machine version.

**Throws**

`NFException` - if one of the following conditions is met:

- The PQSDK SEE machine is not installed, published, or running.
- The Security World is not usable.

#### 6.2.2.4. list()

```
public listResponse list()
```

List all PQC keys

**Returns**

A `listResponse` object encapsulating a list of key hashes.

**Throws**

`NFException` - if one of the following conditions is met:

- The PQSDK SEE machine is not installed, published, or running.
- The Security World is not usable.
- The nShield HSM ran out of memory.

#### 6.2.2.5. getPublic(String)

```
public getPublicResponse getPublic(String alias)
```

Get the public half of a PQC key-pair

**Parameters**

`alias` - the name of the key

**Returns**

A `getPublicResponse` object encapsulating the key

**Throws**

`NFException` - if one of the following conditions is met:

- The PQSDK SEE machine is not installed, published, or running.
- The Security World is not usable.
- The nShield HSM ran out of memory.
- The key did not exist.

### 6.2.2.6. generate(String, int, boolean)

```
public generateResponse generate(String alias, int algorithm, boolean overwrite)
```

Generate a key pair

**Parameters**

`alias` - the alias under which to store the key pair.
`algorithm` - the PQC algorithm (one of the algorithms in `HostCommands.algorithm_*`).
`overwrite` - if true, and `alias` exists, overwrites the existing key pair.

**Returns**

A `generateResponse` object encapsulating the alias and hash of the generated key pair.

**Throws**

`NFException` - if one of the following conditions is met:

- The PQSDK SEE machine is not installed, published, or running.
- The Security World is not usable.
- The nShield HSM ran out of memory.

### 6.2.2.7. generate(String, int)

```
public generateResponse generate(String alias, int algorithm)
```

Generate a key pair

**Parameters**

`alias` - the alias under which to store the key pair.
`algorithm` - the PQC algorithm (one of the algorithms in `HostCommands.algorithm_*`).

**Returns**

A `generateResponse` object encapsulating the alias and hash of the generated key pair.

**Throws**

`NFException` - if one of the following conditions is met:

- The PQSDK SEE machine is not installed, published, or running.
- The Security World is not usable.
- The nShield HSM ran out of memory.

### 6.2.2.8. importKeypair(String, int, byte[], byte[], boolean)

```
public importKeypairResponse importKeypair(String alias, int algorithm, byte[] publicKey, byte[] privateKey,
boolean overwrite)
```

Import a key pair

**Parameters**

`alias` - the alias under which to store the key pair.
`algorithm` - the PQC algorithm (one of the algorithms in `HostCommands.algorithm_*`).
`publicKey` - the public key represented as a byte array.
`privateKey` - the private key represented as a byte array.
`overwrite` - if true, and `alias` exists, overwrites the existing key pair.

**Returns**

A `importKeypairResponse` object encapsulating the alias and hash of the imported key pair.

**Throws**

`NFException` - if one of the following conditions is met:

- The PQSDK SEE machine is not installed, published, or running.
- The Security World is not usable.
- The nShield HSM ran out of memory.

### 6.2.2.9. importKeypair(String, int, byte[], byte[])

```
public importKeypairResponse importKeypair(String alias, int algorithm, byte[] publicKey, byte[] privateKey)
```

Import a key pair

**Parameters**

`alias` - the alias under which to store the key pair.
`algorithm` - the PQC algorithm (one of the algorithms in `HostCommands.algorithm_*`).
`publicKey` - the public key represented as a byte array.
`privateKey` - the private key represented as a byte array.

**Returns**

A `importKeypairResponse` object encapsulating the alias and hash of the imported key pair.

**Throws**

`NFException` - if one of the following conditions is met:

- The PQSDK SEE machine is not installed, published, or running.
- The Security World is not usable.
- The nShield HSM ran out of memory.

### 6.2.2.10. sign(String, byte[], byte[])

```
public signResponse sign(String alias, byte[] keyhash, byte[] message)
```

Sign a message

**Parameters**

`alias` - (optional) the name of the key with which to sign.
`keyhash` - the hash of the key with which to sign.
`message` - the message to sign.

**Returns**

A `signResponse` object encapsulating the message signature.

**Throws**

`IOException` - if the key could not be read.
`NFException` - if one of the following conditions is met:

- The PQSDK SEE machine is not installed, published, or running.
- The Security World is not usable.

#### 6.2.2.11. sign(String, byte[])

```
public signResponse sign(String alias, byte[] message)
```

Sign a message

**Parameters**

`alias` - the name of the key with which to sign.
`message` - the message to sign.

**Returns**

A `signResponse` object encapsulating the message signature.

**Throws**

`IOException` - if the key could not be read.
`NFException` - if one of the following conditions is met:

- The PQSDK SEE machine is not installed, published, or running.
- The Security World is not usable.

#### 6.2.2.12. sign(byte[], byte[])

```
public signResponse sign(byte[] keyhash, byte[] message)
```

Sign a message

**Parameters**

`keyhash` - the hash of the key with which to sign.
`message` - the message to sign.

**Returns**

A `signResponse` object encapsulating the message signature.

**Throws**

`IOException` - if the key could not be read.
`NFException` - if one of the following conditions is met:

- The PQSDK SEE machine is not installed, published, or running.
- The Security World is not usable.

#### 6.2.2.13. verify(String, byte[], byte[], byte[])

```
public verifyResponse verify(String alias, byte[] keyhash, byte[] message, byte[] signature)
```

Verify the signature of message

**Parameters**

`alias` - (optional) the name of the key to verify with.
`keyhash` - the hash of the key to verify with.
`message` - the message to verify.
`signature` - the message signature.

**Returns**

A `verifyResponse` object encapsulating a boolean value indicating the operation status.

**Throws**

`IOException` - if the key could not be read.
`NFException` - if one of the following conditions is met:

- The PQSDK SEE machine is not installed, published, or running.
- The Security World is not usable.

### 6.2.2.14. verify(String, byte[], byte[])

```
public verifyResponse verify(String keyhash, byte[] message, byte[] signature)
```

Verify the signature of message

**Parameters**

`alias` - the name of the key to verify with.
`message` - the message to verify.
`signature` - the message signature.

**Returns**

A `verifyResponse` object encapsulating a boolean value indicating the operation status.

**Throws**

`IOException` - if the key could not be read.
`NFException` - if one of the following conditions is met:

- The PQSDK SEE machine is not installed, published, or running.
- The Security World is not usable.

### 6.2.2.15. verify(byte[], byte[], byte[])

```
public verifyResponse verify(byte[] keyhash, byte[] message, byte[] signature)
```

Verify the signature of message

**Parameters**

`keyhash` - the hash of the key to verify with.
`message` - the message to verify.
`signature` - the message signature.

**Returns**

A `verifyResponse` object encapsulating a boolean value indicating the operation status.

**Throws**

`IOException` - if the key could not be read.
`NFException` - if one of the following conditions is met:

- The PQSDK SEE machine is not installed, published, or running.
- The Security World is not usable.

### 6.2.2.16. verifyImmediate(byte[], int, byte[], byte[])

```
public verifyResponse verifyImmediate(byte[] publicKey, int algorithm, byte[] message, byte[] signature)
```

Verify the signature of message using immediate values

**Parameters**

`publicKey` - the public key to verify with.
`algorithm` - the signature algorithm.
`message` - the message to verify.
`signature` - the message signature.

**Returns**

A `verifyResponse` object encapsulating a boolean value indicating the operation status.

**Throws**

`NFException` - if one of the following conditions is met:

- The PQSDK SEE machine is not installed, published, or running.
- The Security World is not usable.

#### 6.2.2.17. encapsulate(String, byte[])

```
public encapsulateResponse encapsulate(String alias, byte[] keyhash)
```

Encapsulate a shared secret using the public half of a key pair

**Parameters**

`alias` - the name of the public key to encapsulate with.
`keyhash` - the hash of the public key to encapsulate with. Only used if the `alias` is null.

**Returns**

An `encapsulateResponse` object encapsulating a shared secret in plaintext and a ciphertext (encapsulation) of this shared secret.

**Throws**

`RuntimeException` - if the alias passed in does not belong to an existing key.
`NFException` - if one of the following conditions is met:

- The PQSDK SEE machine is not installed, published, or running.
- The Security World is not usable.

#### 6.2.2.18. encapsulate(String)

```
public encapsulateResponse encapsulate(String alias)
```

Encapsulate a shared secret using the public half of a key pair

**Parameters**

`alias` - the name of the public key to encapsulate with.

**Returns**

An `encapsulateResponse` object encapsulating a shared secret in plaintext and a ciphertext (encapsulation) of this shared secret.

**Throws**

`RuntimeException` - if the alias passed in does not belong to an existing key.
`NFException` - if one of the following conditions is met:

- The PQSDK SEE machine is not installed, published, or running.
- The Security World is not usable.

#### 6.2.2.19. encapsulate(byte[])

```
public encapsulateResponse encapsulate(byte[] keyhash)
```

Encapsulate a shared secret using the public half of a key pair

**Parameters**

`keyhash` - the hash of the public key to encapsulate with.

**Returns**

An `encapsulateResponse` object encapsulating a shared secret in plaintext and a ciphertext (encapsulation) of this shared secret.

**Throws**

`RuntimeException` - if the alias passed in does not belong to an existing key.
`NFException` - if one of the following conditions is met:

- The PQSDK SEE machine is not installed, published, or running.
- The Security World is not usable.

#### 6.2.2.20. encapsulateImmediate(byte[], int)

```
public encapsulateImmediateResponse encapsulateImmediate(byte[] publicKey, int algorithm)
```

Encapsulate a shared secret using a public key

**Parameters**

`publicKey` - the public key to encapsulate with.
`algorithm` - the encapsulation algorithm.

**Returns**

An `encapsulateResponse` object encapsulating a shared secret in plaintext and a ciphertext (encapsulation) of this shared secret.

**Throws**

`NFException` - if one of the following conditions is met:

- The PQSDK SEE machine is not installed, published, or running.
- The Security World is not usable.

#### 6.2.2.21. decapsulate(String, byte[], byte[])

```
public decapsulateResponse decapsulate(String alias, byte[] keyhash, byte[] ciphertext)
```

Decapsulate a shared secret using the private half of a key pair

**Parameters**

`alias` - the name of the private key to decapsulate with.
`keyhash` - the hash of the private key to decapsulate with. Only used if the alias is null.
`ciphertext` - the encapsulated secret to decapsulate.

**Returns**

A `decapsulateResponse` object encapsulating the shared secret.

**Throws**

`RuntimeException` - if the alias passed in does not belong to an existing key.
`NFException` - if one of the following conditions is met:

- The PQSDK SEE machine is not installed, published, or running.
- The Security World is not usable.

#### 6.2.2.22. decapsulate(String, byte[])

```
public decapsulateResponse decapsulate(String alias, byte[] ciphertext)
```

Decapsulate a shared secret using the private half of a key pair

**Parameters**

`alias` - the name of the private key to decapsulate with.
`ciphertext` - the encapsulated secret to decapsulate.

**Returns**

A `decapsulateResponse` object encapsulating the shared secret.

**Throws**

`RuntimeException` - if the alias passed in does not belong to an existing key.
`NFException` - if one of the following conditions is met:

- The PQSDK SEE machine is not installed, published, or running.
- The Security World is not usable.

#### 6.2.2.23. decapsulate(byte[], byte[])

```
public decapsulateResponse decapsulate(byte[] keyhash, byte[] ciphertext)
```

Decapsulate a shared secret using the private half of a key pair

**Parameters**

`keyhash` - the hash of the private key to decapsulate with.
`ciphertext` - the encapsulated secret to decapsulate.

**Returns**

A `decapsulateResponse` object encapsulating the shared secret.

**Throws**

`RuntimeException` - if the alias passed in does not belong to an existing key.
`NFException` - if one of the following conditions is met:

- The PQSDK SEE machine is not installed, published, or running.
- The Security World is not usable.

# 7. Examples

There are various example programs included in the `examples` directory. These examples use the `pqsdk.jar` file to interface with the SEE machine and demonstrate how to use the PQSDK API.

## 7.1. Installation with no pre-built examples

In an installation with no pre-built examples, the example programs need to be compiled before they can be run. For example, to execute the `SignVerify` example for a Solo XC run the following commands:

```
cd /opt/nfast/pqsdk/examples/xc
javac -d . -cp /opt/nfast/java/classes/nCipherKM.jar:/opt/nfast/pqsdk/bin/java/pqsdk.jar SignVerify.java
jar -cf examples.jar com/entrust/pqsdk/examples/SignVerify.class
java -cp examples:/opt/nfast/pqsdk/bin/java/pqsdk.jar com.entrust.pqsdk.examples.SignVerify
```

You can use the source code as the basis for your own programs, or modify it to your needs.

## 7.2. Installations with pre-built examples

In an installation with pre-built examples, the example programs are compiled into pqsdk-examples.jar. For example, to execute the `ImportKeypair` example under n5 run the following commands:

```
cd /opt/nfast/pqsdk/examples/n5
java -cp /opt/nfast/pqsdk/bin/java/pqsdk-examples.jar com.entrust.pqsdk.examples.ImportKeypair
fe80::216:3eff:fe6c:1bb%nshield0 8888
```