Introduction

STM32 Trusted Package Creator is part of the STM32CubeProgrammer tool set (STM32CubeProg), and allows the generation of secure firmware and modules to be used for STM32 secure programming solutions which are:

- Secure firmware install (SFI): SFI is a secure mechanism that allows secure installation of OEM firmware in untrusted production environments by having the whole firmware encrypted with an AES-GCM key.

- Secure module install (SMI): SMI is intended to protect a part of the firmware (a section of an ELF file) by also encrypting this section using an AES-GCM key. A combined SFI-SMI image is an SFI image that contains one or more module areas.

- Secure firmware upgrade (SFU): SFU is a solution to allow the upgrade of the STM32 microcontroller built-in program in a secure way. For more information about SFU, please refer to the X-CUBE-SBSFU package on http://www.st.com for further information.

This user manual details the software environment prerequisites, as well as the available features of the STM32 Trusted Package Creator tool software.
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1 System requirements

Supported operating systems and architectures:

- Linux®® 64-bit
- Windows®® 7/8/10 32-bit and 64-bit
- macOS®® (minimum version OS X®® Yosemite)

STM32Cube Programmer and STM32 Trusted Package Creator support STM32 32-bit devices based on Arm®®(a) Cortex®®-M processors.

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a. Arm is a registered trademark of Arm Limited (or its subsidiaries) in the US and or elsewhere.
2 Preparation processes

2.1 SFI preparation process

An SFI (Secure firmware install) image is a format created by STMicroelectronics that contains an encrypted and authenticated piece of firmware using an AES-GCM algorithm. The SFI preparation process is described in Figure 1.

Figure 1. SFI preparation process
Before performing AES-GCM to encrypt an area, the tool calculates the Initialization Vector (IV) as:

$$IV = \text{nonce} + \text{Area Index}$$

Where nonce is a number used only once as a start of an iterated process in the AES-GCM algorithm to give different cipher texts to same blocks of data.

It then, it passes the area descriptor (starting from the magic to the total number of areas) as additional authenticated data (AAD).

- Each segment in the input firmwares constitutes a firmware (F) area in the SFI file.
- Each SMI file (combined case) constitutes a module (M) area.
- The option bytes configuration constitute the configuration (C) area.

To generate a header tag, the tool performs an authenticated only AES-GCM encryption (without a plain text nor a cipher text) using the SFI header as an AAD and the nonce as the IV.

The structure of an SFI file is shown in Figure 2.

**Figure 2. SFI file structure**
To prepare an SFI image from multiple firmware files you have to make sure that there is no overlap between their segments, otherwise you will get the error message: “Overlap between segments, unable to merge firmware files”.

Furthermore, in the case of a combined SFI-SMI image, there is also an overlap check between the areas (in case there is an overlap between firmware and module areas). If the check fails, an error message is shown: “Overlap between SFI areas”.

Also, all SFI areas must be located in Flash memory, otherwise the generation fails giving the error message: “One or more SFI areas are not located in Flash memory”.

2.2 SMI preparation process

An SMI image (Secure Module Install) protects only a module of the firmware.

The SMI preparation process is shown in Figure 3.

The AES-GCM encryption is performed using the following inputs:
- Nonce as the initialization vector (IV)
- The security version as additional authenticated Data (AAD)
Before SMI preparation, the following checks are performed:

- A proprietary code read out protection (PCROP) section must be aligned on a Flash word (256 bits) otherwise a warning is shown
- The section's size must be at least 2 Flash words (512 bits) otherwise a warning is shown
- The section must end on a Flash word boundary (a 256 bit word) or a warning is shown
- If the section immediately following the PCROP area starts in the last Flash word of the PCROP section, the generation fails and an error message is shown.

After the SMI preparation, a clear (that is, not encrypted) ELF file is also generated containing program data and only clear sections of the code.

The structure of an SMI file is shown in *Figure 4.*

*Figure 4. SMI file structure*
2.3 **SFU preparation process**

An SFU image (Secure Firmware Upgrade) allows the upgrade of the STM32 microcontroller built-in program in a secure way to prevent unauthorized updates.

The SFU preparation process is shown in *Figure 5*.

*Figure 5. SFU preparation process*
2 files are generated, the SFU image header and the SFU encrypted firmware image.

For the header generation, the AES-GCM encryption is performed using the following inputs:

- Nonce as the Initialization Vector (IV)
- No Additional Authenticated Data (AAD)

And for the encrypted firmware image generation:

- Nonce as the Initialization Vector (IV)
- The header content as Additional Authenticated Data (AAD)

The structure of an SFU file is shown in Figure 6.

**Figure 6. SFU file structure**
2.4 HSM preparation process

This section describes the steps required to configure a hardware secure module (HSM) to generate firmware licenses for STM32 secure programming using STM32 Trusted Package Creator.

2.4.1 Why we need an HSM

Some STM32 devices offer secure firmware flashing. Firmware can be a complete application, a library, a secure library (for STM32 with TrustZone), or other secret information.

An important secure flashing feature is controlled by the firmware provider of the number of devices that can be programmed. This is where the concept of licenses is important.

The firmware maker provides licenses to its customers, authorizing them to flash the encrypted firmware (SFI and/or SMI) on specific devices.

A license is only valid for a single device, but the firmware provider can distribute as many licenses as required.

STMicroelectronics offers the secure firmware flashing service based on HSM (hardware secure modules) as a license generation tool to be deployed in the programming house. The general scheme is as follows:

1. Generate a firmware key and use it to encrypt the firmware (SFI/SMI) when the firmware provider wishes to distribute a new firmware.
2. While downloading the firmware to a device, a device identifier is sent to the HSM, which returns a license for the identified device. The license contains the encrypted firmware key, and only this device can decrypt it.
3. The number of programmed devices is under HSM control. It is decremented once a license is generated.

STM32 Trusted Package Creator allows HSM configuration for secure firmware flashing as described in the following section.
2.4.2 HSM programming

When an OEM needs to deliver an HSM to a programming house to be deployed as a license generation tool for relevant STM32 device programming, they must perform some customization on his HSM first.

They must program the HSM with all the data needed for the license scheme deployment in the production line.

This OEM data is:

- **Counter**: The counter is set to a maximum value that corresponds to the maximum number of licenses that can be delivered by the HSM, it aims to prevent over programming. It is decremented with each license delivered by the HSM. No more licenses are delivered by the HSM once the counter is equal to zero. The maximum counter value must not exceed the predefined maximum value (1 million units).

- **Firmware key**: This key is 32 bytes and is composed of two fields, the initialization vector (IV) or nonce (first field), and the key (last field) that were used to AES128-GCM encrypt the firmware and generate the SFI file. Both fields are 16 bytes long, but the last 4 bytes of the nonce must be zero (only 96 bits of the nonce are used in the AES128-GCM algorithm). Both fields must remain secret, so they are encrypted before being sent to the chip. The key and the nonce remain the same for all licenses for a given piece of firmware. However, they must be different for different firmware or different versions of the same firmware.

- **Firmware identifier**: Identifies the correct HSM for a given firmware.

Once this data is programed into the HSM, the HSM is automatically locked. *Figure 7: HSM programming tab* shows the GUI provided by the tool for HSM programming by the firmware provider.
The tab parameters are as follows:

- **HSM card index**: Specifies the smart card reader slot number.
- **Firmware identifier**: Identifies the correct HSM for a given piece of firmware.
- **Encryption key file**: A binary file containing the key used to encrypt the firmware and generate the SFI file. The key is 16 bytes long.
- **Nonce file**: A binary file containing the nonce used to encrypt the firmware and generate the SFI file. The nonce is 12 bytes long.
- **Maximum counter**: The maximum number of licenses that can be delivered by the HSM (it aims to prevent over programming). The counter value must not exceed a predefined maximum (1 million units).

When all fields are properly filled in, the user can program the HSM file by clicking on the Program HSM button (the button becomes active).

**Caution**: Once this data is programmed into the HSM, the HSM is automatically locked.
2.4.3 Reading HSM information

The programmed information is verifiable using the HSM information panel shown in Figure 8:

Figure 8. Reading HSM information

This panel displays the Firmware identifier, the maximum counter and the HSM status.

The HSM status can be:

- **OEM_STATE**: HSM not programmed.
- **OPERATIONAL_STATE**: HSM programmed and locked. It can no longer be programmed.
3 STM32 Trusted Package Creator tool commands

3.1 Command line interface (CLI)

The following sections describe how to use the STM32 Trusted Package Creator tool from the command line interface. The available commands are shown in Figure 9.

Figure 9. STM32 Trusted Package Creator tool’s available commands

```
<file path> -A <file name> [other options]

Options:
- h, --help
  Display this help message and exit.
- v, --version
  Output version information and exit.
- c, --cmdline
  Generate CLI commands in a file.
- s, --save
  Save the file to a specified file.
- m, --make
  Generate a Makefile.
- f, --flash
  Flash a file to an assessed chip.
- d, --debug
  Debug mode.
- r, --run
  Run a file.
- n, --name
  Name of the file.
- i, --info
  Display file information.
- b, --build
  Build a file.
- r, --remove
  Remove a file.
- l, --list
  List all files.
- p, --compare
  Compare two files.
- t, --type
  Set the file type.
- q, --quiet
  Quiet mode.
- v, --verbose
  Verbose mode.
- o, --output
  Output file name.
- s, --source
  Source file name.
- d, --destination
  Destination file name.
- c, --compiled
  Compiled file name.
- f, --flash
  Flash a file to an assessed chip.
- r, --run
  Run a file.
- n, --name
  Name of the file.
- i, --info
  Display file information.
- b, --build
  Build a file.
- r, --remove
  Remove a file.
- l, --list
  List all files.
- p, --compare
  Compare two files.
- t, --type
  Set the file type.
- q, --quiet
  Quiet mode.
- v, --verbose
  Verbose mode.
- o, --output
  Output file name.
- s, --source
  Source file name.
- d, --destination
  Destination file name.
```
3.2 SFI generation command

`-sfi, --sfi`

**Description:** This command generates an SFI image file.

In order to generate an SFI image, the user must provide the mandatory inputs by using the options listed below.

`-fir, --firmware`

**Description:** Add an input firmware file. Supported formats are Bin, Hex, Srec and ELF. This option can be used more than once in order to add multiple firmware files.

**Syntax:** `-fir <Firmware_file> [Address]`

- `<Firmware_file>`: Firmware file.
- `[Address]`: Address only for binary firmware.

`-k, --key`

**Description:** Set the AES-GCM encryption key.

**Syntax:** `-k <Key_file>`

- `<Key_file>`: A 16-byte binary file.

`-n, --nonce`

**Description:** Set the AES-GCM nonce.

**Syntax:** `-n <Nonce_file>`


`-v, --ver`

**Description:** Set the image version.

**Syntax:** `-v <Image_version>`

- `<Image_version>`: A value between 0 and 255 in any base.

`-ob, --obfile`

**Description:** Provide an option bytes file.

**Syntax:** `-ob <CSV_file>`

- `<CSV_file>`: A csv file with 9 values.

`-m, --module`

**Description:** Add an input SMI file. This option can be used more than once in order to add multiple SMI files. This is optional (for combined SFI-SMI).

**Syntax:** `-m <SMI_file>`

- `<SMI_file>`: SMI file.
- `[Address]`: Address only for relocatable SMI.

`-o, --outfile`

**Description:** Set the SFI file to be created
Syntax:  
-o <out_file>

Example:

With an ELF file:

STM32TrustedPackageCreator_CLI -sfi -fir ELF_firmware.axf
-k test_firmware_key.bin -n nonce.bin -ob FIR_ob.csv -v 23 -o test.sfi

Figure 10. SFI generation with an ELF file

With a binary file:

STM32TrustedPackageCreator_CLI -sfi -fir bin_firmware.bin
0x8000000 -k test_firmware_key.bin -n nonce.bin -ob FIR_ob.csv -v 23 -o test.sfi

Figure 11. SFI generation with a binary file

Combined SFI-SMI:

STM32TrustedPackageCreator_CLI -sfi -fir ELF_firmware.axf -fir bin_firmware.bin 0x8000000 -m FIR_pcrop.smi -k test_firmware_key.bin -n nonce.bin -ob FIR_ob.csv -v 23 -o test.sfi

Figure 12. Combined SFI-SMI generation
3.3 SMI generation command

-smi, --smi

**Description:** This command generates an SMI image file.

In order to generate an SMI image, the user must provide the mandatory inputs by using the options listed below.

-**elf, --elfile**

  **Description:** Set the input ELF file.

  **Syntax:** `-elf <ELF_file>`

  `<ELF_file>`: ELF file. An ELF file can have any of the extensions: .elf, .axf, .o, so, .out

-**s, --sec**

  **Description:** Set the name of the section to be encrypted.

  **Syntax:** `-s <section_name>`

  `<section_name>`: Section name.

-**k, --key**

  **Description:** Set the AES-GCM encryption key.

  **Syntax:** `-k <Key_file>`

  `<Key_file>`: A 16-byte binary file.

-**n, --nonce**

  **Description:** Set the AES-GCM nonce.

  **Syntax:** `-n <Nonce_file>`

  `<Nonce_file>`: A 12-byte binary file.

-**sv, --sver**

  **Description:** Set the security version file.

  **Syntax:** `-sv <SV_file>`


-**o, --outfile**

  **Description:** Set the SMI file to be created

  **Syntax:** `-o <out_file>`

  `<out_file>`: SMI file to be generated, must have the .smi extension.

-**c, --clear**

  **Description:** Set the clear ELF file to be created.

  **Syntax:** `-c <ELF_file>`

  `<ELF_file>`: Clear ELF file to be generated.
Example

STM32TrustedPackageCreator_CLI -smi -elf FIR_module.axf -s "ER_PCROP" -k test_firmware_key.bin -n nonce.bin -sv svFile -o test.smi -c clear.smi

3.4 SFU generation command

-sfu, --sfu

Description: This command generates an SFU image file.

In order to generate an SFU image, the user must provide the mandatory inputs by using the options listed below.

-fir, --firmware

Description: Set an input firmware file. Supported formats are Bin, Hex, Srec and ELF. The firmware file must contain only one segment.

Syntax: 

-fir <Firmware_file> [Address]

<Firmware_file>: Firmware file.

[Address]: Address only for binary firmwares.

-k, --key

Description: Set the AES-GCM encryption key.

Syntax: 

-k <Key_file>

<Key_file>: A 16-byte binary file

-n, --nonce

Description: Set the AES-GCM nonce.

Syntax: 

-n <Nonce_file>

<Nonce_file>: A 12-byte binary file

-v, --ver

Description: Set the image version.

Syntax: 

-v <Image_version>

<Image_version>: A value between 0 and 255 in any base.

-oh, --outheader

Description: Set the SFU header file to be created.

Syntax: 

-oh <out_file>
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STM32 Trusted Package Creator tool commands

[out_file]: SFU header file to be generated, must have the .sfuh extension.

-os, --outsfu

**Description**: Set the SFU file to be created.

**Syntax**: `-os     <out_file>`

[out_file]: SFU file to be generated, must have the .sfu extension.

**Example**:  
```
SFMIPreparationTool_CLI   -sfu   -fir   bin_firmware.bin   -k 
test_firmware_key.bin   -n   nonce.bin   -v   23
-oh   out.sfuh   -os   out.sfu
```

**Figure 14. SFU generation**

3.5 STM32WB firmware signing

-sign, --sign

**Description**: Sign a binary image using ECDSA algorithm and save the public key in a binary file in the same folder as the private key. You need to provide the information listed below.

`-bin,     --binary`: Input firmware image in a binary format to be signed  
<Img_File>: Binary image file path

`-prvk,     --privatekey`: EC private key in PEM format with Prime256v1 curve.  
<prvk_File>: Private key file Path

`-v,     --version`: Signed image version  
<Img_Ver>: Version number. Should be integer.

`-o,     --outfile`: Output image file path  
<Output_File>: Signed image file path

**Example**:  
```
openssl.exe ecparam -name prime256v1 -genkey -noout -out prvkey.pem
```

Before loading the signed image to STM32WB devices using STM32CubeProgrammer via `-fwupgrade` command, you need to download the binary public key using the `-authkeyupdate` command.

For more information about these STM32CubeProgrammer commands please refer to UM2237.
4 STM32 Trusted Package Creator tool graphical user interface (GUI)

This section describes how to use the STM32 Trusted Package Creator tool with its graphical user interface.

The STM32 Trusted Package Creator tool GUI presents three tabs: one for SFI generation (Figure 15), one for SMI generation (Figure 16) and one for SFU generation (Figure 17).

Figure 15. STM32 Trusted Package Creator tool GUI SFI tab
Figure 16. STM32 Trusted Package Creator tool GUI SMI tab
4.1 SFI generation

To validate the SFI generation request, the user has to fill in the input fields with valid values:

**Firmware files:**

The user must add the input firmware files with the **add** button.

*Note:* If the file is valid, it is added in the firmware files list. Selecting it makes several pieces of related information appear in the Firmware information section (Figure 18), otherwise an error message box is shown saying either the file could not be opened or the file is not valid. If the file is in a binary format, a dialog box appears requesting that an address be provided. A file can be removed with the **remove** button.
Figure 18. Firmware file addition

Encryption key and nonce file:
The encryption key and nonce file can be selected by entering their paths (absolute or relative), or by selection with the open button. Notice that sizes must be respected (16 bytes for the key and 12 bytes for nonce).

Option bytes file:
The option bytes file can be selected the same way. Only csv files are supported.

SMI files:
SMI files can be added the same way as the firmware files. Selecting a file makes several pieces of related information appear in the Firmware information section.

Image version:
Image version value in [0..255].

RAM size:
Size of RAM memory available for SFI programming.
Continuation token address:
Address at which to store the Continuation token. The address must not collide with other areas.

Output file:
An output file can be selected by entering its path (absolute or relative), or with the select folder button, note that with the latter way, a name `out.sfi` is suggested, you can keep or change it.

When all fields are properly filled in, the Generate SFI button becomes active. The user may generate the SFI file by clicking on it.

If everything goes well, a message box indicating successful generation appears (Figure 19) and information about the generated SFI file is displayed in the SFI information section.

Figure 19. Successful SFI generation
4.2 SMI generation

As for SFI generation, the user must provide the input information.

Elf file:

In this case, the input file can be only an elf file.

If the file is valid, information is displayed in the "ELF information" tab (Figure 20), otherwise an error message box is shown saying either the file could not be opened or that the file is not valid.

Figure 20. ELF file selection
Encryption key and nonce file:
As for SFI, the Encryption key and nonce file can be selected in the same way as the firmware file. Notice that sizes must be respected (16 bytes for the key and 12 bytes for nonce).

Security version file:
The security version file size must be 16 bytes.
A security version file is provided under the Security_Version folder.

Section:
This is a section list that can be used to select the name of the section to be encrypted.

output files:
Output files can be selected by entering their paths (absolute or relative), or with the Select folder button, note that with the latter way a name is suggested, which can be kept or changed.

When all fields are properly filled in, the user may generate the SFI file by a click on the Generate SFI button (the button becomes active).

A message box informing the user that generation was successful appears (Figure 21), in addition of information about the generated SMI file, otherwise an error is displayed.
4.3 SFU generation

Input fields in this case are similar to the SFI generation use case.

**Firmwares files:**

The user needs to enter the input firmware files.

If the file is valid, several pieces of related information appear in the Firmware information section (*Figure 22*), otherwise an error message box is shown. Note that the firmware file must have only one segment.
Encryption key and nonce file:
Same as for SFI and SMI use cases.

Image version:
Image version value in [0..255].

output files:
Output files can be selected by entering their paths (absolute or relative), or with the select folder button, note that in the latter way a name is suggested, which can be kept or changed.

When all fields are properly filled in, the Generate SFU button becomes active. The user may generate the SFU file by clicking on it.

If everything goes well, a message box informing that generation is successful appears (Figure 23) and information about the generated SFU file is displayed in the SFU information section.
Figure 23. Successful SFU generation
5 Option bytes file

The option bytes file field is mandatory for SFI applications only, it allows option bytes to be programmed during secure firmware install.

Only CSV (Comma Separated Value) format is supported for such files, it is composed of two vectors: a register name and its value.

All of the 9 option-byte registers must be configured (a total of 9 lines in a csv file).

Figure 24. Example of an option bytes file

![Example of an option bytes file](image)
6 Log dialog

A log can be visualized by clicking the log button in the tools bar or in the menu bar: Options-> log.

Figure 25. Example of a log dialog
7 Settings

The settings dialog can be accessed by clicking the settings button in the tools bar or in the menu bar: Options -> settings.

![Figure 26. Settings dialog](image)

**Padding byte:**

When parsing files, padding may be added to fill the gap between segments separated by 16 bytes or less, in order to merge them and reduce the number of segments. The user may have the choice between 0xFF (default value) or 0x00.

**Settings file:**

When checked, a settings.ini file is generated in the executable folder. It saves the application state: window size and field contents.

**Log file:**

When checked, a log file is generated in the selected path.
8 SFI/SMI checking

SFI/SMI checking can be accessed by clicking the **Check SFI/SMI** button in the tools bar or in the menu bar: File -> Check SFI/SMI.

This allows SFI or SMI file validity to be checked, in addition to displaying information about it.

**Figure 27. SFI checking**
## Reference documents

### Table 1. Document references

<table>
<thead>
<tr>
<th>ID</th>
<th>Revision</th>
<th>Title</th>
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10 Revision history

Table 2. Document revision history

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<tr>
<th>Date</th>
<th>Revision</th>
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<td>20-Dec-2017</td>
<td>1</td>
<td>Initial release.</td>
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<tr>
<td>07-Mar-2019</td>
<td>2</td>
<td>Added Section 3.5: STM32WB firmware signing. Updated:</td>
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<td></td>
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<td>- Section 4.1: SFI generation.</td>
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<td>- Figure 9: STM32 Trusted Package Creator tool's available commands</td>
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<tr>
<td></td>
<td></td>
<td>- Figure 15: STM32 Trusted Package Creator tool GUI SFI tab</td>
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<td>- Figure 18: Firmware file addition</td>
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<tr>
<td>16-Apr-2019</td>
<td>3</td>
<td>Updated Section 1: System requirements</td>
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<td>Updated Section 2.4: HSM preparation process.</td>
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<td></td>
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<td>Updated Figure 15: STM32 Trusted Package Creator tool GUI SFI tab.</td>
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