AN5054
Application note

How to perform secure programming using STM32CubeProgrammer

Introduction

This document specifies the steps and tools required to prepare SFI (secure internal firmware install), SFIx (secure external firmware install), SMI (secure module install) or SSP (secure secret provisioning) images. It then describes how to program these into STM32 MCU devices that support SFI/SFIx on-chip internal memory, external flash memory or, for the SSP install procedure, STM32 MPU devices. It is based on the STM32CubeProgrammer tool set (STM32CubeProg). These tools are compatible with all STM32 devices.

The main objective of the SFI/SFIx and SMI processes is the secure installation of OEM and software-partner's firmware, which prevents firmware cloning.

The STM32MP1 Series supports protection mechanisms allowing protection of critical operations (such as cryptography algorithms) and critical data (such as secret keys) against unexpected access.

This application note also gives an overview of the STM32 SSP solution with its associated tool ecosystem, and explains how to use it to protect OEM secrets during the CM product manufacturing stage.

Refer also to:

- AN4992 *[1]*, which provides an overview of the secure firmware install (SFI) solution, and how this provides a practical level of protection of the IP chain - from firmware development up to programming the device on-chip flash memory.
- AN5510 *[3]*, which provides an overview of secure secret provisioning (SSP).

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1.1 Licensing information

STM32CubeProgrammer supports STM32 32-bit devices based on Arm®(a) Cortex®-M processors.

arm

1.2 Acronyms and abbreviations

Table 1. List of abbreviations

Abbreviations	Definition
AES	Advanced encryption standard
CLI	Command-line interface
CM	Contract manufacturer
GCM	Galois counter mode (one of the modes of AES)
GUI	Graphical user interface
HSM	Hardware security module
HW	Hardware
MAC	Message authentication code
MCU	Microcontroller unit
OEM	Original equipment manufacturer
OTP	One-time programmable
PCROP	Proprietary code read-out protection
PI	Position independent
ROP	Read-out protection
RSS	Root security service (secure)
RSSe	Root security service extension
SFI	Secure (internal) firmware install
SFIx	Secure external firmware install
SMI	Secure modules install
SSP	Secure secret provisioning
STPC	STM32 Trusted Package Creator
STM32	ST family of 32-bit Arm®-based microcontrollers

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

Table 1. List of abbreviations (continued)

Abbreviations	Definition
SW	Software
XO	Execute only

2 How to generate an execute-only and position independent library for SMI preparation

This section describes the requirements and procedures for the preparation of an execute-only (XO) and position independent (PI) library using a partner toolchain.

These kinds of libraries serve in encrypted SMI-module generation.

2.1 Requirements

SMI modules run in execute-only (XO) areas, also called PCROP areas, and must be relocatable to be linkable with the final OEM application. Nevertheless, today, third-party toolchains for STM32 devices (such as MDK-ARM™ for Arm, EWARM for IAR™ and GCC based IDEs) do not allow both features to be activated at the same time. So, starting from particular versions of third-party toolchains, the two features below are possible for SMI support:

- Position independent support (code + rw data + ro data)
- No literal pool generation - needed for the PCROP feature.

2.2 Toolchains allowing SMI generation

Three toolchains allow SMI generation:

- EWARM

  Version 7.42.0 allows execute-only (XO) and position independent (PI) library generation for SMI support through the following options: “--ropi_cb” + “rwpi” + “--no_literal_pool”.

  – “--ropi_cb” + “rwpi” are needed for position independent support

  – option “no_literal_pool” is needed for the PCROP feature.

- MDK-ARM

  The customized version allows execute-only (XO) and position independent (PI) library generation for SMI support through the following options: “-fropi-cb”, “-frwpi”, “-mexecute-only”.

  – “fropi-cb” is needed for ro data independent position

  – “frwpi” is needed for rw data independent position

  – option “-mexecute-only” is needed for the PCROP feature.

  All library symbols being used in the final application must be added to the final project in a “.txt” file format.

- GCC

  The customized version of GCC-based toolchains allows execute-only (XO) and position independent (PI) library generation for SMI support through the following options: “-masset”.

  Option “-masset” has the same role as “--ropi --ropi_cb --rwpi --no_literal_pool” options used for the EWARM toolchain.

2.3 Execute-only/position independent library scenario example under EWARM

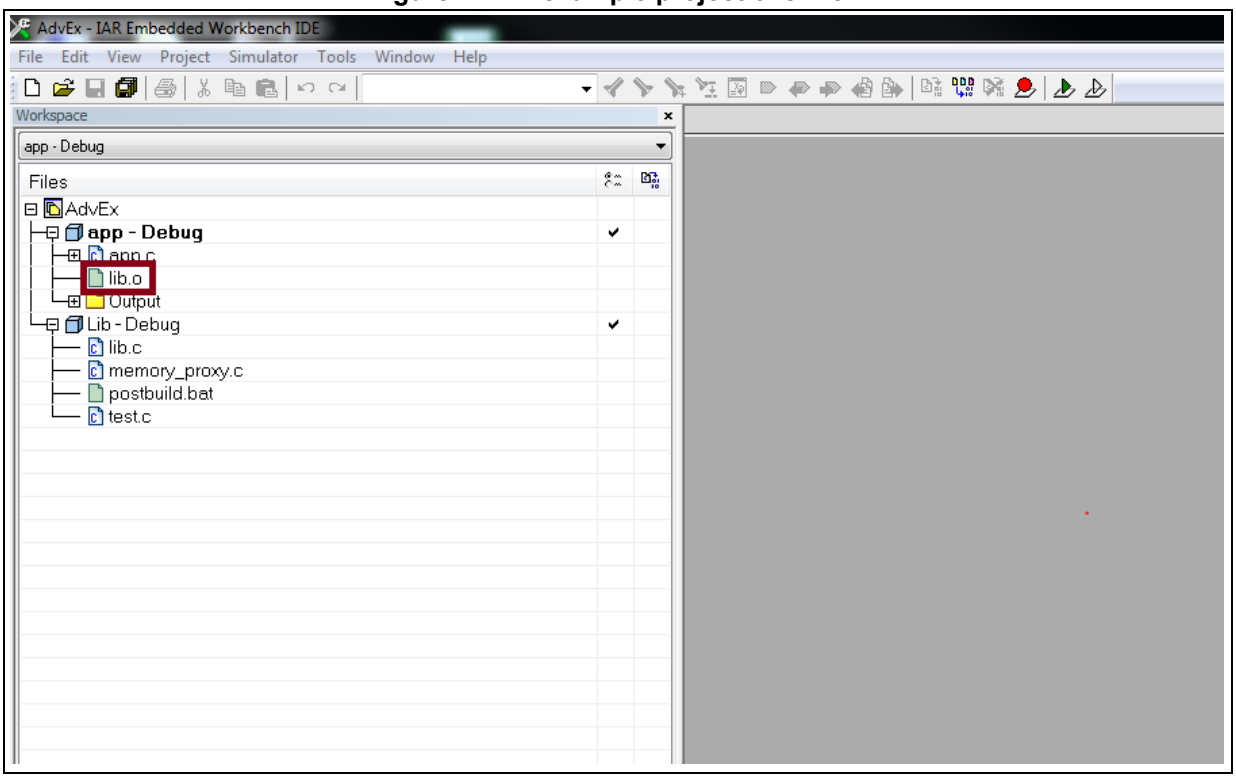
To generate an execute-only (XO) and position independent (PI) library, a customized version of the IAR toolchain must be used: version 7.42.0.

2.3.1 Relocatable library preparation steps

1. Open the project available in the “Example” folder: double-click on *“Example/AdvEx.eww”*.

   The project architecture is illustrated in *Figure 1*.

Figure 1. IAR example project overview

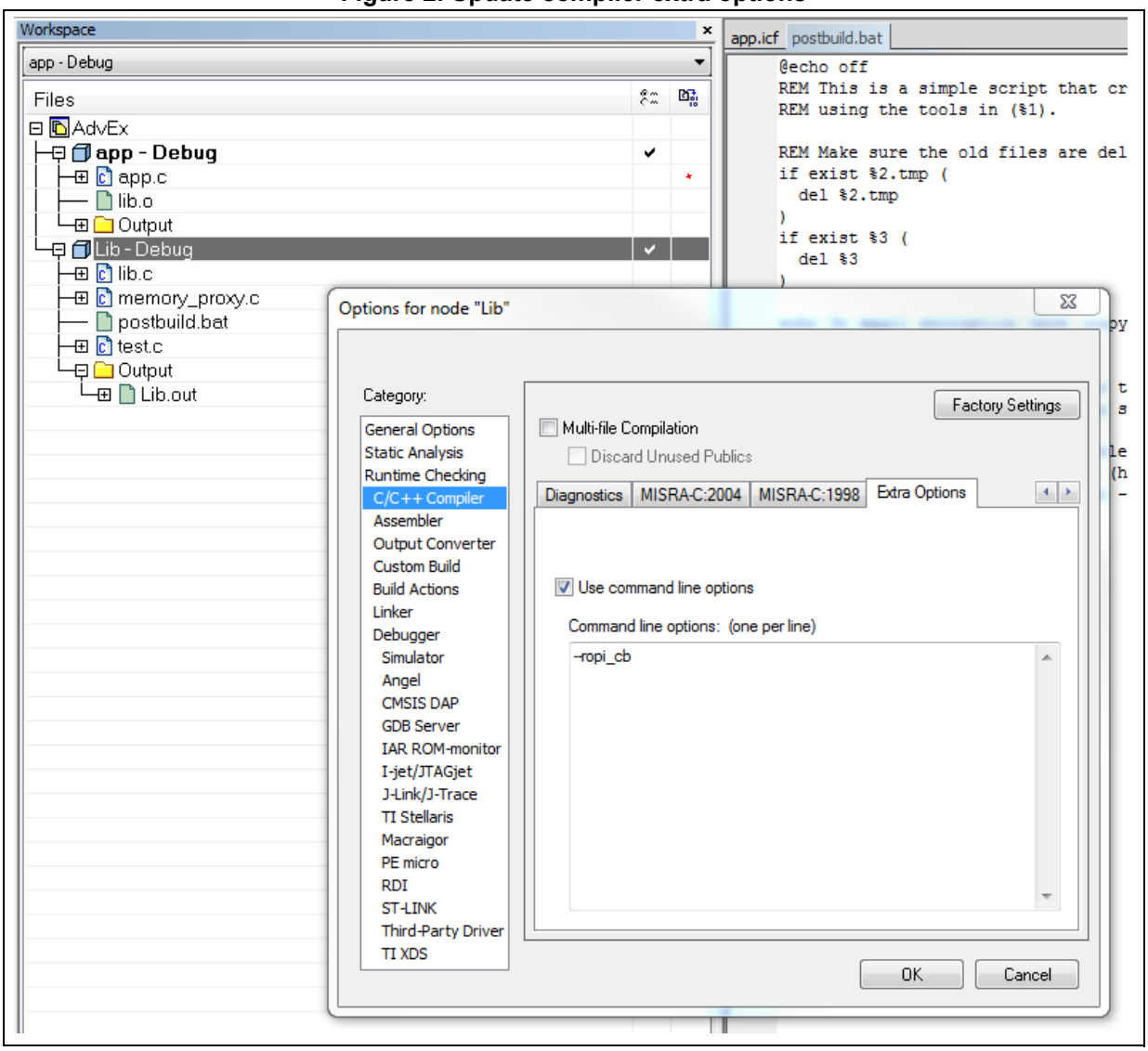


The following steps update the old *“lib.o”* linked to the example application by making it support both PI and XO features:

2. Within Lib-Debug options -> C/C++ Compiler. Go to the tab “Extra Options” and add the following line:
   “--ropi_cb”

   This action is illustrated in *Figure 2*.

Figure 2. Update compiler extra options



3. Within Lib-Debug options -> Linker. Go to the “Extra Options” tab and add the following lines:

   --no_literal_pool

   --ropi_cb

   --loadable

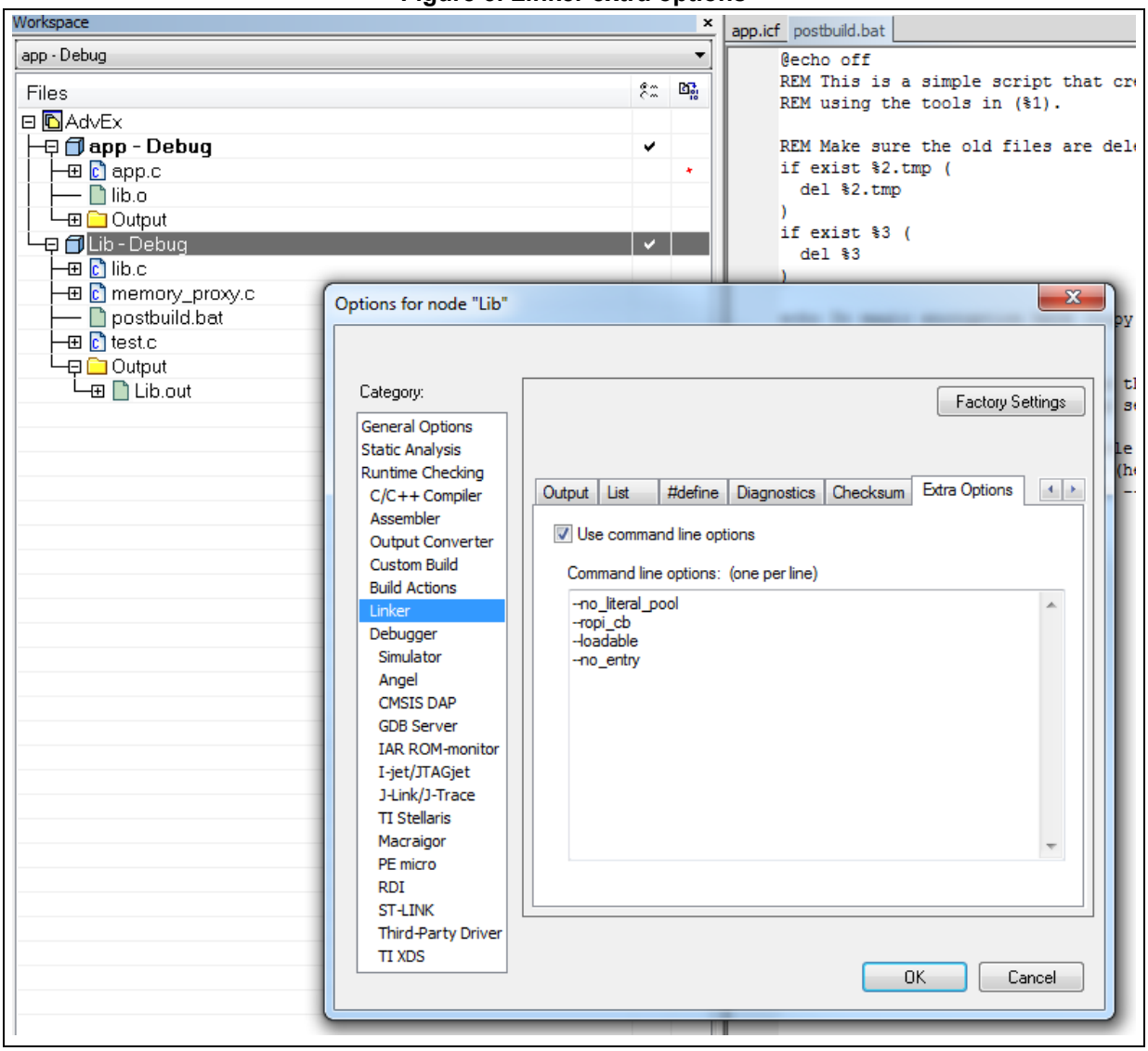
   --no_entry

   This action is illustrated in *Figure 3*.

   – “ropi_cb” is needed for Position Independent support

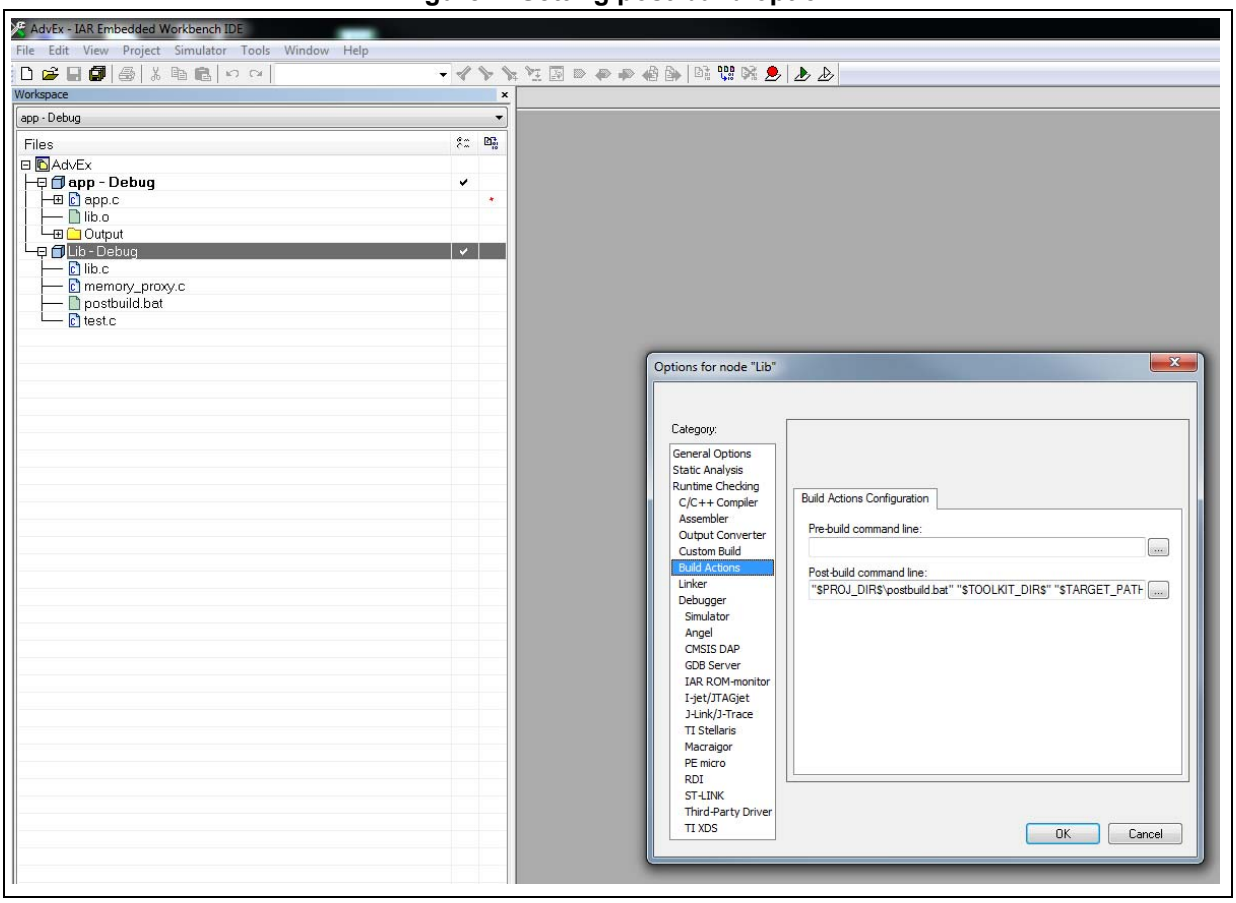
   – the “no_entry” is a linker option that sets the entry point field to zero.

Figure 3. Linker extra options



4. Within Lib-Debug options -> Build actions. In the post, build command line execute the batch file *"postbuild.bat"* by inserting, if it is not already configured, the following command line:
   `"$PROJ_DIR$\postbuild.bat" "$TOOLKIT_DIR$" "$TARGET_PATH$" "$PROJ_DIR$\lib.o"`
   This action is illustrated in *Figure 4*.

Figure 4. Setting post-build option

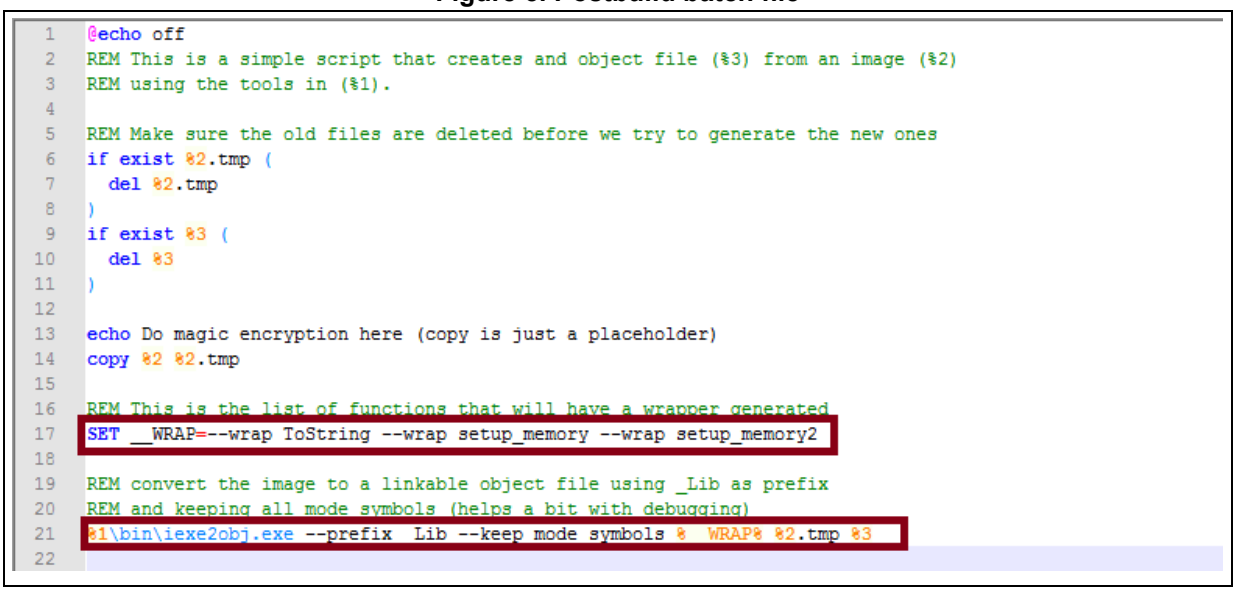


The *"postbuild.bat"* file is used to perform some key actions:

- **--wrap**: adds veneers to library functions to initialize registers used for ropi code
- *"iexe2obj.exe"*: transforms the ELF file into a linkable object file.

See *Figure 5*.

Figure 5. Postbuild batch file



```
@echo off
REM This is a simple script that creates and object file (%3) from an image (%2)
REM using the tools in (%1).

REM Make sure the old files are deleted before we try to generate the new ones
if exist %2.tmp (
  del %2.tmp
)
if exist %3 (
  del %3
)

echo Do magic encryption here (copy is just a placeholder)
copy %2 %2.tmp

REM This is the list of functions that will have a wrapper generated
SET __WRAP=--wrap ToString --wrap setup_memory --wrap setup_memory2

REM convert the image to a linkable object file using _Lib as prefix
REM and keeping all mode symbols (helps a bit with debugging)
%1\bin\iexe2obj.exe --prefix _Lib --keep mode symbols %__WRAP% %2.tmp %3

```

5. Rebuild the project “Lib”

2.3.2 Relocatable SMI module preparation steps

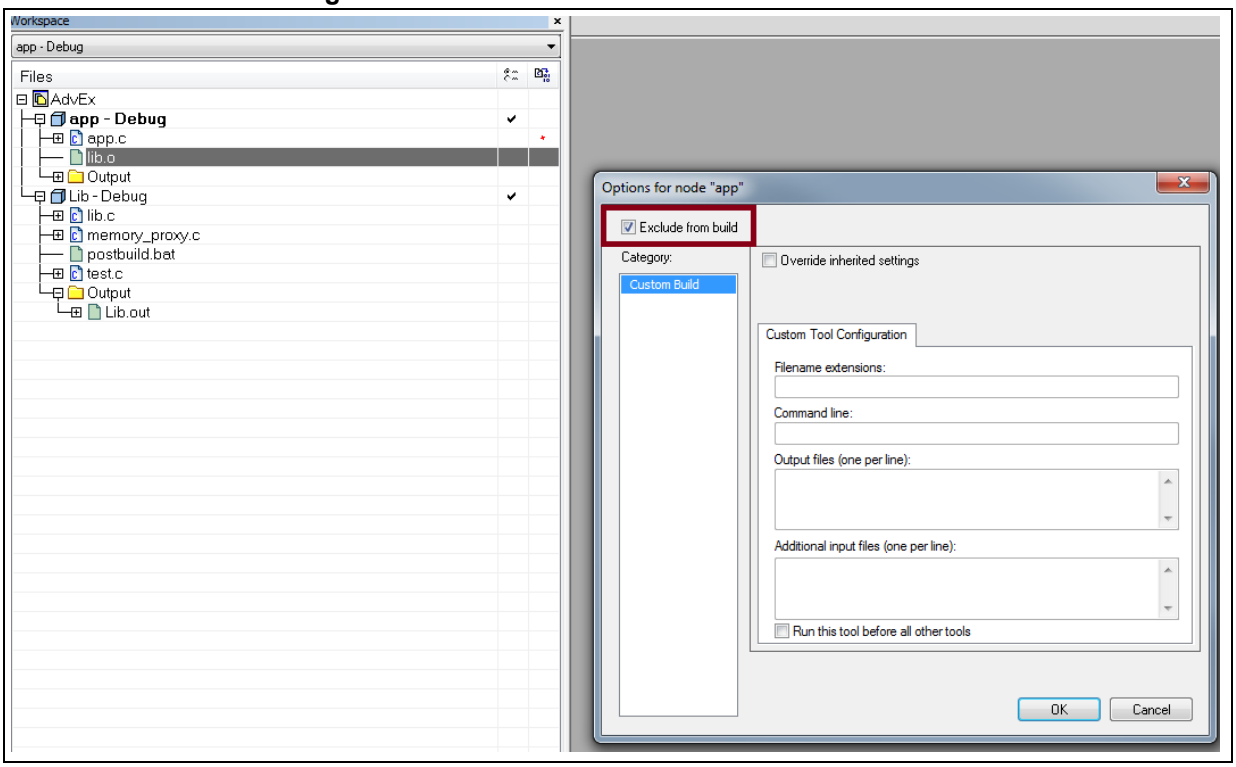
From the object file created, *“lib.o”*, generate the SMI relocatable module using the STM32 Trusted Package Creator tool *“libr.smi”* and its corresponding data clear part (*libr_clear.o*: corresponding to the input *“lib.o”* without the protected section code).

To execute this step, follow the steps explained for SMI generation under section “*Section 3.6.2: Steps for SMI generation (CLI)*”.

2.3.3 Application execution scenario

1. Flash the already generated SMI relocatable module to address 0x08080000 using STM32CubeProgrammer v0.4.0 or newer (see *Section Figure 66.: SFI installation via SWD execution - (2)* to perform this action).
2. Link the data clear part, *"libr_clear.o"*, generated from the STM32 Trusted Package Creator tool to the final IAR example application instead of the old previously used *"lib.o"*.
3. Exclude *"lib.o"* from the build (*Figure 6*).

Figure 6. How to exclude the "lib.o" file from build



4. Rebuild the application.
5. Do these modifications in an example application ICF file:
   a) Define the region for PCROP block.

      define symbol __ICFEDIT_region_PCROP_start__ = 0x08080000;

      define symbol __ICFEDIT_region_PCROP_end__ = 0x0809FFFF;

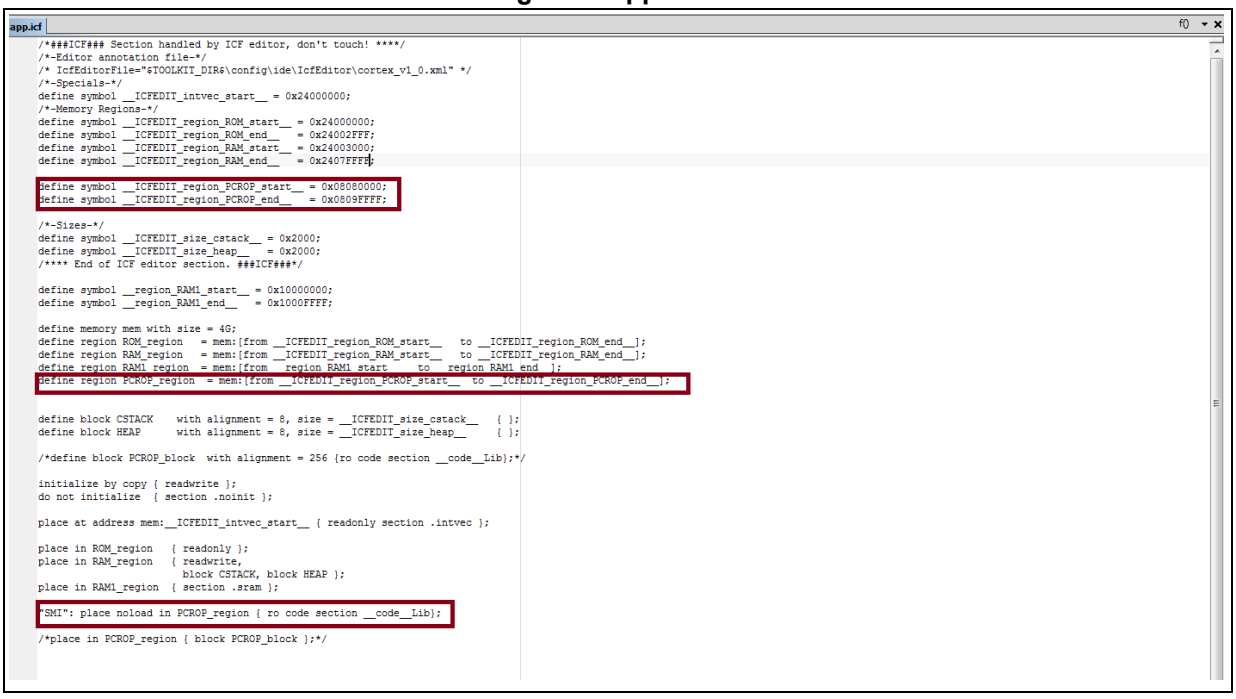
      define region PCROP_region = mem:[from __ICFEDIT_region_PCROP_start__ to __ICFEDIT_region_PCROP_end__];

   b) Define the PCROP region as 'noload' (since it is already installed using the STM32CubeProgrammer, there is no need to load it again.).

      'SMI': place noload in PCROP_region { ro code section __code__Lib};

These modifications are illustrated within the *"app.icf"* file, which is shown in *Figure 7*.

Figure 7. app.icf file



6. To check that the example application is executed successfully on the STM32H7 device:
   a) Check that address 0x08080000 was protected with PCROP.
   b) The expected "`printf`" packets appear in the terminal output.

3 Encrypted firmware (SFI) and module (SMI) preparation using the STPC tool

The STM32 Trusted Package Creator (STPC) tool allows the generation of SFI and SMI images for STM32H7 devices. It is available in both CLI and GUI modes free of charge from *www.st.com*.

3.1 System requirements

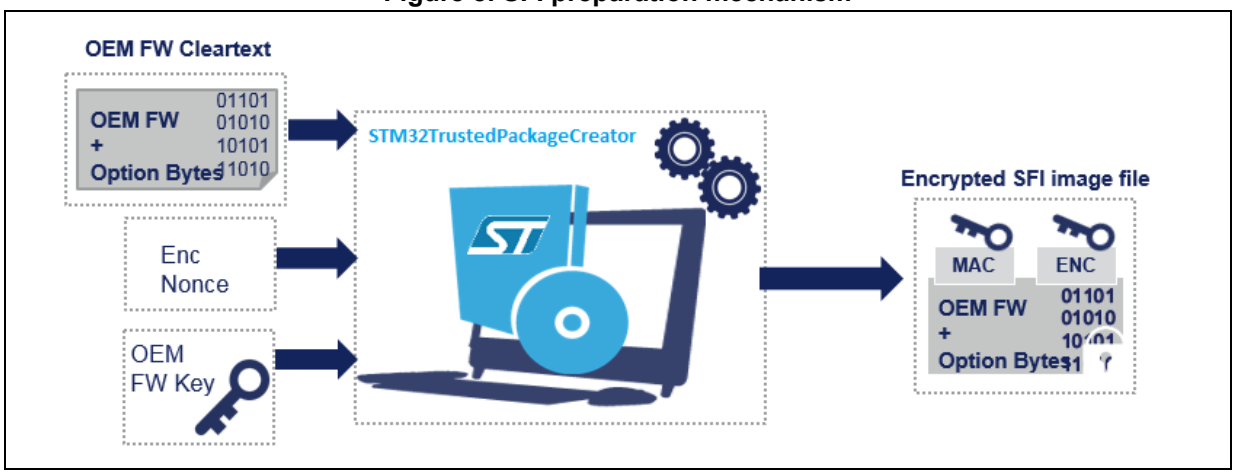
Using the STM32 Trusted Package Creator tool for SFI/SFIx, SMI, and SSP image generation requires a PC running on either Windows®(a), Linux®(b) Ubuntu®(c) or Fedora®(d), or macOS®(e).

Note: Refer to [4] or [5] for the supported operating systems and architectures.

3.2 SFI generation process

The SFI format is an encryption format for internal firmware created by STMicroelectronics that transforms internal firmware (in ELF, Hex, Bin, or Srec formats) into encrypted and authenticated firmware in a SFI format using the AES-GCM algorithm with a 128-bit key. The SFI preparation process used in the STM32 Trusted Package Creator tool is described in *Figure 8*.

Figure 8. SFI preparation mechanism



a. Windows is a trademark of the Microsoft group of companies.

b. Linux® is a registered trademark of Linus Torvalds.

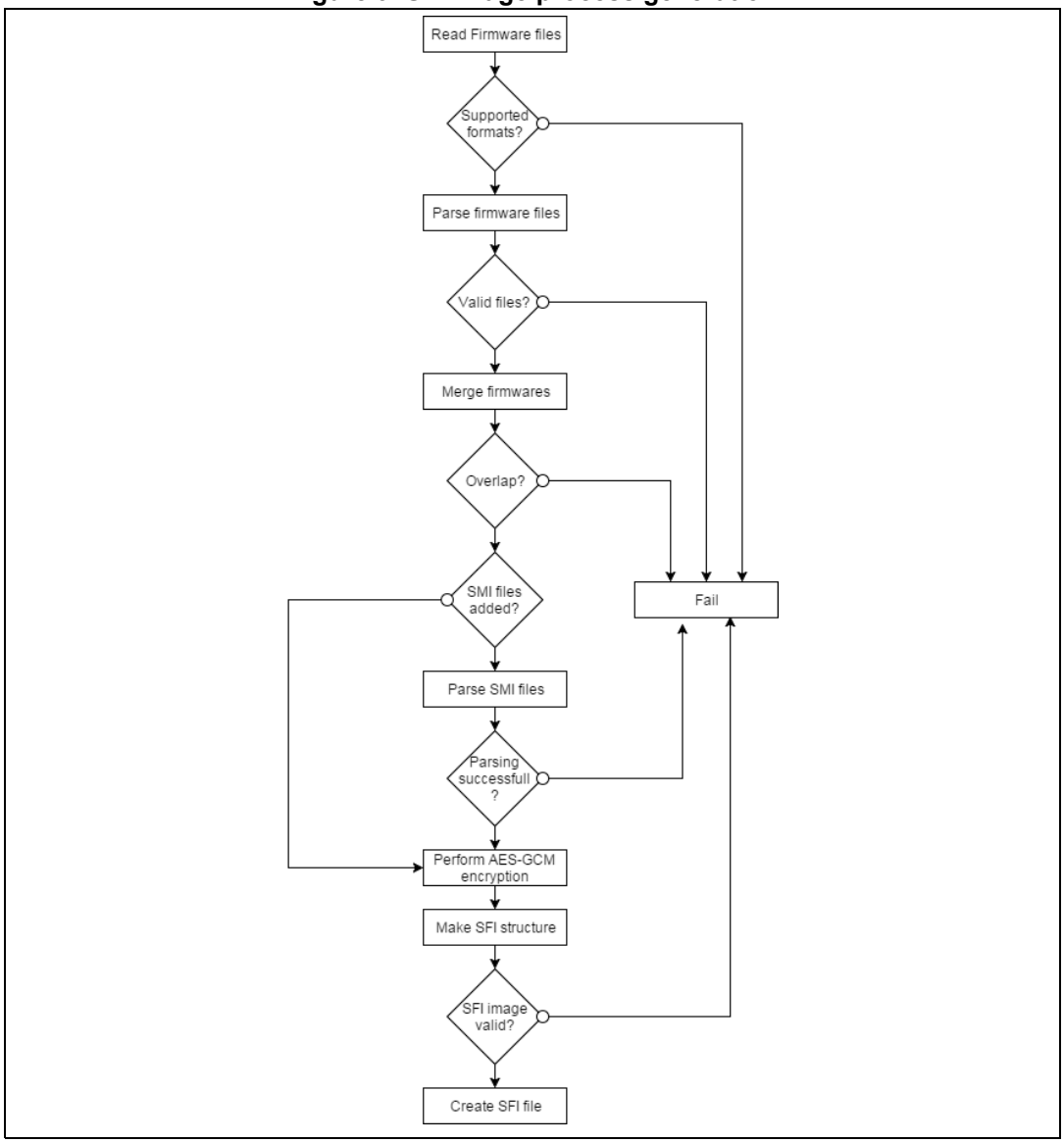
c. Ubuntu® is a registered trademark of Canonical Ltd.

d. Fedora® is a trademark of Red Hat, Inc.

e. macOS® is a trademark of Apple Inc., registered in the U.S. and other countries and regions.

The SFI generation steps as currently implemented in the tool are described in *Figure 9*.

Figure 9. SFI image process generation



Before performing AES-GCM to encrypt an area, we calculate the initialization vector (IV) as:

IV = nonce + area index

The tool partitions the firmware image into several encrypted parts corresponding to different memory areas.

These encrypted parts appended to their corresponding descriptors (the unencrypted descriptive header generated by the tool) are called areas.

These areas can be of different types:

- ‘F’ for a firmware area (a regular segment in the input firmware)
- ‘M’ for a module area (used in SFI-SMI combined-image generation, and corresponds to input from an SMI module)
- ‘C’ for a configuration area (used for option-byte configuration)
- ‘P’ for a “pause” area
- ‘R’ for a “resume area.

Areas ‘P’ and ‘R’ do not represent a real firmware area, but are created when an SFI image is split into several parts, which is the case when the global size of the SFI image exceeds the allowed RAM size predefined by the user during the SFI image creation.

The STM32 Trusted Package Creator overview below (*Figure 10*) shows the ‘RAM size’ input as well as the ‘Continuation token address’ input, which is used to store states in flash memory during SFI programming.

Figure 10. RAM size and CT address inputs used for SFI

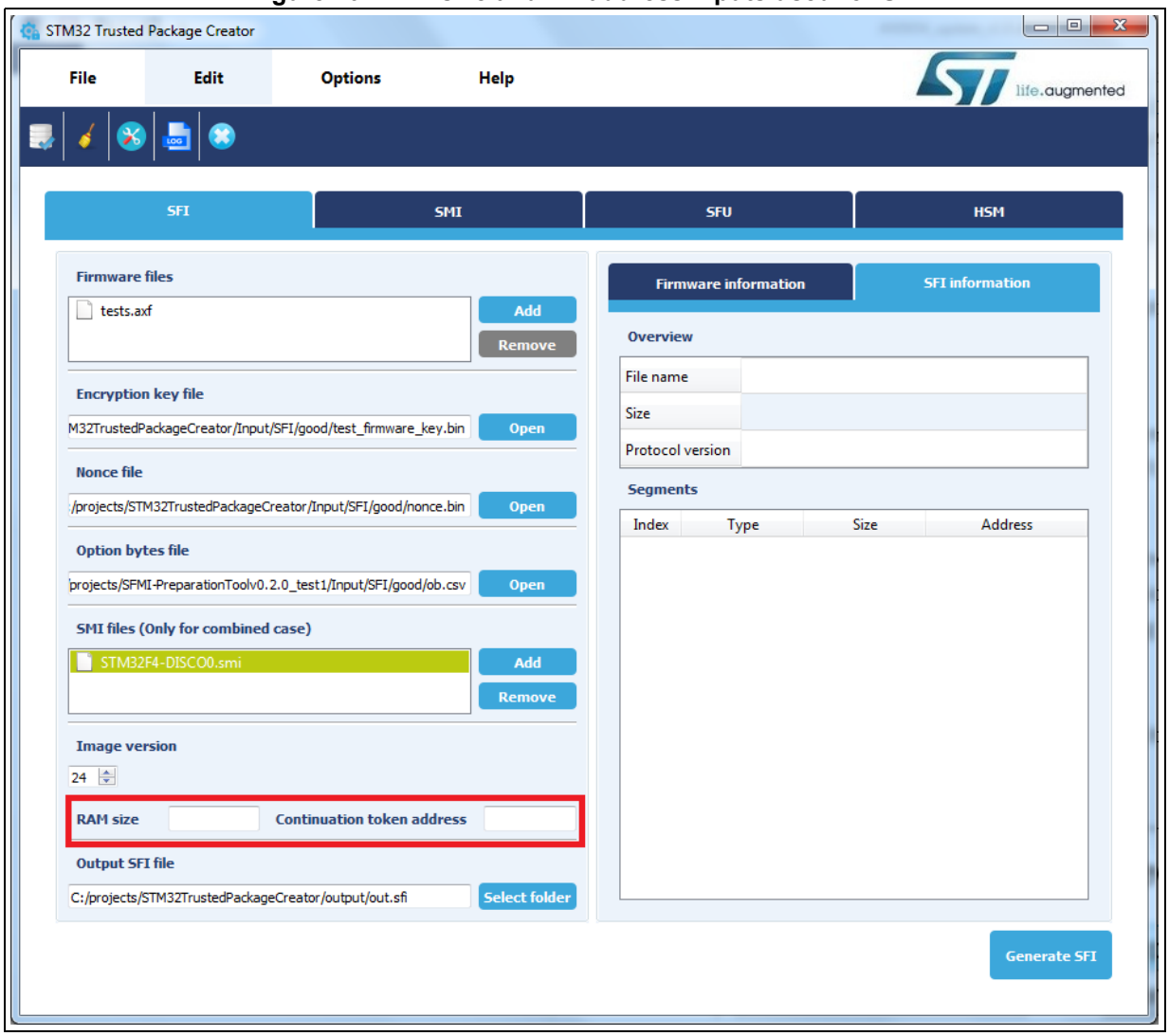
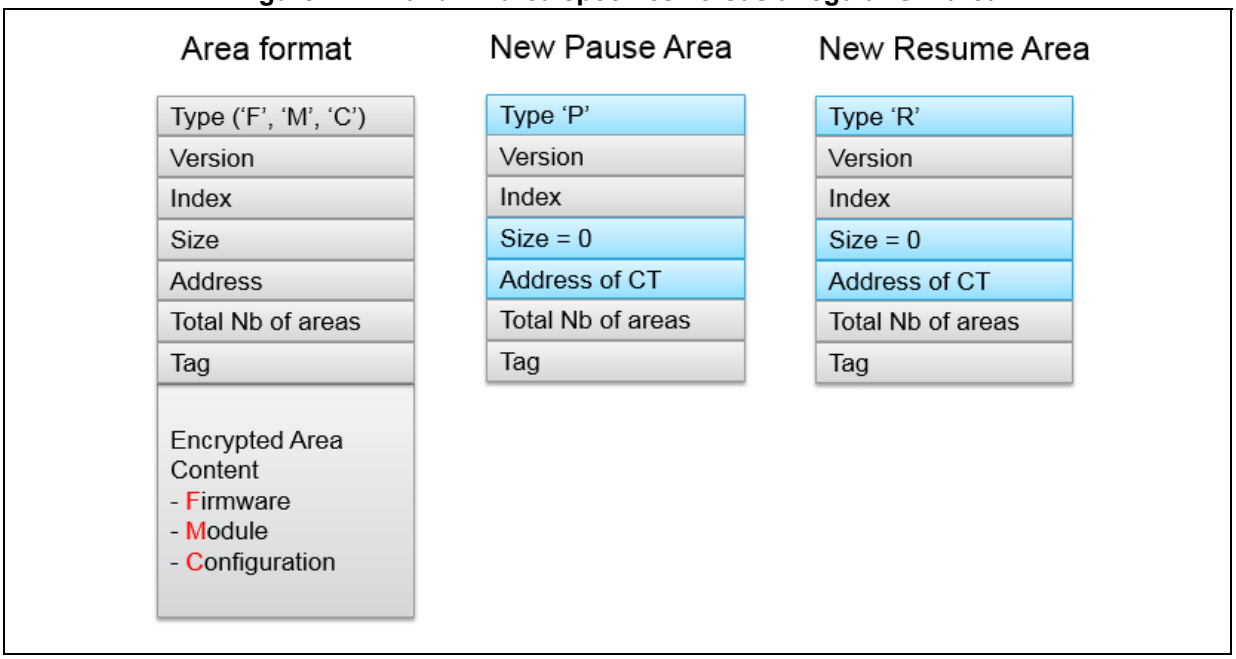


Figure 11 (below) shows the specifics of these new areas compared to a regular SFI area.

Figure 11. 'P' and 'R' area specifics versus a regular SFI area

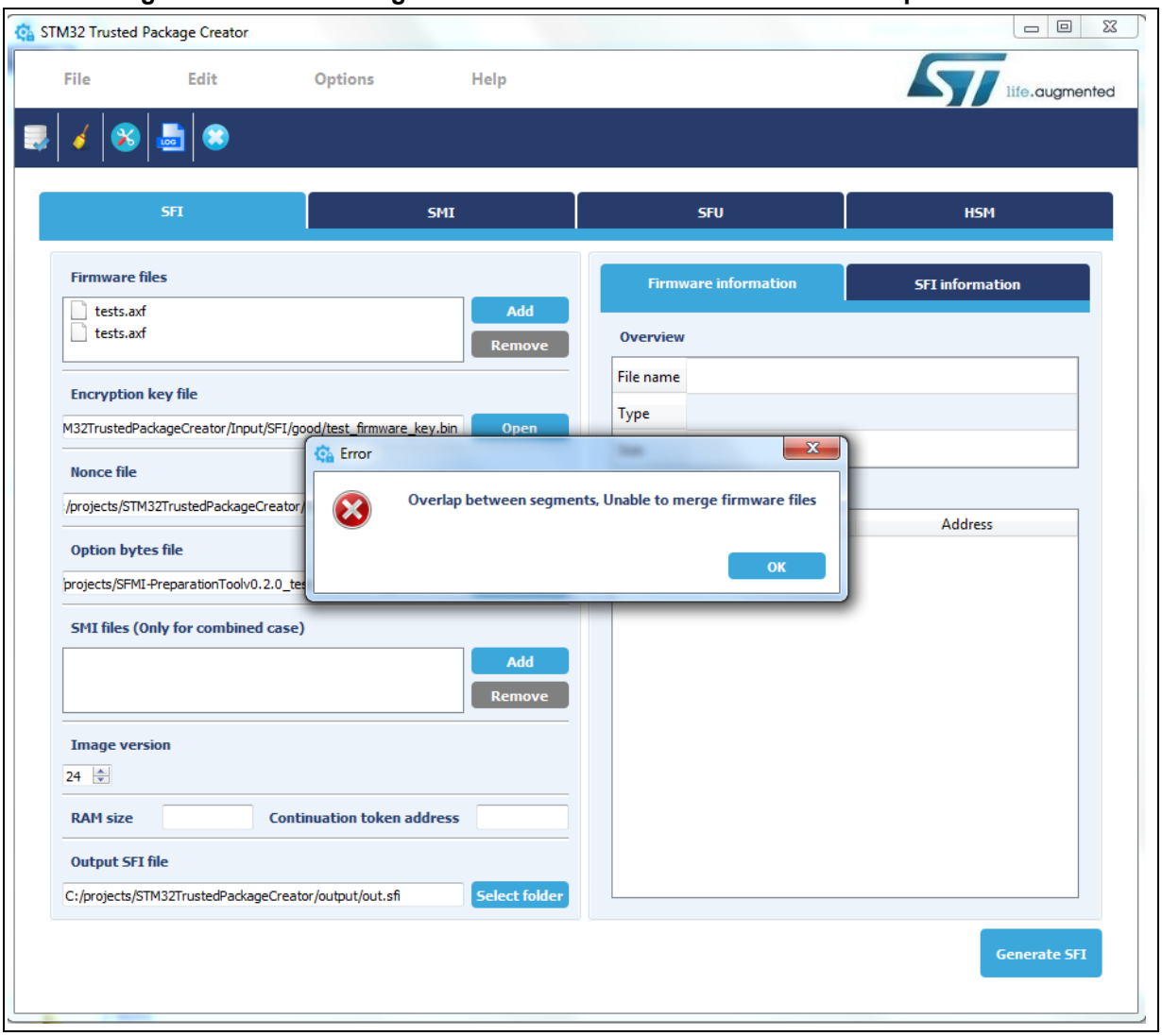


A top-level image header is generated and then authenticated.The tool performs AES-GCM with authentication only (without encryption), using the SFI image header as an AAD, and the nonce as IV.

An authentication tag is generated as output.

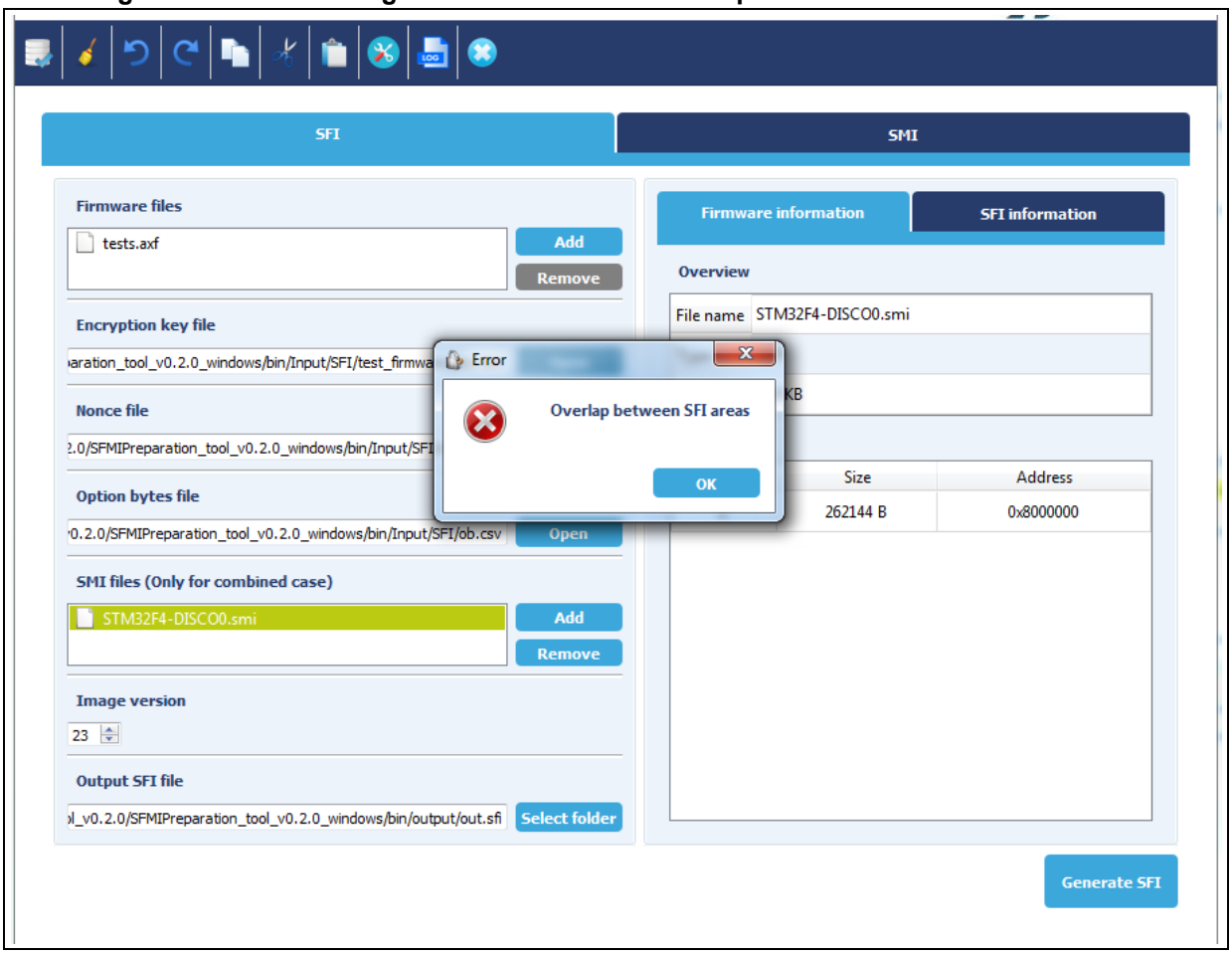
Note: To prepare an SFI image from multiple firmware files, make sure that there is no overlap between their segments, otherwise an error message appears (Figure 12: Error message when firmware files with address overlaps are used).

Figure 12. Error message when firmware files with address overlaps are used



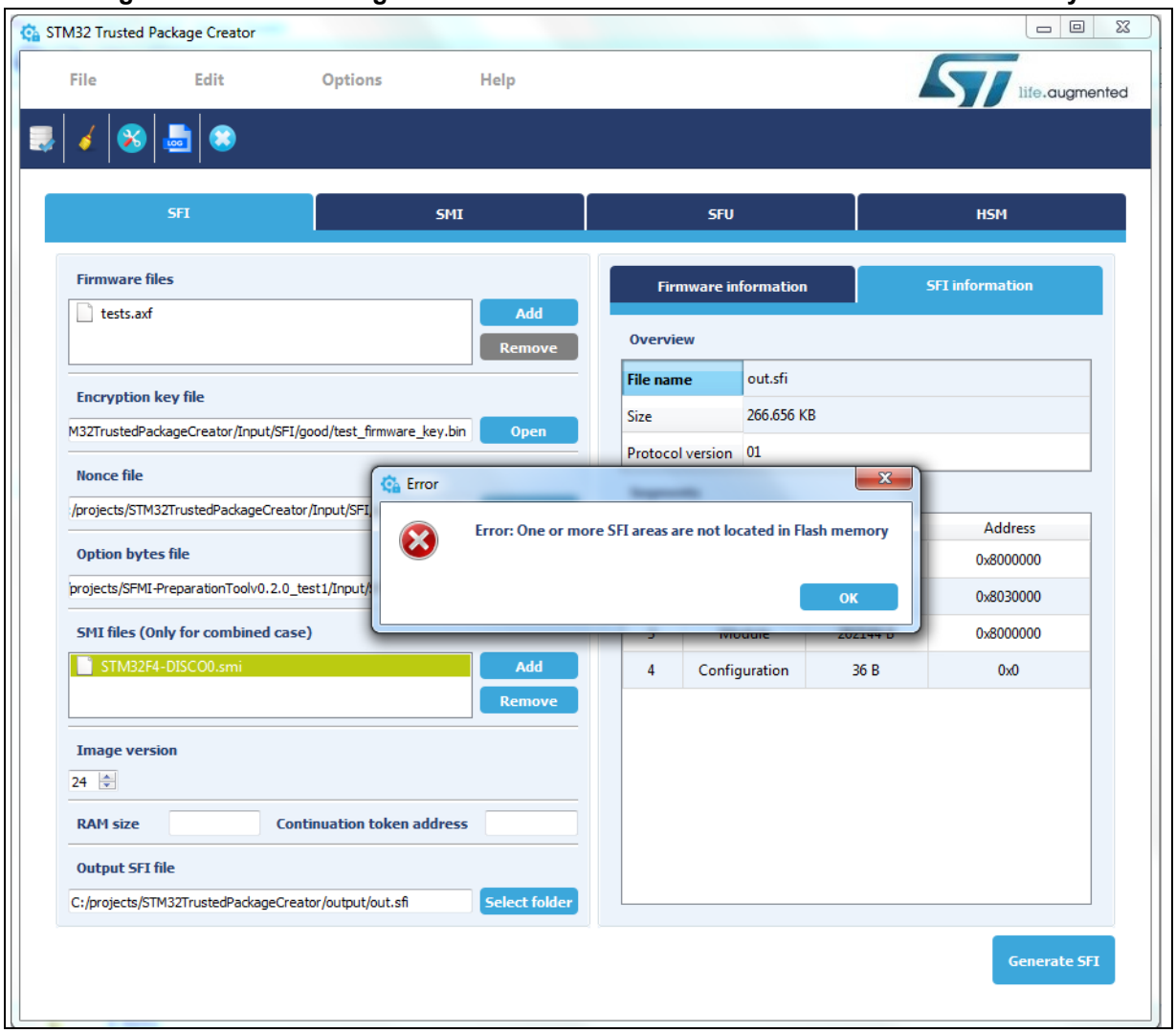
For combined SFI-SMI images, there is also an overlap check between firmware and module areas. If the check fails, an error message appears (*Figure 13*).

Figure 13. Error message when SMI address overlaps with a firmware area address



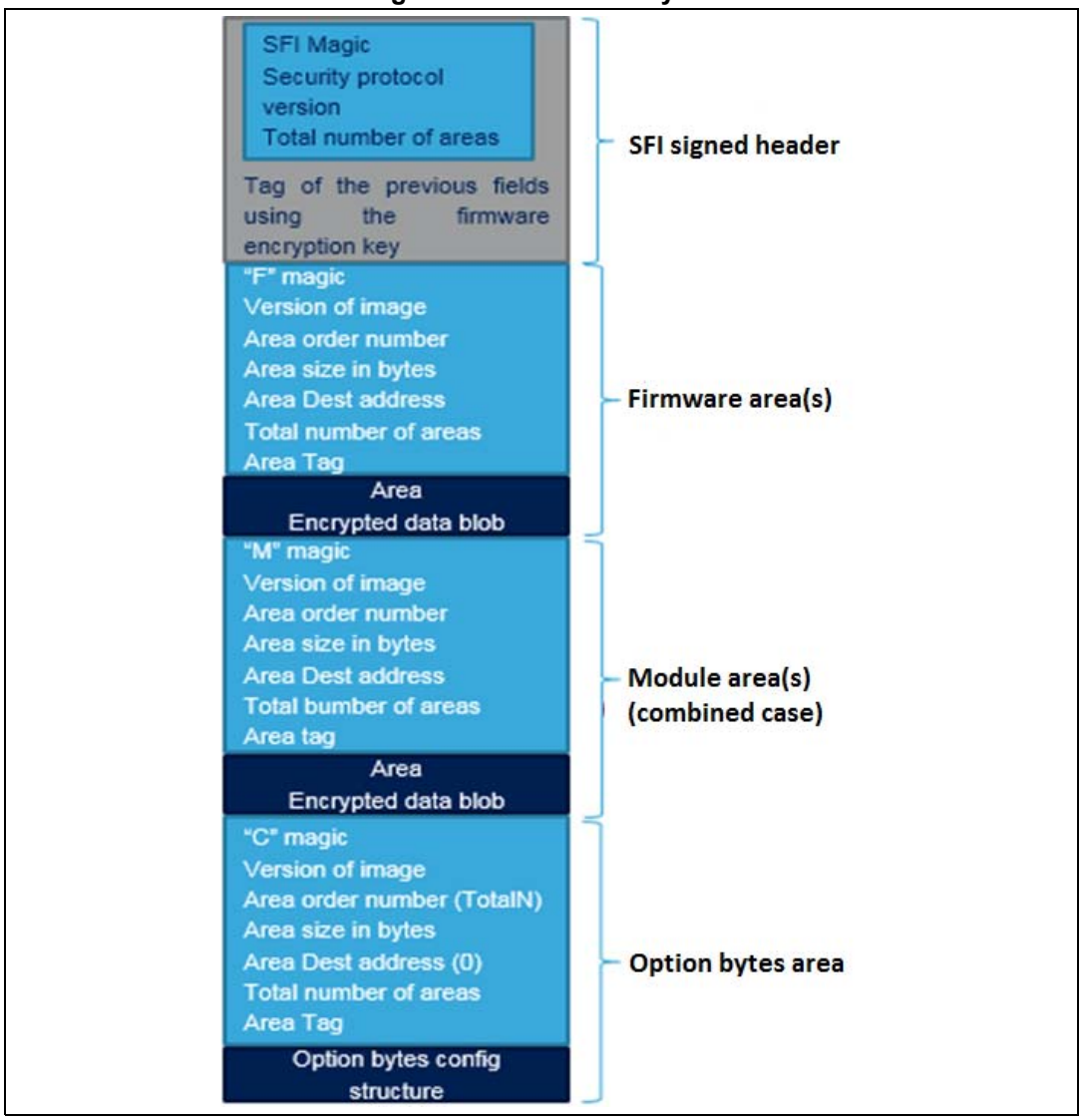
Also, all SFI areas must be located in flash memory, otherwise the generation fails, and the following error message appears (*Figure 14*).

Figure 14. Error message when a SFI area address is not located in flash memory



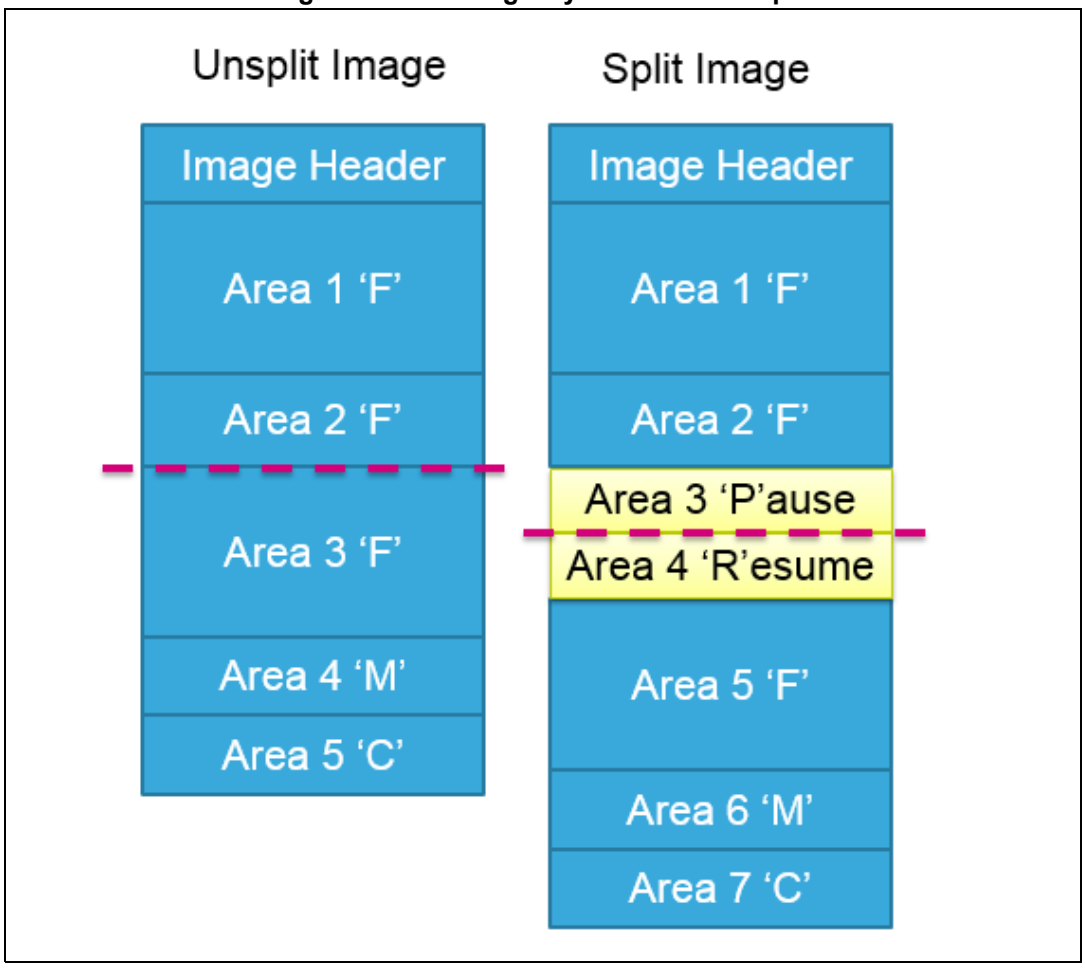
The final output from this generation process is a single file, which is the encrypted and authenticated firmware in ".sfi" format. The SFI format layout is described in *Figure 15*.

Figure 15. SFI format layout



When the SFI image is split during generation, areas ‘P’ and ‘R’ appear in the SFI image layout, as in the following example *Figure 16*.

Figure 16. SFI image layout in case of split



3.3 SFIx generation process

In addition to the SFI preparation process mentioned in the previous section, two extra areas are added in the SFI image for the SFIx preparation process:

- 'E' for an external firmware area
- 'K' for a key area (used for random keys generation)

The key 'K' area is optional and it can be stored in the area 'F'.

Area E

The area ‘E’ is for external flash memory. It includes the following information at the beginning of an encrypted payload:

- OTFD region_number (uint32_t):
  - 0…3: OTFD1 (STM32H7A3/7B3 and STM32H7B0, STM32H723/333 and STM32H725/335, STM32L5, and STM32U5)
  - 4…7: OTFD2 (STM32H7A3/7B3 and STM32H7B0, STM32H723/333, STM32H725/335, and STM32U5)
- OTFD region_mode (uint32_t) bit [1:0]:
  - 00: instruction only AES-CTR)
  - 01: data only (AES-CTR)
  - 10: instruction + data (AES-CTR)
  - 11: instruction only (EnhancedCipher)
- OTFD key_address in internal flash memory (uint32_t).

After this first part, area ‘E’ includes the firmware payload (as for area ‘F’). The destination address of area ‘E’ is in external flash memory (0x9… / 0x7…).

Area K

The area ‘K’ triggers the generation of random keys. It contains N couples; each one defines a key area as follows:

- The size of the key area (uint32_t)
- The start address of the key area (uint32_t): address in internal flash memory.

Example of an area ‘K’:

0x00000010, 0x0C020000

0x00000010, 0x08000060

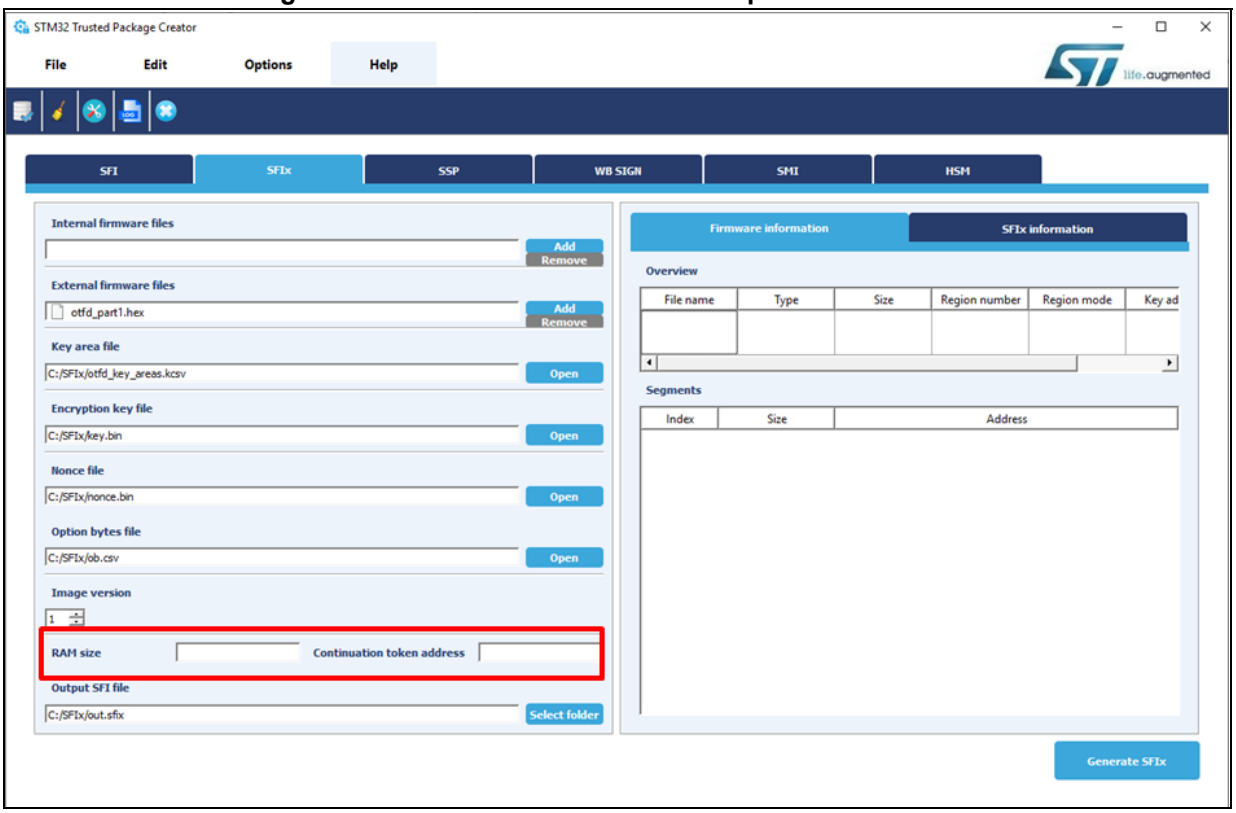
There are two key areas:

- The first key area starts at 0x08010000 with size = 0x80 (8 x 128-bit keys)
- The second key area starts at 0x08010100 with size 0x20 (256-bit key).

The STM32 Trusted Package Creator overview below (*Figure 17: RAM size and CT address inputs used for SFIx*) shows the RAM size input for SFIx image generation, and also the ‘Continuation token address’ input, which is used by SFIx to store states in external/internal flash memory during SFIx programming.

The ‘Continuation token address’ is mandatory due to the image generation that adds areas P and R whatever be the configuration.

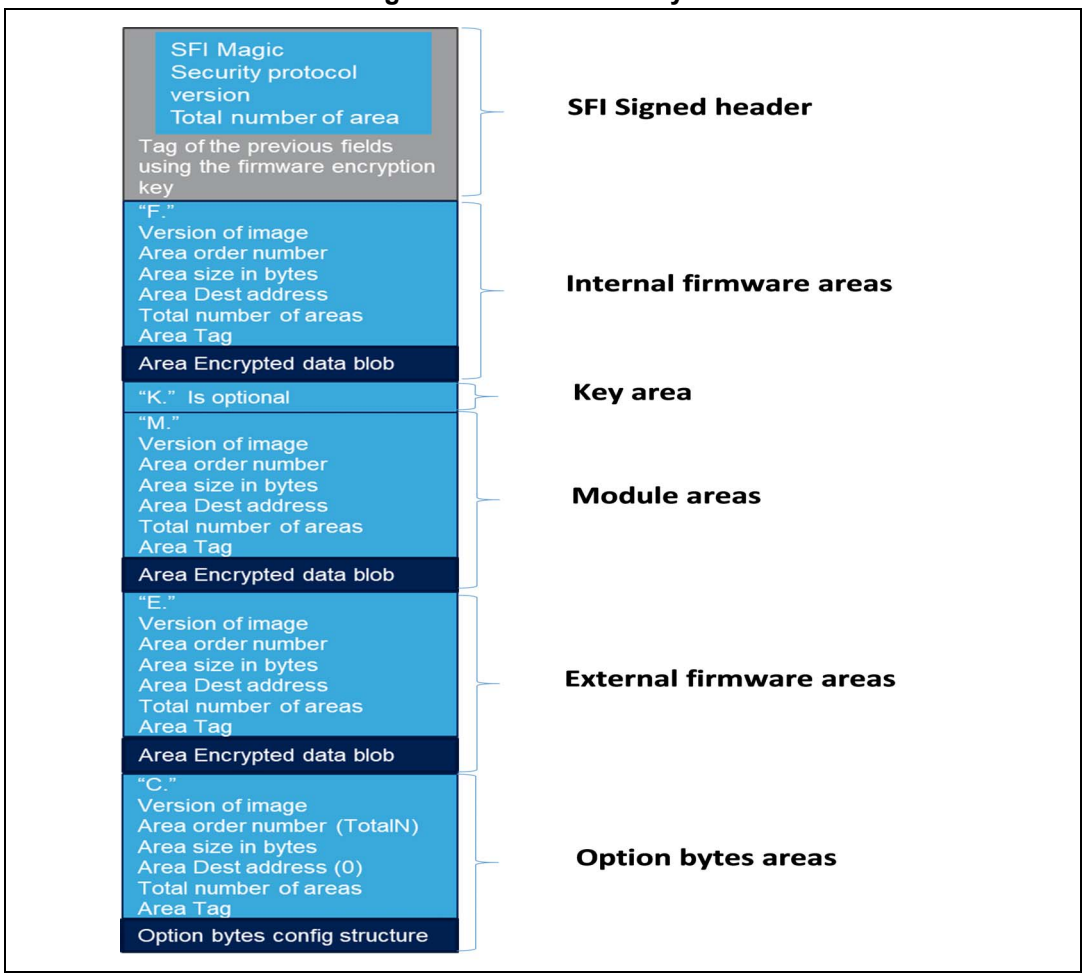
Figure 17. RAM size and CT address inputs used for SFIx



Note: To prepare an SFIx image from multiple firmware files, make sure that there is no overlap between their segments (Intern and extern), otherwise an error message appears as same as in the SFI use case.

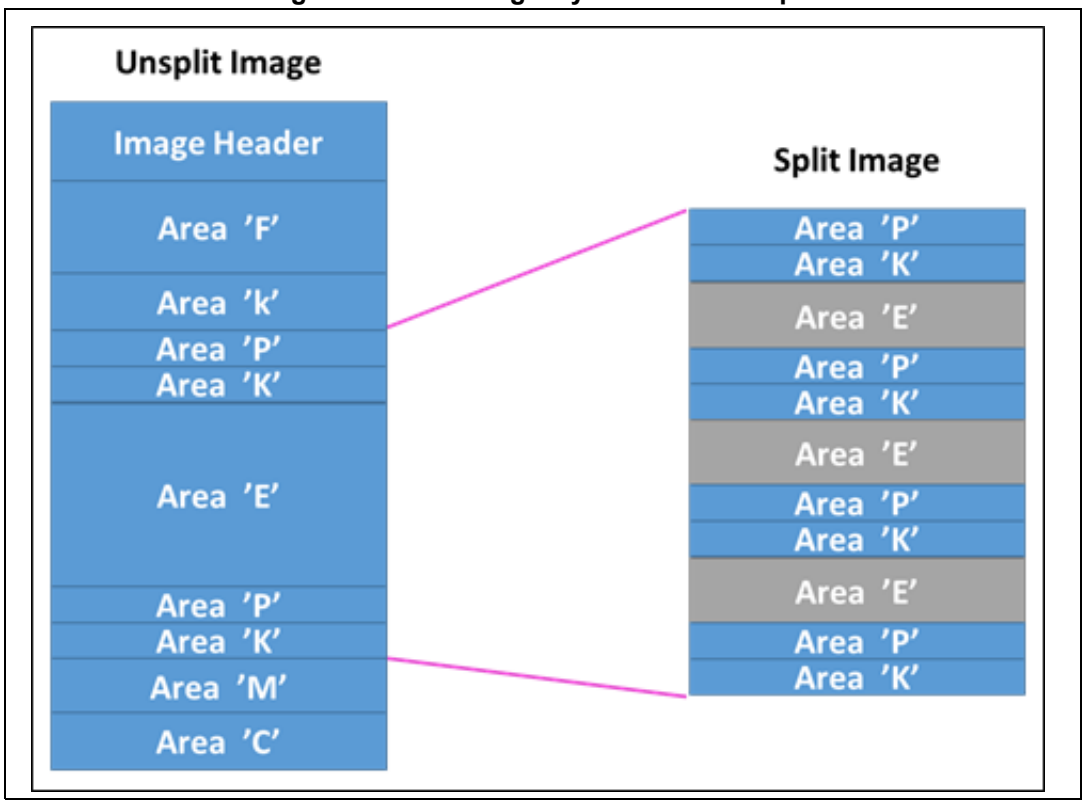
The final output from this generation process is a single file, which is the encrypted and authenticated internal/external firmware in ".sfix" format. The SFIx format layout is described in *Figure 18*.

Figure 18. SFIx format layout



When the SFIx image is split during generation, the areas 'P' and 'R' appear in the SFIx image layout, as in the example below *Figure 19*.

Figure 19. SFIx image layout in case of split

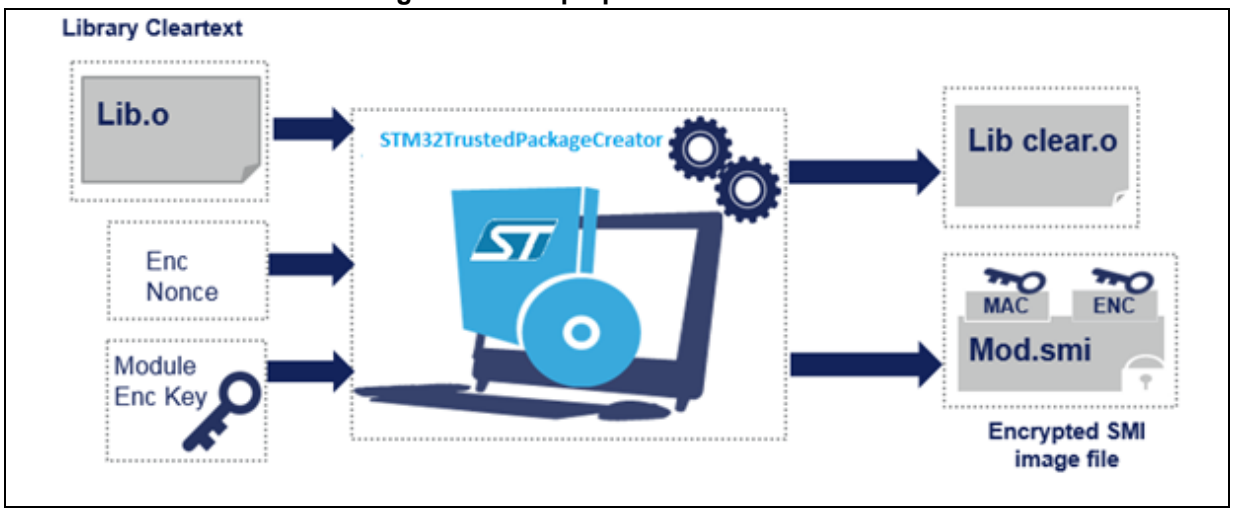


3.4 SMI generation process

SMI is a format created by STMicroelectronics that aims to protect partners' software (SW: software modules and libraries).

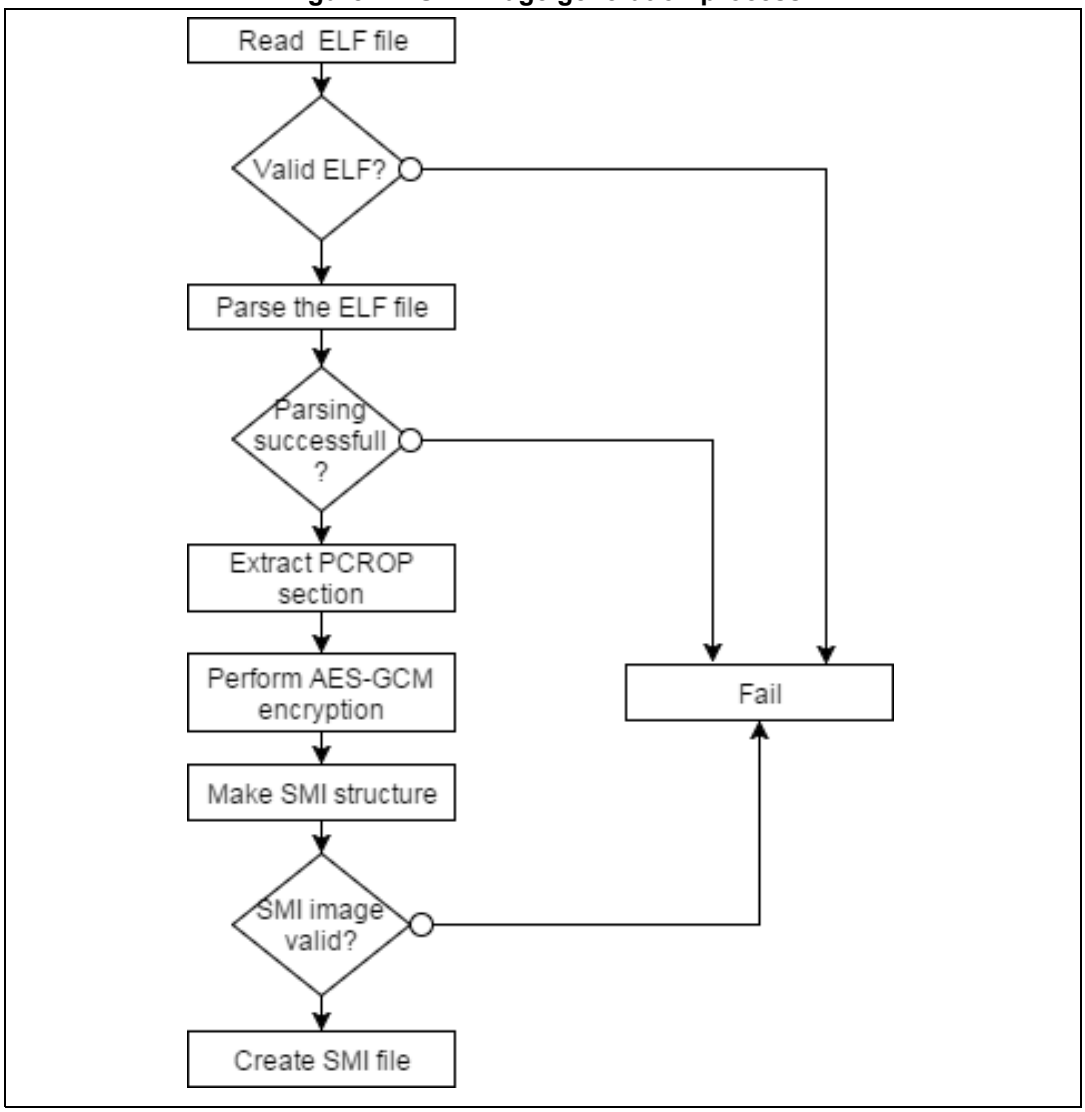
The SMI preparation process is described below (*Figure 20*).

Figure 20. SMI preparation mechanism



The SMI generation steps as currently implemented in the tool are described in the diagram below (*Figure 21*).

Figure 21. SMI image generation process



The AES-GCM encryption is performed using the following inputs:

- 128-bit AES encryption key
- The input nonce as initialization vector (IV)
- The security version as additional authenticated data (AAD).

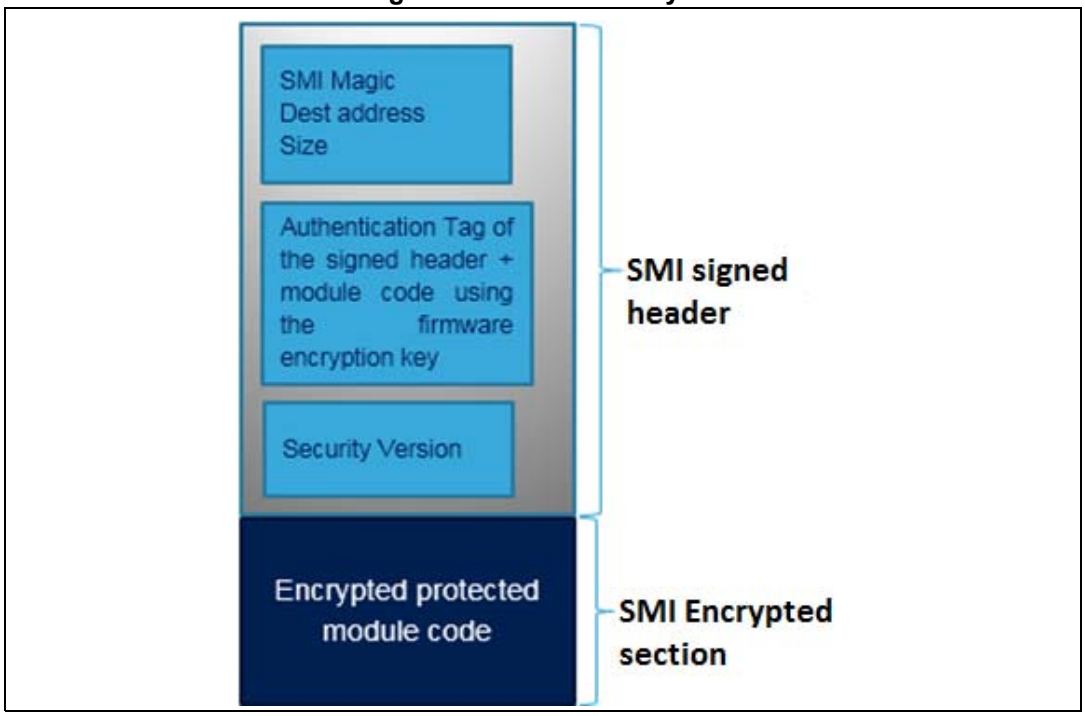
Before SMI image creation, PCROP checks are performed on the SMI image validity:

- A PCROP section must be aligned on a flash memory word (256 bits), otherwise a warning is shown.
- The section's size must be at least two flash memory words (512 bits), otherwise a warning is shown.
- The section must end on a flash memory word boundary (a 256-bit word), otherwise a warning is shown.
- If the start address of the section immediately following the PCROP section overlaps the last flash memory word of the PCROP section (after performing the PCROP alignment constraint), the generation fails and an error message appears.

If everything is OK, tow outputs are created under the specified path:

- The SMI image (*Figure 22* represents the SMI format layout).
- The library data part.

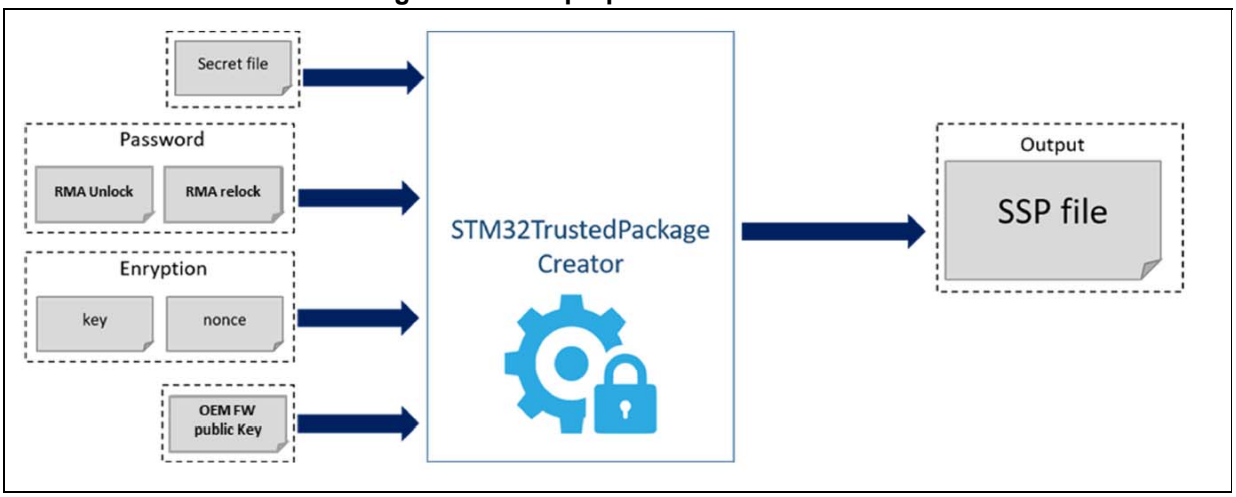
Figure 22. SMI format layout



3.5 SSP generation process

SSP is an encryption format that transforms customer secret files into encrypted and authenticated firmware using an AES-GCM algorithm with a 128-bit key. The SSP preparation process used in the STM32 Trusted Package Creator tool is shown in *Figure 23*.

Figure 23. SSP preparation mechanism



An SSP image must be created before SSP processing. The encrypted output file follows a specific layout that guarantees a secure transaction during transport and decryption based on the following inputs:

- **Secret file**: This 148-byte secret file must fit into the OTP area reserved for the customer. There is no tool or template to create this file.
- **RMA password**: This password is chosen by the OEM. It is part of the secret file and is placed as the first 4-byte word. To make RMA password creation easier and avoid issues, the STM32 Trusted Package Creator tool add sit directly at the beginning of the 148-byte secret file.
- **Encryption key**: AES encryption key (128 bits).
- **Encryption nonce**: AES nonce (128 bits).
- **OEM firmware key**: This is the major part of the secure boot sequence. Based on ECDSA verification, the key is used to validate the signature of the loaded binary.

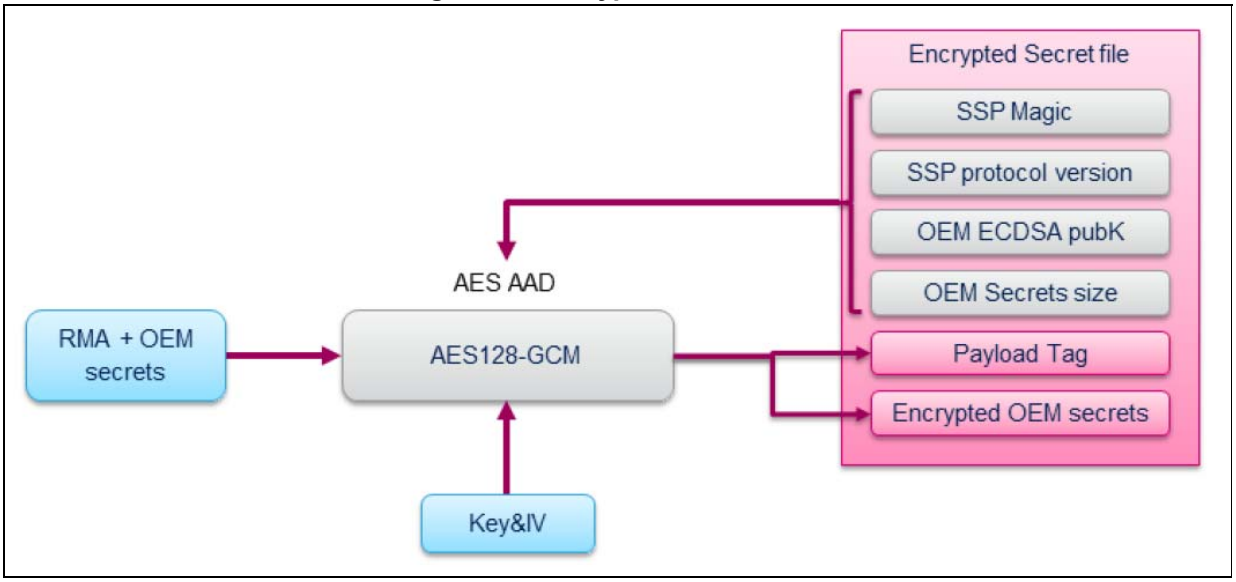
The first layout part (SSP magic, protocol version, ECDSA public key, secret size) is used as additional authenticated data (AAD) to generate the payload tag. This is checked by the ROM code during decryption.

Table 2. SSP preparation inputs

Input	Size (bytes)	Content
SSP magic	4	'SSPP': magic identifier for SSP Payload
SSP Protocol Version	4	Can be used to indicate how to parse the payload, if payload format changes in future
OEM ECDSA public key	64	OEM ECDSA public key
OEM secret size	4	Size of OEM secrets, in bytes
Payload tag	16	Cryptographic signature of all fields above, to ensure their integrity.
Encrypted OEM secrets	152	Encrypted OEM secrets. 152 is given by previous field.

This encrypted file is automatically generated by the STM32 Trusted Package Creator tool.

Figure 24. Encryption file scheme



3.6 STM32 Trusted Package Creator tool in the command-line interface

This section describes how to use the STM32 Trusted Package Creator tool from the command-line interface to generate SFI/SFIx and SMI images. The available commands are listed in *Figure 25*.

Figure 25. STM32 Trusted Package Creator tool - SFI preparation options

```
SFI preparation options

 -sfi,   --sfi          : Generate SFI image,
                          You also need to provide the information listed below
     -devid,   --deviceid  : Add an input device ID
        <device_id>        : Device ID value of the concerning product
     -fir,   --firmware    : Add an input firmware file
        <Firm_File>        : Supported firmware files are ELF HEX SREC BIN
     -firx,   --firmwx     : Add input for external firmware file
        <Firmx_File>       : Supported externalfirmware files are ELF HEX SREC BIN
        [<Address>]        : Only in case of BIN input file (in any base)
        [<Region_Number>]  : Value in any base, [0:3]: OTFD1 (STM32H7A / STM32L5), [4:7]: OTFD2 (STM32H7A/B case)
        [<Region_Mode>]    : Value in any base, only two bit [0:1] where 00 : instruction only (AES-CTR),
                           :                                           01 : data only (AES-CTR),
                           :                                           10 : instruction + data (AES-CTR),
                           :                                           11 : instruction only (EnhancedCipher)
        [<key_address>]    : Value in any base, random key values in internal flash memory
    -k,     --key          : AES-GCM encryption key
        <Key_File>         : Bin file, its size must be 16 bytes
    -kx,    --keyx         :  key area for external firmware
        <Key_area_File>    : CSV file contains a set of couple (size,start address)
    -n,     --nonce        : AES-GCM nonce
        <Nonce_File>       : Bin file, its size must be 12 bytes
    -v,     --ver          : Image version
        <Image_Version>    : Its value must be in <0..255> (in any base)
    -ob,    --obfile       : Option bytes configuration file
        <CSV_File>         : CSV file with 9 values
    -m,     --module       : Add an SMI file (optional for combined case)
       <SMI_File>          : SMI file
        [<Address>]        : Only in case of a relocatable SMI (with Address = 0)
    -rs,    --ramsize      : define available ram size (for multi-image)
        <Size>             : Size in bytes
    -ct,    --token        : Continuation token address (for multi-image)
      <Address>            : Address
    -hash,   --hash        : Generate Hash for integrity check
      <Hash_Flag>          : Possible values        0 : Hash generation disabled
                           :                        1 : Hash generation enabled
                           : By default if this option is not present the Hash is disabled
    -obk,   --ob-keys      : Example: -obk input1.obk input2.obk input3.obk ...
       <obk_Files>           Supported SSFI file extension is .bin .ssfi
    -ssfi,   --ssfi        : Add SSFI module for STM32 devices which supports this security feature.
       <Ssfi_File>         : Supported SSFI file extension is .bin .ssfi
    -o,     --outfile      : Generated SFI/SFIx file
        <Output_File>      : SFI/SFIx file to be created with sfi/sfix extension
```

Figure 26. STM32 Trusted Package Creator tool - SMI preparation options

```
SMI preparation options

 -smi,   --smi,            : Generate SMI image
                           You also need to provide the information listed below
    -elf,   --elfile       : Input ELF file
        <ELF_File>         : ELF file
    -s,     --sec          : Section to be encrypted
        <Section>          : Section name in the ELf file
    -k,     --key          : AES-GCM encryption key
        <Key_File>         : Bin file, its size must be 16 bytes
    -n,     --nonce        : AES-GCM nonce
        <Nonce_File>       : Bin file, its size must be 12 bytes
    -sv,    --sver         : Security version
        <SV_File>          : Its size must be 16 bytes
    -o,     --outfile      : Generated SMI file
        <Output_File>      : SMI file to be created
    -c,     --clear        : Clear ELF file
        <Clear_File>       : Clear ELF file to be generated
```

3.6.1 Steps for SFI generation (CLI)

To generate an SFI/SFIx image in CLI mode, the user must use the “-sfi, --sfi” command followed by the appropriate inputs. Inputs for the “sfi” command are:

-**devid**, **--deviceid**

Description: specify deviceID. If this option is not used, P and R areas are generated by default for all devices.

Syntax: -devid <device_id>

<device_id> :Device ID

-fir, --firmware

Description: adds an input firmware file (supported formats are Bin, Hex, Srec, and ELF). This option can be used more than once to add multiple firmware files.

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

<Firmware_file> :Firmware file.

[<Address>] :Used only for binary firmware.

-firx, --firmwx

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

Syntax: -firx <Firmware_file> [<Address>] [<Region_Number>]

[<Region_Mode>] [<key_address>]

<Firmware_file>: Supported external firmware files are ELF HEX SREC BIN.

[<Address>]:Only in the case of BIN input file (in any base).

<Region_Number> : Only in the case of BIN input file (in any base): [0:3]: OTFD1 (STM32H7A3/7B3, STM32H7B0, or STM32L5), [4:7]: OTFD2 (STM32H7A3/7B3 and STM32H7B0 case).

<Region_Mode>: Only in the case of BIN input file (in any base), only two bits [0:1] where

00: instruction only (AES-CTR)
01: data only (AES-CTR)
10: instruction + data (AES-CTR)
11: instruction only (EnhancedCipher)

<key_address>: Only in the case of BIN input file (in any base), random key values in internal flash memory.

-k, --key

Description: sets the AES-GCM encryption key.

Syntax: -k <Key_file>

< Key _file> : A 16-byte binary file.

-n, --nonce

Description: sets the AES-GCM nonce.

Syntax: -n <Nonce_file>

<Nonce _file> A 12-byte binary file.

-v, --ver

Description: sets the image version.

Syntax: -v <Image_version>

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

-ob, --obfile

Description: provides an option bytes configuration file.
The option bytes file field is only mandatory for SFI applications (first install) to allow option bytes programming, otherwise it is optional.
Only csv (comma separated value) file format is supported as input for this field, it is composed from two vectors: register name and register value respectively.

Note: The number of rows in the CSV file is product dependent (refer to the example available for each product). For instance there are nine rows for all STM32H7 products, with the last row "reserved", except for dual-core devices. It is important to neither change the order of, nor delete, rows.

Example: for STM32H75x devices, nine option byte registers must be configured, and they correspond to a total of nine lines in the csv file (*Figure 27*).

Syntax: -ob <CSV_file>

<CSV_file >: A csv file with nine values.

Figure 27. Option bytes file example

```
1  FOPTSR_PRG,0x1026AAD0
2  FPRAR_PRG_A,0x81000200
3  FPRAR_PRG_B,0x81000200
4  FSCAR_PRG_A,0x81000200
5  FSCAR_PRG_B,0x81000200
6  FWPSN_PRG_A,0xFFFFFFFF
7  FWPSN_PRG_B,0xFFFFFFFF
8  FBOOT7_PRG,0x24000800
9  RESERVED,0x10000810
```

-m, --module

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

Syntax: -m <SMI_file>

<SMI_file >: SMI file.[<Address>]: Address is provided only for relocatable SMI.

-rs, --ramsize

Description: define the available ram size (in the case of SFI)

Syntax: -rs <Size>

< Size >: RAM available size in bytes

Note: The maximum RAM size of each device is mentioned in the descriptor. For example the maximum RAM size of the STM32WL is 20 Kbytes.

-ct, --token

Description: continuation token address (in the case of SFI)

Syntax: -ct <Address>

< Address >: continuation token flash memory address

-o, --outfile

Description: sets the output SFI file to be created.

Syntax: -o <out_file>

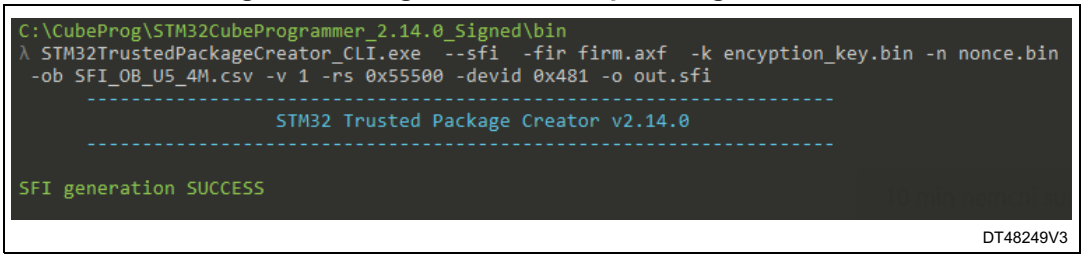
<out_file > : the SFI file to be generated (must have the ".sfi" extension).

Example of SFI generation command using an ELF file:

```
STM32TrustedPackageCreator_CLI.exe  --sfi  -fir firm.axf
-k encyption_key.bin -n nonce.bin  -ob SFI_OB_U5_4M.csv -v 1
-rs 0x55500 -devid 0x481 -o out.sfi
```

The result of the previous command is shown in *Figure 28*.

Figure 28. SFI generation example using an ELF file



3.6.2 Steps for SMI generation (CLI)

In order to generate an SMI image in CLI mode, the user must use the "-smi, --smi" command followed by the appropriate inputs.

Inputs for the "smi" command are:

-elf, --elfile

Description: sets the input ELF file (only ELF format is supported).

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: sets the name of the section to be encrypted.

Syntax: -s <section_name>

<section_name> : Section name.

-k, --key

Description: sets the AES-GCM encryption key.

Syntax: -k <Key_file>

< Key _file> : A 16-byte binary file.

-n, --nonce

Description: sets the AES-GCM nonce.

Syntax: -n <Nonce_file>

<Nonce_file> : A 12-byte binary file.

-sv, --sver

Description: sets the security version file

The security version file is used to make the SMI image under preparation compatible with a given RSS version, since it contains a corresponding identifying code (almost the HASH of the RSS).

Syntax: -sv **<SV_file>**

<SV_file> : A 16-byte file.

-o, --outfile

Description: Sets the SMI file to be created as output

Syntax: -o <out_file>

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

-c, --clear

Description: Sets the clear ELF file to be created as output corresponding to the data part of the input file

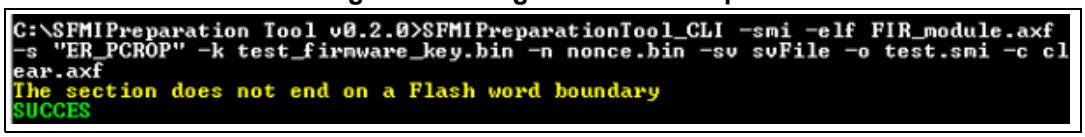
Syntax: -c <ELF_file>

<ELF_file >: Clear ELF file to be generated.

Example SMI generation command:

```
STM32TrustedPackageCreator_CLI.exe –smi -elf
FIR_module.axf -s “ER_PCROP” -k test_firmware_key.bin
-n nonce.bin -sv svFile -o test.smi -c clear.smi
```

Figure 29. SMI generation example



3.6.3 Steps for SSP generation (CLI)

To generate an SSP image in CLI mode, the user must use the “-ssp, --ssp” command followed by the appropriate inputs.

Inputs for the “ssp” command are:

-ru, --rma_unlock

Description: RMA unlock password

Syntax: -ru <RMA_Unlock>

<RMA_Unlock> : Hexadecimal value 0x0000 to 0x7FFF

-rr, --rma_relock

Description: RMA relock password

Syntax: -rr <relock_value>

<relock_value> : Hexadecimal value 0x0000 to 0x7FFF

-b, --blob

Description: Binary to encrypt

Syntax: -b <Blob>

<Blob> : Secrets file of size 148 bytes

-pk, --pubk

Description: OEM public key file

Syntax: -pk <PubK.pem>

<PubK> : pem file of size 178 bytes

-k, --key

Description: AES-GCM encryption key

Syntax: -k <Key_File>

<Key_File> : Bin file, its size must be 16 bytes

-n, --nonce

Description: AES-GCM nonce

Syntax: -n <Nonce_File>

<Nonce_File> : Bin file, its size must be 16 bytes

-o, --out

Description: Generate an SSP file

Syntax: -out <Output_File.ssp>

<Output_File> : SSP file to be created with (extension .ssp)

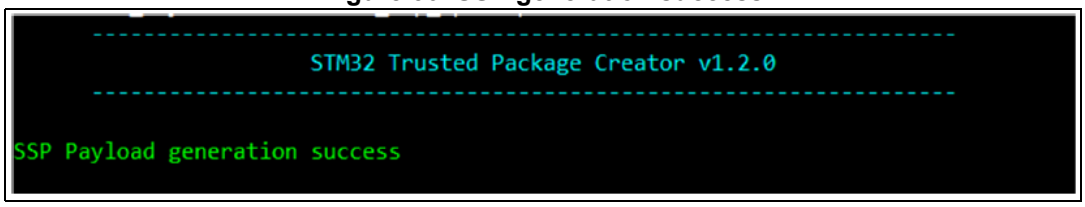
If all input fields are validated, an SSP file is generated in the directory path already mentioned in the “-o” option.

Example SSP generation command:

```
STM32TrustedPackageCreator_CLI -ssp -ru 0x312 -rr 0xECA
-b "C:\SSP\secrets\secrets.bin"
-pk "C:\SSP\OEMPublicKey.pem" -k "C:\SSP\key.bin"
-n "C:\SSP\nonce.bin" -o "C:\out.ssp"
```

Once the operation is done, a green message is displayed to indicate that the generation was finished successfully. Otherwise, an error occurred.

Figure 30. SSP generation success



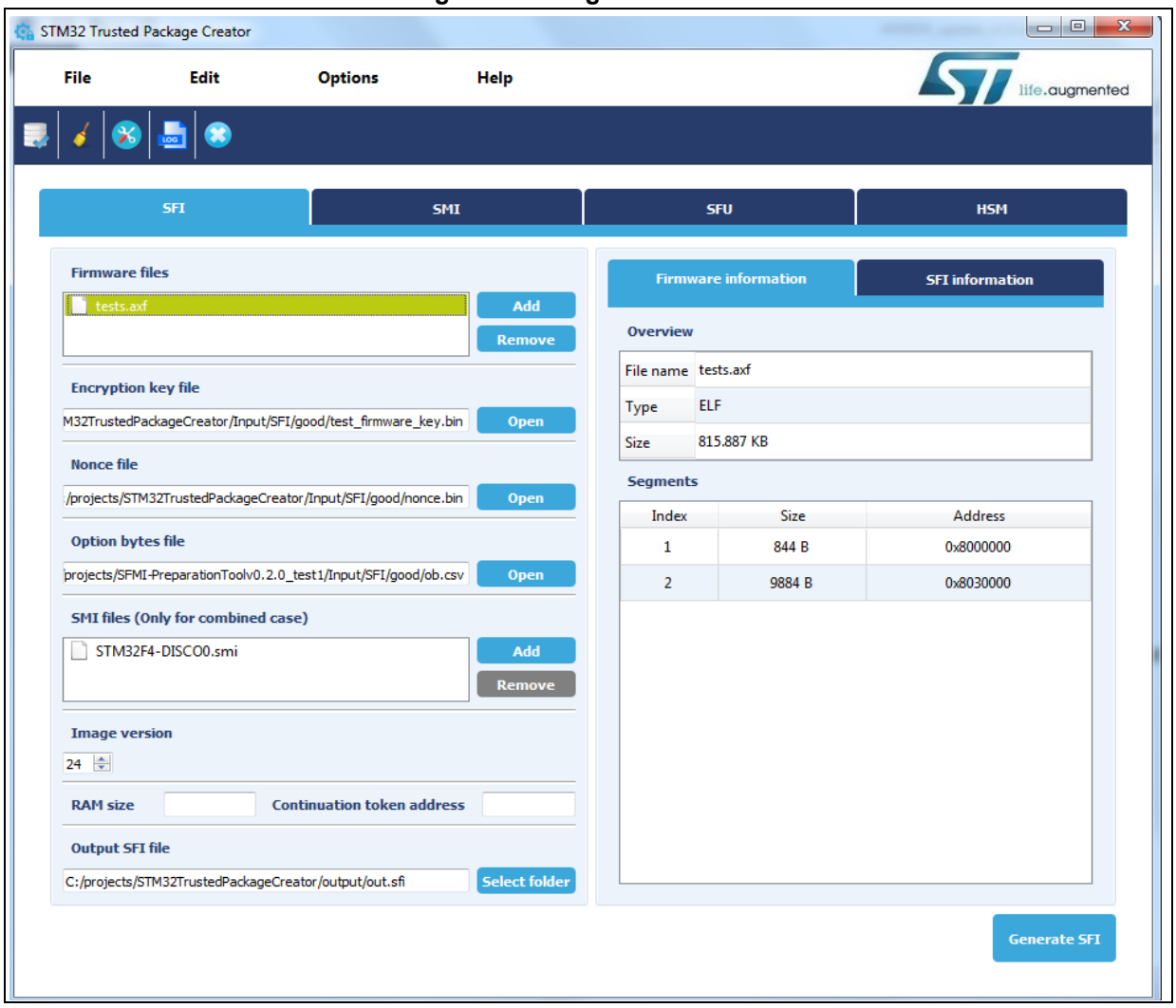
3.7 Using the STM32 Trusted Package Creator tool graphical user interface

The STPC is also available in graphical mode. This section describes its use. The STM32 Trusted Package Creator tool GUI presents two tabs, one for SFI generation, one for SFIx generation and one for SMI generation.

3.7.1 SFI generation using STPC in GUI mode

Figure 31 shows the graphical user interface tab corresponding to SFI generation.

Figure 31. SFI generation Tab



To generate an SFI image successfully from the supported input firmware formats, the user must fill in the interface fields with valid values.

SFI GUI tab fields

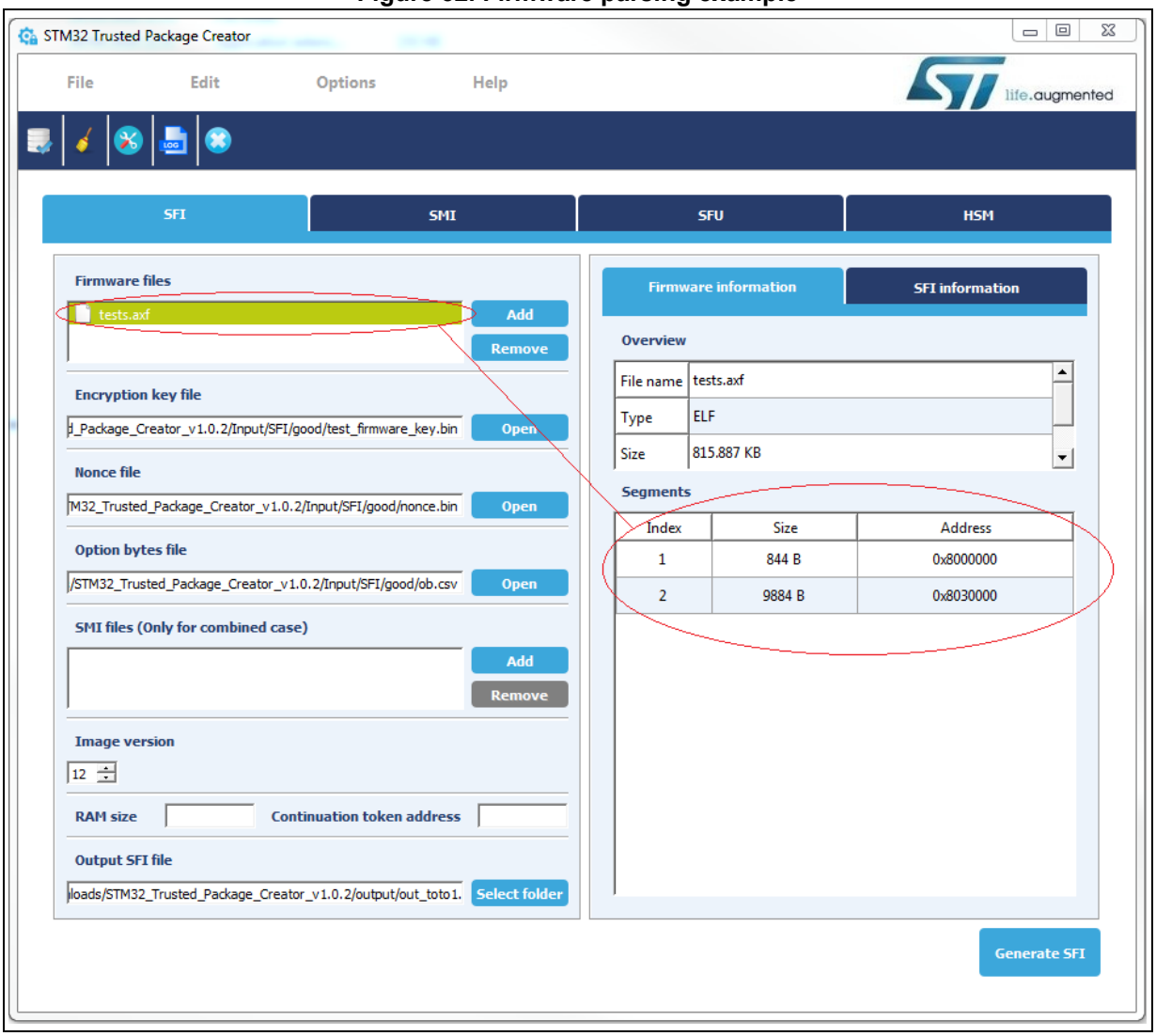
- Firmware files:

  The user needs to add the input firmware files with the “Add” button.

  If the file is valid, it is appended to the “input firmware files“ list, otherwise an error message box appears to notify the user that either the file could not be opened, or the file is not valid.

  Clicking on “input firmware file“ causes related information to appear in the “Firmware information” section (*Figure 32*).

Figure 32. Firmware parsing example



- Encryption key and nonce file:

  The encryption key and nonce file are selected by entering their paths (absolute or relative), or by selecting them with the “Open” button. Notice that sizes must be respected (16 bytes for the key and 12 bytes for the nonce).
- Option bytes file:

  The option bytes file is selected the same way as the encryption key and nonce. Only csv files are supported.

Note: STM32CubeProgrammer v2.8.0 and later provide one option byte file example for each product.
It is located in the directory: STM32CubeProgrammer\vx.x.x\bin\SFI_OB_CSV_FILES

The option bytes are described in the product reference manual.

In the case of customization of a provided example file, care must be taken not to change the number of rows, or their order.

- SMI files:

  SMI files are added the same way as the firmware files. Selecting a file causes related information to appear in the “Firmware information” section.
- Image version:

  Choose the image version value of the SFI under generation within this interval: [0..255].
- Output file:

  Sets the folder path in which the SFI image is to be created. This is done by entering the folder path (absolute or relative) or by using the “Select folder” button.

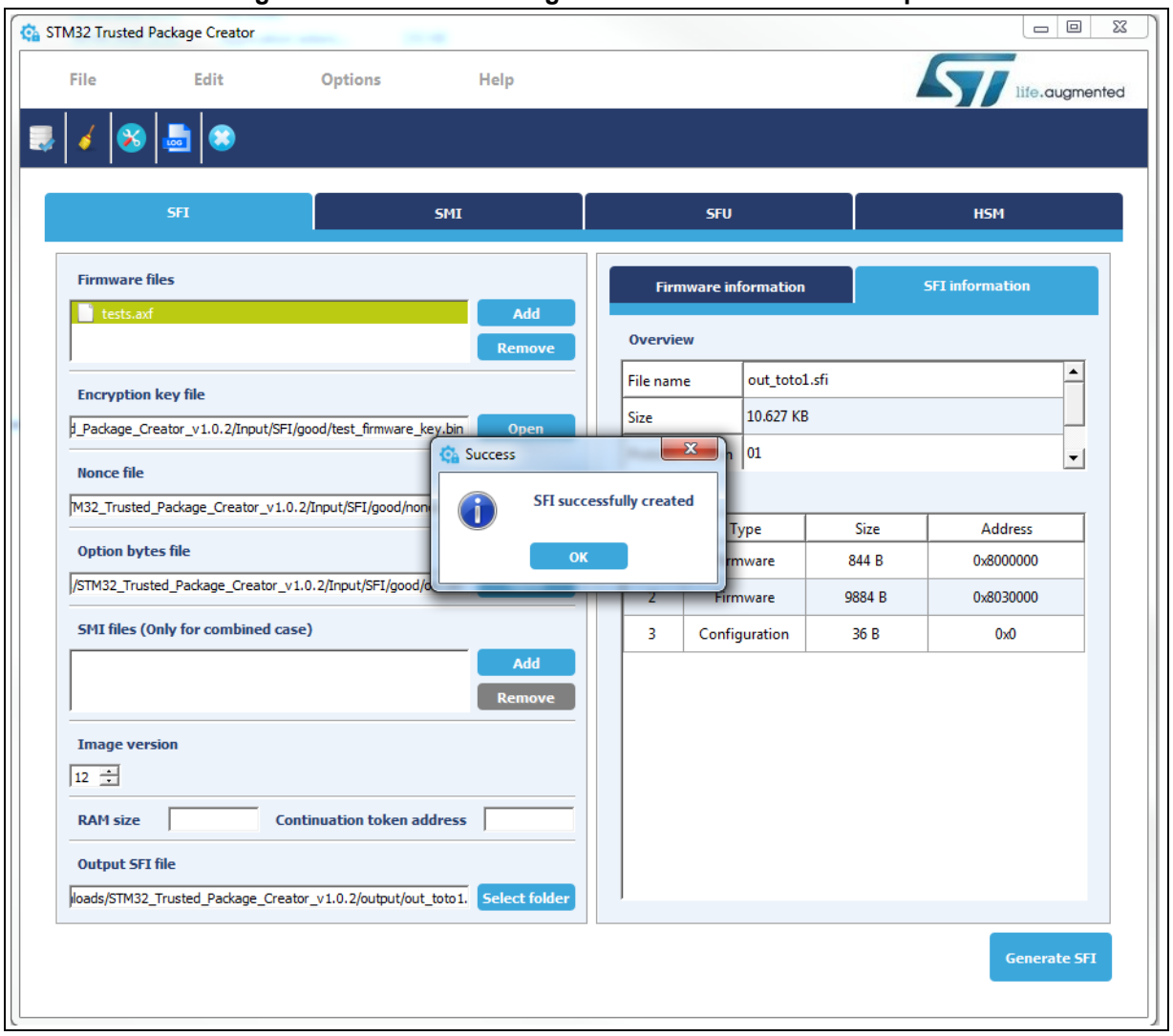
Note: By using the “Select folder” button, the name “out.sfi” is automatically suggested. This can be kept or changed.

- ‘Generate SFI’ button:

  Once all fields are filled in properly, the “Generate SFI” button becomes enabled. The user can generate the SFI file by a single click on it.

  If everything goes well, a message box indicating successful generation appears (*Figure 33: SFI successful generation in GUI mode example*) and information about the generated SFI file is displayed in the SFI information section.

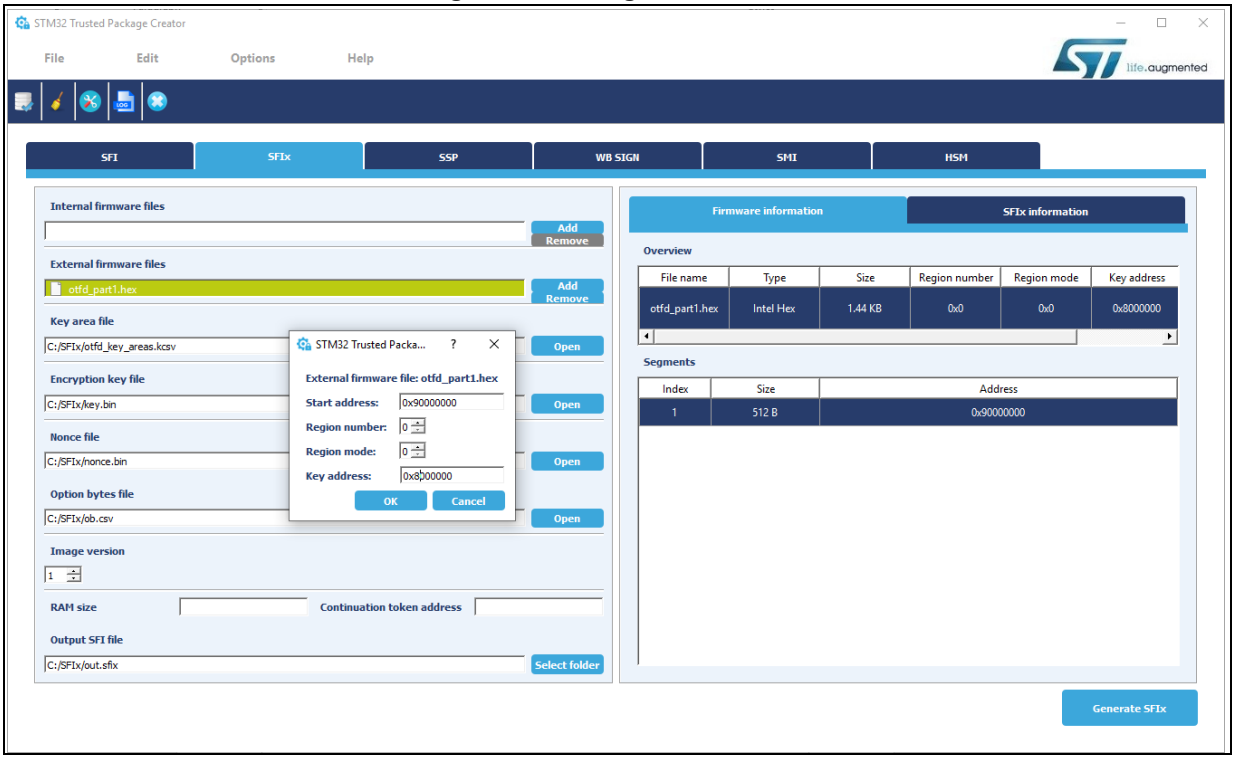
Figure 33. SFI successful generation in GUI mode example



3.7.2 SFIx generation using STPC in GUI mode

Figure 34 shows the graphical user interface tab corresponding to SFIx generation.

Figure 34. SFIx generation Tab

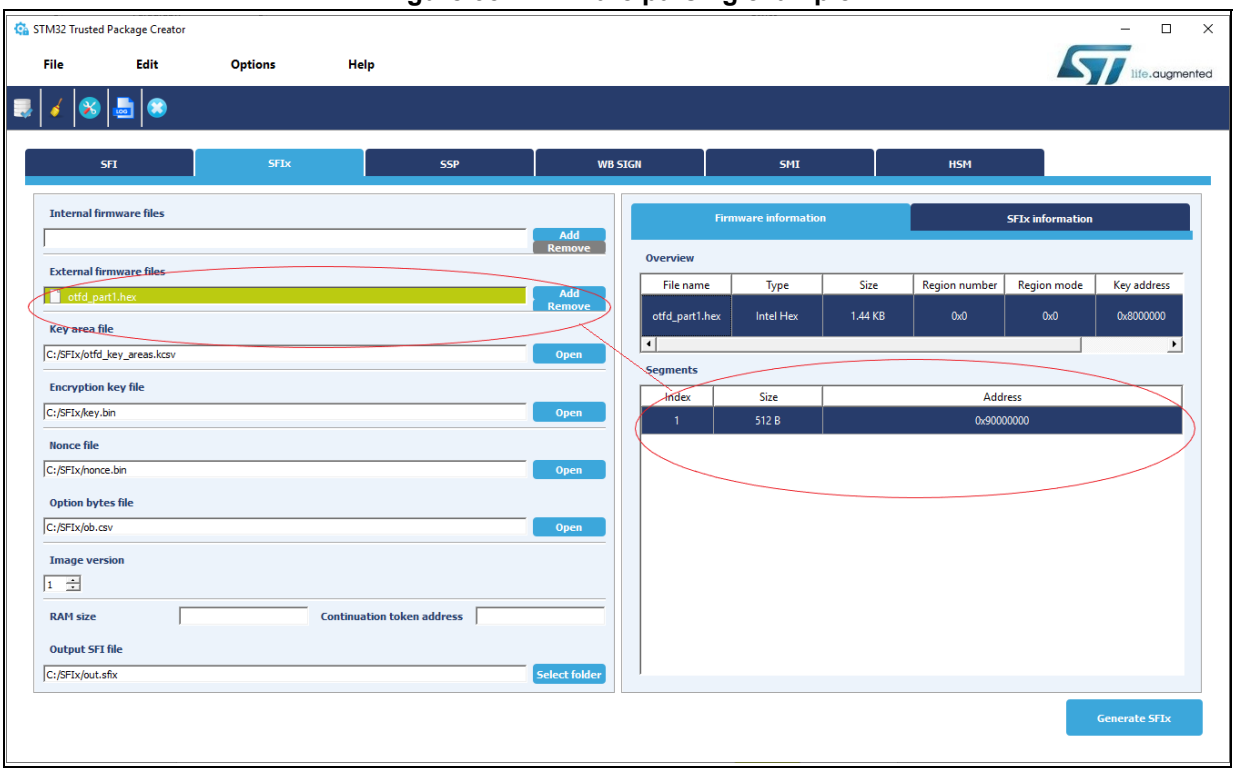


To generate an SFIx image successfully from the supported input firmware formats, the user must fill in the interface fields with valid values.

SFIx GUI tab fields

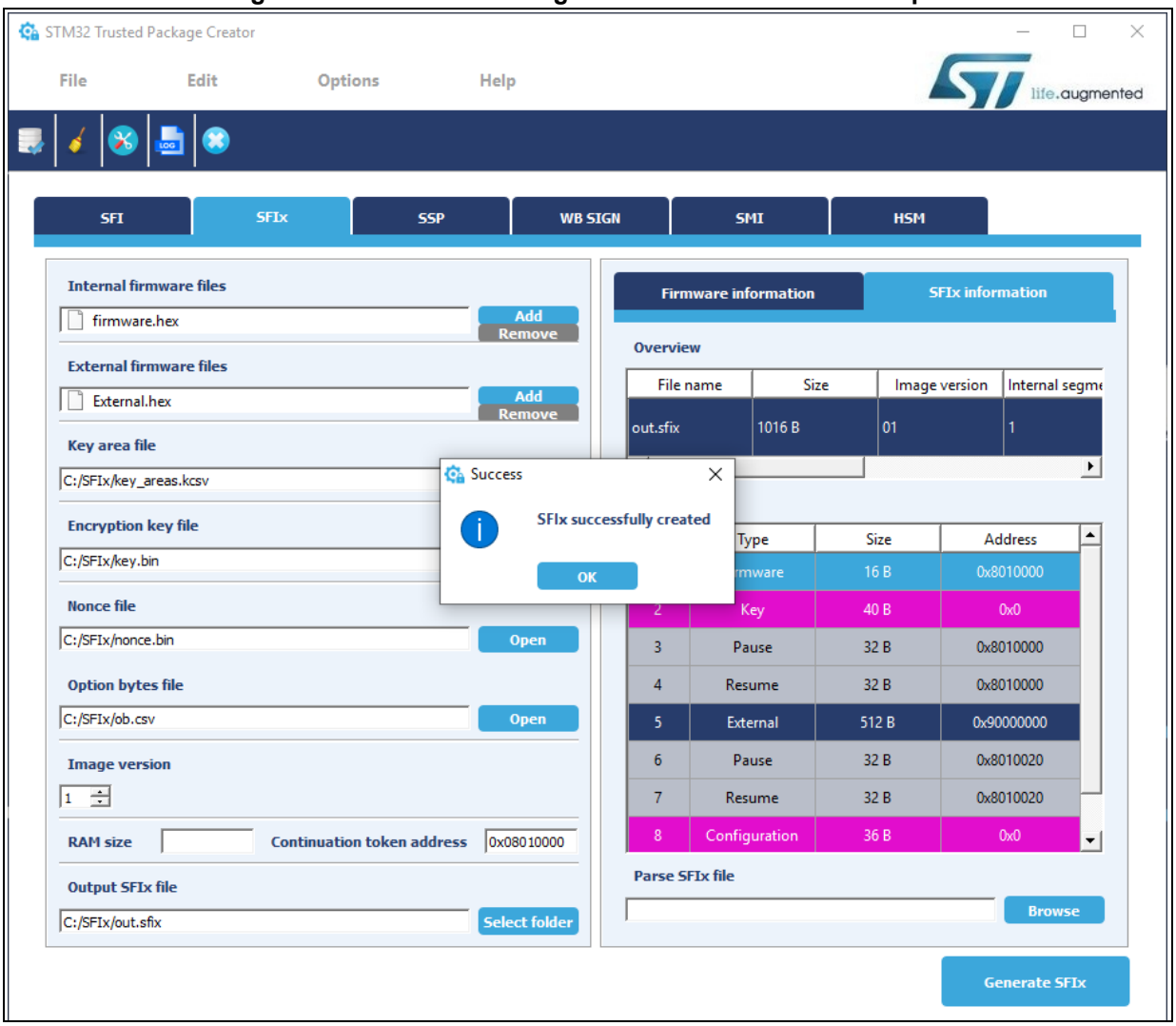
Firmware files: The user needs to add the input firmware files with the “Add” button. If the file is valid, it is appended to the “input firmware files “list, otherwise an error message box appears to notify the user that either the file could not be opened, or the file is not valid. Clicking on “input firmware file“ causes information related information to appear in the “Firmware information” section (*Figure 35*).

Figure 35. Firmware parsing example



As is the case for the SFI use case, once all fields are filled in properly, the “Generate SFIx” button becomes enabled. The user can generate the SFIx file by a single click on it. If everything goes well, a message box indicating successful generation appears (*Figure 36: SFIx successful generation in GUI mode example*) and information about the generated SFIx file is displayed in the SFIx information section.

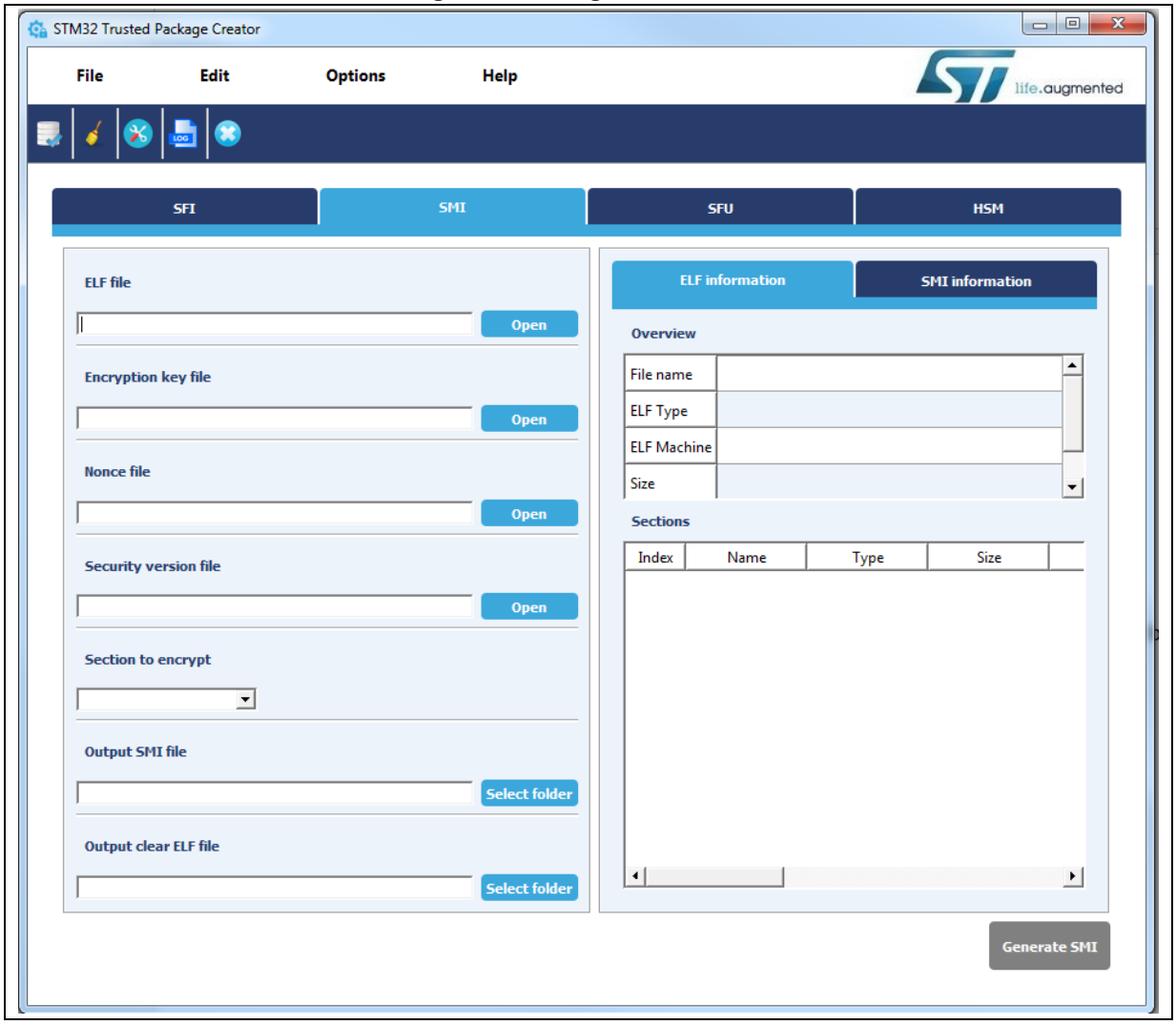
Figure 36. SFIx successful generation in GUI mode example



3.7.3 SMI generation using STPC in GUI mode

Figure 37 shows the graphical user interface tab corresponding to SMI generation.

Figure 37. SMI generation Tab



To generate an SMI image successfully from an ELF file, the user must fill in the interface fields with valid values.

SMI GUI tab fields

- ELF file:

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

  If the file is valid, information is displayed in the “ELF information” tab, otherwise an error message box appears to notify the user that either the file could not be opened or the file is not valid.
- Encryption key and nonce file:

  As for SFI, the encryption key and nonce file are selected in the same way as the ELF file. Notice that sizes must be respected (16 bytes for the key and 12 bytes for the nonce file).
- Security version file:

  The security version file is used for the same purpose as explained in the CLI section.

  The security version file size must be 16 bytes.
- Section:

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

  Sets the folder path into which the SMI image and its clear part are to be created. This is done by entering the folder path (absolute or relative) or by using the “Select folder” button.

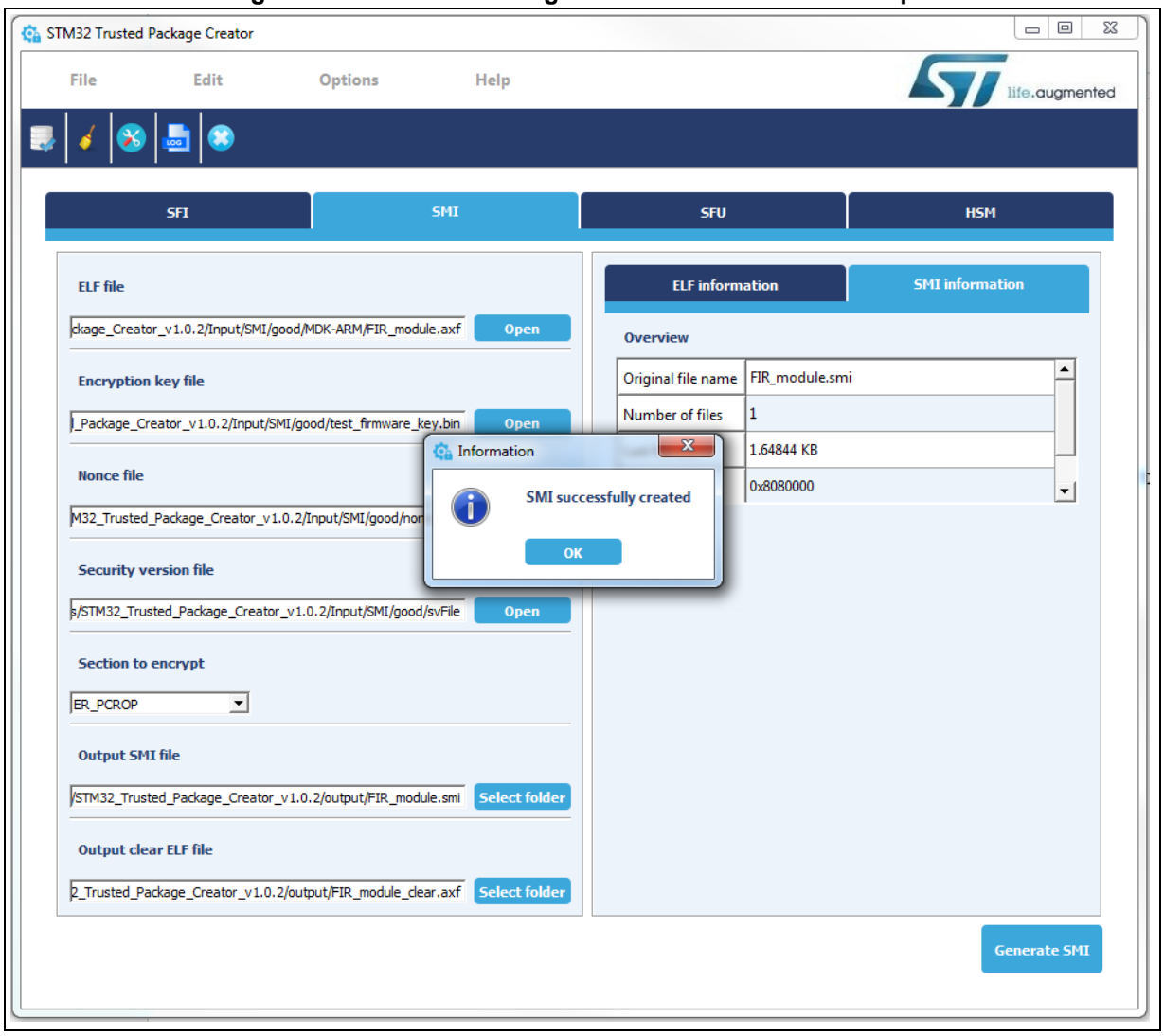
Note: For both output fields, when using the “Select folder” button, a name is suggested automatically. This can be kept or changed.

- ‘Generate SMI’ button:

  When all fields are filled in properly the ‘Generate SMI’ button is enabled, and the user can generate the SMI file and its corresponding clear data part by a single click on it.

  A message box informing the user that generation was successful must appear (*Figure 38: SMI successful generation in GUI mode example*), with additional information about the generated SMI file displayed in the ‘SMI information’ section. In the case of invalid input data, an error message box appears instead.

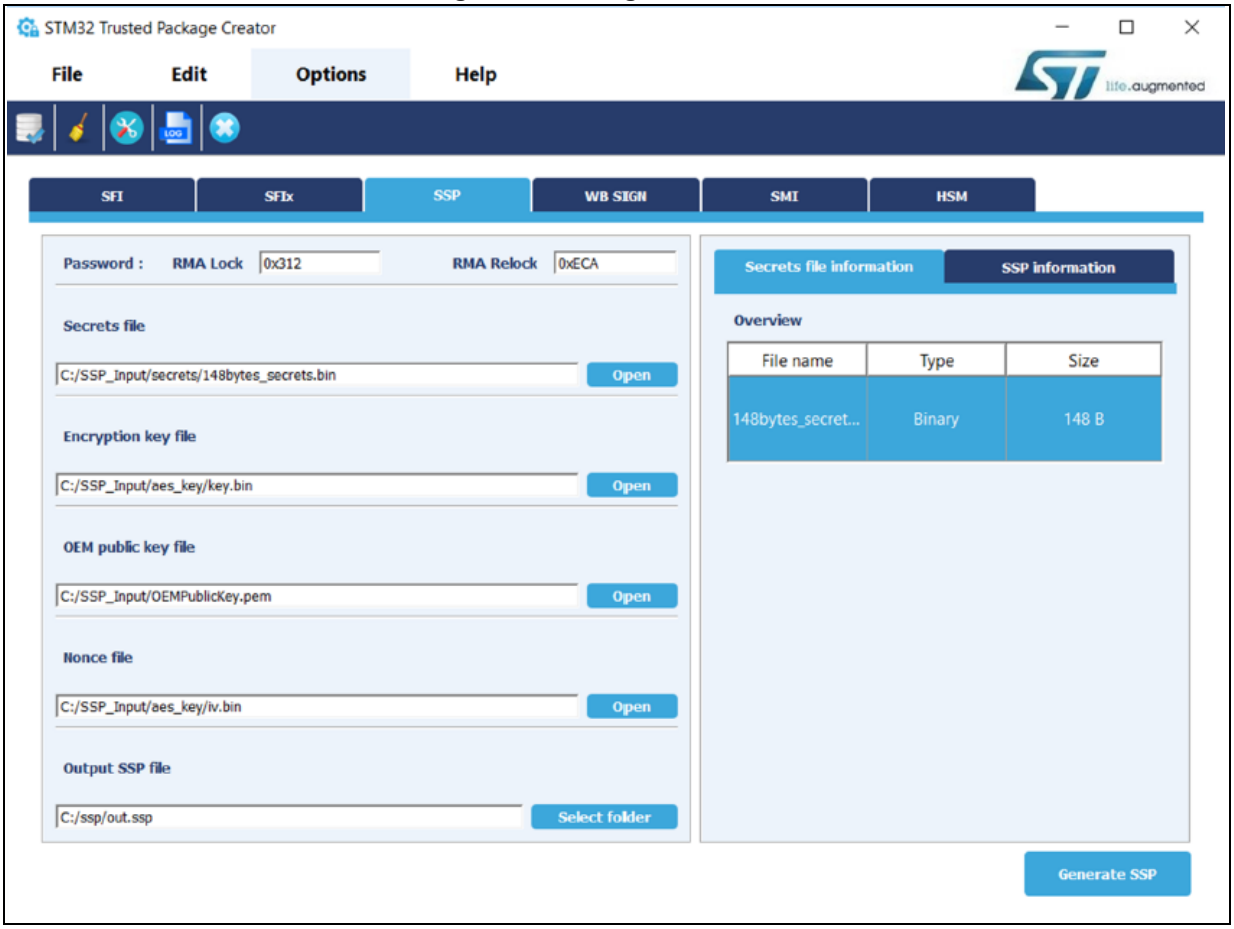
Figure 38. SMI successful generation in GUI mode example



3.7.4 SSP generation using STPC in GUI mode

Figure 39 shows the SSP generation graphical user interface tab.

Figure 39. SSP generation tab



To generate an SSP image successfully from the supported firmware input formats, the user must fill in the interface fields with valid values.

SSP GUI tab fields

RMA Lock: Unlock password, hexadecimal value from 0x0000 to 0x7FFF

RMA Relock: Relock password, hexadecimal value from 0x0000 to 0x7FFF

Secrets file: Binary file of size 148 bytes to be encrypted. Can be selected by entering the file path (absolute or relative), or by selection with the **Open** button.

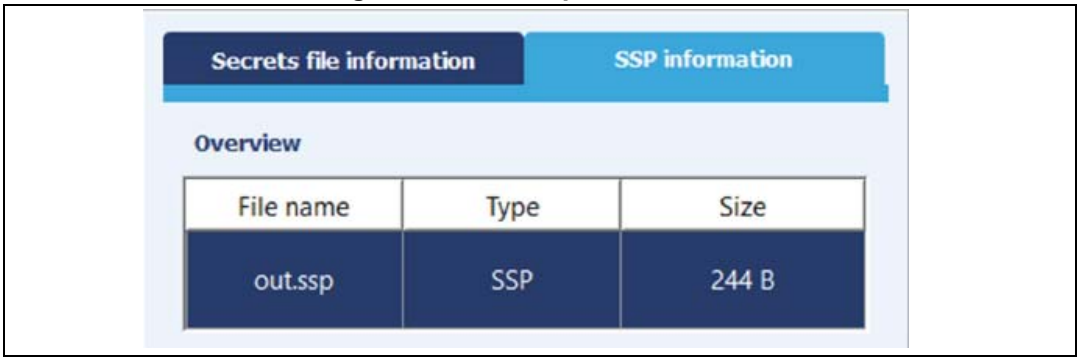
Encryption key and nonce files: The encryption key and nonce file can be selected by entering their paths (absolute or relative), or by selection with the **Open** button. Notice that sizes must be respected (16 bytes for the key and 12 bytes for the nonce).

OEM public key file: 178-byte .pem file.

Output SSP file: Select the output directory by entering the SSP file name to be created with a .ssp extension.

When all fields are properly filled in, the user can start the generation by clicking on the **Generate SSP** button (the button becomes active).

Figure 40. SSP output information



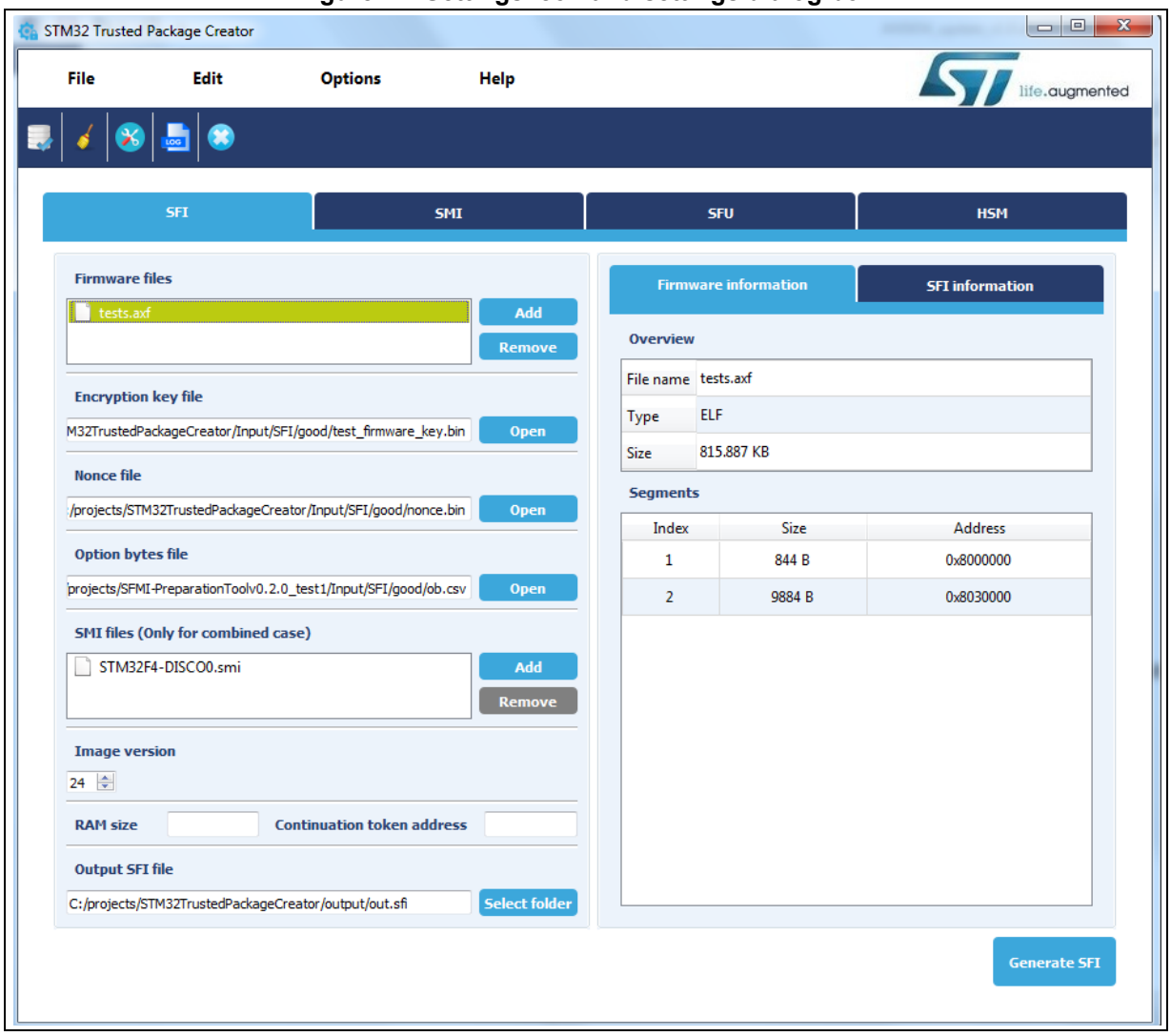
When the generation is complete, SSP information is available in the SSP overview section.

- **File name**: SSP output file name.
- **Type**: SSP format.
- **Size**: indicates the generated file size including all data fields.

3.7.5 Settings

The STPC allows generation to be performed respecting some user-defined settings. The settings dialog is displayed by clicking the settings icon (see *Figure 41*) in the tool bar or in the menu bar by choosing: Options -> settings.

Figure 41. Settings icon and settings dialog box



Settings can be performed on:

- Padding byte:

  When parsing Hex and Srec files, padding can be added to fill gaps between close segments to merge them and reduce the number of segments. The user might choose to perform padding either with 0xFF (the 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:

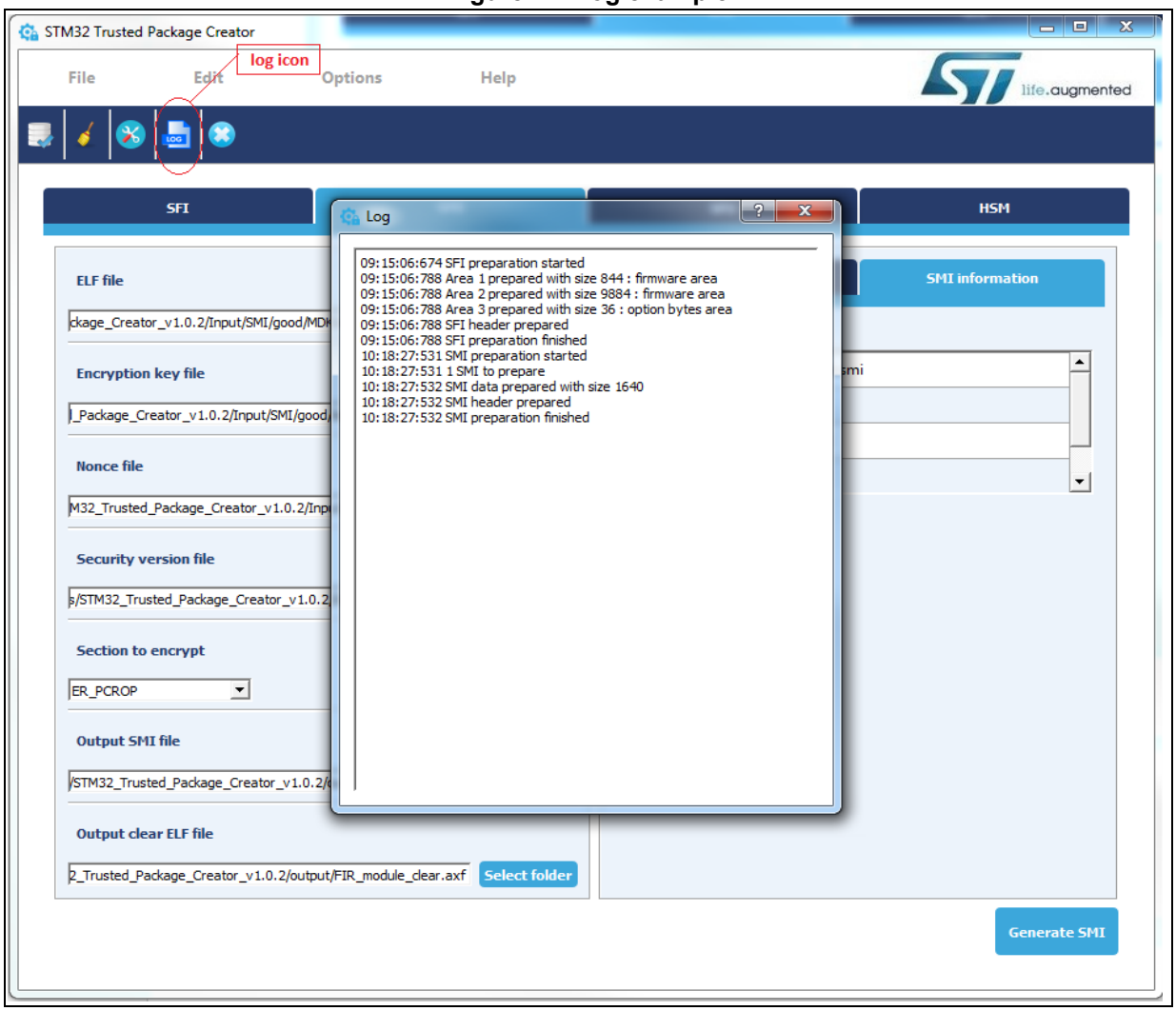
  When checked, a log file is generated in the selected path.

3.7.6 Log generation

A log can be visualized by clicking the “log” icon in the tool bar or menu bar: Options-> log.

Figure 42 shows a log example:

Figure 42. Log example



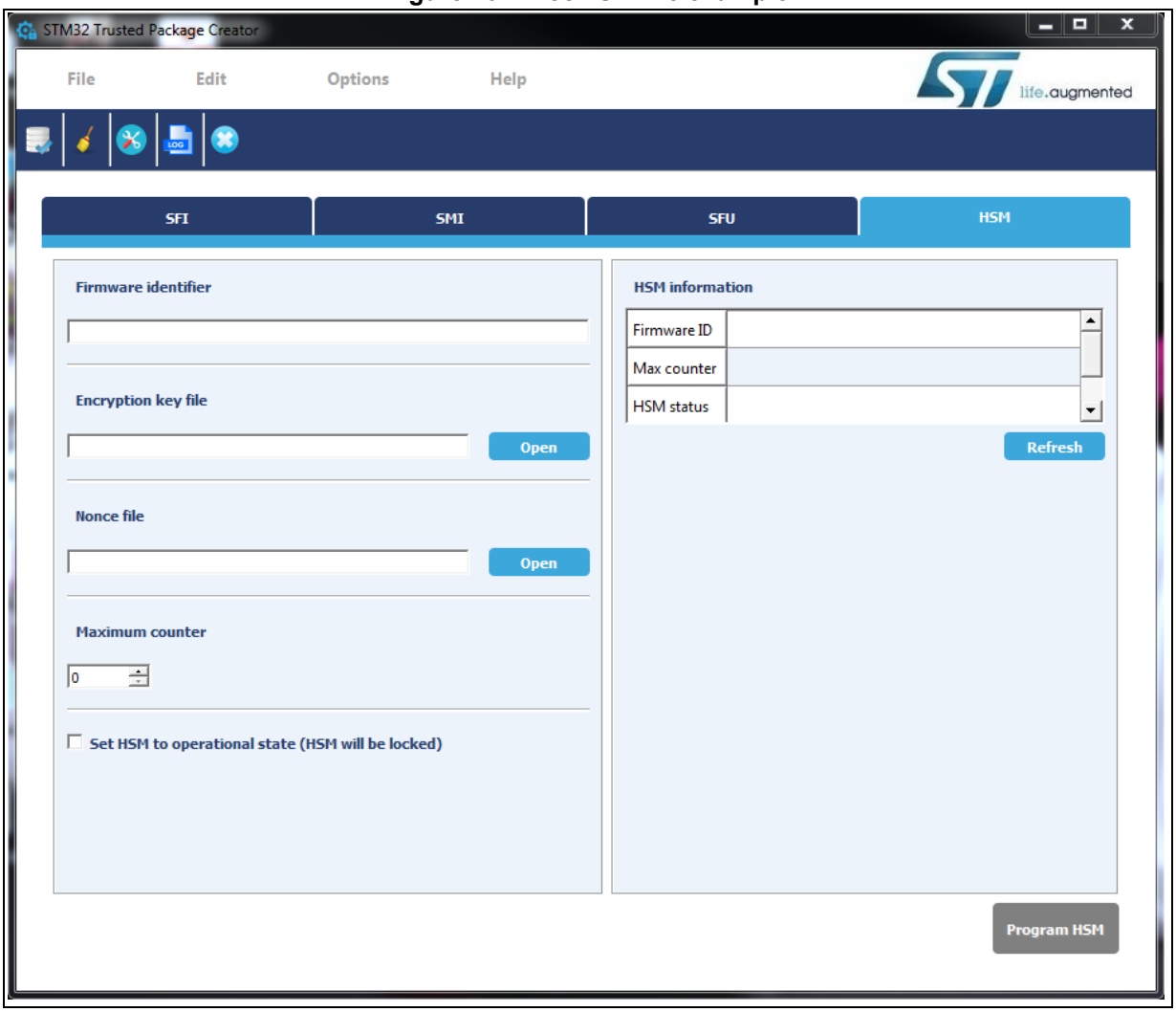
3.7.7 SFI and SMI file checking function

This function checks the validity and information parsing of an SFI or SMI file.

It is accessed by clicking the Check SFI/SMI button in the tool bar or the menu bar: File -> Check SFI/SMI.

Figure 43 shows a check SFI example:

Figure 43. Check SFI file example



4 Encrypted firmware (SFI/SFIx)/ module (SMI) programming with STM32CubeProgrammer

STM32CubeProgrammer is a tool for programming STM32 devices through UART, USB, SPI, CAN, I^2C, JTAG, and SWD interfaces. So far, programming via JTAG/SWD is only supported with an STLINK probe.

The STM32CubeProgrammer tool currently also supports secure programming of SFI and SMI images using UART, USB, SPI, JTAG/SWD interfaces, and SFIx using only JTAG/SWD interfaces. The tool is currently available only in CLI mode, it is available free of charge from *www.st.com*.

4.1 Chip certificate authenticity check and license mechanism

The SFI solution was implemented to provide a practical level of IP protection chain from the firmware development up to flashing the device, and to attain this objective, security assets are used, specifically device authentication and license mechanisms.

4.1.1 Device authentication

The device authentication is guaranteed by the device's own key.

In fact, a certificate is related to the device's public key and is used to authenticate this public key in an asymmetric transfer: the certificate is the public key signed by a Certificate Authority (CA) private key. (This CA is considered as fully trusted).

This asset is used to counteract usurpation by any attackers who could substitute the public key with their own key.

4.1.2 License mechanism

One important secure flashing feature is the ability of the firmware provider to control the number of chips that can be programmed. This is where the concept of licenses comes in to play. The license is an encrypted version of the firmware key, unique to each device and session. It is computed by a derivation function from the device's own key and a random number chosen from each session (the nonce).

Using this license mechanism, the OEM is able to control the number of devices to be programmed, since each license is specific to a unique chip, identified by its public key.

License mechanism general scheme

When a firmware provider wants to distribute new firmware, they generate a firmware key, and use it to encrypt the firmware.

When a customer wants to download the firmware to a chip, they send a chip identifier to the provider server, HSM, or any provider license generator tool, which

returns a license for the identified chip. The license contains the encrypted firmware key, and only this chip can decrypt it.

License distribution

There are many possible ways for the firmware provider to generate and distribute licenses.

ST solution is based on STM32HSM: a standalone chip in a smartcard form factor that could be programmed during the SFI/SMI preparation then used on the device production line. This solution is securing end to end transport of the firmware. Only the STM32 is capable to authenticate and decrypt the firmware. In addition, an ST solution based on STM32HSM is protecting device production against cloning.

Other solutions could be considered and STMicroelectronics, through its partnership program, is offering programming services. Find yours from the following link: Global Services from Partners - STMicroelectronics.

HSM programming by OEM for license distribution

Before an OEM delivers an HSM to a programming house for deployment as a license generation tool for programming of relevant STM32 devices, some customization of the HSM must be done first.

The HSM needs to be programmed with all the data needed for the license scheme deployment. In the production line, a dedicated API is available for HSM personalization and provisioning.

This data is as follows:

- **The 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 overprogramming.

  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 a maximum predefined value, which depends on the HSM used.
- **The firmware key**: the key size is 32 bytes. It is composed of two fields: the initialization vector field (IV) and the key field, which are used for AES128-GCM firmware encryption.

  Both fields are 16 bytes long, but the last 4 bytes of the IV must be zero (only 96 bits of IV are used in the AES128-GCM algorithm).

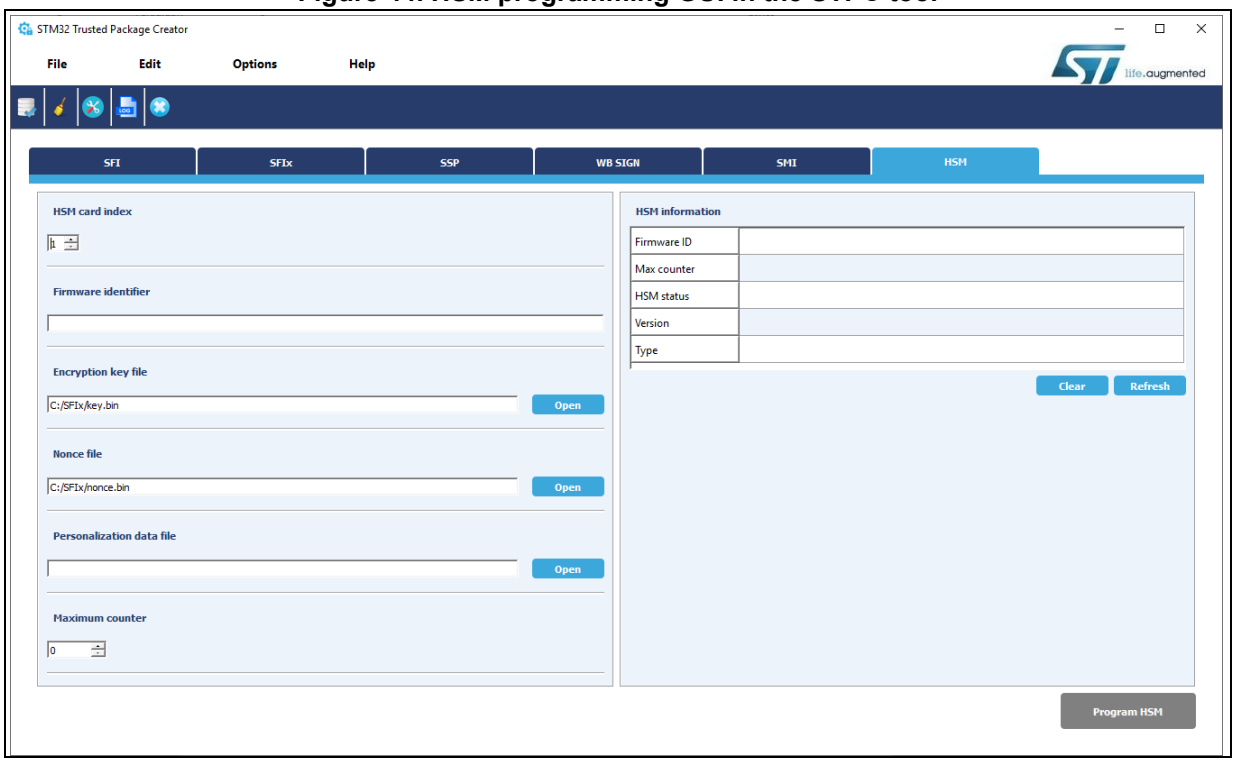
  Both fields must remain secret; that is why there are encrypted before being sent to the chip.

  The key and IV remains 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.
- **The firmware identifier**: allows the correct HSM to be identified for a given firmware.
- **The personalization data**: this is specific to each MCU and delivered inside the TPC directory. More info about personalization data in *Section 5.3.5: Performing HSM programming for license generation using STPC (CLI mode)*.

The HSM must be in “OPERATIONAL STATE” (locked) when shipped by the OEM to guarantee the OEM’s data confidentiality and privacy.

STMicroelectronics provides the tools needed to support SFI/SFIx via HSM. In fact, HSM programming is supported by the STM32 Trusted Package Creator tool. *Figure 44* shows the GUI for HSM programming in the STPC tool.

Figure 44. HSM programming GUI in the STPC tool



During SFI install, STM32CubeProgrammer communicates with the device to get the chip certificate, upload it into the HSM to request the license. Once the license is generated by the HSM, it gives it back to the STM32 device.

4.2 Secure programming using a bootloader interface

4.2.1 Secure firmware installation using a bootloader interface flow

The production equipment on the OEM-CM production line needs to be equipped with a flashing tool (FT) supporting the programming of SFI images. The flashing tool to be used on OEM-CM production line is STM32CubeProgrammer, which is given the data blob prepared by the STPC, containing the image header and the encrypted image data blob.

Note: The SFI install is performed successfully only if a valid license is given to the flashing tool.

STM32CubeProgrammer supports secure firmware install for such devices as well as all STM32H7, STM32L4, STM32L5, STM32WL, STM32U5, and STM32MP1 devices available so far.

For more details on SFI over these STM32 devices, refer to AN4992 *[1]*. This document is available on *www.st.com*.

The general flow of the secure firmware installation using a bootloader interface on a chip for STM32H7 and STM32L4 secure devices is shown respectively in *Figure 45* and *Figure 46* below.

Figure 45. Secure programming via STM32CubeProgrammer overview on STM32H7 devices

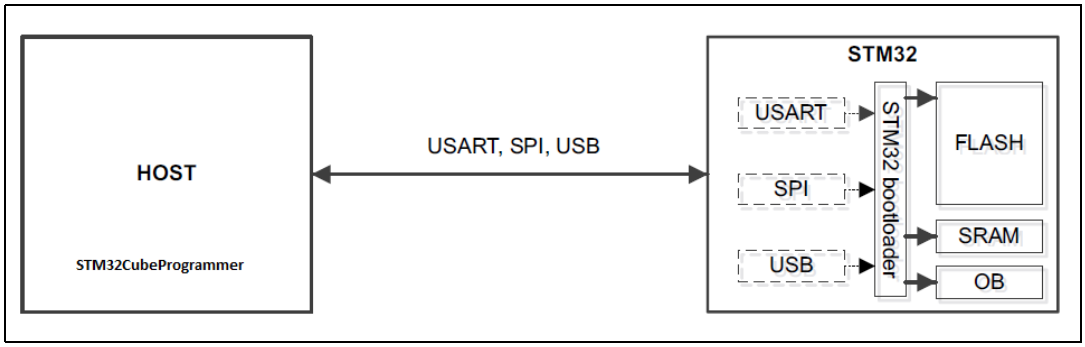
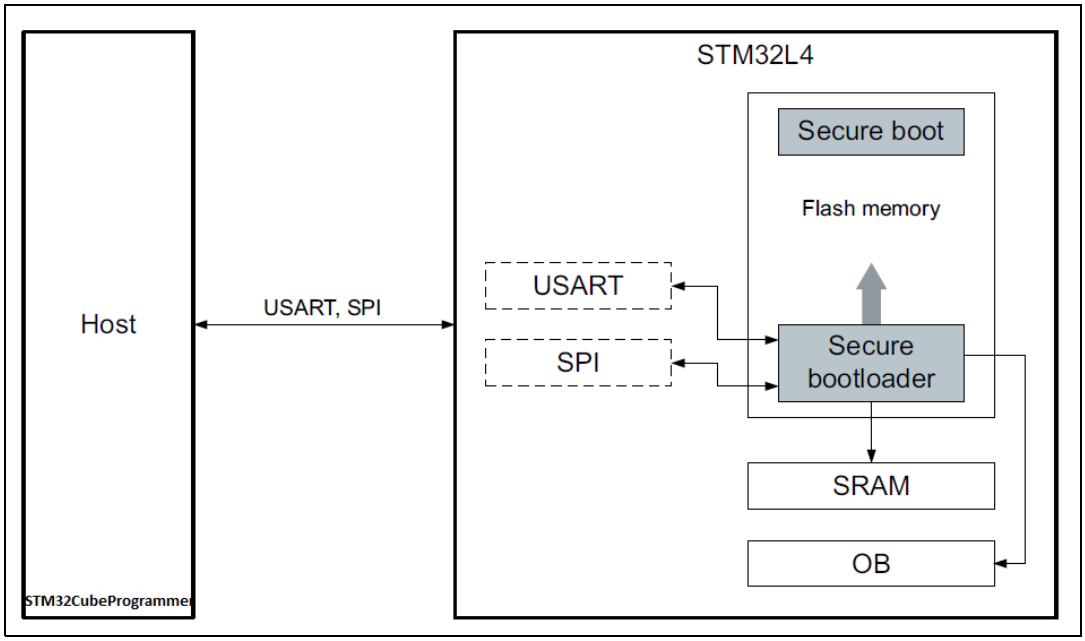


Figure 46. Secure programming via STM32CubeProgrammer overview on STM32L4 devices



4.2.2 Secure module installation using a bootloader interface flow

As explained in *Section 3.4: SMI generation process*, outputs are generated for this particular use case:

- The first part, not encrypted: this is a regular ELF/AXF file, containing all the sections except the code section extracted by the STPC to prepare the SMI module.
- The encrypted SMI module, which contains the protected code.

The first part is programmed into the chip using any means (JTAG flasher, UART bootloader, and so on, as for any regular ELF/AXF file.

The full content of the SMI image file and its corresponding license are given to STM32CubeProgrammer that places them in RAM.

The SMI has to be invoked via the secure bootloader.

Note: The SMI install is performed successfully only if the adequate license is given to the flashing tool.

4.2.3 STM32CubeProgrammer for SFI using a bootloader interface

For SFI programming, the STM32CubeProgrammer is used in CLI mode (the only mode so far available) by launching the following command:

-sfi, --sfi

Syntax: -sfi protocol=<Ptype> <file_path> <licenseFile_path>

[<protocol=Ptype>] : Protocol type to be used: static/live
Only a static protocol is supported so far

Default value static

<file_path> : Path of sfi file to be programmed

[hsm=0|1] : Set a user option for HSM use value in
{0 (do not use HSM), 1 (use HSM)}
Default value : hsm = 0

<lic_path|slot=slotID> : Path to the SFI license file (if hsm = 0)
or reader slot ID if HSM is used (hsm = 1)

[<licMod_path>|slot=slotID]: List of the integrated SMI license file paths

If hsm = 1, the user must provide the slot ID parameter.

If hsm = 0, the user must provide the license path file that can be generated separately using the following command line, provided an HSM card is available:

```
-hsmgetlicense
```

During th SFI process, the generated license can be used multiple times with the same MCU, without the need of an HSM card.

Example using the UART bootloader interface:

To use an HSM, the command is:

```
STM32_Programmer.exe -c port=COM1 br=115200 -sfi "C:\SFI\data.sfi"
hsm=1 slot=1
```

To use a license file, the command is:

```
STM32_Programmer.exe -c port=COM1 br=115200 -sfi
"C:\SFI\data.sfi" --sfi hsm=0 "C:\SFI\license.bin"
```

This command allows secure installation of firmware *“data.sfi”* into a dedicated flash memory address.

4.2.4 STM32CubeProgrammer for SMI via a bootloader interface

For SMI programming, STM32CubeProgrammer is used in CLI mode by launching the following command:

-smi, --smi

Syntax: -smi protocol=<Ptype> <file_path> [<address>] <licenseFile_path>

<protocol=Ptype> : Protocol type to be used: static/live
Only a static protocol is supported so far
Default value static

<file_path> : Path of smi file to be programmed

[hsm=0|1] : Set user option for HSM use
value in {0 (do not use HSM), 1 (use HSM)}
Default value: hsm=0

[<address>] : Destination address of the smi module
needed only for relocatable SMI

<lic_path|slot=slotID> : Path to the SMI license file (if hsm=0) or reader slot ID if HSM is used (hsm=1)

Example using the UART bootloader interface:

```
STM32_Programmer.exe -c port=COM1 br=115200 -sfi
"C:\SFI\data.sfi" hsm=0 "C:\SFI\license.bin"
```

This command allows programming of the SMI specified file *“data.smi”* into a dedicated PCROPed area.

4.2.5 STM32CubeProgrammer for SSP via a bootloader interface

In this part, the STM32CubeProgrammer tool is used in CLI mode (the only mode available so far for secure programming) to program the SSP image already created with STM32 Trusted Package Creator. STM32CubeProgrammer supports communication with STMicroelectronics HSMs (hardware secure modules based on smartcard) to generate a license for the connected STM32 MPU device during SSP install.

The SSP flow can be performed using both USB or UART interfaces (not the STLINK interface).

STM32CubeProgrammer exports a simple SSP command with some options to perform the SSP programming flow.

-ssp, --ssp

Description: Program an SSP file

Syntax: -ssp <ssp_file_path> <ssp-fw-path> <hsm=0|1> <license_path|slot=slotID>

<ssp_file_path> : SSP file path to be programmed, bin, or ssp extensions

<ssp-fw-path> : SSP signed firmware path

<hsm=0|1> : Set user option for HSM use (do not use HSM / use HSM)

Default value : hsm=0

<license_path|slot=slotID> :Path to the license file (if hsm=0)

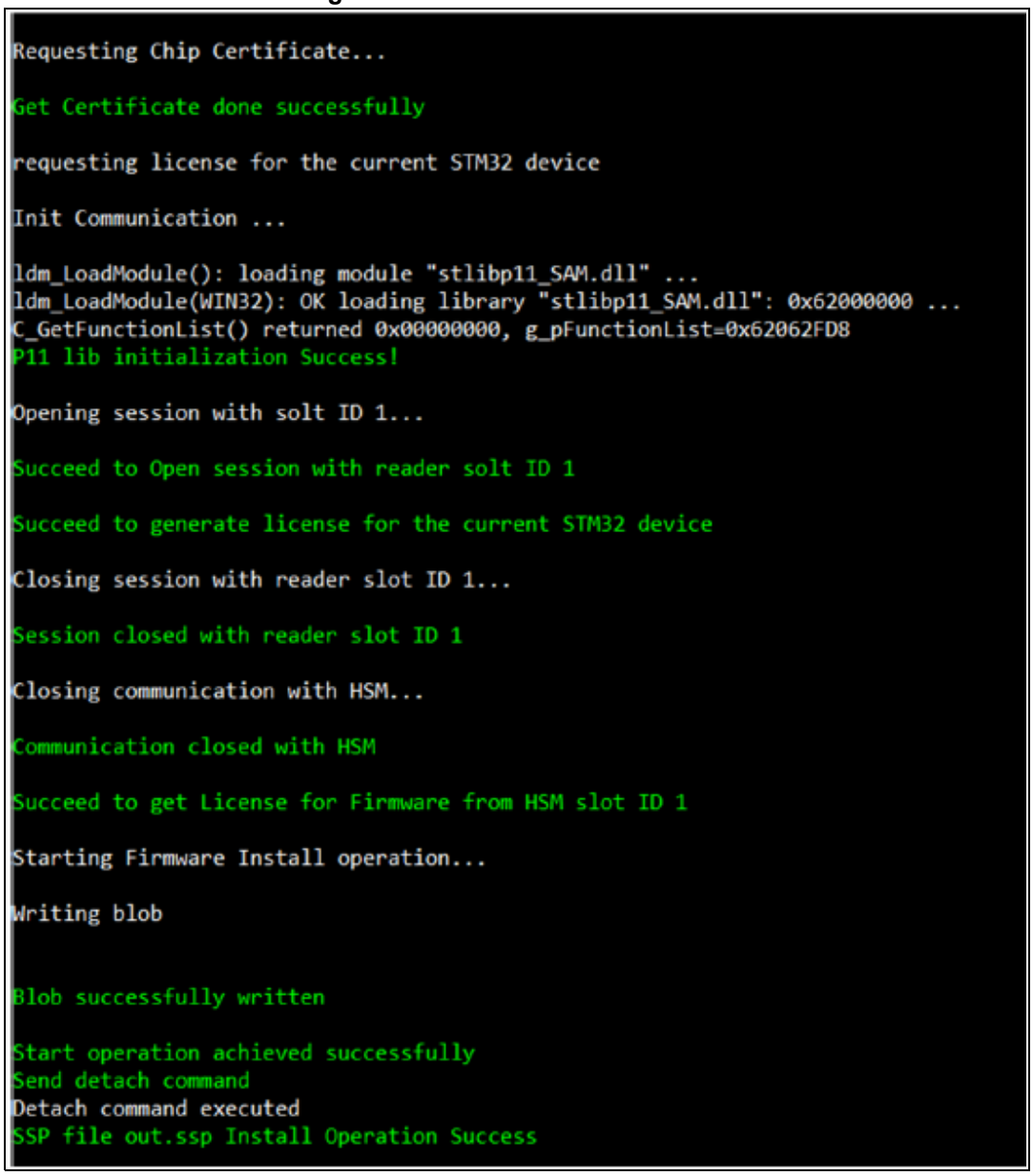
Reader slot ID if HSM is used (if hsm=1)

Example using USB DFU bootloader interface:

STM32_Programmer_CLI.exe -c port=usb1 –ssp “out.ssp” “tf-a-ssp-stm32mp157f-dk2-trusted.stm32” hsm=1 slot=1

Note: All SSP traces are shown on the output console.

Figure 47. SSP installation success



If there is any faulty input, the SSP process is aborted, and an error message is displayed to indicate the root cause of the issue.

4.2.6 STM32CubeProgrammer get certificate via a bootloader interface

To get the chip certificate, STM32CubeProgrammer is used in CLI mode by launching the following command:

-gc, --getcertificate

Syntax: –gc <file_path>

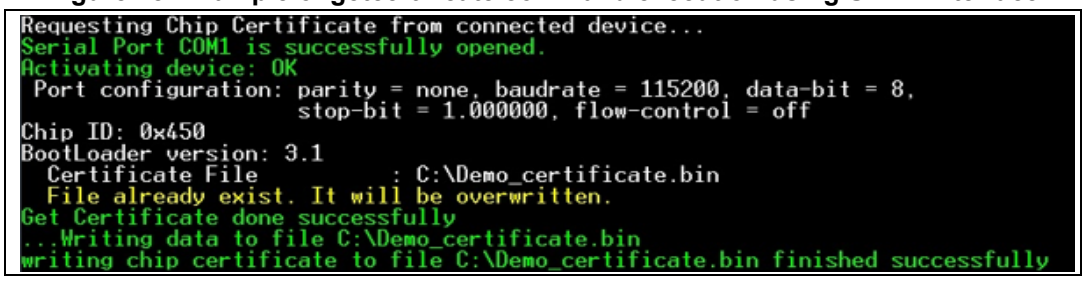
Example using the UART bootloader interface:

```
STM32_Programmer.exe -c port=COM1 -gc
"C:\Demo_certificate.bin"
```

This command allows the chip certificate to be read and uploaded into the specified file: *"C:\Demo_certificate.bin"*

The execution results are shown in *Figure 48*.

Figure 48. Example of getcertificate command execution using UART interface



4.3 Secure programming using the JTAG/SWD interface

4.3.1 SFI/SFIx programming using JTAG/SWD flow

It is also possible to program the SFI/SFIx image using the JTAG interface. Here the readout protection mechanism (RDP level 1) cannot be used during SFI/SFIx as user flash memory is not accessible after firmware chunks are written to RAM through the JTAG interface.

The whole process happens in RDP level 0. In the case of SFIx programming the code is protected by the OTFDEC encryption.

SFI via debug interface is currently supported for STM32H753XI, STM32H7A3/7B3 and STM32H7B0, STM32H723/333 and STM32H725/335, and STM32L5 devices.

SFIx via debug interface is currently supported for STM32H7A3/7B3 and STM32H7B0, STM32H723/733, STM32L5, and STM32U5 devices.

For these devices, there is around 1 Mbyte of RAM available, with 512 Kbytes in main SRAM. This means that the maximum image size supported is 1 Mbyte, and the maximum area size is 512 Kbytes.

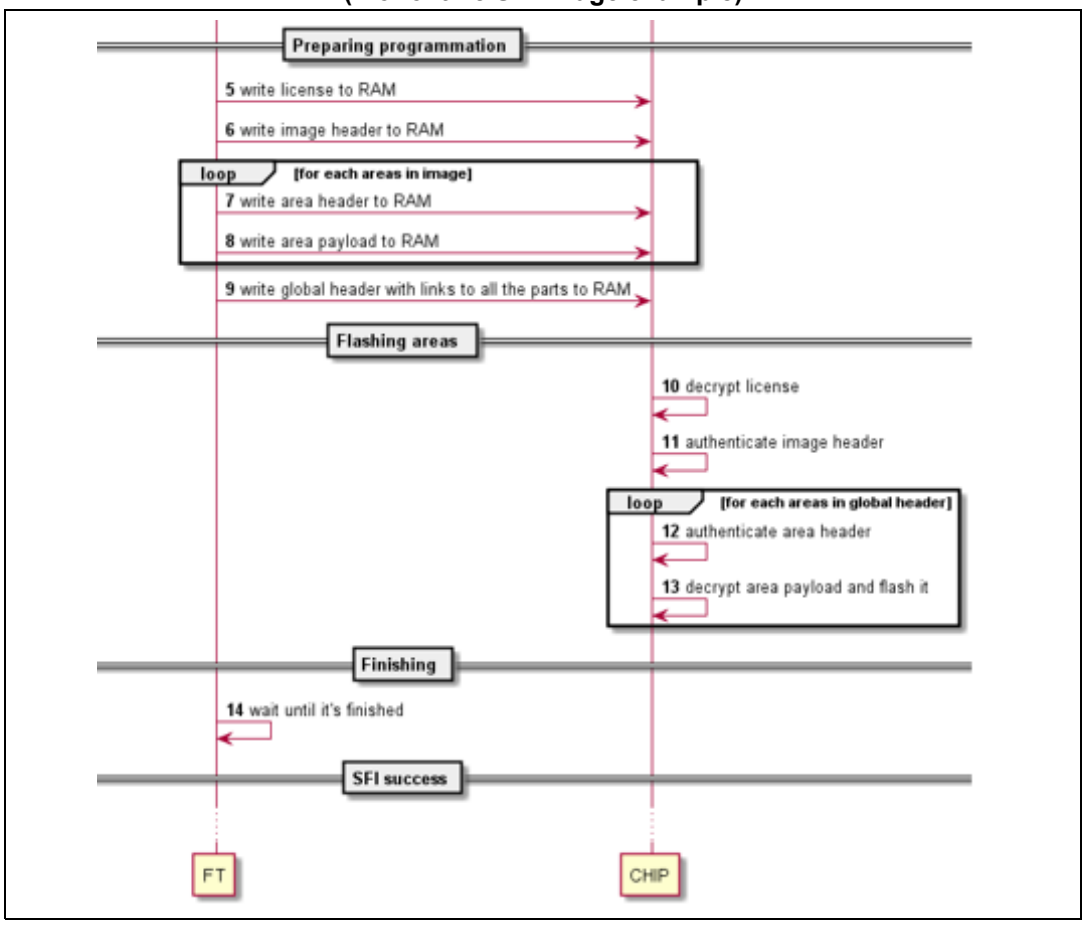
To remedy this, the SFI/SFIx image is split into several parts, so that each part fits into the allowed RAM size.

An SFI/SFIx is then performed. Once all its SFI/SFIx parts are successfully installed, the global SFI/SFIx image install is successful.

Other limitations are that security must be left activated in the configuration area if there is a PCROP area. In the case of STM32L5 and STM32U5 devices, STM32CubeProgrammer sets the RDP Level on 0.5.

The SFI flow for programming through JTAG is described in *Figure 49*.

Figure 49. SFI programming by JTAG/SWD flow overview (monolithic SFI image example)



4.3.2 SMI programming through JTAG/SWD flow

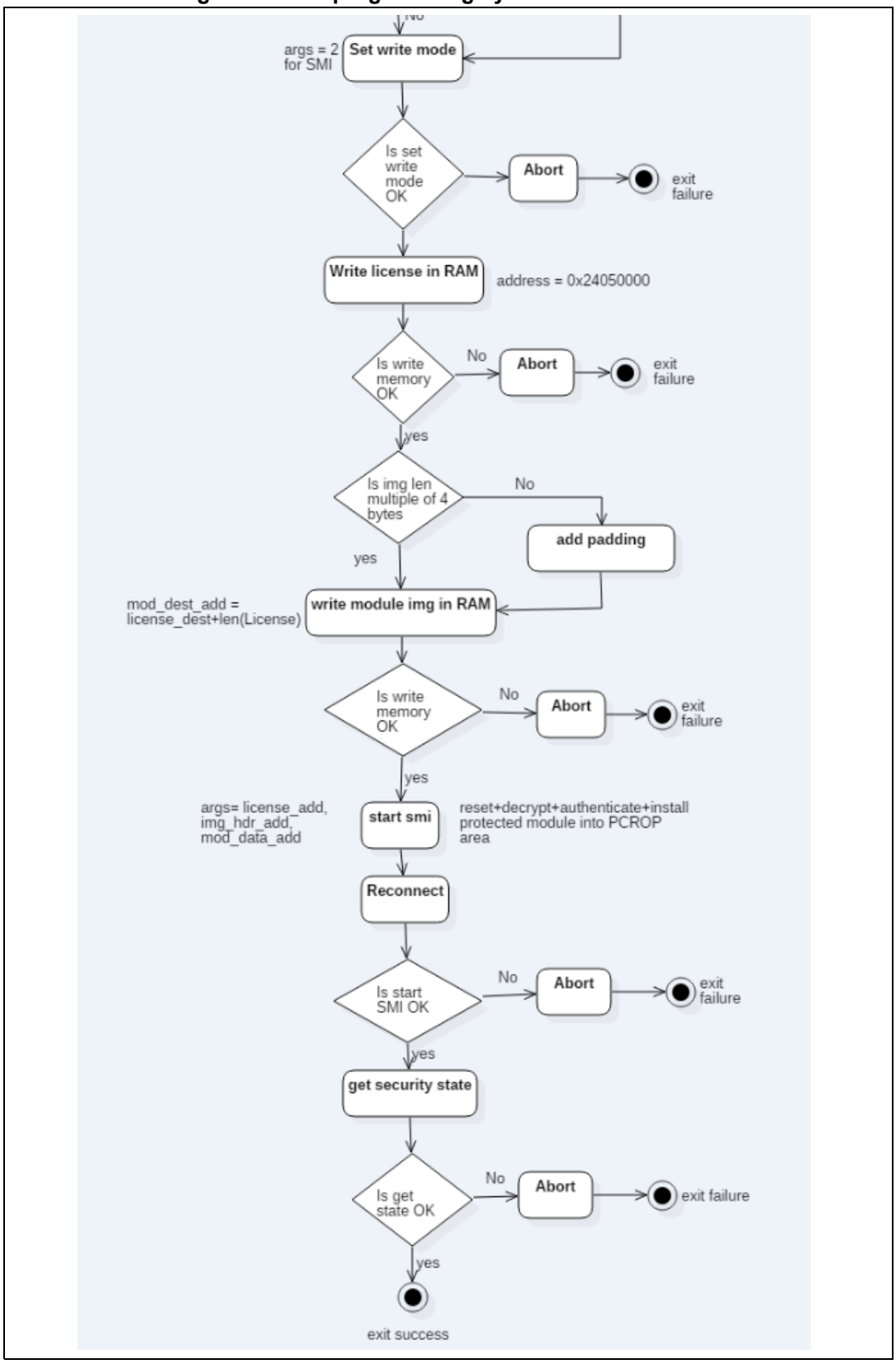
For SMI programming through JTAG/SWD the process flow is similar to that using the UART bootloader.

This means that the whole SMI image and its corresponding license must be transferred to RAM before starting. Then, there are two options to access SMI services through JTAG:

- Write a small program in RAM that calls the public API (API details are available under a nondisclosure agreement)
- Use the secure API directly.

The essential steps of the SMI programming by JTAG flow are described in *Figure 50: SMI programming by JTAG flow overview*.

Figure 50. SMI programming by JTAG flow overview



4.3.3 STM32CubeProgrammer for secure programming using JTAG/SWD

The only modification in the STM32CubeProgrammer secure command syntax is the connection type that must be set to “jtag” or “swd”, otherwise all secure programming syntax for supported commands is identical.

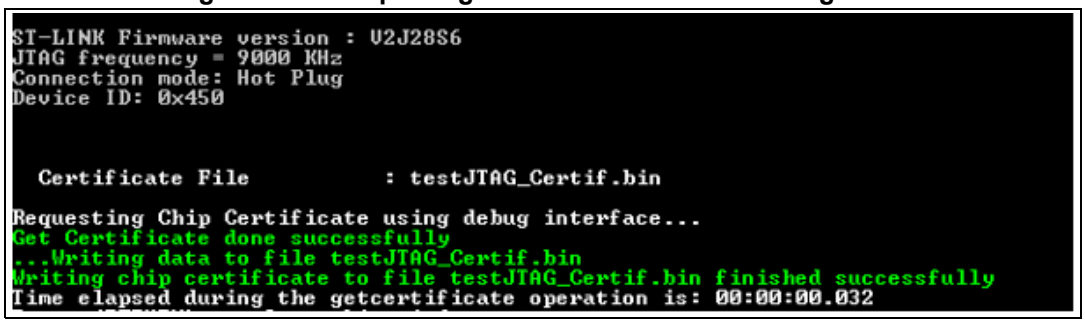
Note: Using a debug connection “HOTPLUG” mode must be used with the connect command.

Example “getcertificate” command using JTAG

```
STM32_Programmer.exe -c port=jtag mode=HOTPLUG -gc
testJTAG_Certif.bin
```

The result of this example is shown in *Figure 51*.

Figure 51. Example of getcertificate command using JTAG



Example “smi” command using SWD

```
-c port=swd mode=HOTPLUG -smi protocol=static
"RefSMI_MDK/FIR_module.smi" "RefSMI_MDK/licenseSMI.bin" -vb 3
-log
```

4.4 Secure programming using bootloader interface (UART/I^{2}C/SPI/USB)

It is also possible to program the SFI/SFIx image using the bootloader interface (UART/I^{2}C/SPI/USB). FDCAN is not supported by STLINK-V3.

The whole process happens in RDP level 0.5. In the case of SFIx programming the code is protected by the OTFDEC encryption.

SFI via the bootloader interface (UART/I^{2}C/SPI/USB) is currently supported for STM32L5 devices. It needs to load an external loader using the **-elbl** command in the SRAM.

For STM32L5 devices, 1 Mbyte of SRAM is available, with 512 Kbytes in the main SRAM. This means that the maximum image size supported is 1 Mbyte, and the maximum area size is 512 Kbytes.

To remedy this, the SFI/SFIx image is split into several parts, so that each part fits into the allowed SRAM size.

An SFI/SFIx is then performed. Once all its SFI/SFIx parts are successfully installed, the global SFI/SFIx image install is successful.

SFI example

```
STM32_Programmer_CLI.exe -c port=usb1 -sfi out.sfix hsm=0
license.bin -rsse RSSe\L5\enc_signed_RSSe_sfi_bl.bin
```

SFIx example

```
STM32_Programmer_CLI.exe -c port=usb1 -elbl
MX25LM51245G_STM32L552E-EVAL-SFIX-BL.stldr -sfi out.sfix
hsm=0 license.bin -rsse RSSe\L5\enc_signed_RSSe_sfi_bl.bin
```

5 Example of SFI programming scenario

5.1 Scenario overview

The actual user application to be installed on the STM32H753XI (or STM32L5) device makes "`printf`" packets appear in serial terminals. The application was encrypted using the STPC.

The OEM provides tools to the CM to get the appropriate license for the concerned SFI application.

5.2 Hardware and software environment

For successful SFI programming, some hardware and software prerequisites apply:

- STM32H743I-EVAL board
- STM32H753XI with bootloader and RSS programmed
- RS-232 cable for SFI programming via UART
- Micro-B USB for debug connection
- PC running on either Windows®, Linux® Ubuntu® or Fedora®, or macOS®
- STM32 Trusted Package Creator v0.2.0 (or greater) package available from *www.st.com*
- STM32CubeProgrammer v0.4.0 (or greater) package available from *www.st.com*

Note: Refer to [4] or [5] for the supported operating systems and architectures.

5.3 Step-by-step execution

5.3.1 Build OEM application

OEM application developers can use any IDE to build their own firmware.

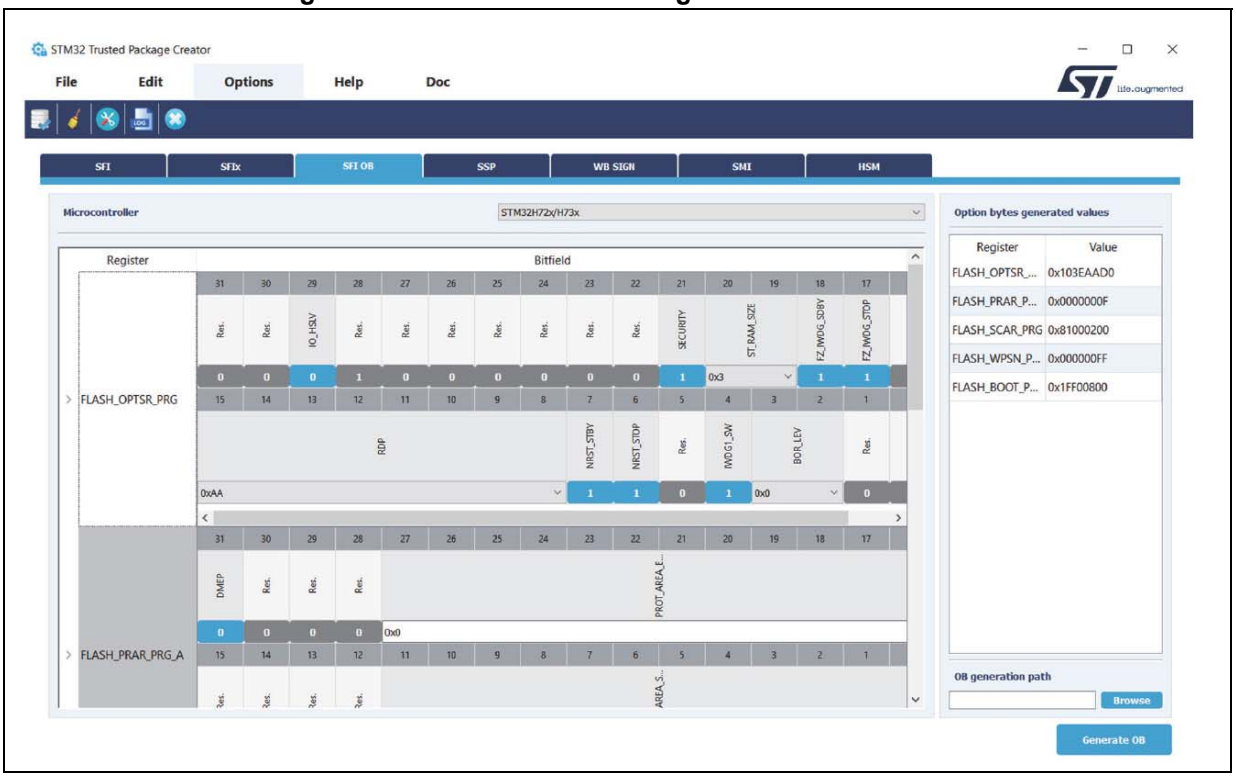
5.3.2 Performing the option byte file generation (GUI mode)

The STM32 Trusted Package Creator tool GUI presents an SFI OB tab to generate an option bytes CSV file with a custom option byte value.

To generate an SFI CSV option bytes file, the user must:

1. Select the concerned product.
2. Fill the option bytes fields with desired values.
3. Select the generation path.
4. Click on the *Generate OB* button.

Figure 52. STM32Trusted Package Creator SFI OB GUI



5.3.3 Perform the SFI generation (GUI mode)

To be encrypted with the STM32 Trusted Package Creator tool, OEM firmware is provided in AXF format in addition to a CSV file to set the option bytes configuration. A 128-bit AES encryption key and a 96-bit nonce are also provided to the tool. They are available in the *"SFI_ImagePreparation"* directory.

An *".sfi"* image is then generated (*out.sfi)*.

Note: STM32CubeProgrammer v2.8.0 and later provide one option byte file example for each product.
It is located in the directory: STM32CubeProgrammer\vx.x.x\bin\SFI_OB_CSV_FILES

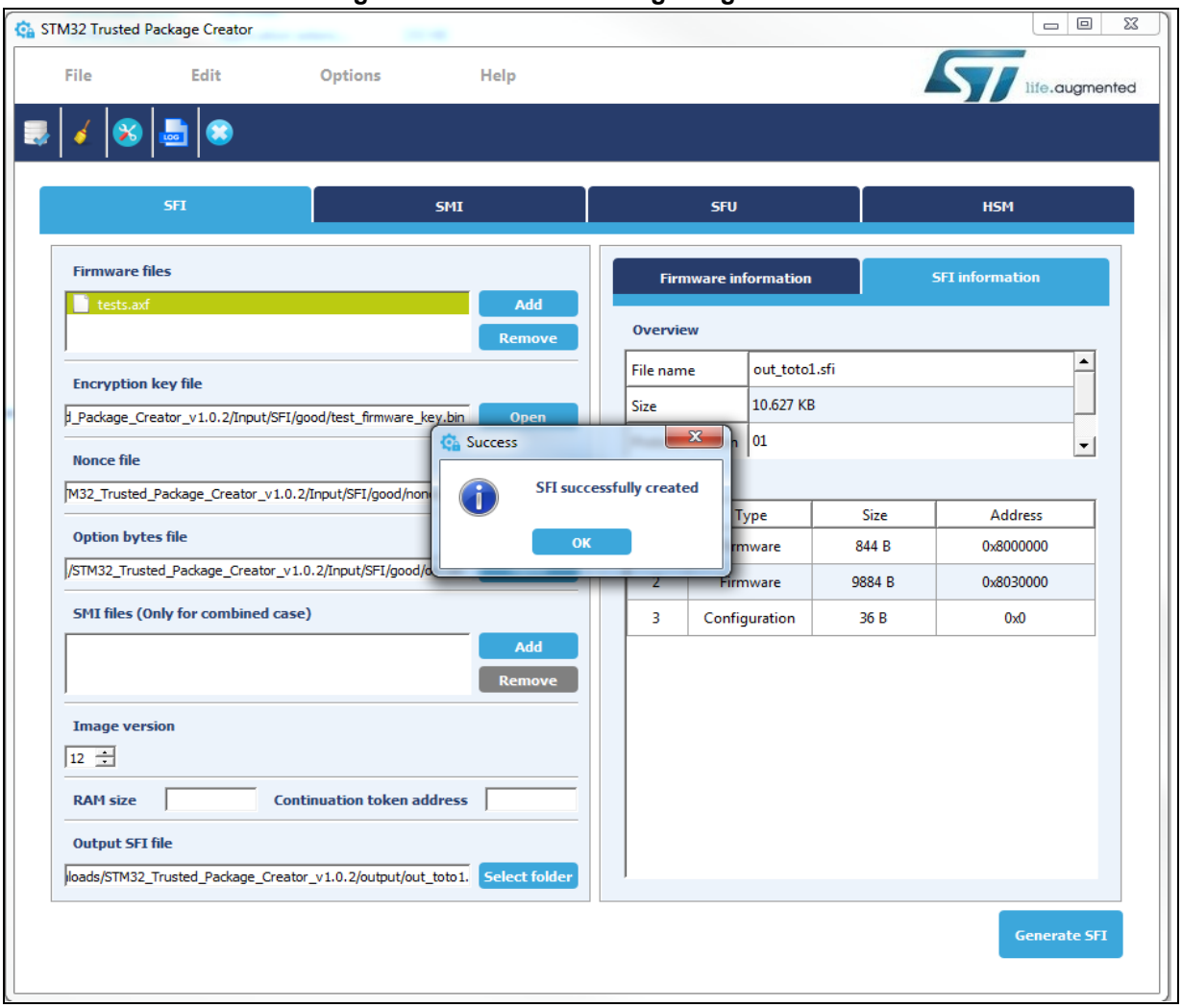
The option bytes are described in the product reference manual.

In the case of customization of a provided example file, care must be taken not to change the number of rows, or their order.

Note: If you want to reopen the Device using the Debug Authentication mechanism, a DA ObKey file must be included in the SFI image, otherwise the device becomes inaccessible.

Figure 53: STPC GUI during SFI generation shows the STPC GUI during the SFI generation.

Figure 53. STPC GUI during SFI generation



5.3.4 Performing HSM programming for license generation using STPC (GUI mode)

The OEM must provide a license generation tool to the programming house to be used for license generation during the SFI install process.

In this example, HSMs are used as license generation tools in the field. See *Section 4.1.2: License mechanism* for HSM use and programming.

Figure 54 shows an example for HSM programming by OEM to be used for SFI install.

The maximum number of licenses delivered by the HSM in this example is 1000.

This example uses HSM version 2, and is also valid for version 1 when the 'version' field is set accordingly. The HSM version can be identified before performing the programming operation by clicking the Refresh button to make the version number appear in the 'version' field.

The STM32 Trusted Package Creator tool provides all personalization package files ready to be used on SFI/SFIx and SSP flows. To get all the supported packages, go to the **PersoPackages** directory residing in the tool's install path.

Each file name starts with a number, which is the product ID of the device. Select the correct one.

To obtain the appropriate personalization data, you first need to obtain the product ID:

- Use the STM32CubeProgrammer tool to launch a Get Certificate command to generate a certificate file containing some chip security information, bearing in mind that this command is only recognized only for devices that support the security feature:

  ```
  STM32_Programmer_CLI -c port=swd -gc "certificate.bin"
  ```

  A file named "certificate.bin" is created in the same path of the STM32CubeProgrammer executable file.
- Open the certificate file with a text editor tool, then read the eight characters from the header, which represents the product ID.

  For example:
  - When using the STM32H7 device, you find: 45002001.
  - When using the STM32L4 device, you find: 46201002.

Once you have the product ID, you can differentiate the personalization package to be used on the HSM provisioning step respecting the following naming convention:

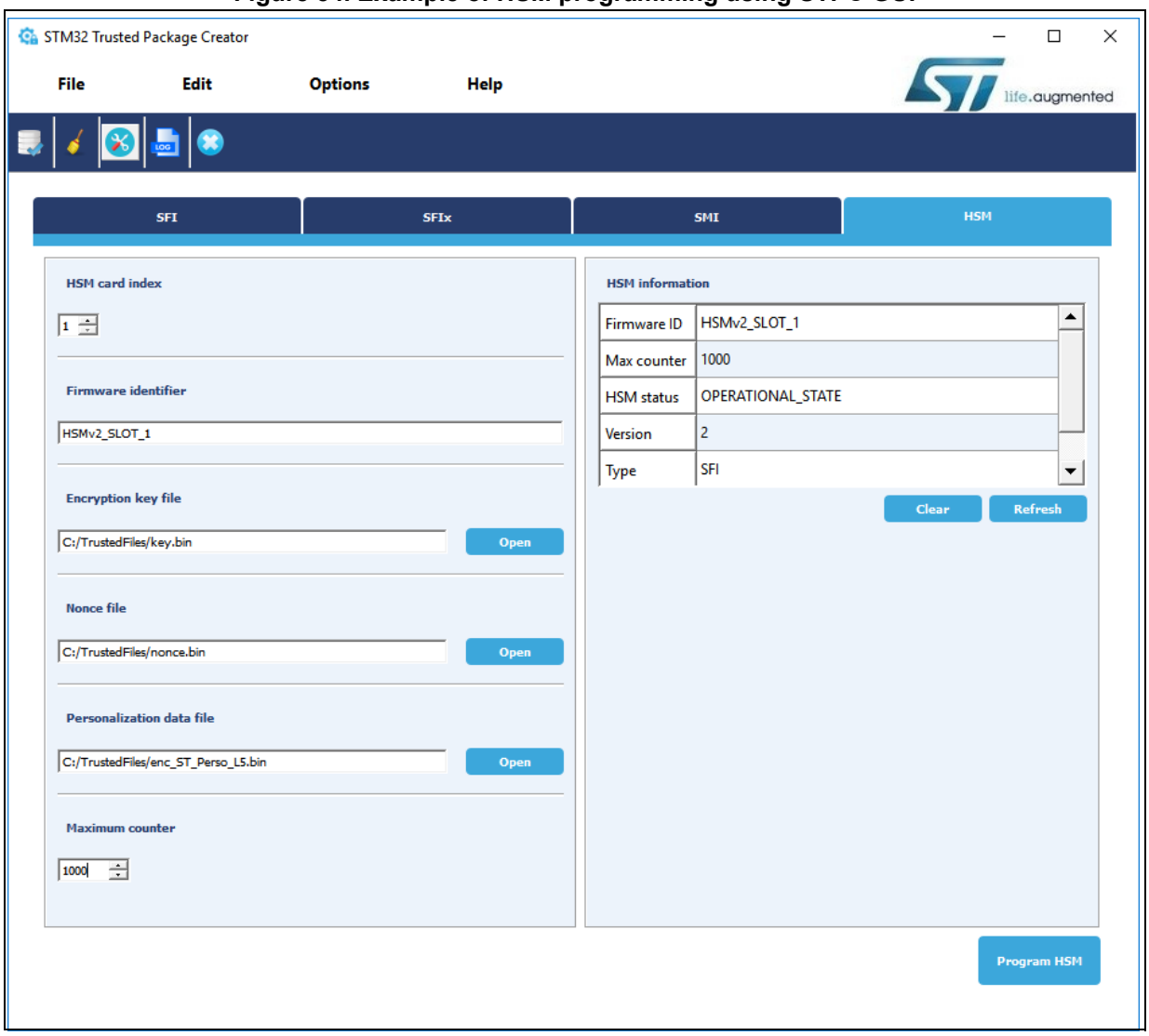
ProdcutID_FlowType_LicenseVersion_SecurityVersion.enc.bin

For example: 47201003_SFI._01000000_00000000.enc.bin

Based on this name we can retrieve the associated information:

- Product ID = 47201003 for STM32L5 devices (0x472 as device ID).
- Type = SFI
- License version = 01 (Large endian)
- Security version = 0

Figure 54. Example of HSM programming using STPC GUI



Note: When using HSM version1, the "Personalization data file" field is ignored when programming starts. It is only used with HSM version 2.

When the card is successfully programmed, a popup window message "HSM successfully programmed" appears, and the HSM is locked. Otherwise, an error message is displayed.

5.3.5 Performing HSM programming for license generation using STPC (CLI mode)

STM32 Trusted Package Creator provides CLI commands to program HSM cards. To configure the HSM before programming, the user must provide the mandatory inputs by using the specific options.

Example of HSM version 1 provisioning

```
STM32TrustedPackageCreator_CLI -hsm -i 1 -k "C:\TrustedFiles\key.bin" -n
"C:\TrustedFiles\nonce.bin" -id HSMv1_SLOT_1-mc2000
```

- -i: select the slot ID
- -k: set the encryption key file path
- -n: set the nonce file path
- -id: set the firmware identifier
- -mc: set the maximum number of licenses.

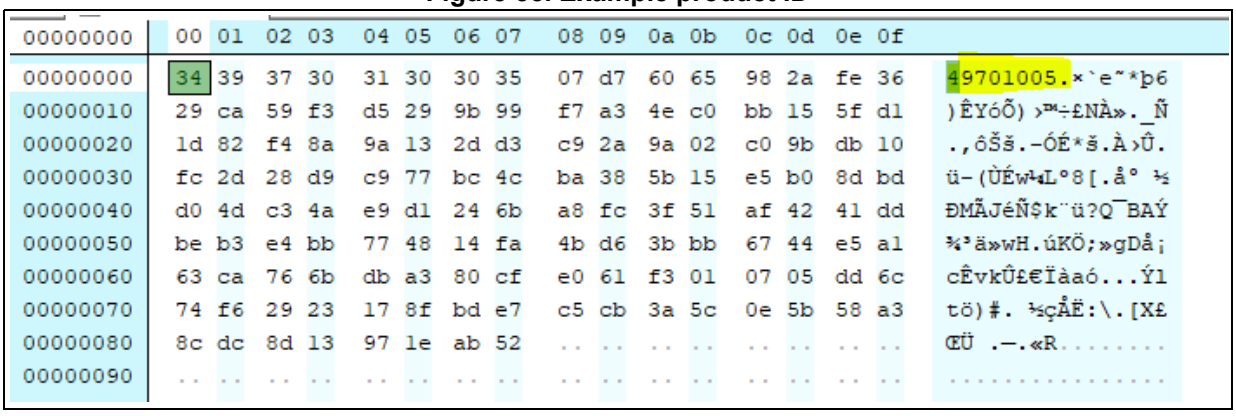
HSMv2 allows users to personalize their own HSM to achieve, for example, compatibility with the desired STM32 device. This solution covers the limitations of HSMv1 (static behavior), so it is possible to support new devices that are not available on HSMv1.

To perform this operation the user first needs to know the product ID of the device. This information is provided in the STM32 device certificate, which can be obtained with the following command:

```
STM32_Programmer.exe -c port=COM1 -gc "C:\SFI\Certificate.bin"
```

After getting the binary file of the device certificate, it is necessary to open this file using a HEX editor application. Once these steps are done the user can read the product ID.

Figure 55. Example product ID



The product ID of the STM32WL used is: 49701005

In the second step, the users provision their own HSMv2 by programming it using STPC. The personalization data file .bin can be found under *"..\bin\PersoPackages"*.

Example of HSM version 2 provisioning

A new option [-pd] must be inserted to include the personalization data:

```
STM32TrustedPackageCreator_CLI -hsm -i 1 -k "C:\TrustedFiles\key.bin" –n
"C:\TrustedFiles\nonce.bin" -id HSMv2_SLOT_2 -mc 2000 -pd
"C:\TrustedFiles\enc_ST_Perso_L5.bin"
```

- -pd: Set the personalization data file path.

To obtain the appropriate personalization data file and for further information, refer to *Section 5.3.5: Performing HSM programming for license generation using STPC (CLI mode)*.

Note: A green message display indicates that the programming operation succeeded, otherwise a red error message is displayed.

If the HSM is already programmed and there is a new attempt to reprogram it, an error message being displayed to indicate that the operation failed, and the HSM is locked.

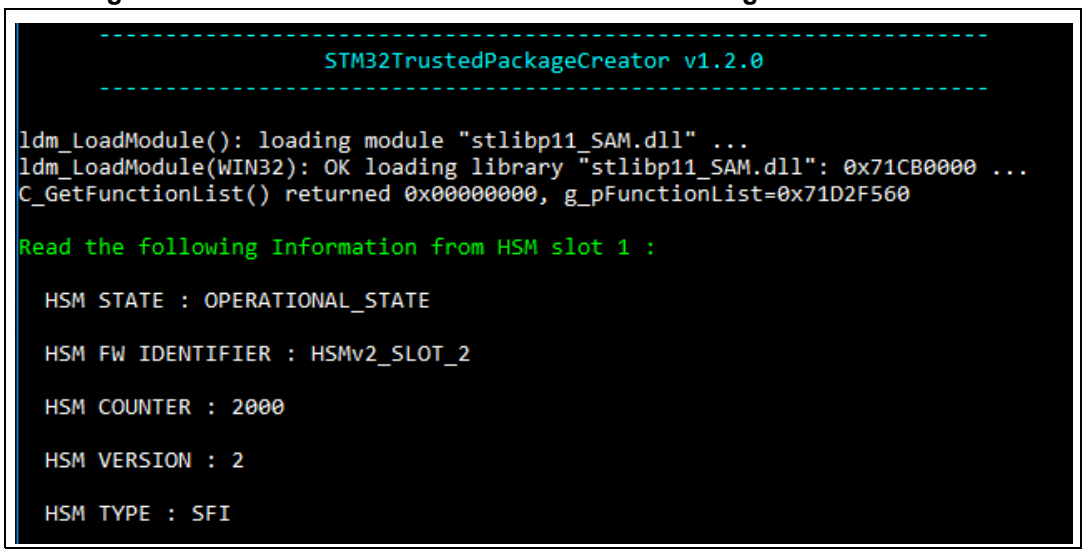
HSM v1 supports a list of a limited number of STM32 devices such as STM32L4, STM32H7, STM32L5, and STM32WL.

Example of HSM get information

If the HSM is already programmed or is virgin yet and whatever the version, a get information command can be used to show state details of the current HSM by using the command below:

```
STM32TrustedPackageCreator_CLI -hsm –i 1 –info
```

Figure 56. HSM information in STM32 Trusted Package Creator CLI mode



5.3.6 Programming input conditions

Before performing an SFI install make sure that:

- Flash memory is erased.
- No PCROPed zone is active, otherwise destroy it.
- The chip must support security (a security bit must be present in the option bytes).
- When using a UART interface, the user security bit in option bytes must be enabled before launching the SFI command. For this, the following STM32CubeProgrammer command is launched:
  - Launch the following command (UART bootloader used => Boot0 pin set to VDD):
    `-c port=COM9 -ob SECURITY=1`
- When using a UART interface the Boot0 pin must be set to VSS:
  - After enabling security (boot0 pin set to VDD), a power off/power on is needed when switching the Boot0 pin from VDD to VSS: power off, switch pin then power on.
- When performing an SFI install using the UART bootloader then, no debug interface must be connected to any USB host. If a debug interface is still connected, disconnect it then perform a power off/power on before launching the SFI install to avoid any debug intrusion problem.
- Boot0 pin set to VDD When using a debug interface.
- A valid license generated for the currently used chip must be at your disposal, or a license generation tool to generate the license during SFI install (HSM).
- For STM32L5 products, TZEN must be set at 0 (TZEN=0).

5.3.7 Performing the SFI install using STM32CubeProgrammer

In this section, the STM32CubeProgrammer tool is used in CLI mode (the only mode so-far available for secure programming) to program the SFI image *“out.sfi”* already created in the previous section.

STM32CubeProgrammer supports communication with STMicroelectronics HSMs (Hardware secure modules based on smartcard) to generate a license for the connected STM32 device during SFI install.

Using JTAG/SWD

After making sure that all the input conditions are respected, open a cmd terminal and go to *<STM32CubeProgrammer_package_path>/bin*, then launch the following STM32CubeProgrammer command:

```
STM32_Programmer_CLI.exe -c port=swd mode=HOTPLUG -sfi protocol=static
"<local_path>/out.sfi" hsm=1 slot=<slot_id>
```

Note: In the case of an STM32L5 device the SFI install uses the RSSe and its binary file is located in the STM32CubeProgrammer bin/RSSe folder.

The STM32CubeProgrammer command is as follows:

```
STM32_Programmer_CLI.exe -c port=swd mode=HOTPLUG -sfi protocol=static
"<local_path>/out.sfi" hsm=1 slot=<slot_id> -rsse <RSSe_path>
```

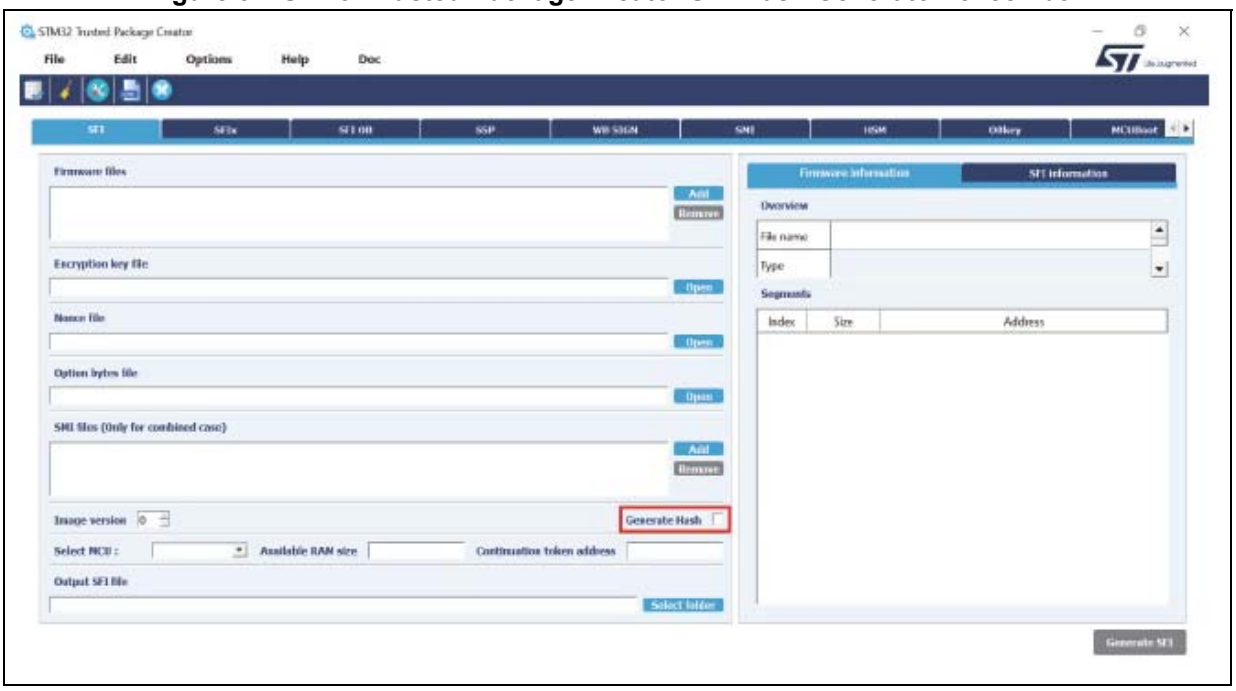
5.3.8 SFI with Integrity check (for STM32H73)

For the STM32H73, an integrity check mechanism is implemented. STM32 Trusted Package Creator calculates the input firmware hash and integrates it into the SFI firmware. The STM32H73 MCU is able to use this hash input to check the firmware integrity.

Enabling this mechanism is mandatory for STM32H73, and it can be done through GUI and CLI.

For the GUI part, hash is enabled by checking Generate hash.

Figure 57. STM32Trusted Package Creator SFI 'hash Generator 'check box



For the CLI part SFI command line must integrate the -hash option.

Usage example:

```
STM32TrustedPackageCreator_CLI.exe -sfi -fir OEM_Dev.bin
0x08000000 -k aeskey.bin -n nonce.bin -ob ob.csv -v 0 --
ramsize 0x1E000 --token 0x080FF000 -hash 1 -o outCLI.sfi
```

Figure 58 shows the SFI install via SWD execution and the HSM as license generation tool in the field.

Figure 58. SFI installation success using SWD connection (1)

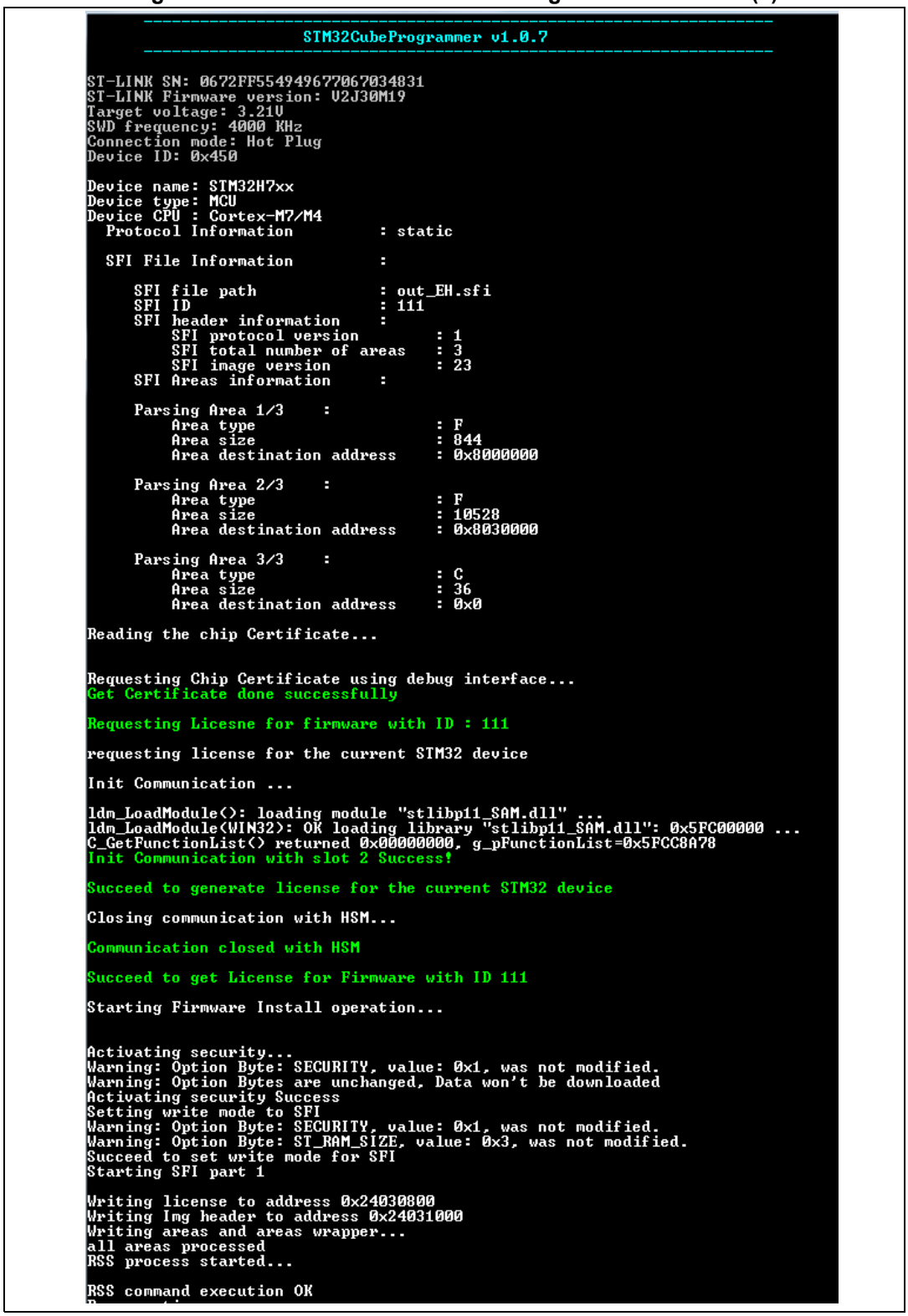
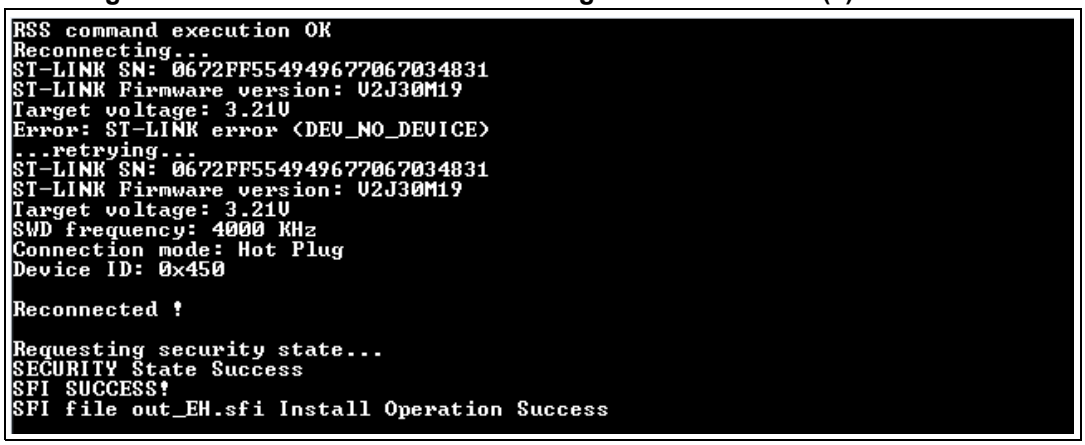


Figure 59. SFI installation success using SWD connection (2)



6 Example of SFI programming scenario for STM32WL

6.1 Scenario overview

The user application is developed by the OEM and encrypted by STPC. The OEM provides the following elements to the programming house:

- The encrypted firmware of STM32WL
- HSMv1 or provisioned HSMv2
- STM32CubeProgrammer

With these inputs, the untrusted manufacturer is able to securely program the encrypted firmware.

6.2 Hardware and software environment

For successful SFI programming, the following hardware and software prerequisites apply:

- STM32WL5x board with bootloader and RSS programmed
- RS-232 cable for SFI programming via UART
- Micro-B USB for debug connection
- PC running on either Windows®, Linux® Ubuntu® or Fedora®, or macOS®
- STM32 Trusted Package Creator v1.7.0 (or greater) package available from *www.st.com*
- STM32CubeProgrammer v2.16.0 (or greater) package available from *www.st.com*
- HSMv1 or HSMv2

Note: Refer to [4] or [5] for the supported operating systems and architectures.

6.3 Step-by-step execution

6.3.1 Build OEM application

OEM application developers can use any IDE to build their own firmware.

6.3.2 Perform the SFI generation (GUI mode)

The first step to install the secure firmware on STM32 devices is the encryption of the user OEM firmware (already provided in AXF format) using the STM32 Trusted Package Creator tool.

This is done by adding the following files in the STPC tool:

- OEM firmware
- A .csv file containing option bytes configuration
- A 128-bit AES encryption key
- A 96-bit nonce

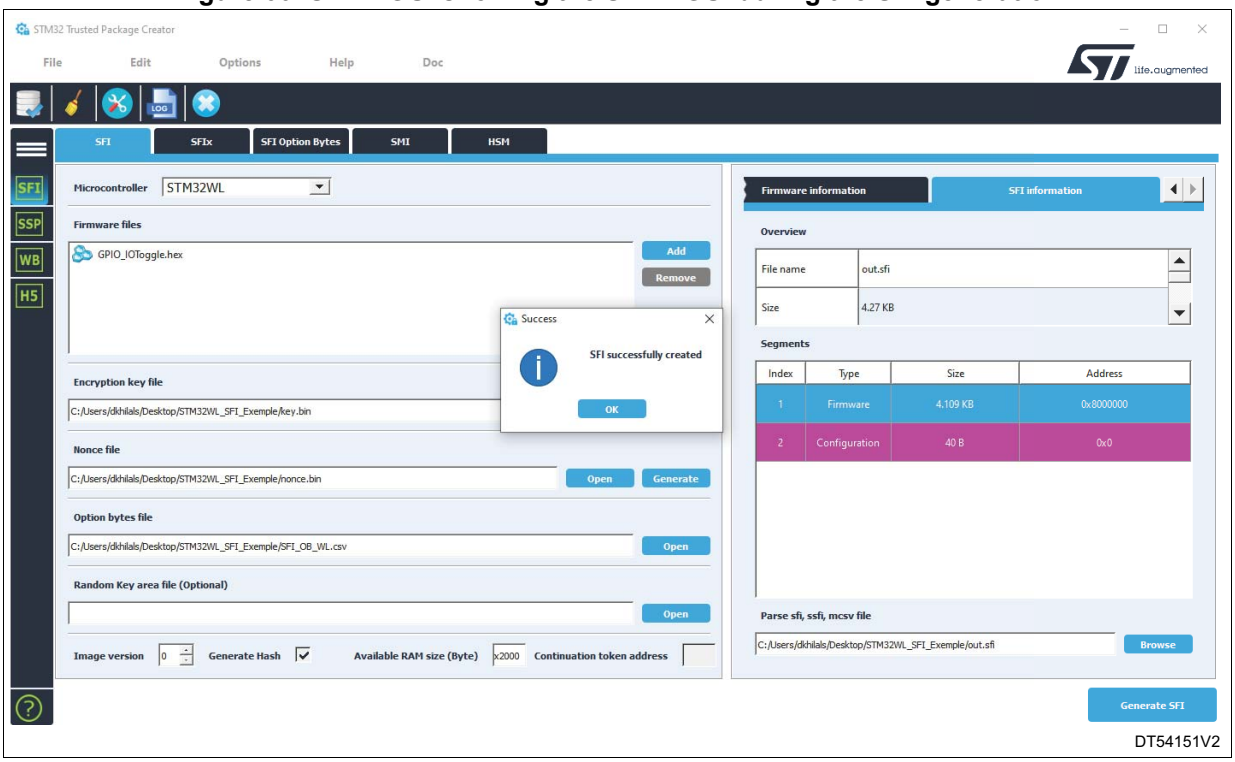
Note: STM32CubeProgrammer v2.8.0 and later provide one option byte file example for each product.
It is located in the directory: STM32CubeProgrammer\vx.x.x\bin\SFI_OB_CSV_FILES

The option bytes are described in the product reference manual.

In the case of customization of a provided example file, care must be taken not to change the number of rows, or their order.

A programmed HSM card must be inserted in the PC, and an *"out.sfi"* image is then generated.

Figure 60. STPC GUI showing the STPC GUI during the SFI generation



Note: To perform HSM programming for license generation using STPC (GUI mode and CLI mode) refer to the following sections:

Section 5.3.4: Performing HSM programming for license generation using STPC (GUI mode)

Section 5.3.5: Performing HSM programming for license generation using STPC (CLI mode)

6.3.3 Programming input conditions

Before performing an SFI install on STM32WL devices make sure that:

- Flash memory is erased
- No PCROPed zone is active, otherwise remove it
- The chip supports security (a security bit must be present in the option bytes)
- The security must be disabled, if activated
- The option bytes of the device are set to default values. This step is done by the two commands given below.

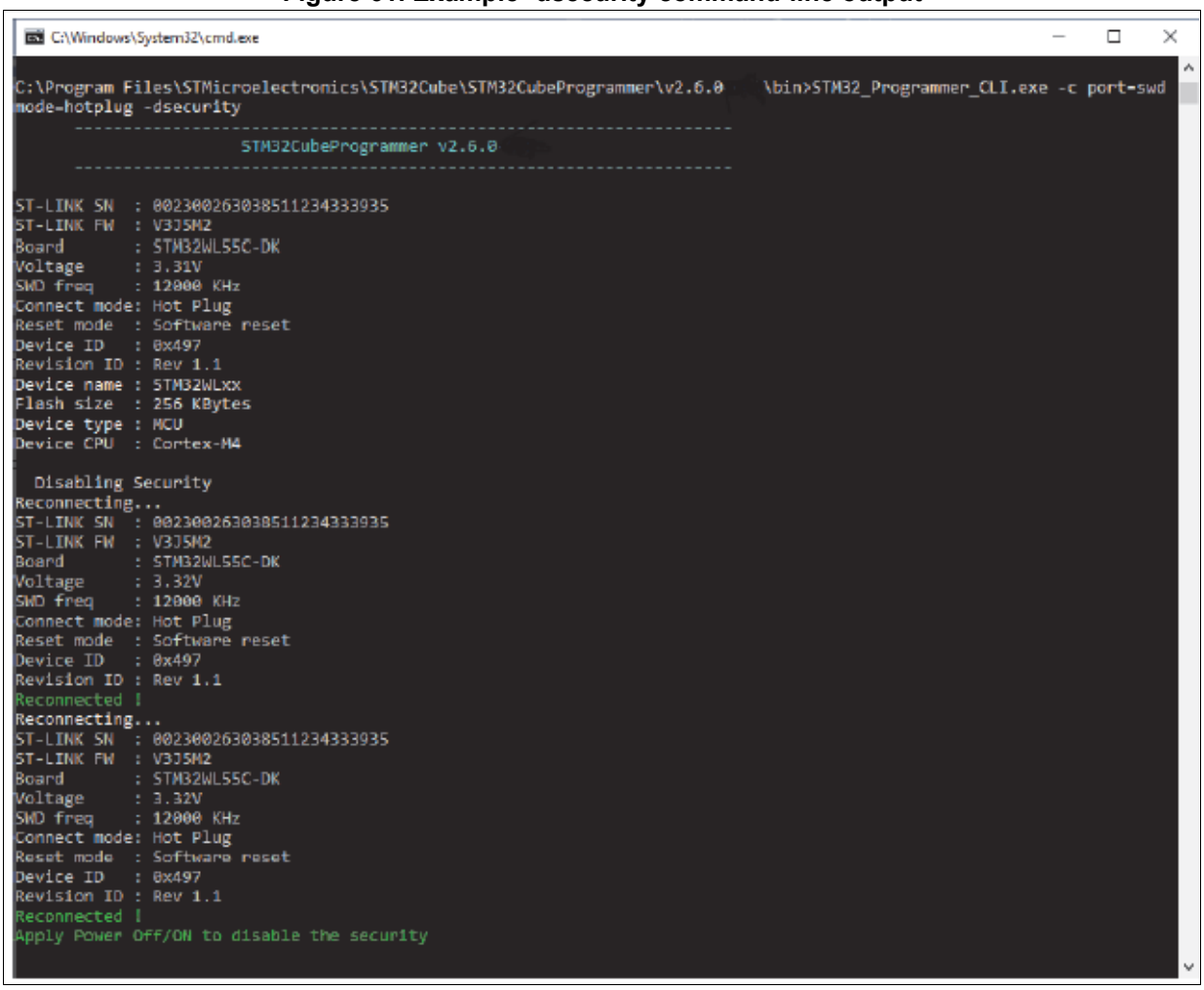
-desurity: this option allows the user to disable security. After executing this command, a power OFF / power ON must be done.

Example:

```
STM32_Programmer_CLI.exe -c port=swd mode=hotplug -dsecurity
```

Figure 61 hows the resulting output on the command line.

Figure 61. Example -dsecurity command-line output



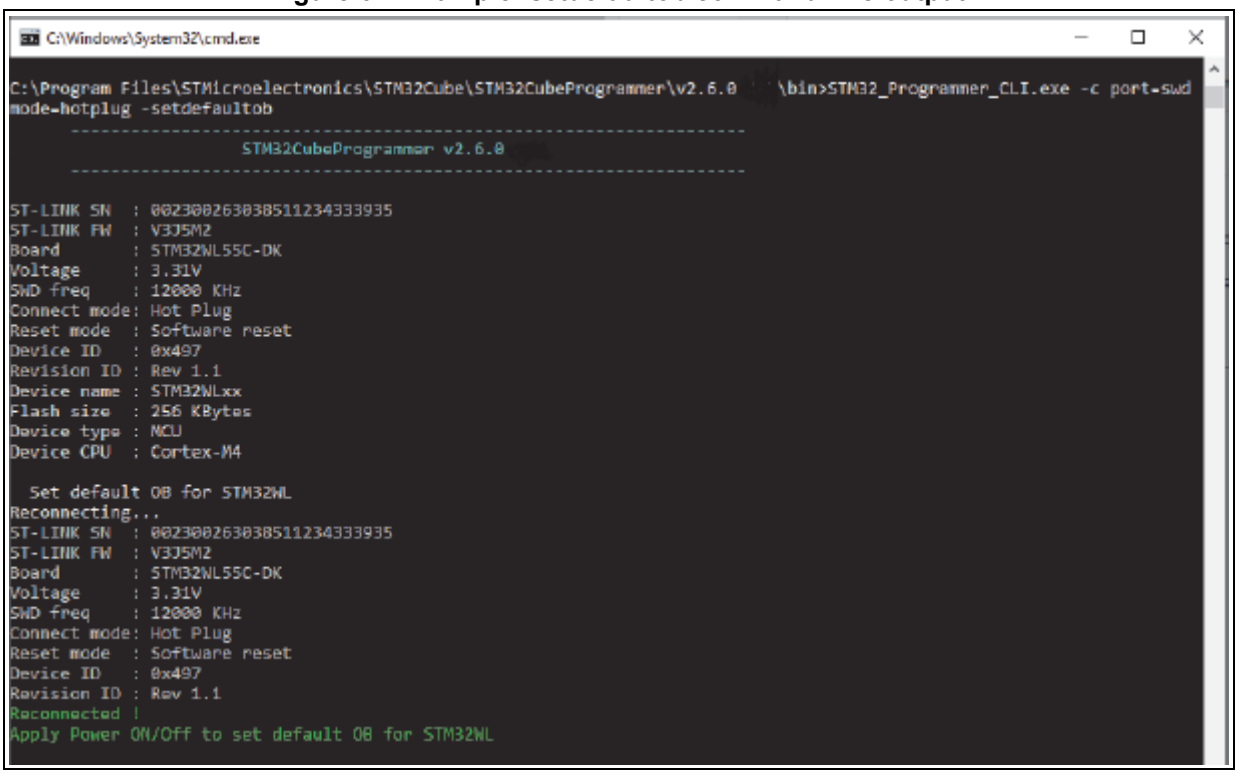
-setdefaultob: this command allows the user to configure option bytes to their default values. After executing this command, a power OFF/power ON must be done.

Example:

```
STM32_Programmer_CLI.exe -c port=swd mode=hotplug -setdefaultob
```

Figure 62 shows the resulting output on the command line.

Figure 62. Example -setdefaultob command-line output



6.3.4 Perform the SFI install using STM32CubeProgrammer

In this section, the STM32CubeProgrammer tool is used in CLI mode (the only mode so-far available for secure programming) to program the SFI image “out.sfi” already created in the previous section.

STM32CubeProgrammer supports communication with STMicroelectronics HSMs (Hardware secure modules based on smartcard) to generate a license for the connected STM32 device during SFI install.

Using JTAG/SWD

After making sure that all the input conditions are respected, open a cmd terminal and go to *<STM32CubeProgrammer_package_path>/bin*, then launch the following STM32CubeProgrammer command:

```
STM32_Programmer_CLI.exe -c port=swd mode=HOTPLUG -sfi
"<local_path>/out.sfi" hsm=1 slot=<slot_id> -rsse "< RSSe_path >"
```

Note: The RSSe and its binary file are located in the STM32CubeProgrammer bin/RSSe/WL folder.

Figure 63 shows the SFI install via SWD execution.

Figure 63. SFI installation via SWD execution command-line output

```
C:\Program Files\STMicroelectronics\STM32Cube\STM32CubeProgrammerv2.14.0-RO\bin>STM32_Programmer_CLI.exe -c port=swd mode=hotplug -sfi "C:\Users\dkhilals\Desktop\STM32WL_SFI_Exemple\out.sfi" hsm=0 "C:\Users\
dkhilals\Desktop\STM32WL_SFI_Exemple\license_wl.bin" -rsse "C:\Program Files\STMicroelectronics\STM32Cube\STM32CubeProgrammerv2 14.0-RO\bin\RSSe\WL\enc_signed_RSSe_sfi.bin"
      -------------------------------------------------------------------
                        STM32CubeProgrammer v2.14.0
      -------------------------------------------------------------------

ST-LINK SN  : 002A000B5553500820393256
ST-LINK FW  : V3J10M3
Board       : NUCLEO-WL55JC
Voltage     : 3.27V
SWD freq    : 30000 KHz
Connect mode: Hot Plug
Reset mode  : Software reset
Device ID   : 0x497
Revision ID : Rev Y
Device name : STM32WLxx
Flash size  : 256 KBytes
Device type : MCU
Device CPU  : Cortex-M4
BL Version  : 0xC3

  Protocol Information         : static

  SFI File Information         :

     SFI file path             : C:\Users\dkhilals\Desktop\STM32WL_SFI_Exemple\out.sfi
     SFI license file path     : C:\Users\dkhilals\Desktop\STM32WL_SFI_Exemple\license_wl.bin
     SFI header information    :
         SFI protocol version        : 2
         SFI total number of areas   : 2
         SFI image version           : 0
     SFI Areas information     :

     Parsing Area 1/2    :
         Area type                   : F
         Area size                   : 4208
         Area destination address    : 0x8000000

     Parsing Area 2/2    :
         Area type                   : C
         Area size                   : 40
         Area destination address    : 0x0

Installing RSSe
[                                                  ]


Memory Programming ...
Opening and parsing file: enc_signed_RSSe_sfi.bin
  File          : enc_signed_RSSe_sfi.bin
  Size          : 23.23 KB
  Address       : 0x20002020


Erasing memory corresponding to segment 0:
Download in Progress:
[                                                  ] 100%

File download complete
Time elapsed during download operation: 00:00:00.073
Boot on RSS...
Reconnecting...
ST-LINK SN  : 002A000B5553500820393256
ST-LINK FW  : V3J10M3
Board       : NUCLEO-WL55JC
Voltage     : 3.27V
SWD freq    : 30000 KHz
Connect mode: Hot Plug
Reset mode  : Software reset
Device ID   : 0x497
Revision ID : Rev Y
Reconnected !
RSSE SFI INITIALISED


RSS version = 2.3.0


RSSe version = 5.0.0

Starting SFI

Processing license...
RSSE SFI LICENSE OK
Processing Image Header
RSSE SFI IMAGE HEADER OK
Processing Area 1...
RSSE SFI AREA OK
Area Address = 0x8000000
Area Type    = F
Processing Area 2...
Can not verify last area
Area Address = 0x0
Area Type    = C
SFI Process Finished!
SFI file C:\Users\dkhilals\Desktop\STM32WL_SFI_Exemple\out.sfi Install Operation Success

Time elapsed during SFI install operation: 00:00:07.728
```

DT54154V2

7 Example of SFI programming scenario for STM32U5

7.1 Scenario overview

The actual user application to be installed on the STM32U5 device makes "`printf`" packets appear in serial terminals. The application was encrypted using the STPC.

The OEM provides tools to the CM to get the appropriate license for the concerned SFI application.

7.2 Hardware and software environment

For successful SFI programming, some hardware and software prerequisites apply:

- STM32U5 board with bootloader and RSS programmed
- RS-232 cable for SFI programming via UART
- Micro-B USB for debug connection
- PC running on either Windows®, Linux® Ubuntu® or Fedora®, or macOS®
- STM32 Trusted Package Creator v1.2.0 (or greater) package available from *www.st.com*
- STM32CubeProgrammer v2.8.0 (or greater) package available from *www.st.com*
- HSMv2

Note: Refer to [4] or [5] for the supported operating systems and architectures.

7.3 Step-by-step execution

7.3.1 Build OEM application

OEM application developers can use any IDE to build their own firmware.

7.3.2 Perform the SFI generation (GUI mode)

The first step to install the secure firmware on STM32 devices is the encryption of the user OEM firmware (already provided in AXF format) using the STM32 Trusted Package Creator tool. This step is done by adding the following files in the STPC tool:

- An OEM firmware
- A .csv file containing option bytes configuration
- A 128-bit AES encryption key
- A 96-bit nonce

Note: STM32CubeProgrammer v2.8.0 and later provide one option byte file example for each product.
It is located in the directory: STM32CubeProgrammer\vx.x.x\bin\SFI_OB_CSV_FILES

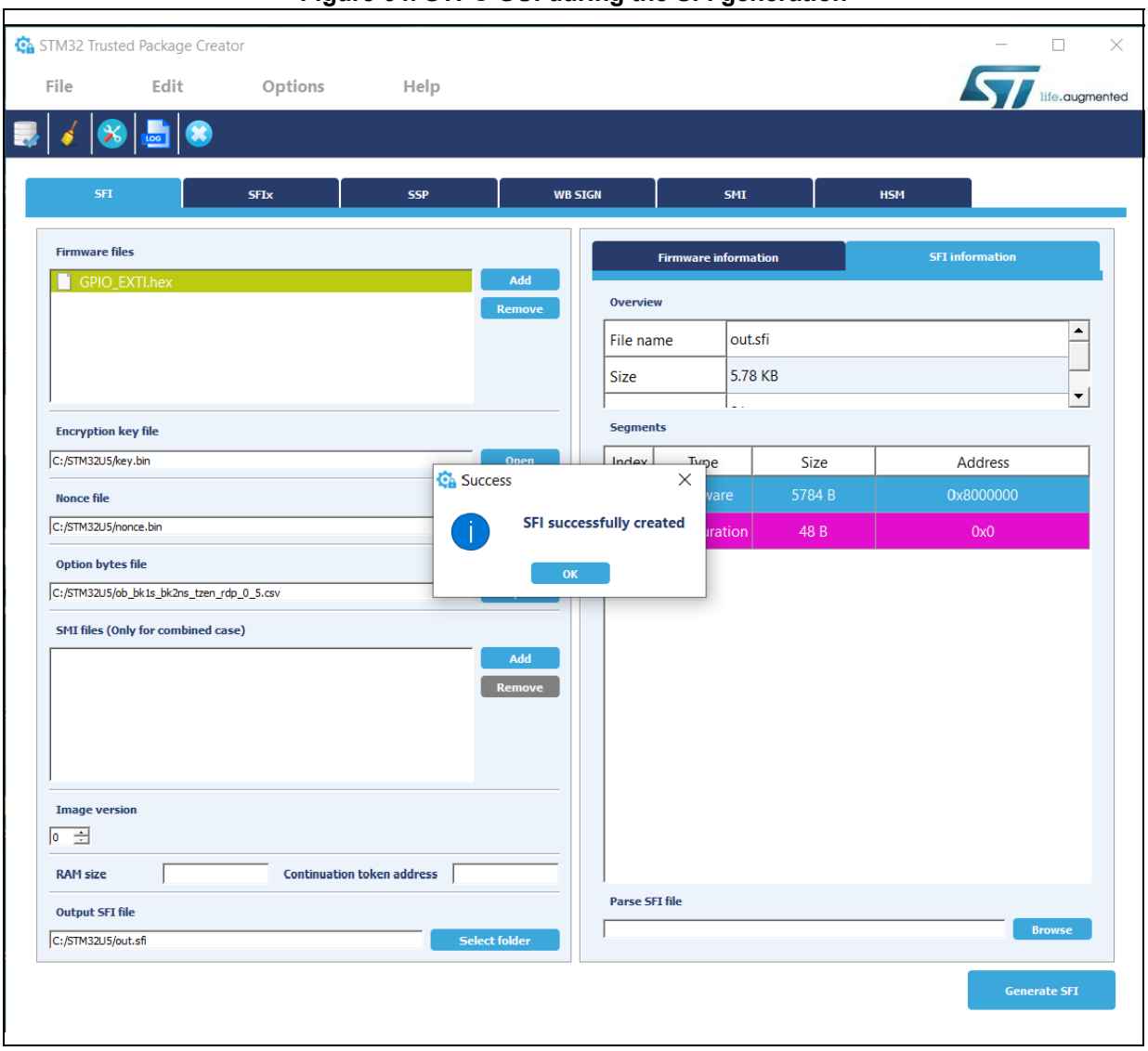
The option bytes are described in the product reference manual.

In the case of customization of a provided example file, care must be taken not to change the number of rows, or their order.

In addition, a programmed HSM card must be inserted in the PC. An "*out.sfi*" image is then generated.

Figure 64 shows the STPC GUI during SFI generation.

Figure 64. STPC GUI during the SFI generation



Note: To perform HSM programming for license generation using STPC (GUI and CLI modes), refer to Section 5.3.4: Performing HSM programming for license generation using STPC (GUI mode) and Section 5.3.5: Performing HSM programming for license generation using STPC (CLI mode).

7.3.3 Programming input conditions

Before performing an SFI install on STM32U5 devices, make sure that:

- The flash memory is erased.
- No WRP zone is active, otherwise destroy it.
- The chip supports security (a security bit must be present in the option bytes).
- If the security is activated, disable it.

7.3.4 Perform the SFI install using STM32CubeProgrammer

In this section, the STM32CubeProgrammer tool is used in CLI mode (the only mode so far available for secure programming) to program the SFI image "*out.sfi*" already created in the previous section.

STM32CubeProgrammer supports communication with STMicroelectronics HSMs (hardware secure modules based on smartcards) to generate a license for the connected STM32 device during the SFI install process.

Using JTAG/SWD

First make sure that all the input conditions are respected, then open a cmd terminal, go to *<STM32CubeProgrammer_package_path>/bin* and launch the following STM32CubeProgrammer command:

```
STM32_Programmer_CLI.exe -c port=swd mode=HOTPLUG -sfi
"<local_path>/out.sfi" hsm=1 slot=<slot_id> -rsse "< RSSe_path >"
```

Note: The RSSe and the corresponding binary file are located in the STM32CubeProgrammer bin/RSSe/U5 *folder.*

Figure 65 and *Figure 66* show the STM32CubeProgrammer command used for the SFI install process via SWD execution.

Figure 65. SFI installation via SWD execution (1)

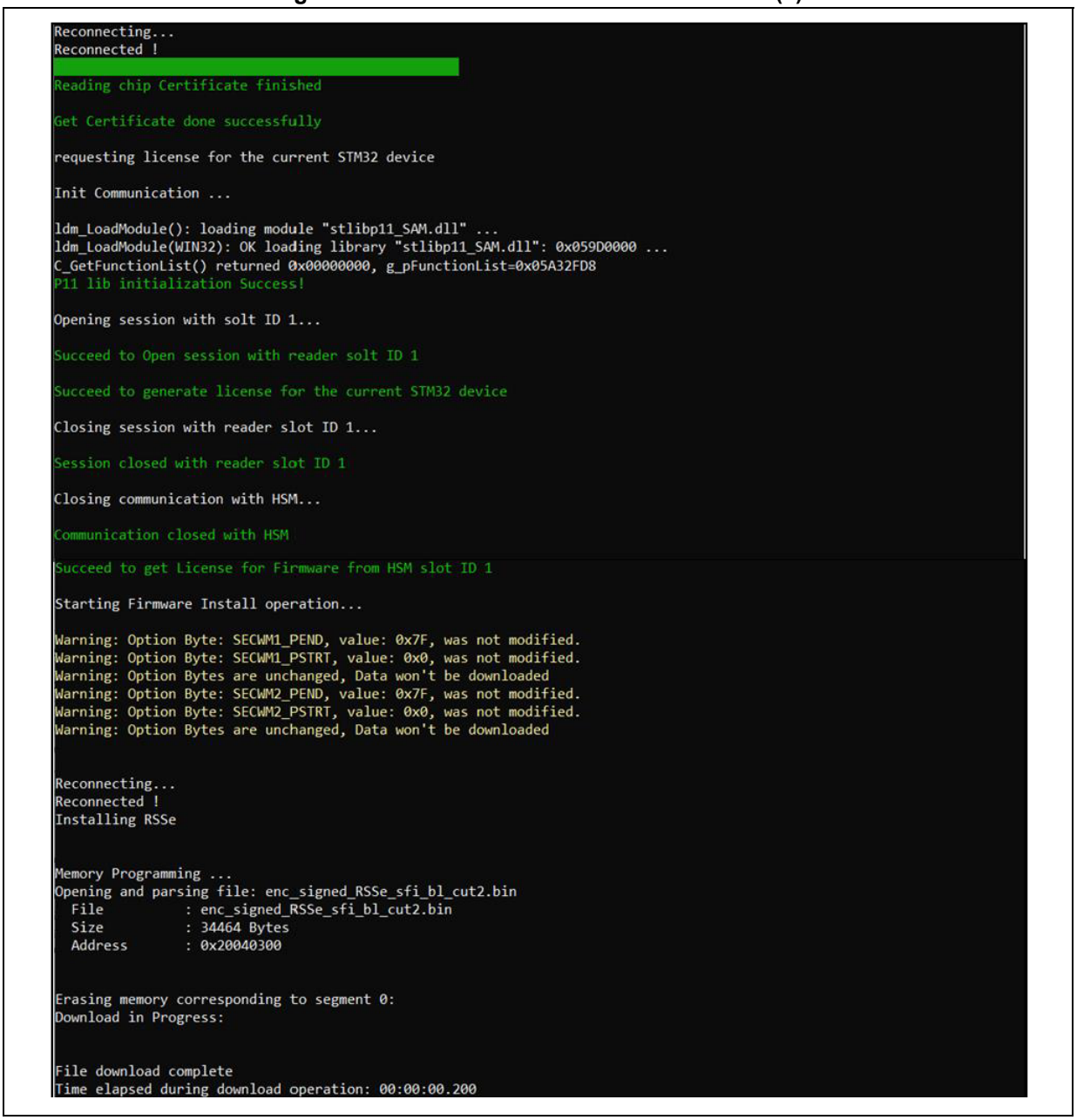
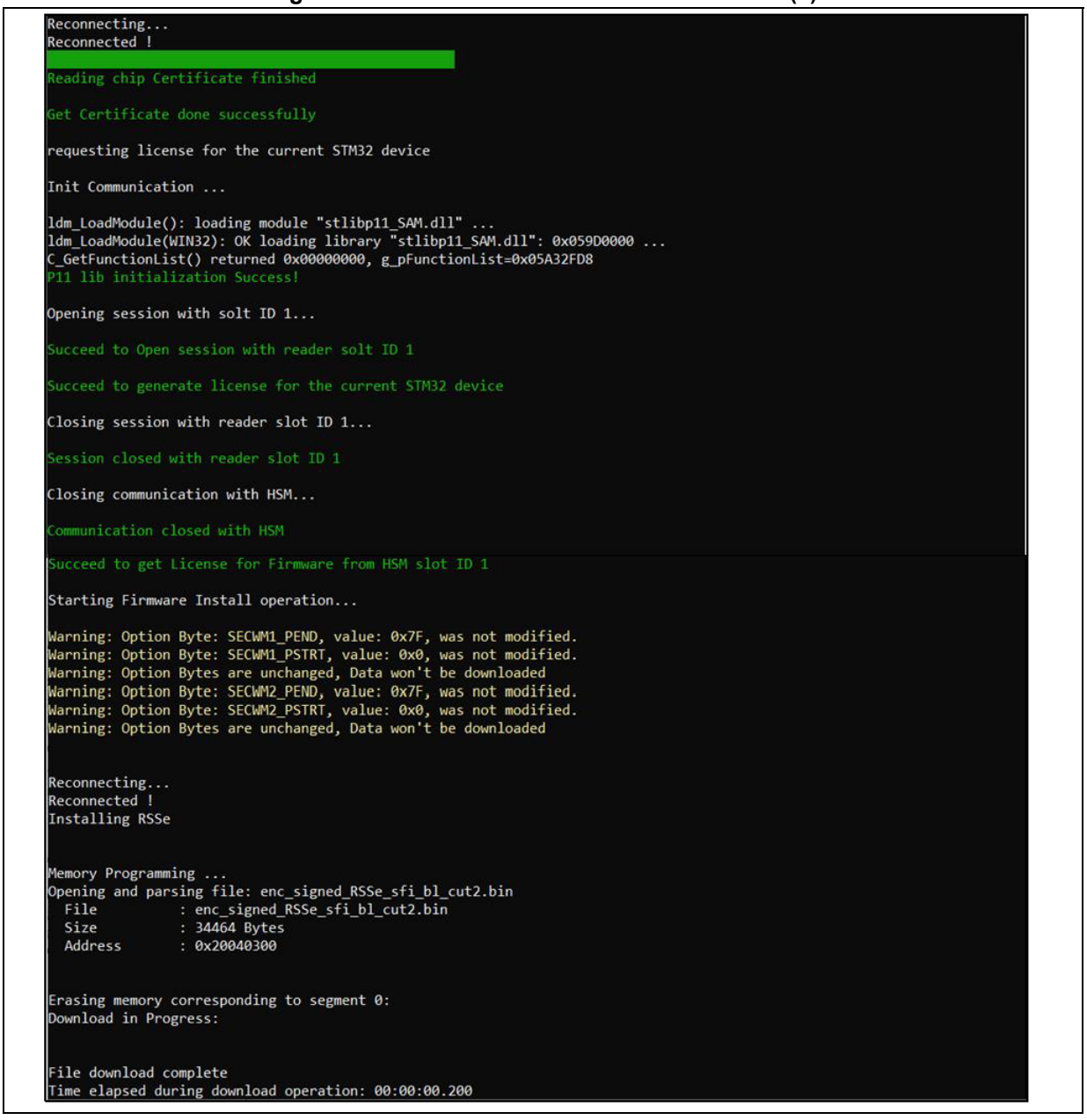


Figure 66. SFI installation via SWD execution - (2)



8 Example of SFI programming scenario for STM32WBA5

8.1 Scenario overview

The actual user application to be installed on the STM32WBA5 device. The application was encrypted using the STPC. The OEM provides tools to the CM to get the appropriate license for the concerned SFI application

8.2 Hardware and software environment

For successful SFI programming, some hardware and software prerequisites apply:

- STM32WBA5 board with bootloader and RSS programmed
- RS-232 cable for SFI programming via UART
- Micro-B USB for debug connection
- PC running on either Windows®, Linux® Ubuntu® or Fedora®, or macOS®
- STM32 Trusted Package Creator v1.7.0 (or greater) package available from *www.st.com*
- STM32CubeProgrammer v2.16.0 (or greater) package available from *www.st.com*
- HSMv2

Note: Refer to [4] or [5] for the supported operating systems and architectures.

8.3 Step-by-step execution

8.3.1 Build OEM application

OEM application developers can use any IDE to build their own firmware.

8.3.2 Perform the SFI generation (GUI mode)

The first step to install the secure firmware on STM32 devices is the encryption of the user OEM firmware (already provided in AXF format) using the STM32 Trusted Package Creator tool. This step is done by adding the following files in the STPC tool:

- An OEM firmware
- A .csv file containing option bytes configuration
- A128-bit AES encryption key
- A 96-bit nonce

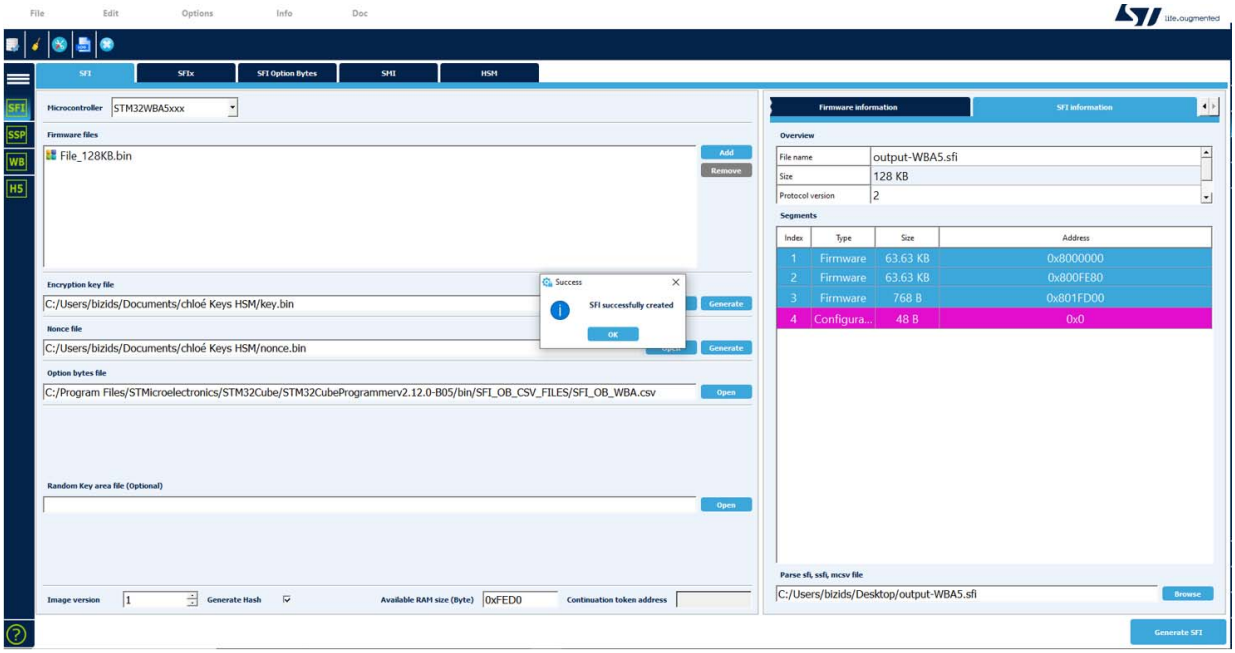
Note: STM32CubeProgrammer v2.8.0 and later provide one option byte file example for each product. It is located in the directory: STM32CubeProgrammer\vx.x.x\bin\SFI_OB_CSV_FILES

The option bytes are described in the product reference manual. In the case of customization of a provided example file, care must be taken not to change the number of rows, or their order.

In addition, a programmed HSM card must be inserted in the PC. An “output-WBA5.sfi” image is then generated.

Figure 67 shows the STPC GUI during SFI generation.

Figure 67. STPC GUI during the SFI generation



Note: To perform HSM programming for license generation using STPC (GUI and CLI modes), refer to Section 13.3.3: Performing HSM programming for license generation using STPC (GUI mode) and Section 5.3.5: Performing HSM programming for license generation using STPC (CLI mode).

8.3.3 Programming input conditions

Before performing an SFI install on STM32WBA5 devices, make sure that:

- The flash memory is erased.
- No WRP zone is active, otherwise destroy it.
- The chip supports security (a security bit must be present in the option bytes).
- If the security is activated, disable it.

8.3.4 Perform the SFI install using STM32CubeProgrammer

In this section, the STM32CubeProgrammer tool is used in CLI mode to program the SFI image **“**output-WBA5.sfi**”** already created in the previous section.

STM32CubeProgrammer supports communication with STMicroelectronics HSMs (hardware secure modules based on smartcards) to generate a license for the connected STM32 device during the SFI install process.

Using the UART interface

First make sure that all the input conditions are respected, then open a cmd terminal, go to /bin and launch the following STM32CubeProgrammer command:

STM32_Programmer_CLI.exe -c port=COM204 -sfi protocol=static "/output-WBA5.sfi" hsm=1 slot=1 -rsse "< RSSe_path >"

Note: The RSSe and the corresponding binary file are located in the STM32CubeProgrammer bin/RSSe/WBA folder.

Figure 68 shows the STM32CubeProgrammer command used for the SFI install process via UART execution.

Figure 68. SFI installation via UART execution using CLI

```
Serial Port COM204 is successfully opened.
Port configuration: parity = even, baudrate = 115200, data-bit = 8,
                    stop-bit = 1.0, flow-control = off
Activating device: OK
Board       : --
Chip ID: 0x492
BootLoader protocol version: 3.1
Device name : STM32WBA52/54/55
Flash size  : 1 MBytes (default)
Device type : MCU
Revision ID : --
Device CPU  : Cortex-M33
  Protocol Information          : static

  SFI File Information          :

     SFI file path              : C:\Users\bizids\Desktop\output-WBA5.sfi
     SFI HSM slot ID            : 1
     SFI header information     :
         SFI protocol version         : 2
         SFI total number of areas    : 4
         SFI image version            : 1
     SFI Areas information      :

     Parsing Area 1/4    :
         Area type                    : F
         Area size                    : 65152
         Area destination address     : 0x8000000

     Parsing Area 2/4    :
         Area type                    : F
         Area size                    : 65152
         Area destination address     : 0x800FE80

     Parsing Area 3/4    :
         Area type                    : F
         Area size                    : 768
         Area destination address     : 0x801FD00

     Parsing Area 4/4    :
         Area type                    : C
         Area size                    : 48
         Area destination address     : 0x0

Reading the chip Certificate...


Requesting Chip Certificate from device ...
```

```
ldm_LoadModule(): loading module "C:/Program Files/STMicroelectronics/STM32Cube/STM32C
ldm_LoadModule(WIN32): OK loading library "C:/Program Files/STMicroelectronics/STM32Cu
C_GetFunctionList() returned 0x00000000, g_pFunctionList=0x5CF643F0
P11 lib initialization Success!

Opening session with slot ID 1...

Succeed to Open session with reader slot ID 1

Succeed to generate license for the current STM32 device

Closing session with reader slot ID 1...

Session closed with reader slot ID 1

Closing communication with HSM...

Communication closed with HSM

Succeed to get License for Firmware from HSM slot ID 1

Starting Firmware Install operation...



Reconnection after Option Bytes Programming
Time elapsed during option Bytes configuration: 00:00:02.177
Warning: Option Byte: SECWM_PEND, value: 0x7F, was not modified.
Warning: Option Byte: SECWM_PSTRT, value: 0x0, was not modified.
Warning: Option Bytes are unchanged, Data won't be downloaded
Time elapsed during option Bytes configuration: 00:00:00.006


Reconnection after Option Bytes Programming
Time elapsed during option Bytes configuration: 00:00:02.193
Warning: Option Byte: SRAM2_RST, value: 0x1, was not modified.
Warning: Option Bytes are unchanged, Data won't be downloaded
Time elapsed during option Bytes configuration: 00:00:00.006


Reconnection after Option Bytes Programming
Verifying Read Out Protection...
Time elapsed during option Bytes configuration: 00:00:02.293
Installing RSSe


Memory Programming ...
Opening and parsing file: enc_signed_RSSe_sfi_WBA5_1M.bin
  File          : enc_signed_RSSe_sfi_WBA5_1M.bin
  Size          : 31.92 KB
  Address       : 0x20008100


Erasing memory corresponding to segment 0:
Not flash Memory : No erase done
Download in Progress:
```

```
File download complete
Time elapsed during download operation: 00:00:03.519
Get RSSe status...
Warning: Option Byte: TZEN, value: 0x1, was not modified.
Warning: Option Byte: nBoot0, value: 0x0, was not modified.
Warning: Option Byte: nSWBoot0, value: 0x0, was not modified.
Warning: Option Bytes are unchanged, Data won't be downloaded
Time elapsed during option Bytes configuration: 00:00:00.007


RSS version = 1.5.0


RSSe version = 1.1.0

Starting SFI

Processing license...
Get RSSe status...
Processing Image Header
Get RSSe status...
Processing Area 1...
Get RSSe status...
Area Address = 0x8000000
Area Type    = F
Processing Area 2...
Get RSSe status...
Area Address = 0x800FE80
Area Type    = F
Processing Area 3...
Get RSSe status...
Area Address = 0x801FD00
Area Type    = F
Processing Area 4...
Can not verify last area
Area Address = 0x0
Area Type    = C
SFI Process Finished!
SFI file C:\Users\bizids\Desktop\output-WBA5.sfi Install Operation Success

Time elapsed during SFI install operation: 00:00:34.373
```

MSv7379

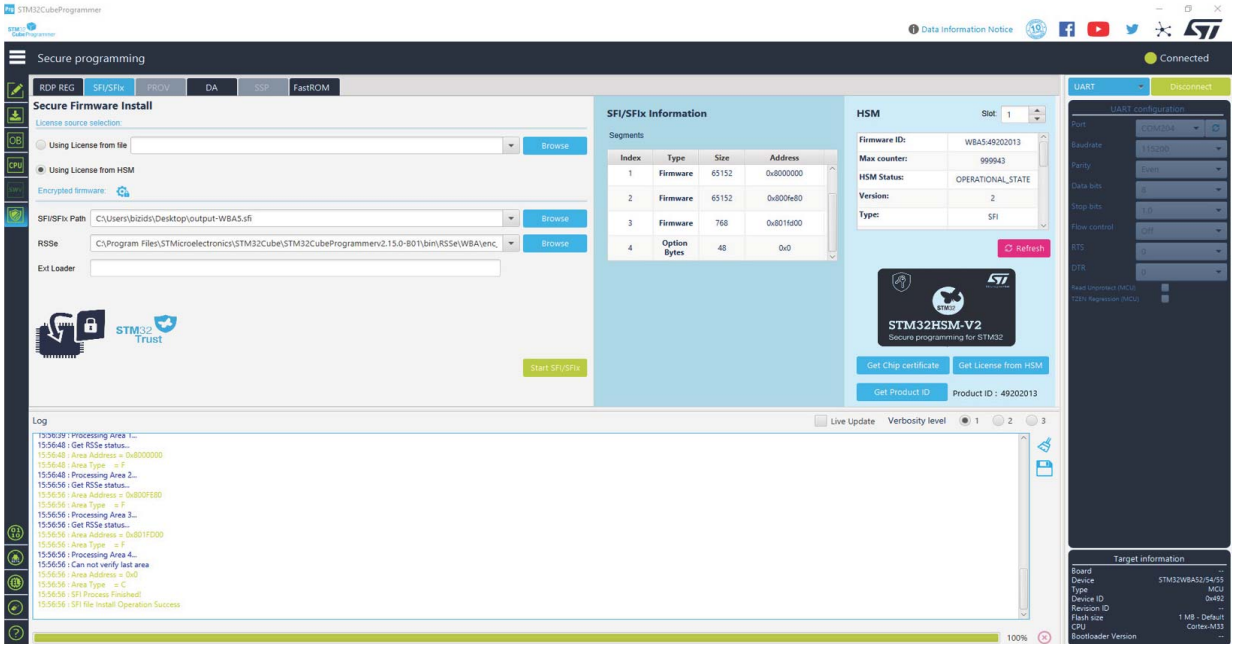
Graphical user interface mode

Open the STM32CubeProgrammer and connect the board through the UART interface with the right COM port. Press on the "Security" panel and select the SFI/SFIx from the tab options with the following inputs:

- License source selection: "Using License from HSM"
- SFI/SFIx path: output-WBA5.sfi
- RSSe: /RSSe/WBA/enc_signed_RSSe_sfi_WBA5_1M.bin

Click on the "Start SFI/SFIx" button to launch the SFI installation.

Figure 69. STM32WBA5 SFI successful programming via UART interface using GUI



9 Example of SFIA programming scenario for STM32WBA5

9.1 Scenario overview

SFIA is an SFI operation without a mass erase. It means that the user should perform an SFI install when all the flash memory is empty, or when the data written in the user flash memory is outside of the SFI firmware to install. (For more details refer to *[1]*).

In this example, the SFI is installed when the flash memory is already empty. The actual user application to be installed on the STM32WBA5 device. The application is encrypted using the STPC. The OEM provides the tools to the CM to get the appropriate license for the concerned SFIA application.

9.2 Hardware and software environment

For a successful SFIA programming, the following hardware and software prerequisites are needed:

- An STM32WBA5 board with boot loader and RSS programmed
- An RS-232 cable for SFIA programming via UART
- A Micro-B USB for debug connection
- A PC running on either Windows®, Linux® Ubuntu® or Fedora®, or macOS®
- STM32 Trusted Package Creator v2.17.0 (or greater) package available from *www.st.com*
- STM32CubeProgrammer v2.17.0 (or greater) package available from *www.st.com*
- HSMv2 (To generate the SFIA license)

Note: Refer to [4] or [5] for the supported operating systems and architectures.

9.3 Step-by-step execution

9.3.1 Build an OEM application

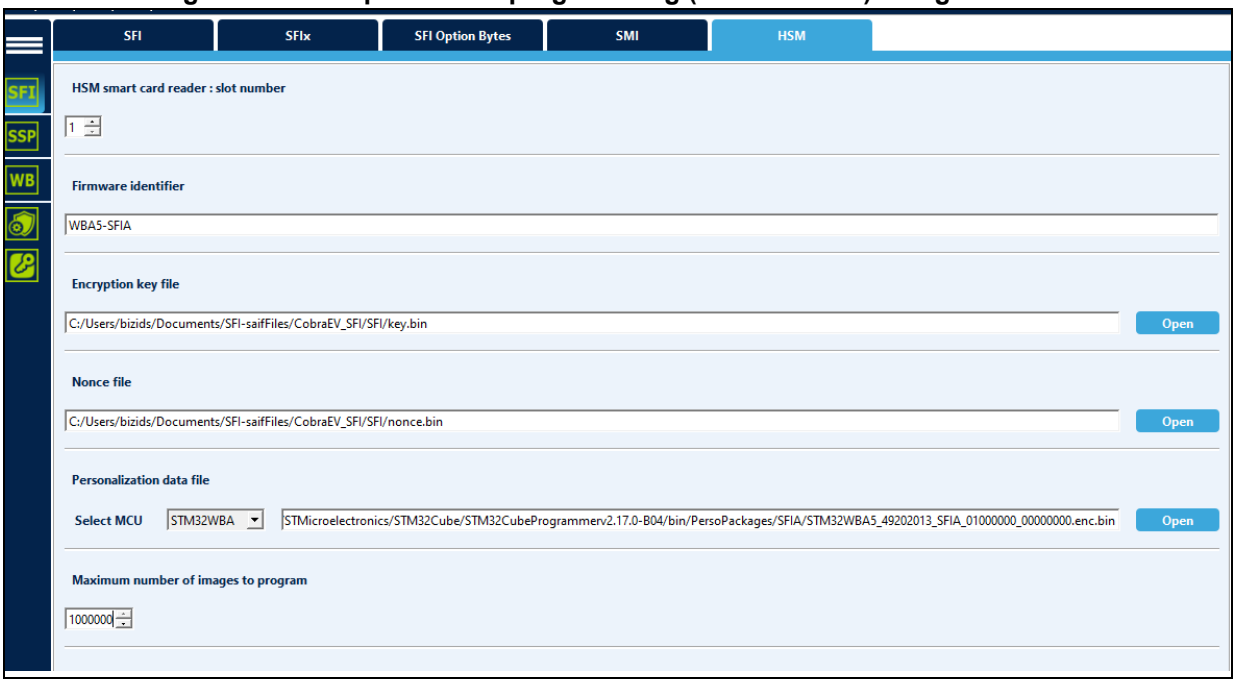
OEM application developers can use any IDE to build their own firmware.

9.3.2 Perform the HSM programming for the SFIA license generation (GUI mode)

The STM32 Trusted Package Creator tool provides all the personalization package files ready to be used on the SFI/SFIA/SFIx and SSP flows. To get all the supported **SFIA** packages, go to the **PersoPackages/SFIA** directory in the install path of the tool. Each file name starts with a number, which is the product ID of the device. Select the correct one.

In this case, select: STM32WBA5_49202013_**SFIA**_01000000_00000000.enc.bin to program the HSM card.

Figure 70. Example of HSM programming (SFIA License) using STPC GU



9.3.3 Perform the SFI generation (GUI mode)

The first step to install the secure firmware on STM32 devices is the encryption of the user OEM firmware. The firmware is already provided in AXF format. The installation is done using the STM32 Trusted Package Creator tool.

The steps described in *Section 8.3.2: Perform the SFI generation (GUI mode)* can be followed.

9.3.4 Programming input conditions

Before performing an SFI install on STM32WBA5 devices, the user must ensure that:

- The flash memory is erased.
- No WRP zone is active, otherwise it should be destroyed.
- The chip supports security (a security bit must be present in the option bytes).
- The security is disabled.

9.3.5 Perform the SFI installation using STM32CubeProgrammer

In this section, the STM32CubeProgrammer tool is used in CLI mode to program the SFI image "*output-WBA5.sfi*" that was created in the previous section.

The STM32CubeProgrammer supports communication with STMicroelectronics HSMs (hardware secure modules based on smartcards) to generate a license for the connected STM32 device during the SFI install process.

The user must ensure that all the input conditions are respected, and then follow the steps described in *Section 8.3.4: Perform the SFI install using STM32CubeProgrammer*.

10 Example of SFI programming scenario for STM32H5

10.1 Scenario overview

The user application is developed by the OEM and encrypted by STPC. The OEM provides the following elements to the programming house:

- The encrypted STM32H5 firmware
- A global license binary
- STM32CubeProgrammer

The untrusted manufacturer is then required to securely program the encrypted firmware using these inputs.

10.2 Hardware and software environment

For successful SFI programming, the following hardware and software prerequisites apply:

- STM32H5-based board with bootloader and RSS programmed
- SFI programming via UART (use RS-232 cable or STLINK VCOM)
- PC running on either Windows®, Linux® Ubuntu® or Fedora®, or macOS®
- aSTM32 Trusted Package Creator v2.14.0 (or greater) package available from *www.st.com*
- STM32CubeProgrammer v2.14.0 (or greater) package available from *www.st.com*

Note: Refer to [4] or [5] for the supported operating systems and architectures.

10.3 Step-by-step execution

10.3.1 Build OEM application

OEM application developers can use any IDE to build their own firmware.

10.3.2 Perform the SFI generation (GUI mode)

The first step to install the secure firmware on STM32H5 devices is the encryption of the user OEM firmware using the STM32 Trusted Package Creator tool.

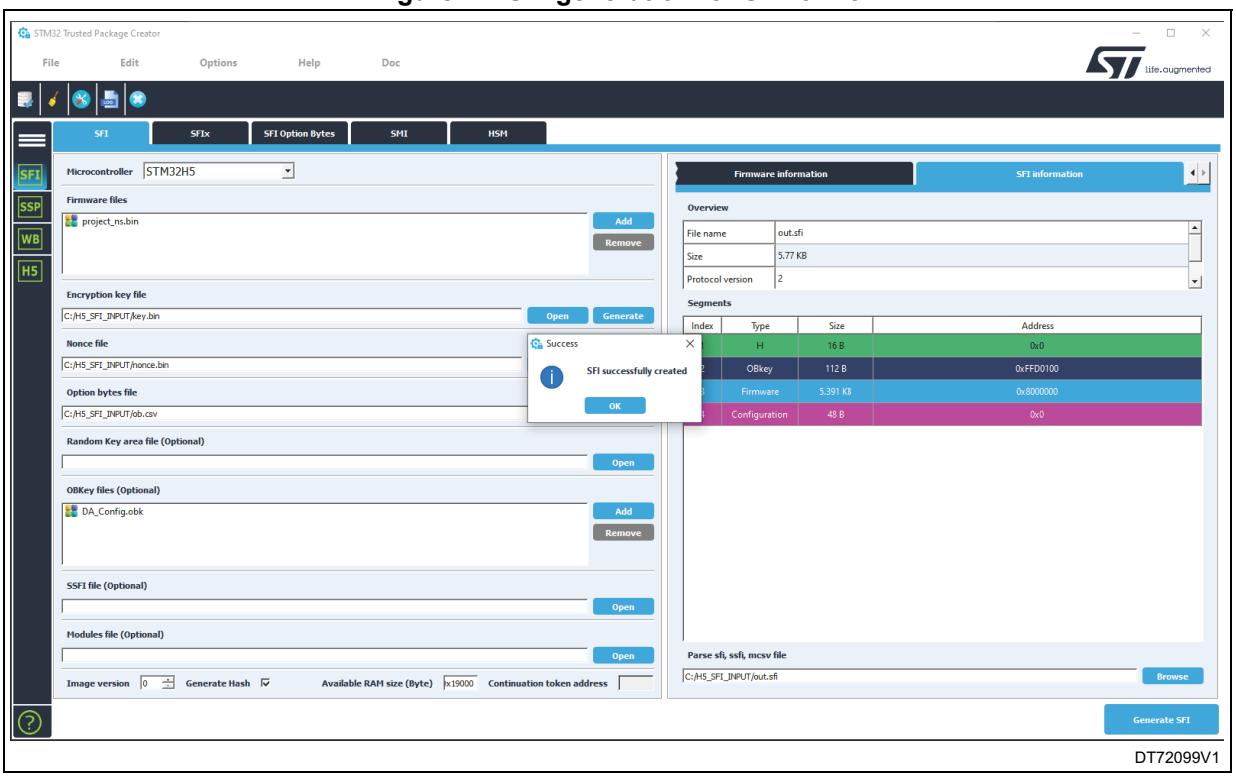
This step is done by including the following files in the STPC tool:

- An OEM firmware
- A .csv file containing option bytes configuration
- A 128-bit AES encryption key
- A 96-bit nonce
- OBKey files for device configuration (optional)
- An SSFI file to integrate the STMicroelectronics SFI image (optional, only for STM32H573)

Note: It is recommended to use the "SFI Option Bytes" feature from the "H5" panel of the STM32 Trusted Package Creator tool to obtain the option bytes file (.csv file).

Note: If you want to reopen the device using the Debug Authentication mechanism, a DA ObKey file must be included in the SFI image, otherwise the device becomes inaccessible.

Figure 71. SFI generation for STM32H5



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10.3.3 Programming input requirements

Before performing an SFI install on STM32H5 devices, make sure that:

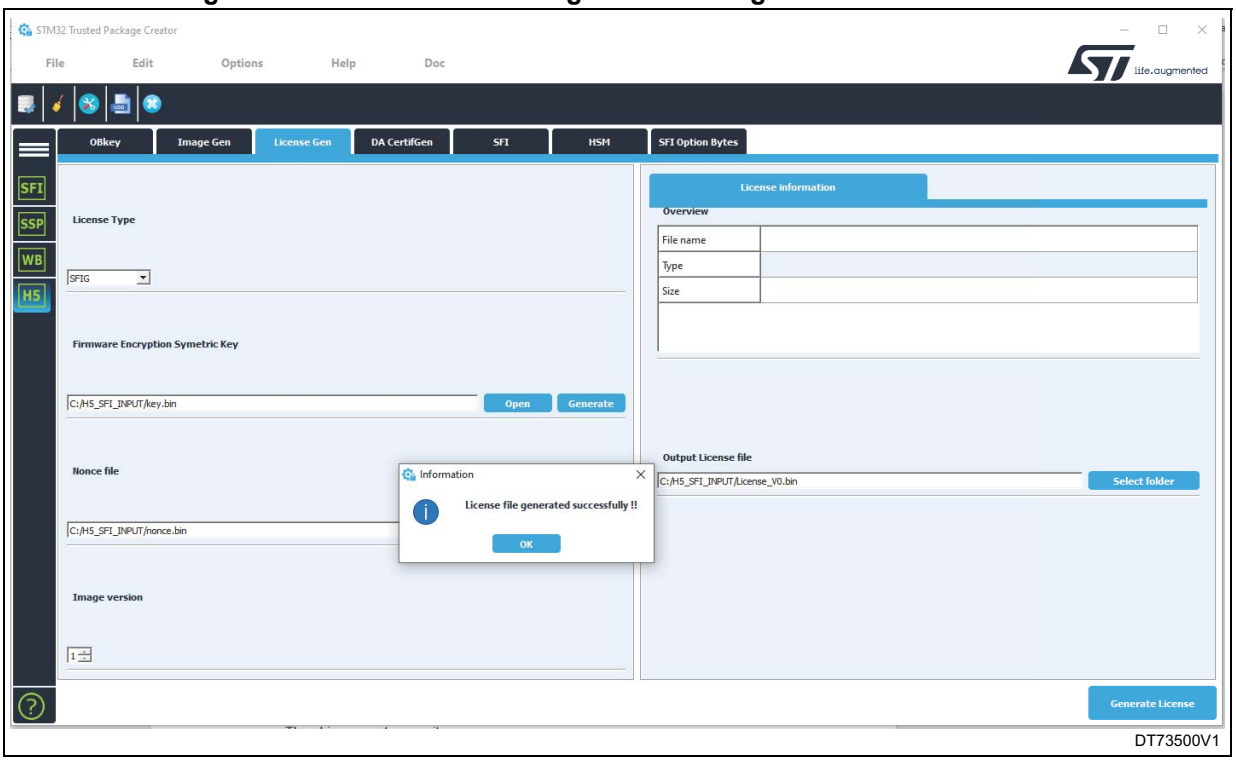
- Flash memory erased
- Chip supporting cryptography for a Secure Manager usage
- Product state open: 0xED
- Boot on bootloader: UART interface
- RSSe binary
- STMicroelectronics global license file (no need for an HSM card in this use case)

Note: The RSSe binary file is in the STM32CubeProgrammer bin/RSSe/H5 folder.

Note: To embed an SSFI image into the SFI image, it is recommended to follow a specific secure sequence and choose an adequate start address of the nonsecure application that depends on the SSFI configuration. See the details in STM32CubeH5 MCU Package available from www.st.com.

To generate an STMicroelectronics global license binary, use the “H5” panel of the STM32 Trusted Package Creator GUI and select the "License Gen" option. Then, include the same key and nonce previously used to generate the SFI image (see the figure below).

Figure 72. STMicroelectronics global license generation for STM32H5



10.3.4 Perform the SFI install using STM32CubeProgrammer

In this section, the STM32CubeProgrammer tool is used in CLI mode to program the SFI image “out.sfi” already created in the previous section.

STM32CubeProgrammer communicates with the device through the UART interface after it is confirmed that all the input conditions are respected.

Note that the same operation is possible using STLINK (SWD/JTAG) or any bootloader interface.

Command-line mode

Open a cmd terminal, go to /bin in the install path, and then launch the following command:

```
STM32_Programmer_CLI.exe -c port=COM8
-sfi "out.sfi" hsm=0 "ST_Global_License_V0.bin"
-rsse "\RSSe\H5\enc_signed_RSSe_SFI_STM32H5_v2.0.0.0"
```

Figure 73 shows the SFI execution traces.

Figure 73. STM32H5 SFI successful programming via CLI

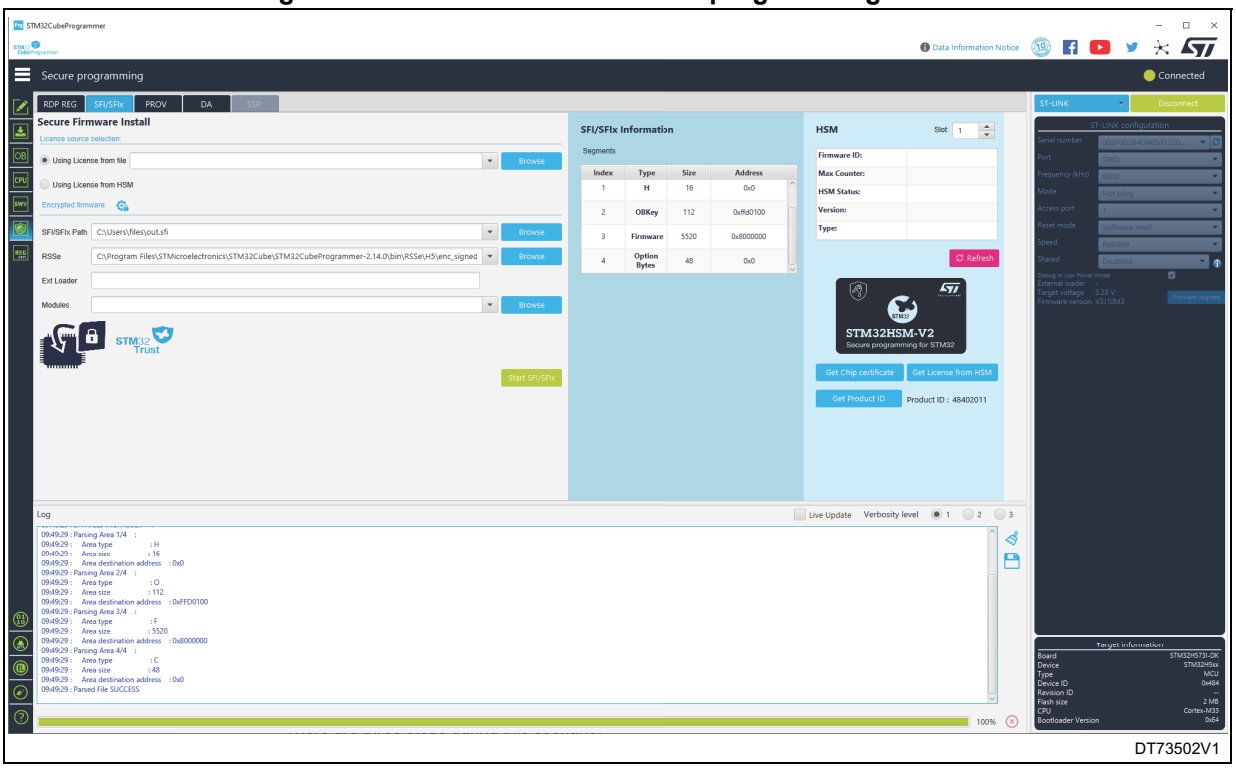
Graphical user interface mode

Open the STM32CubeProgrammer and connect the board through the UART interface with the right COM port. Press on the "Security" panel and select the SFI/SFIx from the tab options with the following inputs:

- License source selection: "Using License from file"
- SFI/SFIx path: out.sfi
- RSSe: \RSSe\H5\ enc_signed_RSSe_SFI_STM32H5_v2.0.0.0.bin

Click on the "Start SFI/SFIx" button to launch the SFI installation.

Figure 74. STM32H5 SFI successful programming via GUI



DT73502V1

11 Example of SFI programming scenario for STM32H7RS

11.1 Scenario overview

There are three steps during this scenario:

- *Generate STM32H7RS encrypted firmware using the STPC*
- *HSM card provisioning via STPC*
- *Use STM32CubeProgramer to perform the SFI process.*

11.2 Hardware and software environment

For successful SFI programming, some hardware and software prerequisites apply:

- An STM32H7RS-based board and system flash security package (SFSP) v1.1.0 or greater
- USB Type-C® cable for SWD connection
- A PC running on either Windows®, Linux® Ubuntu® or Fedora®, or macOS®
- An STM32 Trusted Package Creator v2.16.0 (or later) package is available from *www.st.com*
- An STM32CubeProgrammer v2.16.0 (or later) package is available from *www.st.com*
- An HSMv2 smartcard
  Note: Refer to [4] or [5] for the supported operating systems and architectures.

11.3 Step-by-step execution

11.3.1 Build an OEM application

OEM application developers can use any IDE to build their own firmware.

11.3.2 Perform the SFI generation (GUI mode)

The first step to install the secure firmware on STM32H7RS devices is the encryption of the user OEM firmware using the STM32 Trusted Package Creator tool.

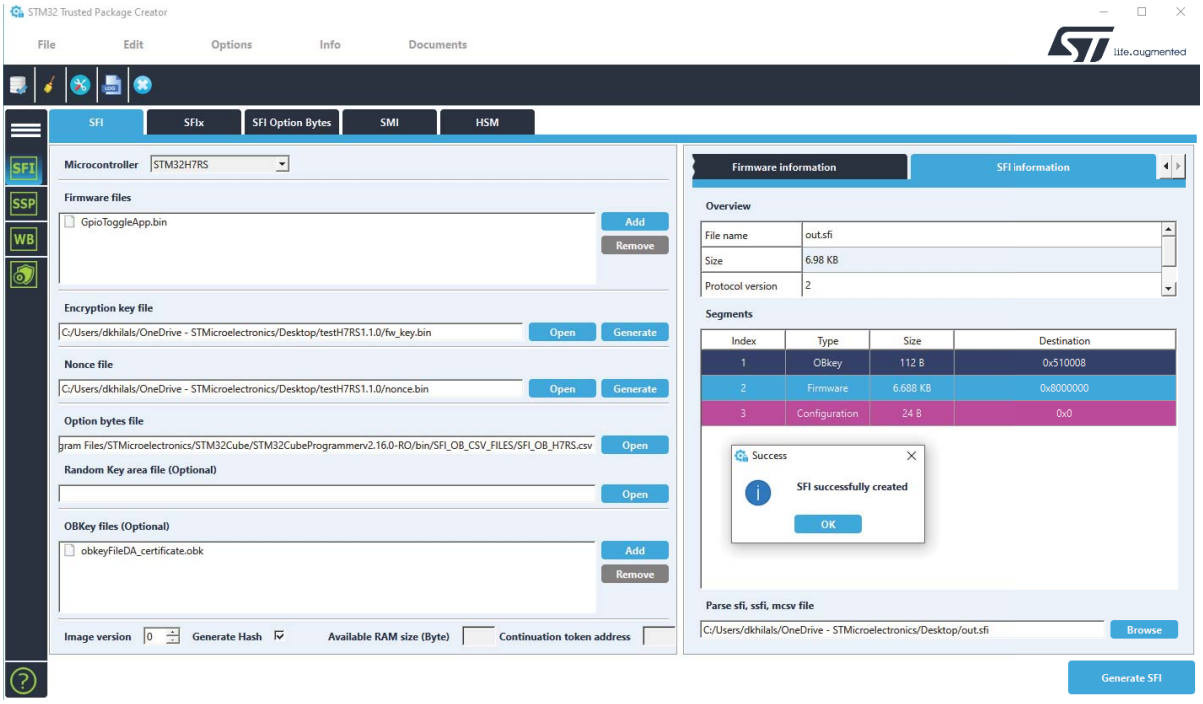
This step is done by including the following files in the STPC tool:

- An OEM firmware
- A .csv file containing option bytes configuration
- A 128-bit AES encryption key
- A 96-bit nonce
- Random key area file (optional)
- OBKey files for device configuration (optional)

Note: It is recommended to use the "SFI Option Bytes" feature of the STM32 Trusted Package Creator tool to obtain the option bytes file (.csv file).

Note: If you want to reopen the device using the Debug Authentication mechanism, a DA ObKey file must be included in the SFI image, otherwise the device becomes inaccessible.

Figure 75. Figure4 SFI generation for STM32H7RS



11.3.3 Programming input requirements

Before performing an SFI install on STM32H7RS devices, make sure that:

- Product state is open: 0x39
- A ready generated SFI image using the STPC tool
- RSSe binary
- STMicroelectronics global license file (no need for an HSM card in this use case)

Note: Using a non STM32H7RS sfi image may result in errors or issues during the installation process.

Note: The RSSe binary file is in the STM32CubeProgrammer bin/RSSe/H7RS folder.

11.3.4 Perform the SFI install using STM32CubeProgrammer

In this section, the STM32CubeProgrammer tool is used in CLI mode to program the SFI image *"out.sfi"* already created in the previous section.

STM32CubeProgrammer communicates with the device through the SWD interface after it is confirmed that all the input conditions are respected.

Note that the same operation is possible using STLINK (SWD/JTAG) or any bootloader interface.

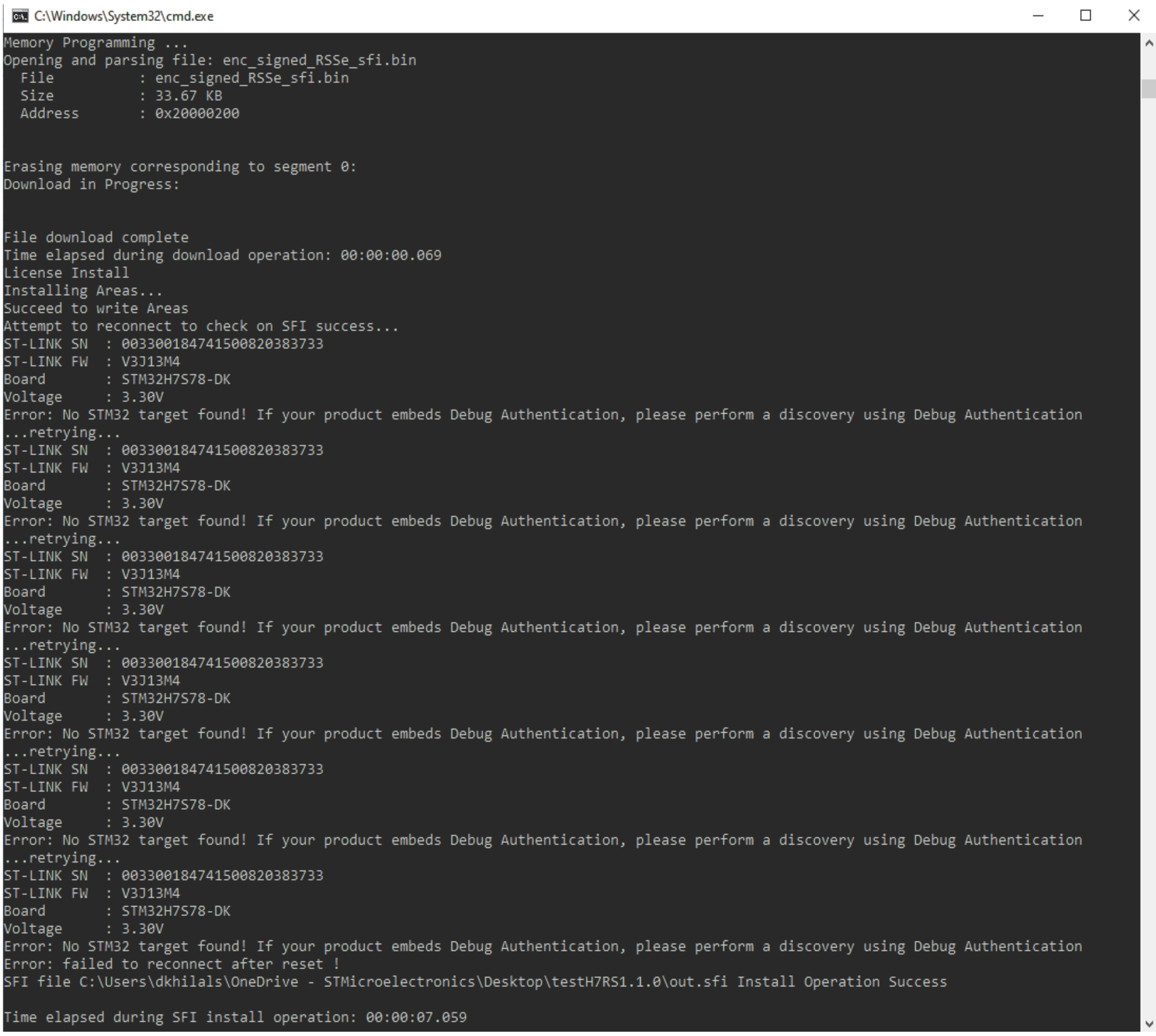
Command-line mode

Open a cmd terminal, go to /bin in the install path, and then launch the following command:

```
STM32_Programmer_CLI.exe -c port=swd mode=hotplug -sfi "out.sfi"
hsm=0 "ST_Global_License_V0.bin" -rsse "\RSSe\H7RS\
enc_signed_RSSe_sfi.bin"
```

Figure 5 shows the SFI execution traces.

Figure 76. STM32H7RS SFI successful programming via CLI



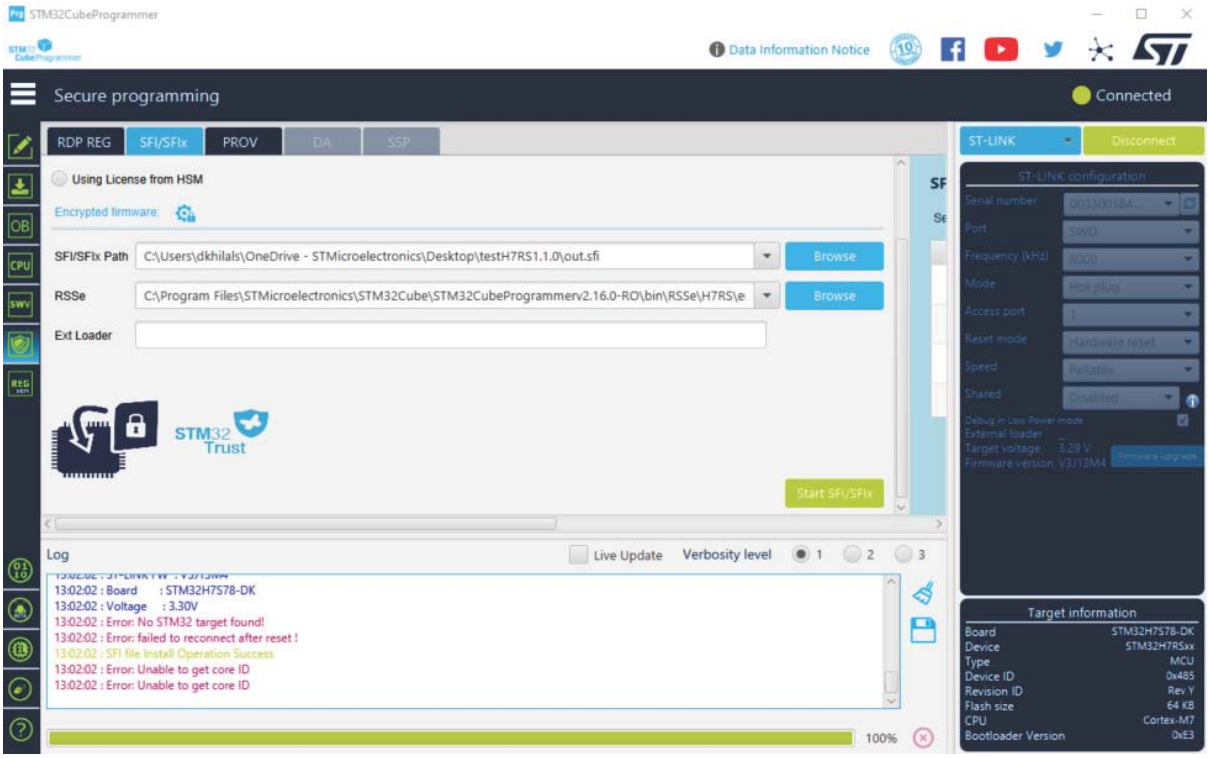
Graphical user interface mode

Open the STM32CubeProgrammer and connect the board through the SWD. Go to the security panel and select the SFI/SFIx from the tab options with the following inputs:

- License source selection: "Using License from file"
- SFI/SFIx path: out.sfi
- RSSe: \RSSe\H7RS\ enc_signed_RSSe_sfi.bin

Click on the "Start SFI/SFIx" button to launch the SFI installation.

Figure 77. STM32H7RS SFI successful programming via GUI



12 Example of SMI programming scenario

12.1 Scenario overview

In this scenario, the third-party library to be installed on the STM32H753XI device makes "printf" packets appear in the serial terminal if the library code execution called by the application does not crash.

The library code was encrypted using the STPC.

The OEM provides tools to the CM to get the appropriate license for the concerned SMI module.

12.2 Hardware and software environment

The same environment as explained in *Section 4.1.1: Device authentication*.

12.3 Step-by-step execution

12.3.1 Build a third-party library

STMicroelectronics or third-party developers can use any IDE to build the library to be encrypted and installed into the STM32H7 device.

In this scenario, the SMI module based on the built library is not relocatable. The destination address is hardcoded in the SMI module to the following value: 0x08080000.

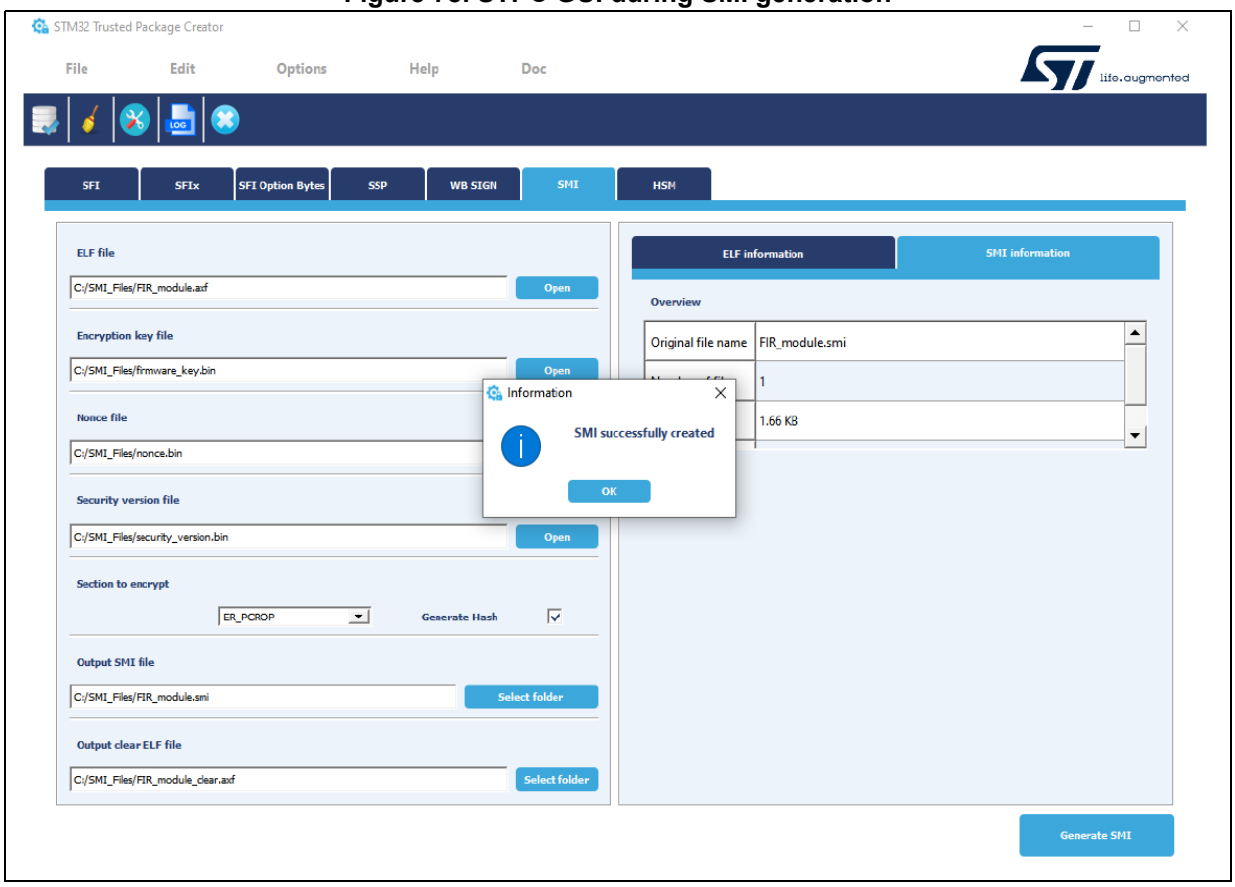
12.3.2 Perform the SMI generation

For encryption with the STM32 Trusted Package Creator tool, the third-party module is provided in ELF format. A 128-bit AES encryption key, a 96-bit nonce and a security version file are also provided to the tool. They are available in the "*SMI_ImagePreparation"* directory. After choosing the name of the section to be encrypted, a *".smi"* image is then generated (*FIR_module.smi)*.

The clear data part of the library without the encrypted section is also created in ELF format (*FIR_module_clear.axf*).

Figure 78 shows the STPC GUI during SMI generation.

Figure 78. STPC GUI during SMI generation



12.3.3 Programming input conditions

Before performing the SMI install make sure that:

- The SMI module destination address is not already PCROPed, otherwise destroy this PCROPed area.
- The Boot0 pin is set to VDD.
- The chip supports security (existing security bit in option bytes).
- When performing an SMI install using the UART bootloader, no debug interface is connected to any USB host. If a debug interface is still connected, disconnect it then perform a power off/power on before launching the SMI install to avoid any debug intrusion problem.
- The proper license generated for the currently used chip must be at your disposal (or an HSM or secure server to generate it during SMI programming).

12.3.4 Perform the SMI install

Using JTAG/SWD

After making sure that all the input conditions are respected, open a cmd terminal and go to <STM32CubeProgrammer_package_path>/bin, then launch the following STM32CubeProgrammer command:

```
STM32_Programmer_CLI.exe -c port=swd mode=HOTPLUG -smi
protocol=static "<local_path>/FIR_module.smi"
"<local_path>/<licenseSMI.bin>"
```

This command allows the SMI specified file “*FIR_module.smi*” to be programmed into a dedicated PCROPed area at address (0x08080000).

Figure 79: SMI install success via debug interface shows the SMI install via SWD execution.

Figure 79. SMI install success via debug interface

12.3.5 How to test for SMI install success

1. Flash the clear data part *"FIR_module_clear.hex"* (available under the "*Tests"* directory) into address 0x08084000 using STM32Cubeprogrammer or any other flashing tool.
2. flash the test application *"tests.hex"* (which is based on the SMI module), available under the "*Tests"* directory at start user flash memory address "0x08000000" using STM32Cubeprogrammer or any other flashing tool.

   The option bytes configuration becomes as below (*Figure 80*).

Figure 80. OB display command showing that a PCROP zone was activated after SMI

```
OPTION BYTES BANK: 0
  Read Out Protection:
    RDP           : 0xAA (Level 0, no protection)
  RSS:
    RSS1          : 0x0 (No SFI process on going)
  BOR Level:
    BOR_LEV       : 0x0 (reset level is set to 2.1 V)
  User Configuartion:
    IWDG1         : 0x1 (Independent watchdog is controlled by hardware)
    NRST_STOP_D1  : 0x1 (STOP mode on Domain 1 is entering without reset)
    NRST_STBY_D1  : 0x1 (STANDBY mode on Domain 1 is entering without reset)
    FZ_IWDG_STOP  : 0x1 (Independent watchdog is running in STOP mode)
    FZ_IWDG_SDBY  : 0x1 (Independent watchdog is running in STANDBY mode)
    SECURITY      : 0x1 (Security feature enabled)
    BCM7          : 0x1 (CM-7 boot enabled)
    NRST_STOP_D2  : 0x1 (STOP mode on Domain 2 is entering without reset)
    NRST_STBY_D2  : 0x1 (STANDBY mode on Domain 2 is entering without reset)
    SWAP_BANK     : 0x0 (after boot loading, no swap for user sectors)
    DMEPA         : 0x1 (delete PcROP protection and earse protected area)
    DMESA         : 0x1 (delete Secure protection and erase protected area)
  Boot address Option Bytes:
    BOOT_CM7_ADD0: 0x800  (0x8000000)
    BOOT_CM7_ADD1: 0x1FF0  (0x1FF00000)
  PCROP Protection:
    PCROPA_str    : 0x800  (0x8010000)
    PCROPA_end    : 0x806  (0x8080600)
  Secure Protection:
    SECA_str      : 0xFF  (0x8001FE0)
    SECA_end      : 0x0  (0x80000FF)
  DTCM RAM Protection:
    ST_RAM_SIZE   : 0x2 (8 KB)
  Write Protection:
    nWRP0         : 0x1 (Write protection not active on this sector)
    nWRP1         : 0x1 (Write protection not active on this sector)
    nWRP2         : 0x1 (Write protection not active on this sector)
    nWRP3         : 0x1 (Write protection not active on this sector)
    nWRP4         : 0x1 (Write protection not active on this sector)
    nWRP5         : 0x1 (Write protection not active on this sector)
    nWRP6         : 0x1 (Write protection not active on this sector)
    nWRP7         : 0x1 (Write protection not active on this sector)
```

3. If a UART connection is available on the board used, open the “*Hercule.exe”* serial terminal available under the *“Tests*” directory, open the connection. On reset, the dedicated `“printf”` packet appears.

13 Example of SFIx programming scenario for STM32H7

13.1 Scenario overview

There are three steps during this scenario:

- Generate an SFIx image using the STPC.
- Provisioning HSM card via STPC.
- Use the STM32CubeProgrammer to perform the SFIx process.

Once this scenario is successfully installed on the STM32H7B3I-EVAL, follow the steps below:

- Write internal firmware data in the internal flash memory starting at the address 0x08000000.
- Write external firmware data in the external flash memory starting at the address 0x90000000.
- Verify that the option bytes were correctly programmed (depends on area C).

13.2 Hardware and software environment

For successful SFIx programming, some hardware and software prerequisites apply:

- STM32H7B3I-EVAL board containing external flash memory.
- Micro-B USB for debug connection.
- PC running on either Windows®, Linux® Ubuntu® or Fedora®, or macOS®
- STM32 Trusted Package Creator v1.2.0 (or greater) package available from *www.st.com*
- STM32CubeProgrammer v2.3.0 (or greater) package available from *www.st.com*
- HSMv1.1 card

Note: Refer to [4] or [5] for the supported operating systems and architectures.

13.3 Step-by-step execution

13.3.1 Build OEM application

OEM application developers can use any IDE to build their own firmware.

Note: In this use case, there are different user codes. Each one is specific to a flash memory type (internal/external).

13.3.2 Perform the SFIx generation (GUI mode)

To be encrypted with the STM32 Trusted Package Creator tool, OEM firmware is provided in Bin/Hex/AXF format in addition to a CSV file to set the option bytes configuration. A 128-bit AES encryption key and a 96-bit nonce are also provided to the tool.

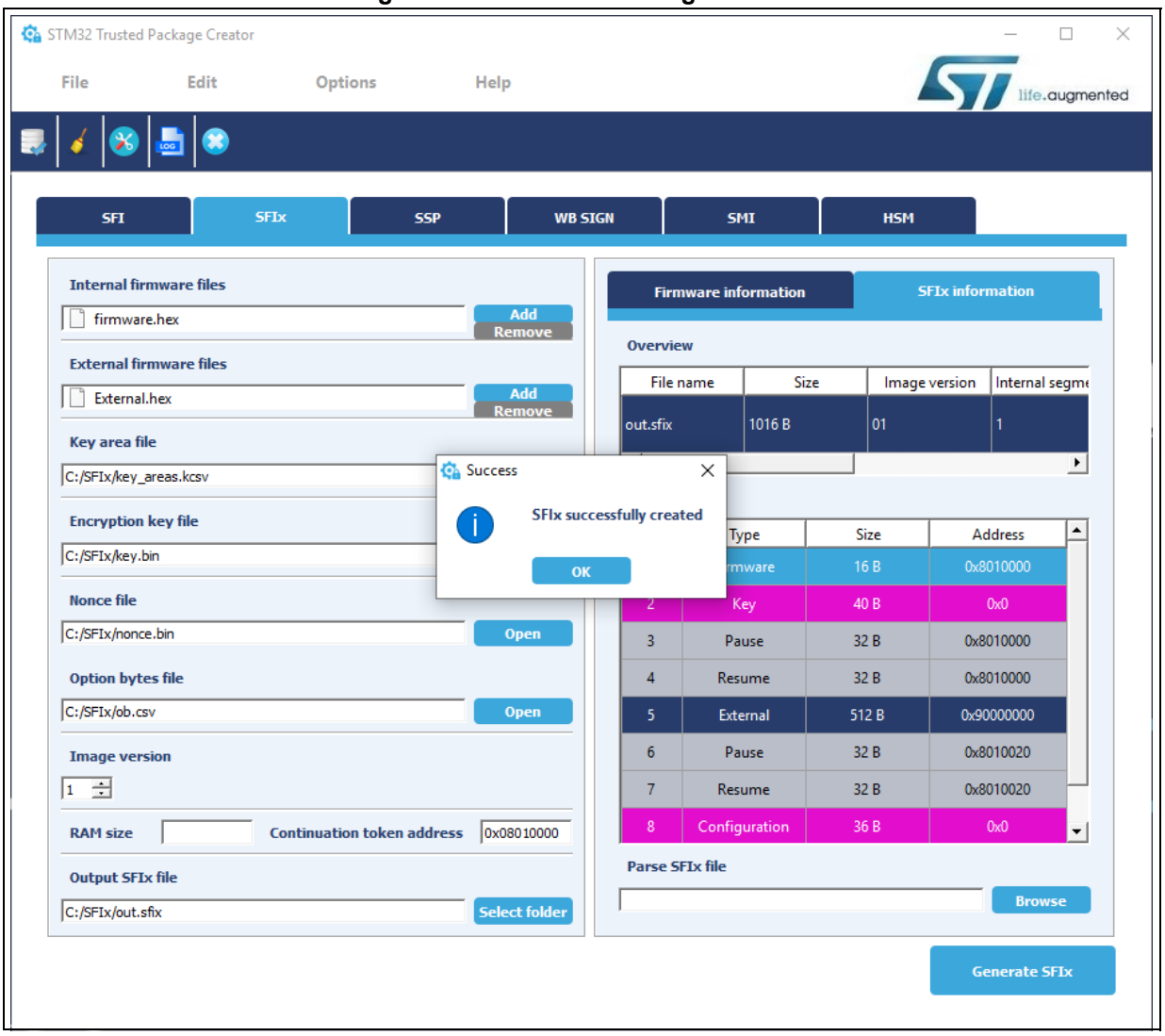
Note: STM32CubeProgrammer v2.8.0 and later provide one option byte file example for each product.
It is located in the directory: STM32CubeProgrammer\vx.x.x\bin\SFI_OB_CSV_FILES

The option bytes are described in the product reference manual.

In the case of customization of a provided example file, care must be taken not to change the number of rows, or their order.

An *".sfix"* image is then generated (*out.sfix)*.

Figure 81. Successful SFIx generation



13.3.3 Performing HSM programming for license generation using STPC (GUI mode)

The OEM must provide a license generation tool to the programming house to be used for license generation during the SFI install process.

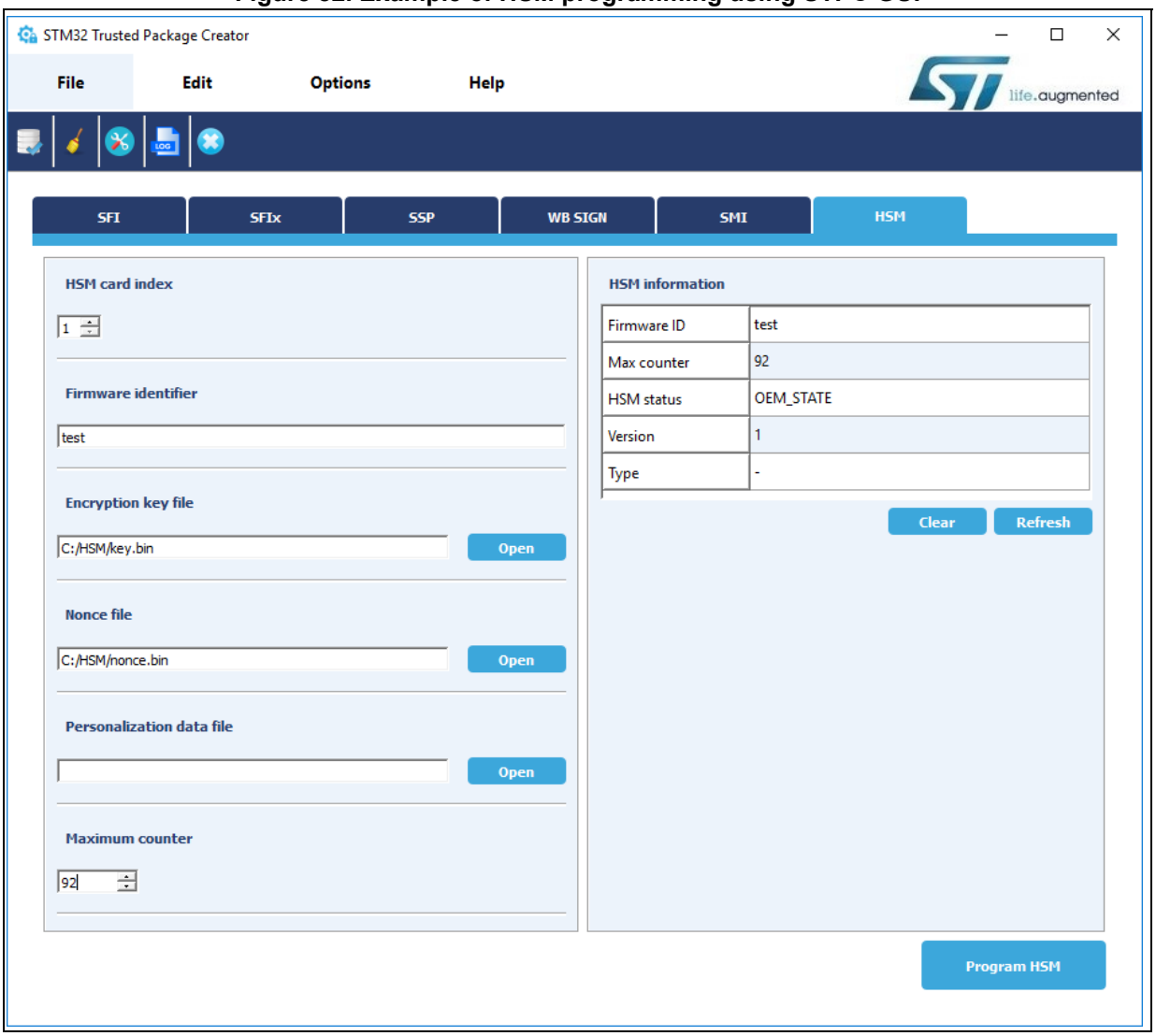
In this example, HSMs are used as license generation tools in the field. See *Section 4.1.2: License mechanism* for HSM use and programming.

Figure 82: Example of HSM programming using STPC GUI shows an example for HSM programming by OEM to be used for SFIx install.

The maximum number of licenses delivered by the HSM in this example is 1000.

This example uses HSM version 1. The HSM version can be identified before performing the programming operation by clicking the “Refresh” button to make the version number appear in the version field.

Figure 82. Example of HSM programming using STPC GUI



Note: When using HSM version 1, the "Personalization data file" field is ignored when programming starts. It is only used with HSM version 2.

When the card is successfully programmed, a popup window message "HSM successfully programmed" appears, and the HSM is locked. Otherwise, an error message is displayed.

13.3.4 Performing HSM programming for license generation using STPC (CLI mode)

Refer to *Section 5.3.5: Performing HSM programming for license generation using STPC (CLI mode)*.

13.3.5 Programming input conditions

Before performing an SFIx install, make sure that:

- Use the JTAG/SWD interface.
- No PCROPed zone is active, otherwise disable it.
- The chip must support security (a security bit must be present in the option bytes).
- The SFIx image must be encrypted by the same key/nonce used in the HSM provisioning.

13.3.6 Perform the SFIx installation using STM32CubeProgrammer

In this section, the STM32CubeProgrammer tool is used in CLI mode (the only mode so-far available for secure programming) to program the SFIx image *"out.sfix"* already created in the previous section.

STM32CubeProgrammer supports communication with STMicroelectronics HSMs (hardware secure modules based on smartcard) to generate a license for the connected STM32 device during SFIx install.

After making sure that all the input conditions are respected, open a cmd terminal and go to *<STM32CubeProgrammer_package_path>/bin*, then launch the following STM32CubeProgrammer command:

Using JTAG/SWD

```
STM32_Programmer_CLI.exe -c port=swd mode=HOTPLUG -sfi protocol=static
"<local_path>/out.sfix" hsm=1 slot=<slot_id> -el <ExternalLoader_Path>
```

Figure 83: SFIx installation success using SWD connection (1) through *Figure 86: SFIx installation success using SWD connection (4)* shows the SFIx install via SWD execution and the HSM as license generation tool in the field.

Figure 83. SFIx installation success using SWD connection (1)

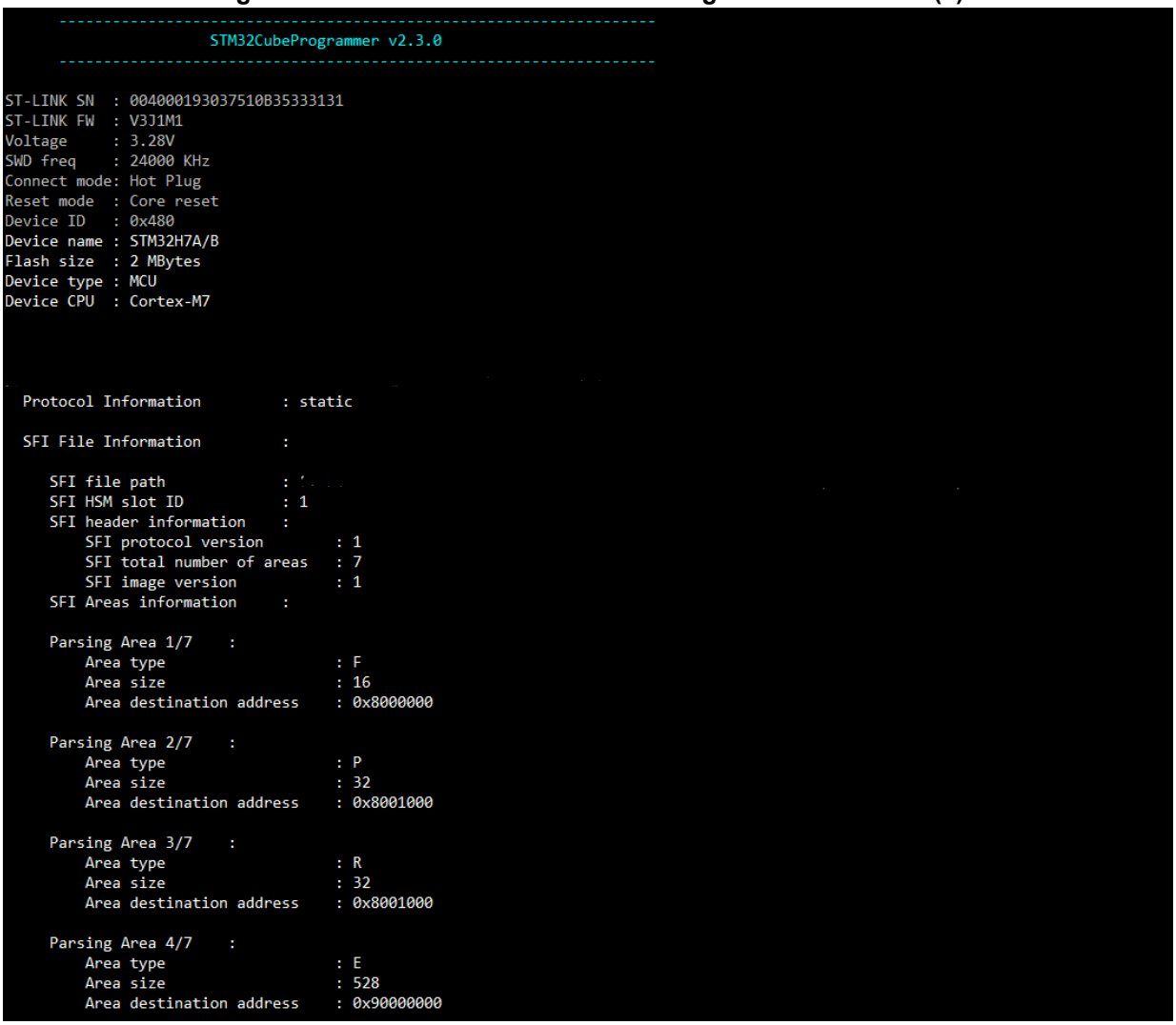


Figure 84. SFIx installation success using SWD connection (2)

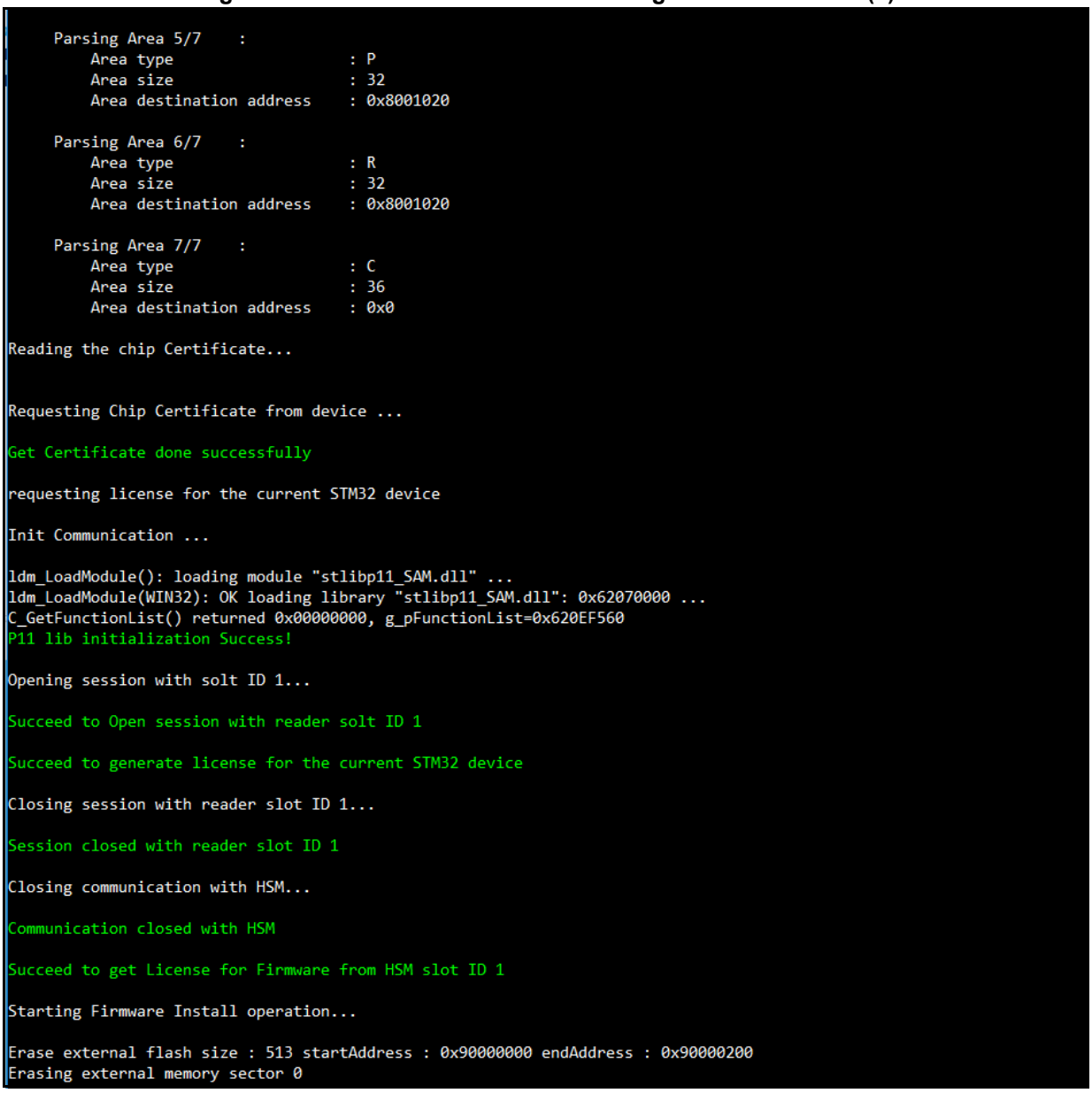
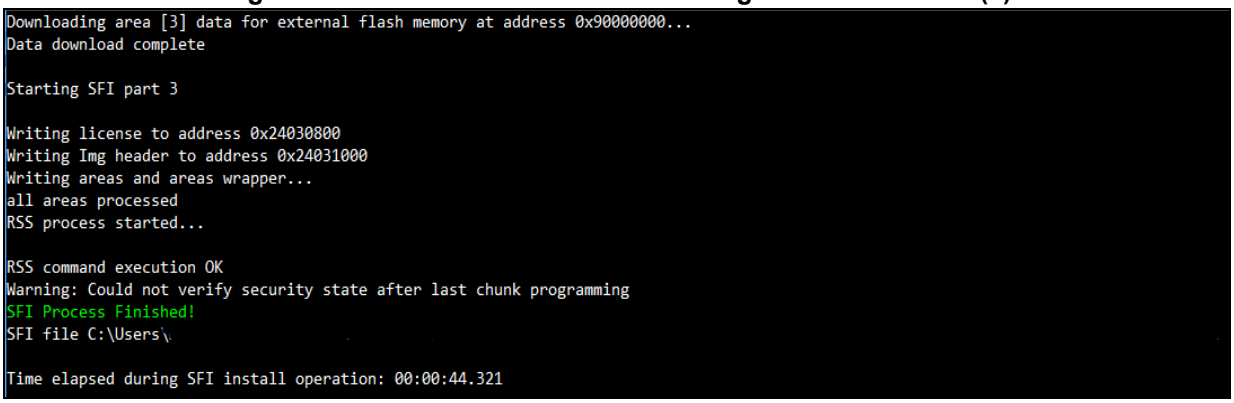


Figure 85. SFIx installation success using SWD connection (3)

```
Activating security...
Warning: Option Byte: SECURITY, value: 0x1, was not modified.
Warning: Option Bytes are unchanged, Data won't be downloaded
Activating security Success
Setting write mode to SFI
Warning: Option Byte: SECURITY, value: 0x1, was not modified.
Warning: Option Byte: ST_RAM_SIZE, value: 0x3, was not modified.
Warning: Option Bytes are unchanged, Data won't be downloaded
Succeed to set write mode for SFI

Starting SFI part 1

Writing license to address 0x24030800
Writing Img header to address 0x24031000
Writing areas and areas wrapper...
RSS process started...

RSS command execution OK
RSS complete Value = 0x0
Reconnecting...
ST-LINK SN  : 004000193037510B35333131
ST-LINK FW  : V3J1M1
Voltage     : 3.28V
SWD freq    : 24000 KHz
Connect mode: Hot Plug
Reset mode  : Core reset
Device ID   : 0x480
Reconnected !

Requesting security state...
Warning: Could not verify security state after last chunk programming

Starting SFI part 2

Writing license to address 0x24030800
Writing Img header to address 0x24031000
Writing areas and areas wrapper...
RSS process started...

RSS command execution OK
RSS complete Value = 0x0
Reconnecting...
ST-LINK SN  : 004000193037510B35333131
ST-LINK FW  : V3J1M1
Voltage     : 3.28V
SWD freq    : 24000 KHz
Connect mode: Hot Plug
Reset mode  : Core reset
Device ID   : 0x480
Reconnected !

Requesting security state...
Warning: Could not verify security state after last chunk programming
```

Figure 86. SFIx installation success using SWD connection (4)



14 Example of SFIx programming scenario for STM32L5/STM32U5

14.1 Scenario overview

There are three steps during this scenario:

1. Generate an SFIx image using the STPC
2. HSM card provisioning via STPC
3. Use STM32CubePrg to perform the SFIx process.

Successful installation of this scenario on the STM32L5 provides the following results:

- The internal flash memory is readable from base addresses 0x08000000 and 0x08040000. It contains the internal firmware.
- The external flash memory is programmed so as to be readable with the external flash memory loader. You can then read the external flash memory encrypted by the OTFDEC keys. The pattern of values must be present in the binary files of external firmware.
- If the application works correctly, the onboard LED blinks.

14.2 Hardware and software environment

For successful SFIx programming, some hardware and software prerequisites apply:

- An STM32L5/STM32U5-based evaluation board containing external flash memory
- A Micro-B USB for debug connection
- A PC running on either Windows®, Linux® Ubuntu® or Fedora®, or macOS®
- An STM32 Trusted Package Creator v2.11.0 (or greater) package is available from *www.st.com*
- An STM32CubeProgrammer v2.11.0 (or greater) package is available from *www.st.com*
- An HSMv1.1 card

Note: Refer to [4] or [5] for the supported operating systems and architectures.

14.3 Step-by-step execution

14.3.1 Build an OEM application

OEM application developers can use any IDE to build their own firmware. Note that in this use case there are different user codes, each being specific for a flash memory type (internal/external).

14.3.2 Perform the SFIx generation (GUI mode)

To be encrypted with the STM32 Trusted Package Creator tool, OEM firmware is provided in Bin/Hex/AXF format in addition to a CSV file to set the option bytes configuration. A 128-bit AES encryption key and a 96-bit nonce are also provided to the tool.

Note: STM32CubeProgrammer v2.11.0 and later provide one option byte file example for each product.
It is located in the directory: STM32CubeProgrammer\vx.x.x\bin\SFI_OB_CSV_FILES

The option bytes are described in the product reference manual.

In the case of customization of a provided example file, care must be taken not to change the number of rows, or their order.

An *".sfix"* image is then generated (*out.sfix)*.

Use case 1: generation of SFIx without key area for STM32L5

Internal firmware files:

1. Add a nonsecure binary with a start address equal to 0x08040000.
2. Add an internal binary file at 0x0C000000 (application to be executed after downloading SFIx to verify full process success by blinking an LED).
3. Add an OTFDEC key binary at 0x0C020000 (to be used as the key in OTFD ENC-DEC).

External firmware files: add an external binary at 0x90000000 with these parameters:

- Region number = 0
- Region mode = 0x2
- Key address = 0x0C020000 (same as the OTFDEC key binary).

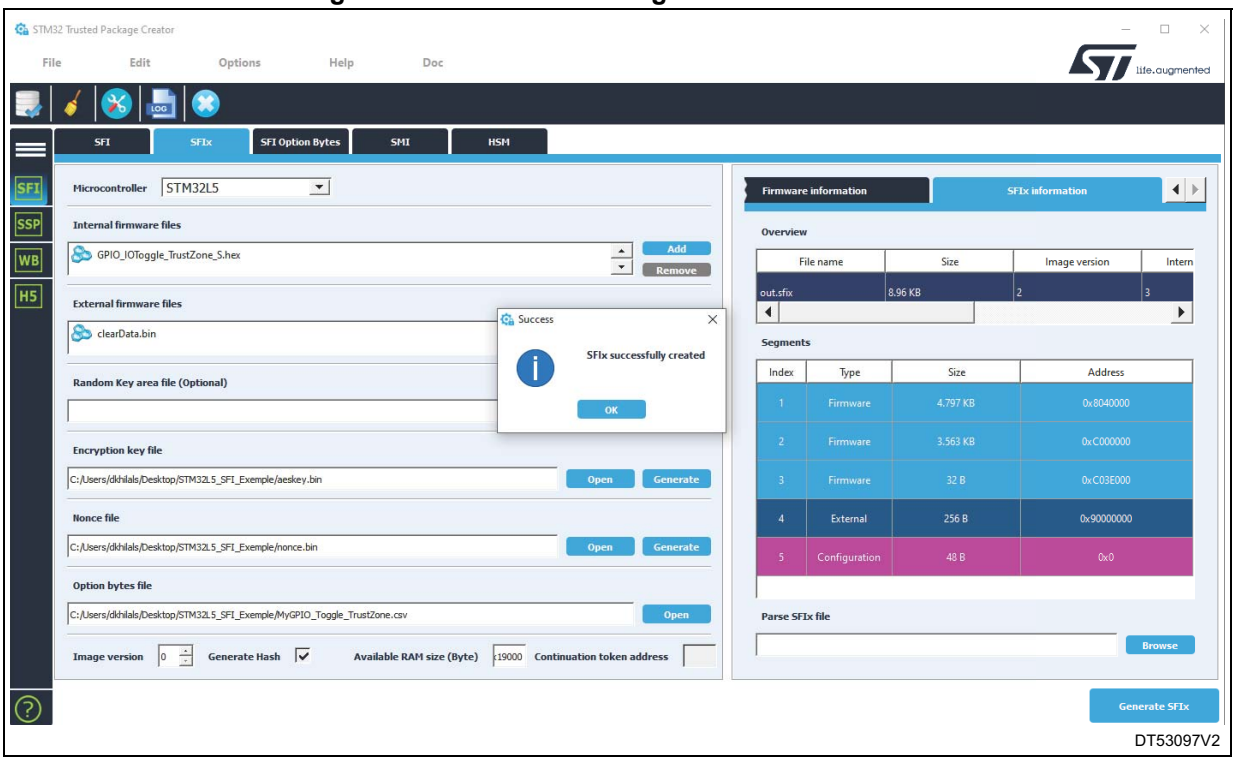
Encryption key: use the same key as HSM.

Nonce file: use the same nonce as HSM.

Option bytes file: use .csv contains the option-byte configuration.

RAM size: 0x19000 to split the input areas avoiding memory overflow.

Figure 87. Successful SFIx generation use case 1



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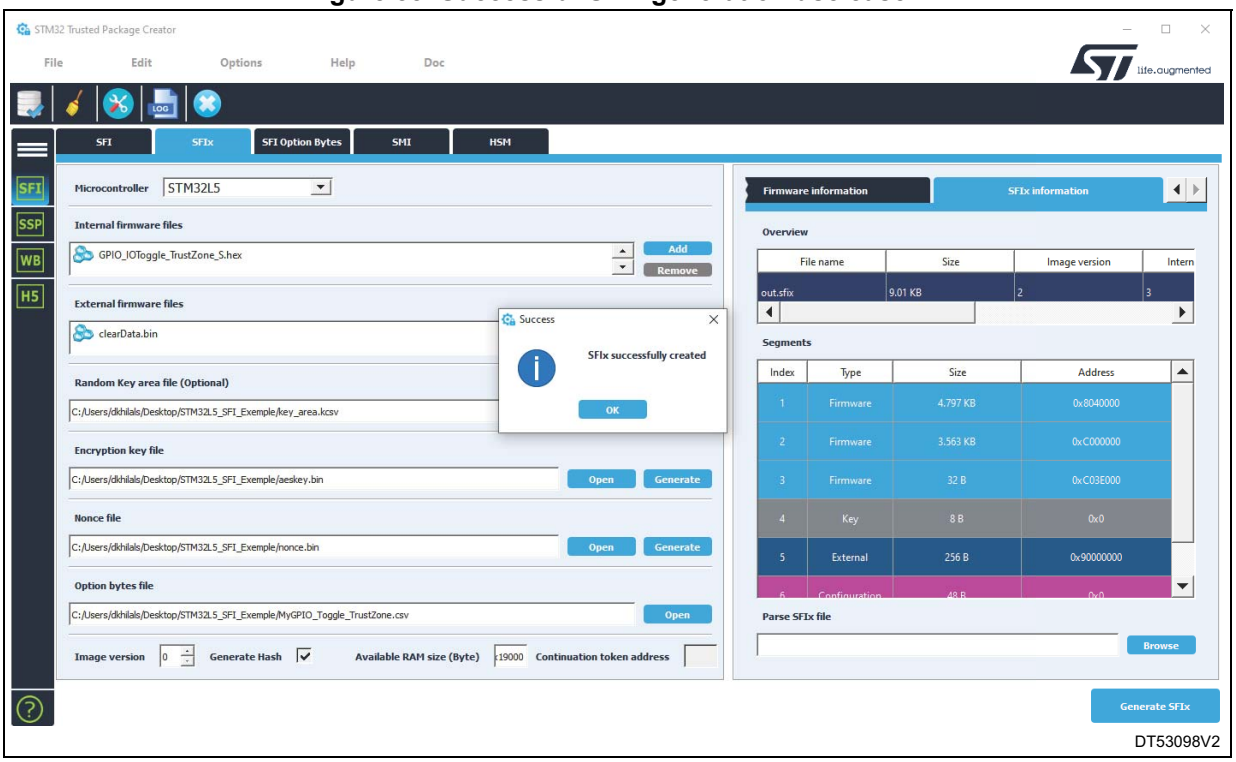
Use case 2: generation of SFIx with key area for STM32L5

This is essentially the same process as test case1. The main difference is:

- Add a ".kcsv" file (to be used in OTFD ENC-DEC during SFIx downloading) in the key area field, instead of using an OTFDEC key binary file.
- The key address for external firmware files is the first address of the area 'K' key file, which is 0x0C020000.

Figure 88. Successful SFIx generation use case 2



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After the generation of the SFIx image in this use case the output file contains 12 internal segments (F area), and 166 external segments (E area).

Use case 3: generation of SFIx without key area for STM32U5

Find below an example for STM32U585xx.

Internal firmware files:

1. Add a nonsecure binary with a start address equal to 0x08100000.
2. Add an internal binary file at 0x0C000000 (application to be executed after downloading SFIx to verify full process success by blinking an LED).
3. Add an OTFDEC key binary at 0x0800A000 (to be used as the key in OTFD ENC-DEC).

External firmware files: add an external binary (at 0x70000000 for STM32U585xx) with these parameters:

- Region number = 4
- Region mode = 1
- Key address = 0x0800A000 (same as the OTFDEC key binary).

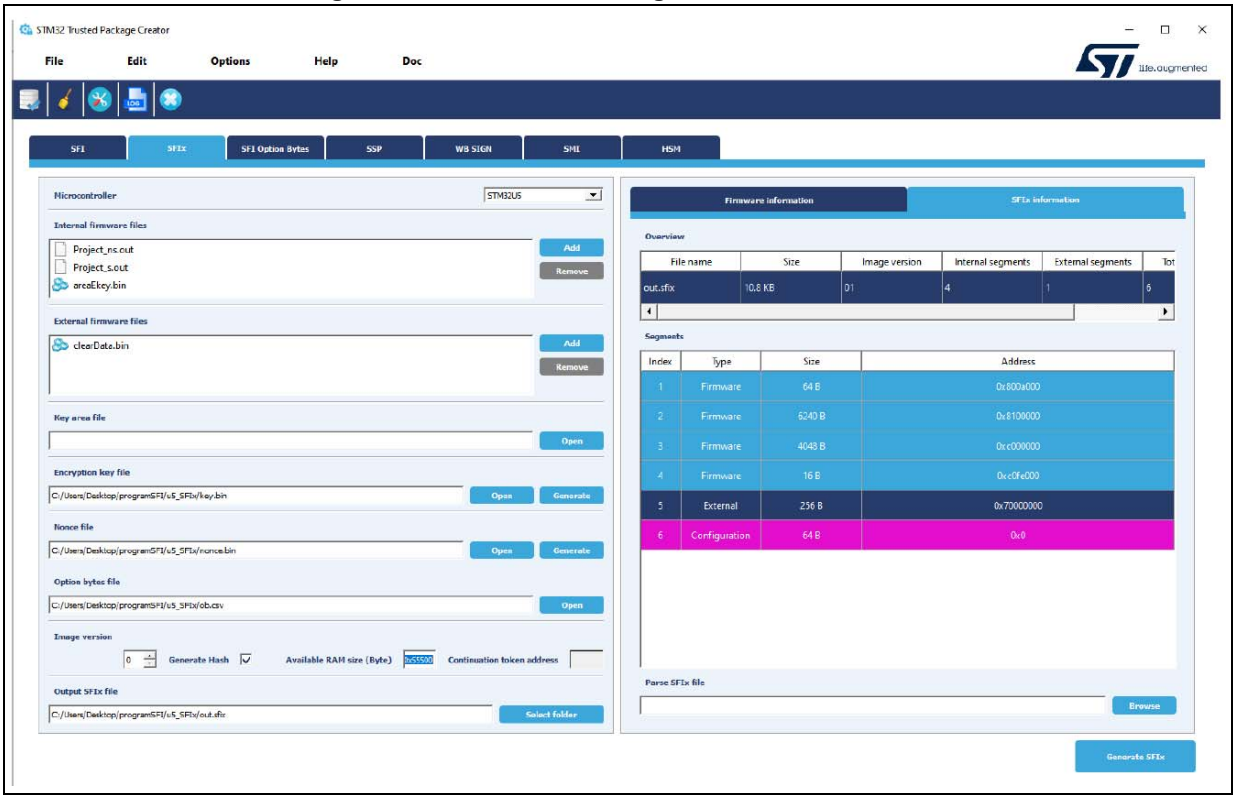
Encryption key: use the same key as HSM.

Nonce file: use the same nonce as HSM.

Option bytes file: use .csv contains the option-byte configuration.

RAM size: 0x55500 to split the input areas avoiding memory overflow.

Figure 89. Successful SFIx generation use case 3



Find below an example for STM32U59xxx, STM32U5Axxx, STM32U5Fxxx, and STM32U5Gxxx.

Internal firmware files:

1. Add a nonsecure binary with a start address equal to 0x08100000.
2. Add an internal binary file at 0x0C000000. It is an application to be executed after downloading SFIx to verify the full process success through a blinking LED.
3. Add an OTFDEC key binary at 0x0800A000. It is used as the key in OTFD ENCDEC.

External firmware files:

Add an external binary at 0x90000000 with these parameters:

- Region number = 3
- Region mode = 1
- Key address = 0x0800A000. It is the same as the OTFDEC key binary.

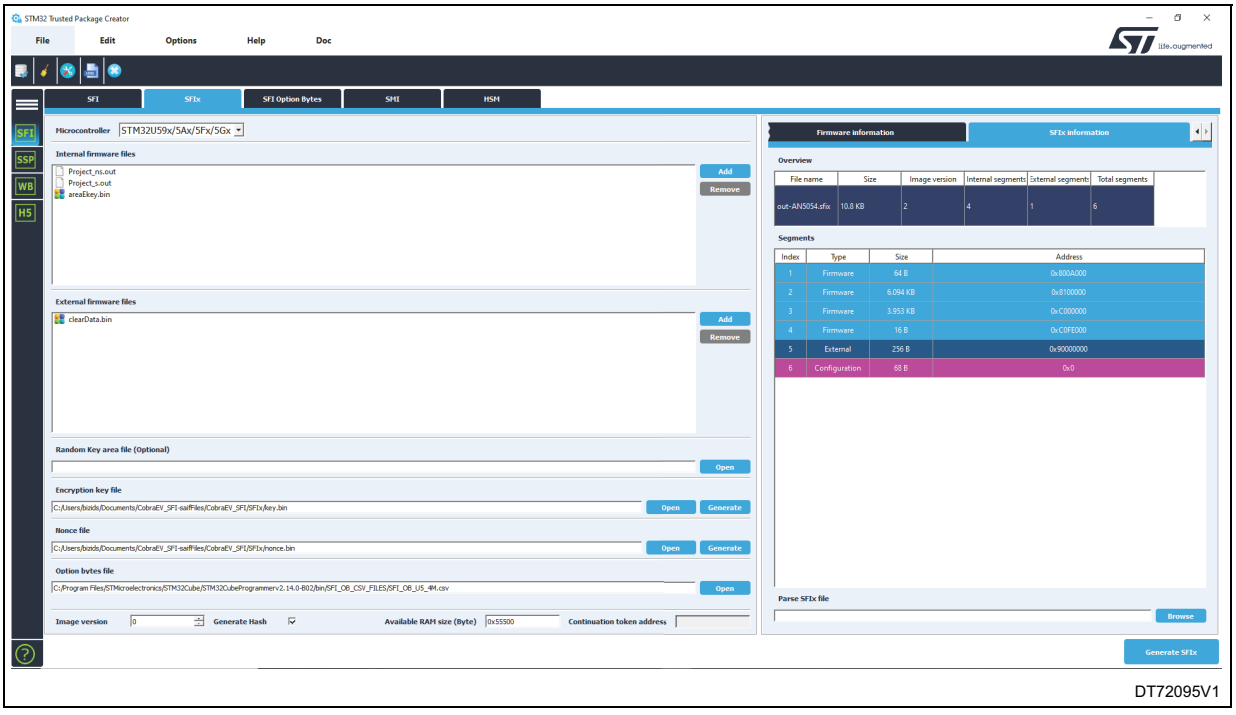
Encryption key: use the same key as HSM.

Nonce file: use the same nonce as HSM.

Option bytes file: use the .csv file that contains an option-byte configuration.

- **RAM size**: it is 0x55500 to split the input areas to avoid a memory overflow.

Figure 90. Successful SFIx generation use case 3 for STM32U59xxx, STM32U5Axxx, STM32U5Fxxx, and STM32U5Gxxx



Use case 4: generation of SFIx with key area for STM32U5

This is essentially the same process as test case1. The main difference is:

- Add a ".kcsv" file (to be used in OTFD ENC-DEC during SFIx downloading) in the key area field, instead of using an OTFDEC key binary file.
- The key address for external firmware files is the first address of the area 'K' key file, which is 0x0800A000.

Figure 91. Successful SFIx generation use case 4

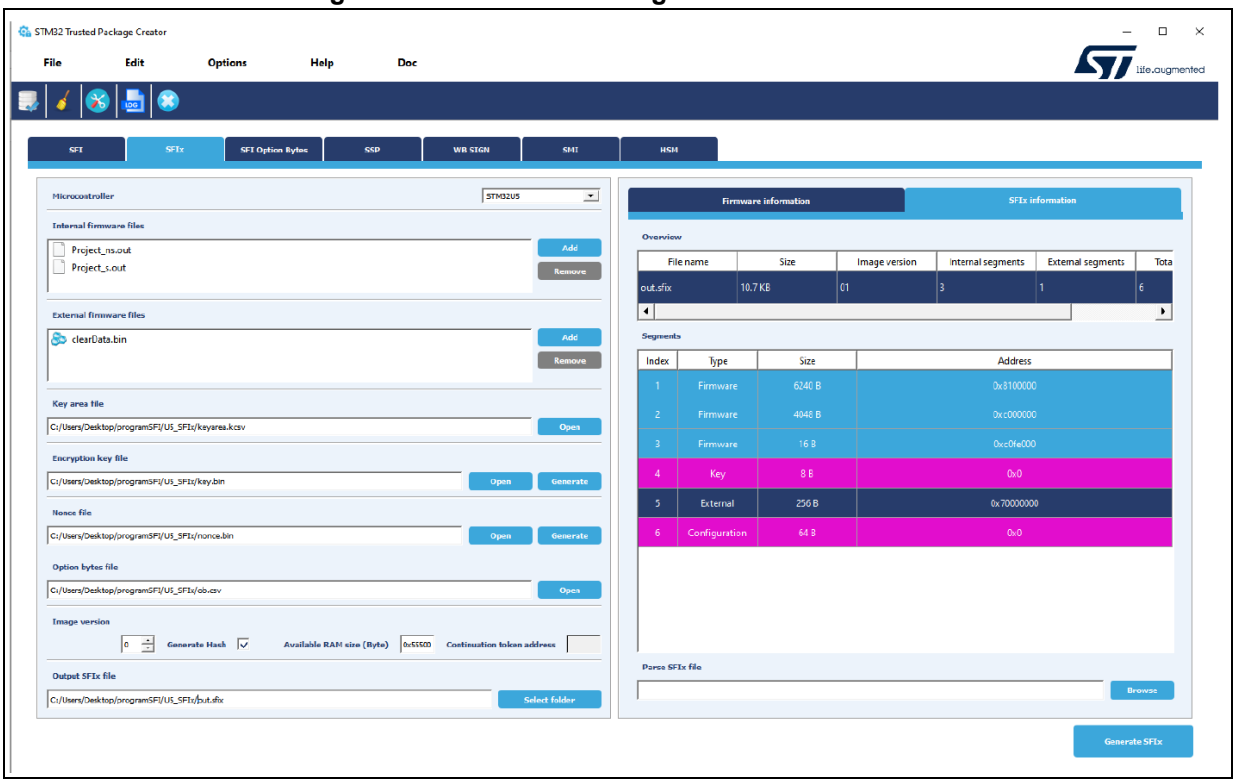
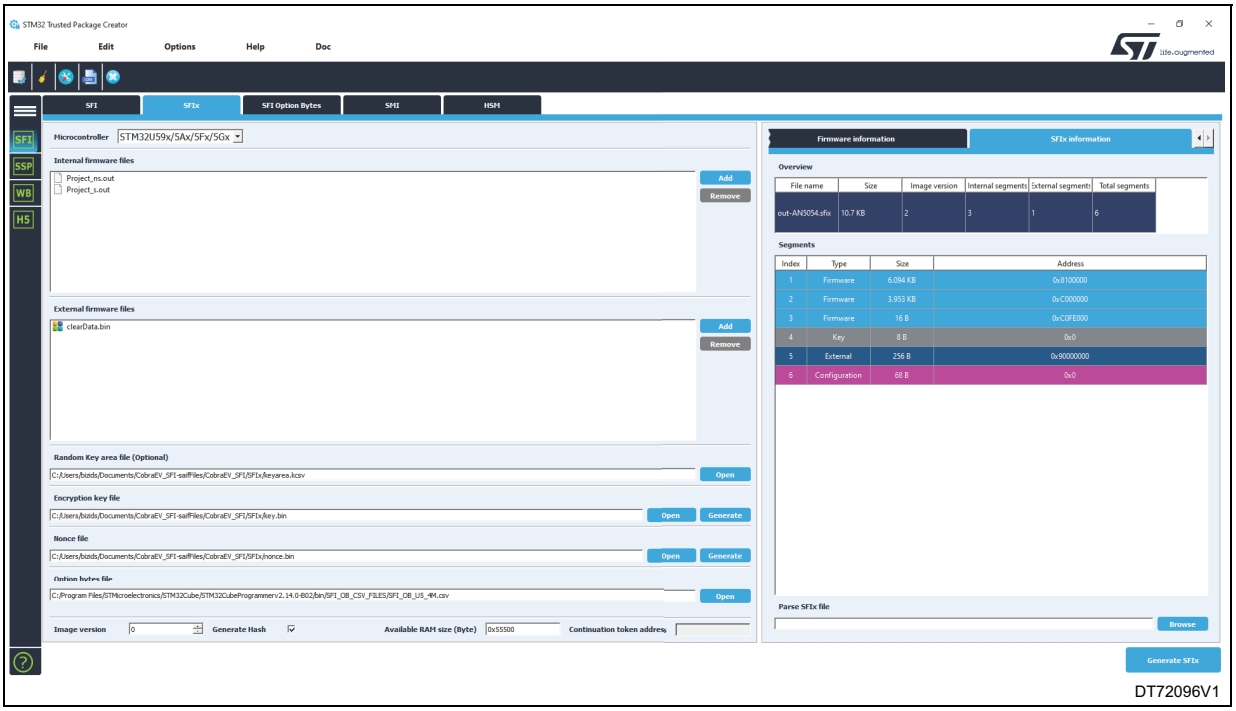


Figure 92. Successful SFIx generation use case 4 for STM32U59xxx, STM32U5Axxx, STM32U5Fxxx, and STM32U5Gxxx



14.3.3 Performing HSM programming for license generation using STPC (GUI mode)

Refer to *Section 13.3.3: Performing HSM programming for license generation using STPC (GUI mode)*.

14.3.4 Performing HSM programming for license generation using STPC (CLI mode)

Refer to *Section 13.3.4: Performing HSM programming for license generation using STPC (CLI mode)*.

14.3.5 Programming input conditions

Before performing an SFIx install, make sure that:

- A JTAG/SWD interface is used
- The chip supports security (a security bit must be present in the option bytes)
- The SFIx image is encrypted by the same key/nonce as is used in the HSM provisioning.
- The option bytes are:
  - DBank=1
  - nSWBOOT0=1
  - nBOOT0=1
  - RDP=AA

14.3.6 Perform the SFIx installation using STM32CubeProgrammer

In this section, the STM32CubeProgrammer tool is used in CLI mode (the only mode so-far available for secure programming) to program the SFIx image *"out.sfix"* already created in the previous section.

STM32CubeProgrammer supports communication with STMicroelectronics HSMs (Hardware secure modules based on smartcard) to generate a license for the connected STM32 device during SFIx install.

Using JTAG/SWD

After making sure that all the input conditions are respected, open a cmd terminal and go to *<STM32CubeProgrammer_package_path>/bin*, then launch the following STM32CubeProgrammer command:

```
STM32_Programmer_CLI.exe -c port=swd mode=HOTPLUG -sfi protocol=static
"<local_path>/out.sfix" hsm=1 slot=<slot_id> -rsse <RSSe_Path>  -el
<ExternalLoader_Path>
```

Note: The RSSe binary file is located in the STM32CubeProgrammer install path in the bin/RSSe folder.

Figure 93: SFIx installation success using SWD connection (1) through *Figure 95: SFIx installation success using SWD connection (3)* show the SFIx install via SWD execution and the HSM as license generation tool in the field.

Figure 93. SFIx installation success using SWD connection (1)

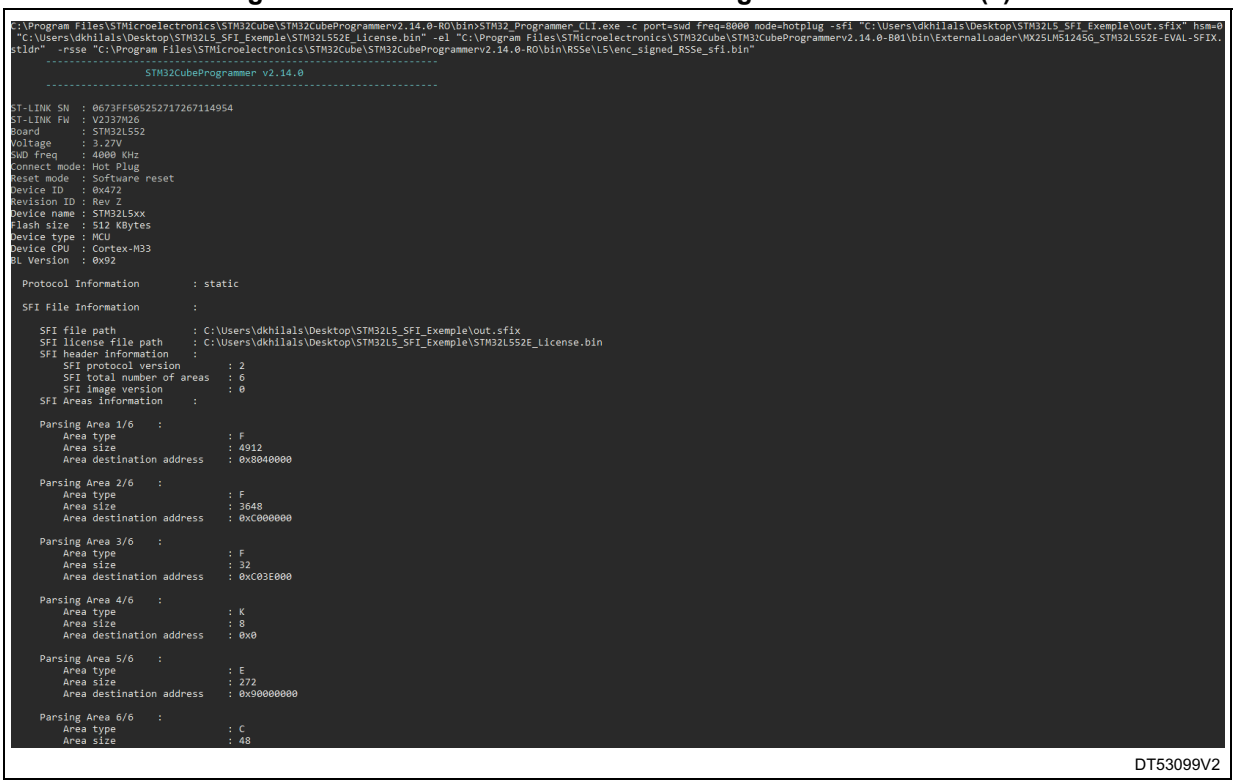


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Figure 94. SFIx installation success using SWD connection (2)

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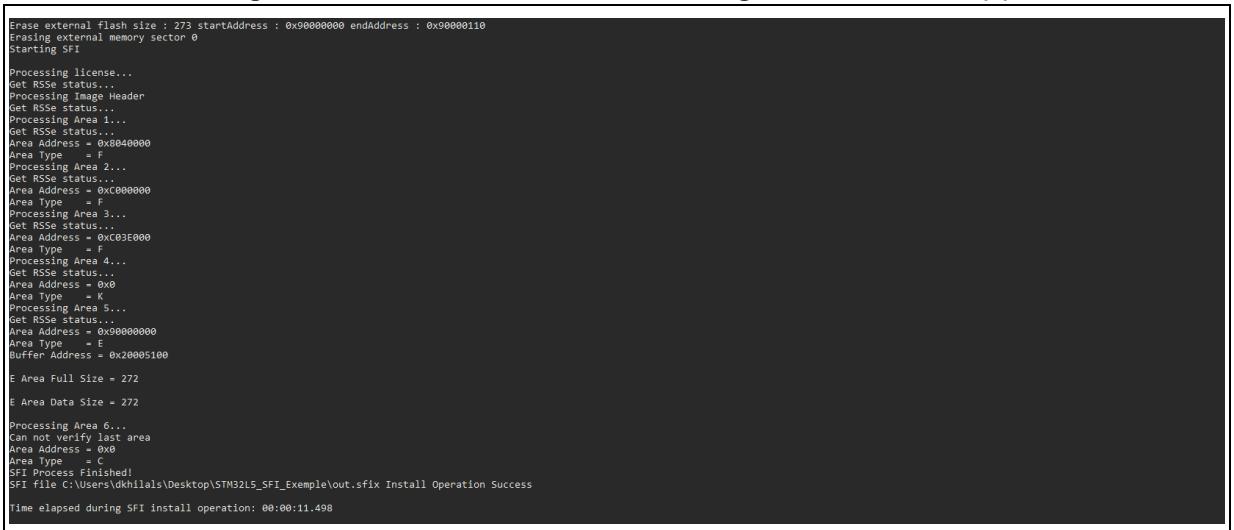
Figure 95. SFIx installation success using SWD connection (3)



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15 Example of SFIx programming scenario for STM32H5

15.1 Scenario overview

There are three steps during this scenario:

1. Generate an SFIx image using the STPC
2. HSM card provisioning via STPC
3. Use STM32CubePrg to perform the SFIx process.

15.2 Hardware and software environment

For successful SFIx programming, some hardware and software prerequisites apply:

- An STM32H5-based board with an external flash memory and system flash security package (SFSP) v2.4.0 or greater
- SFI programming via SWD
- A PC running on either Windows®, Linux® Ubuntu® or Fedora®, or macOS®
- An STM32 Trusted Package Creator v2.14.0 (or greater) package is available from *www.st.com*
- An STM32CubeProgrammer v2.14.0 (or greater) package is available from *www.st.com*
- An HSMv2 smartcard

Note: Refer to [4] or [5] for the supported operating systems and architectures.

15.3 Step-by-step execution

15.3.1 Build an OEM application

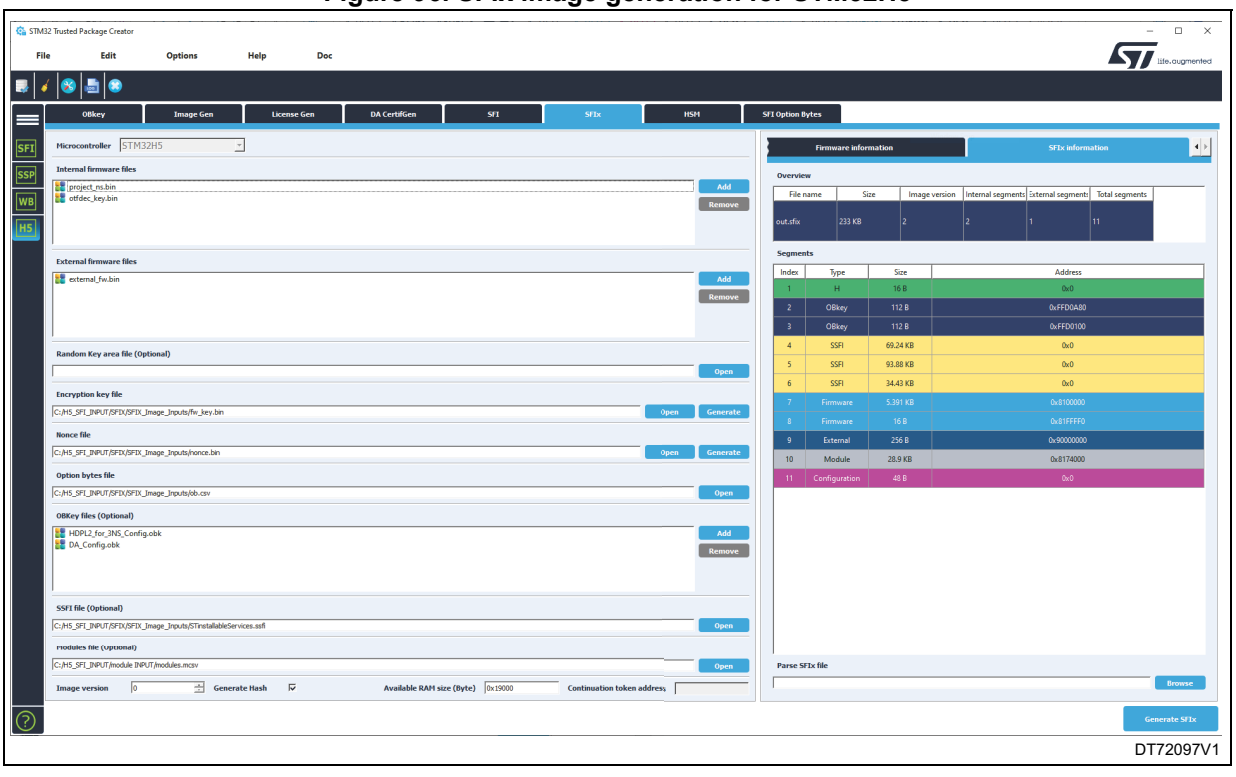
OEM application developers can use any IDE to build their own firmware.

15.3.2 Perform the SFIx generation (GUI mode)

The first step to install the secure firmware on STM32H5 devices is the encryption of the user OEM firmware using the STM32 Trusted Package Creator tool. This step is done by including the following files:

- An OEM firmware at 0x08100000
- A .csv file containing option bytes configuration
- A 128-bit AES encryption key
- A 96-bit nonce
- A binary file for an external firmware file
- OBKey files for device configuration
- An SSFI file to integrate the STMicroelectronics SFI image
- An OTFDEC key binary at 0x081FFFF0 (to be used as the key in OTFD ENC/DEC)
- External firmware files. Add an external binary at 0x90000000 with the following parameters:
  - Region number = 0
  - Region mode = 0x2
  - Key address = 0x081FFFF0 (same as the OTFDEC key binary)
- An MCSV file to insert the modules list:
  ./module.bin, ./LicenseV0.bin, 0x8172000

Figure 96. SFIx image generation for STM32H5



15.3.3 Programming input conditions

Before performing an SFIx install on STM32H5 devices, make sure that:

- There is an accessible external memory loader file such as MX25LM51245G_STM32H573I-DK-RevB-SFIx.stldr
- The chip supports security and boots on system memory
- The product state is open: 0xED
- An RSSe binary is available
- The HSMv2 is provisioned for the STM32H5 product

Note: The RSSe binary file is in the STM32CubeProgrammer bin/RSSe/H5 folder.

Note: To embed an SSFI image into the SFI image, it is recommended to follow a specific secure sequence and choose an adequate start address of the nonsecure application that depends on the SSFI configuration. See the details in STM32CubeH5 MCU Package available from www.st.com.

15.3.4 Perform the SFIx installation using STM32CubeProgrammer CLI

In this section, the STM32CubeProgrammer tool is used in CLI mode to program the SFIx image *"out.sfix"* already created in the previous section.

STM32CubeProgrammer communicates with the device through the SWD interface after it is confirmed that all the input conditions are respected.

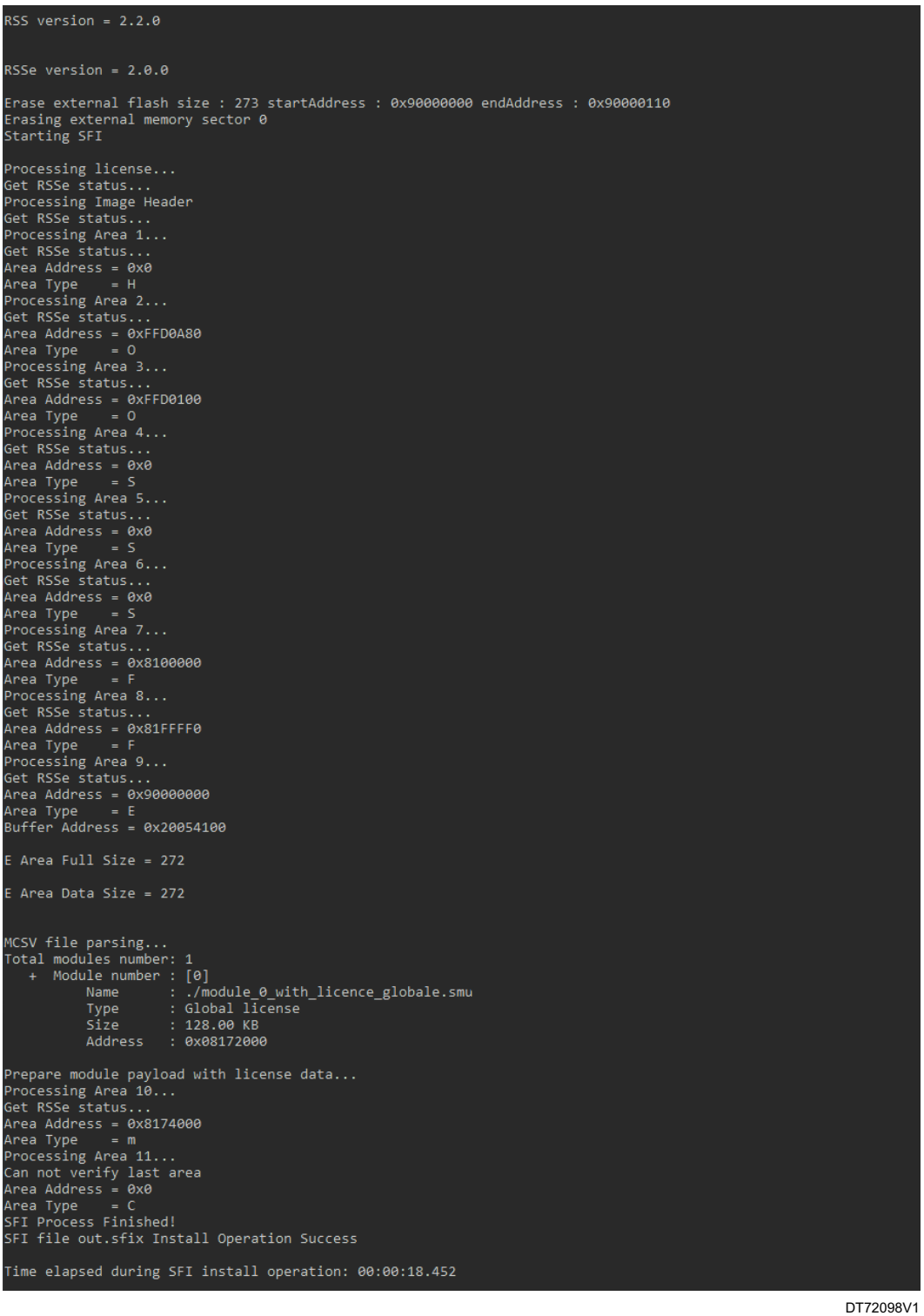
Open a cmd terminal, go to /bin in the install path, and then launch the following command:

Using JTAG/SWD

After making sure that all the input conditions are respected, open a cmd terminal and go to *<STM32CubeProgrammer_package_path>/bin*, then launch the following STM32CubeProgrammer command:

```
STM32_Programmer_CLI.exe -c port=swd mode=hotplug ap=1
-sfi "out.sfix" hsm=1 slot=1 -rsse
"\RSSe\H5\enc_signed_RSSe_SFI_STM32H5_v2.0.0.0.bin"
-el "\ExternalLoader\MX25LM51245G_STM32H573I-DK-RevB-
SFIx.stldr"
-mcsv ".\modules.mcsv"
```

Figure 97. SFIx installation success for STM32H5



16 Example of a combined SFI-SMI programming scenario

16.1 Scenario overview

The user application to be installed on the STM32H753XI device makes "`printf`" packets appear in the serial terminal.

In this case, the OEM application is built based on a third-party's library as explained in IAR example (*Section 2.3: Execute-only/position independent library scenario example under EWARM*).

The application is encrypted using the STPC, the SMI module corresponding to third-party's library code is uploaded as input during combined SFI generation and represented as an area of type 'M' within firmware application areas.

The SFI OEM application firmware can then be uploaded (on an OEM server for example) with all the inputs needed for license generation by the CM.

The OEM provides tools to the CM to get the appropriate licenses for the SFI application concerned and one or more integrated SMI modules.

16.2 Hardware and software environment

The same environment as explained in *Section 5.2: Hardware and software environment*.

16.3 Step-by-step execution

1. Build the OEM application.

   OEM application developers may use any IDE to build their firmware as well as using SMI modules provided by STMicroelectronics or third parties for example.

   In this example, we use firmware based on a single library (just one SMI module is integrated in the SFI image).

2. Perform the SFI generation.

   For encryption with the STM32 Trusted Package Creator tool, OEM firmware and the clear data part are both provided in Hex format (corresponding to the SMI module to be integrated within the SFI image). A CSV file to set the option bytes configuration is also necessary. The SMI module used is also provided as an input to the tool, in addition to a 128-bit AES encryption key and a 96-bit nonce. All inputs needed are available in the *"SFI_ImagePreparation/Combined"* directory. A *".sfi"* image is then generated (*out_comb.sfi*).

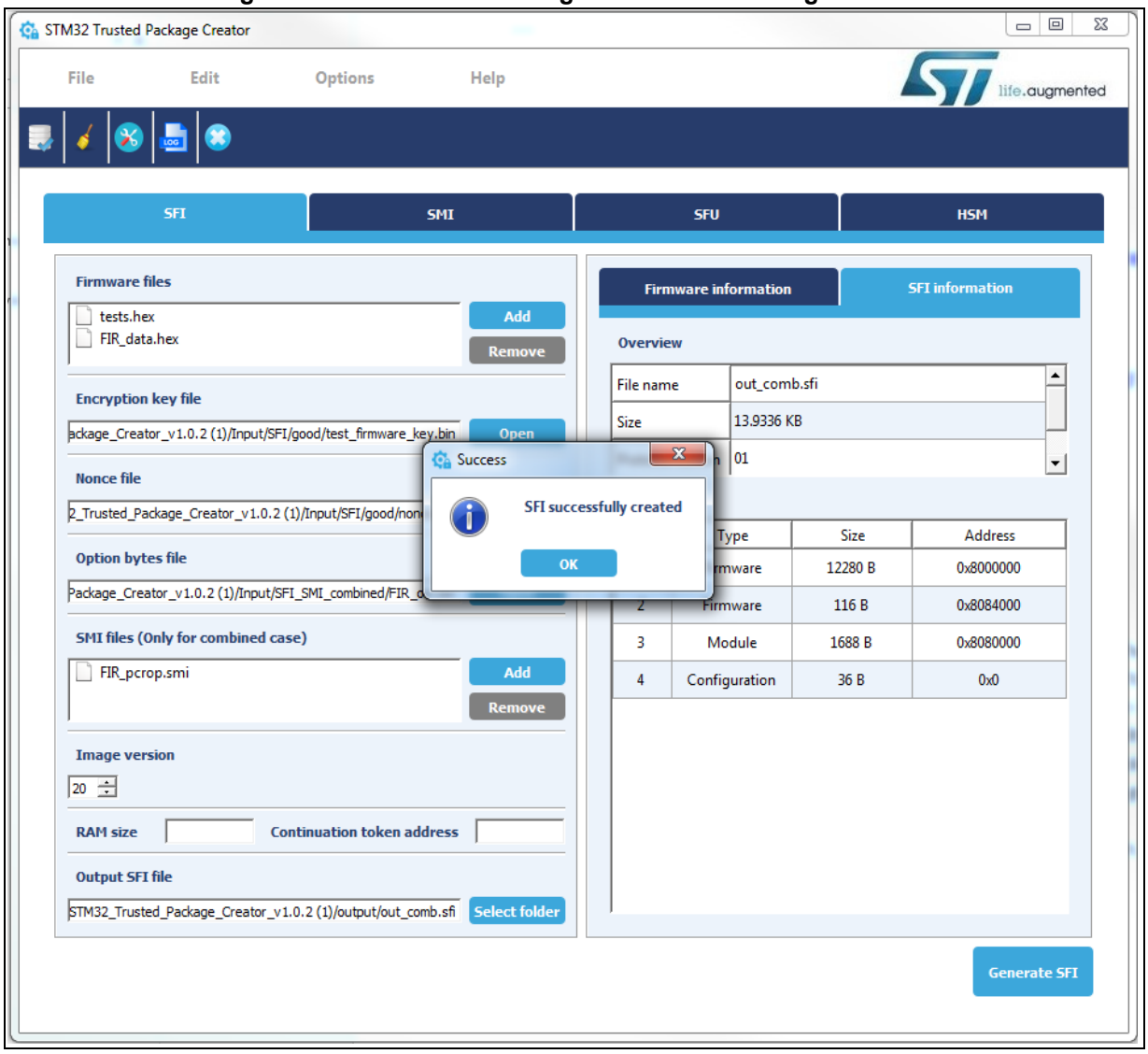
Note: STM32CubeProgrammer v2.8.0 and later provide one option byte file example for each product.
It is located in the directory: STM32CubeProgrammer\vx.x.x\bin\SFI_OB_CSV_FILES

The option bytes are described in the product reference manual.

In the case of customization of a provided example file, care must be taken not to change the number of rows, or their order.

Figure 98 shows the STPC GUI during combined SFI generation.

Figure 98. GUI of STPC during combined SFI-SMI generation



3. Programming input conditions are the same as for the SFI programming scenario (*Section 5.3.5: Performing HSM programming for license generation using STPC (CLI mode)*).
4. Perform the SFI install using the SWD/JTAG or a bootloader interface (here the SWD interface is used).

16.3.1 Using JTAG/SWD

Once all input conditions are respected, go to the "*stm32_programmer_package_v0.4.1/bin"* directory and launch the following command:

```
STM32_Programmer_CLI.exe -c port=swd mode=HOTPLUG -sfi
protocol=static "<local_path>/out_comb.sfi" "<local_path>/
<licenseSFI.bin>"
```

Once all input conditions are respected, go to the "*<STM32CubeProgrammer_package_path>/bin"* directory and launch the following command:

```
STM32_Programmer_CLI.exe -c port=swd mode=HOTPLUG -sfi
protocol=static "<local_path>/out_comb.sfi"
"<local_path>/<licenseSFI.bin>"
```

Figure 99: Combined SFI-SMI programming success using debug connection shows the combined SFI-SMI install trace success.

Figure 99. Combined SFI-SMI programming success using debug connection

16.3.2 How to test the combined SFI install success

The option bytes configuration must be modified as shown in *Figure 100: Option bytes after combined SFI-SMI installation success*.

- Third-party library module is programed into a PCROP area
- The SFI image is protected using RDP level1.

If a UART connection is available on the board used, open the "*Hercule.exe*" serial terminal available under the *"Tests*" directory, open the connection and on reset the dedicated `"printf"` packets appears.

Figure 100. Option bytes after combined SFI-SMI installation success

17 Example of SSP programming scenario for STM32MP1

17.1 Scenario overview

On each SSP install step, STM32 ecosystem tools are used to manage the secure programming and SSP flow.

Three main steps are done using SSP tools:

- Encrypted secret file generation with STM32 Trusted Package Creator
- HSM provisioning with STM32 Trusted Package Creator
- SSP procedure with STM32CubeProgrammer.

17.2 Hardware and software environment

The following prerequisites are needed for successful SSP programming:

- an STM32MP157F-DK2 board
- a Micro-B USB for DFU connection
- a PC running on either Windows®, Linux® Ubuntu® or Fedora®, or macOS®
- STM32 Trusted Package Creator v1.2.0 (or greater) package available from *www.st.com*
- STM32CubeProgrammer v2.5.0 (or greater) package available from *www.st.com*
- an HSMv2 card

Note: Refer to [4] or [5] for the supported operating systems and architectures.

17.3 Step-by-step execution

17.3.1 Building a secret file

A secret file must be created before SSP processing. This secret file must fit into the OTP area reserved for the customer. OTP memory is organized as 32-bit words.

On an STM32MP1 microprocessor:

- One OTP word is reserved for RMA password (unlock/relock): OTP 56.
- 37 free words are reserved for customer use. The secret size can be up to 148 bytes: OTP 59 to 95.

There is no tool or template to create this file. A 148-byte binary file must be used as the reference to construct the secret file.

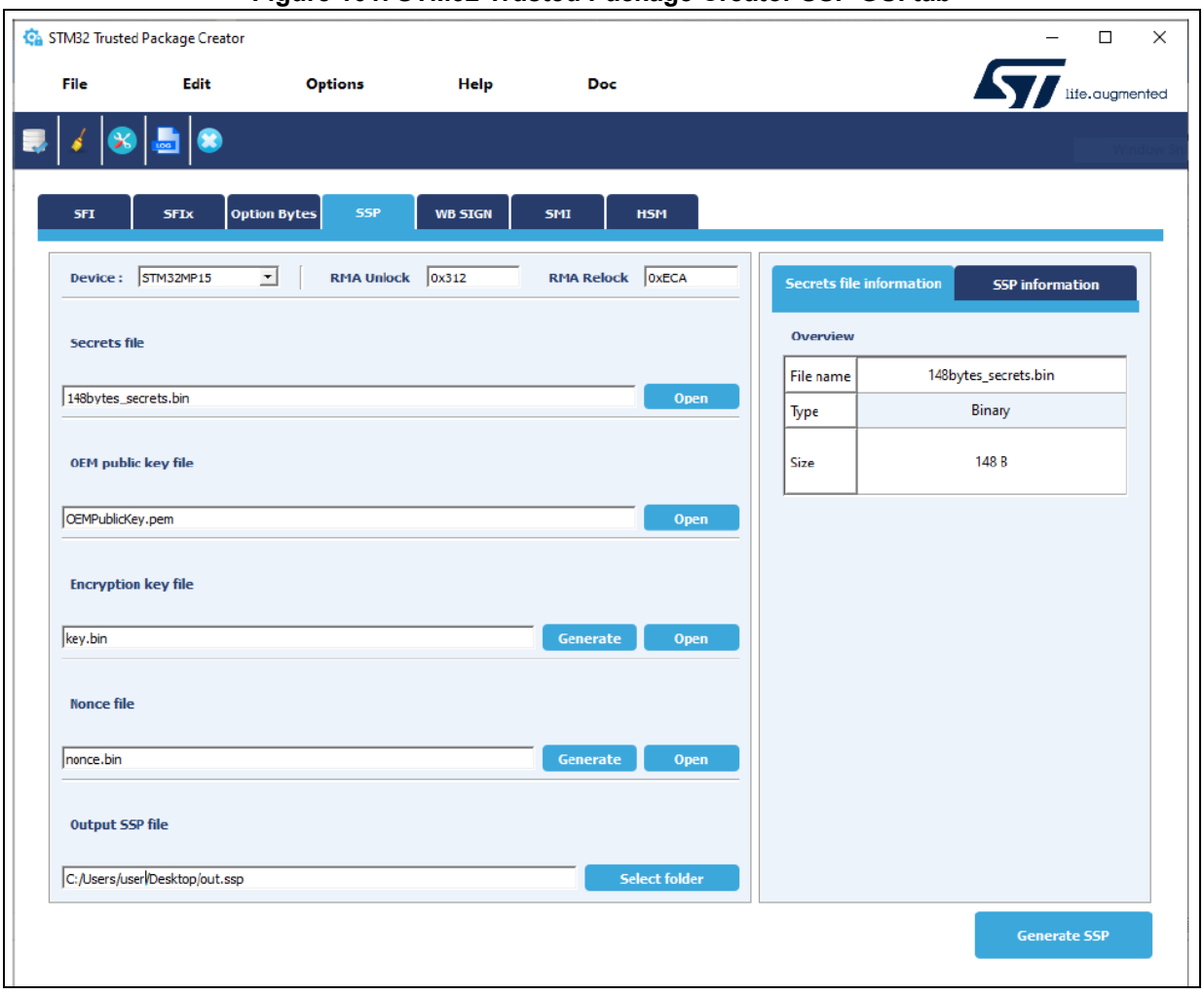
17.3.2 Performing the SSP generation (GUI mode)

For encryption with the STM32 Trusted Package Creator tool, the secret file is provided in BIN format in addition to the RMA password values.

An OEM public key, a 128-bit AES encryption key and a 96-bit nonce are also provided to the tool.

An *".ssp"* image is then generated (*out.ssp*).

Figure 101. STM32 Trusted Package Creator SSP GUI tab



17.3.3 Performing HSM programming for license generation using STPC (GUI mode)

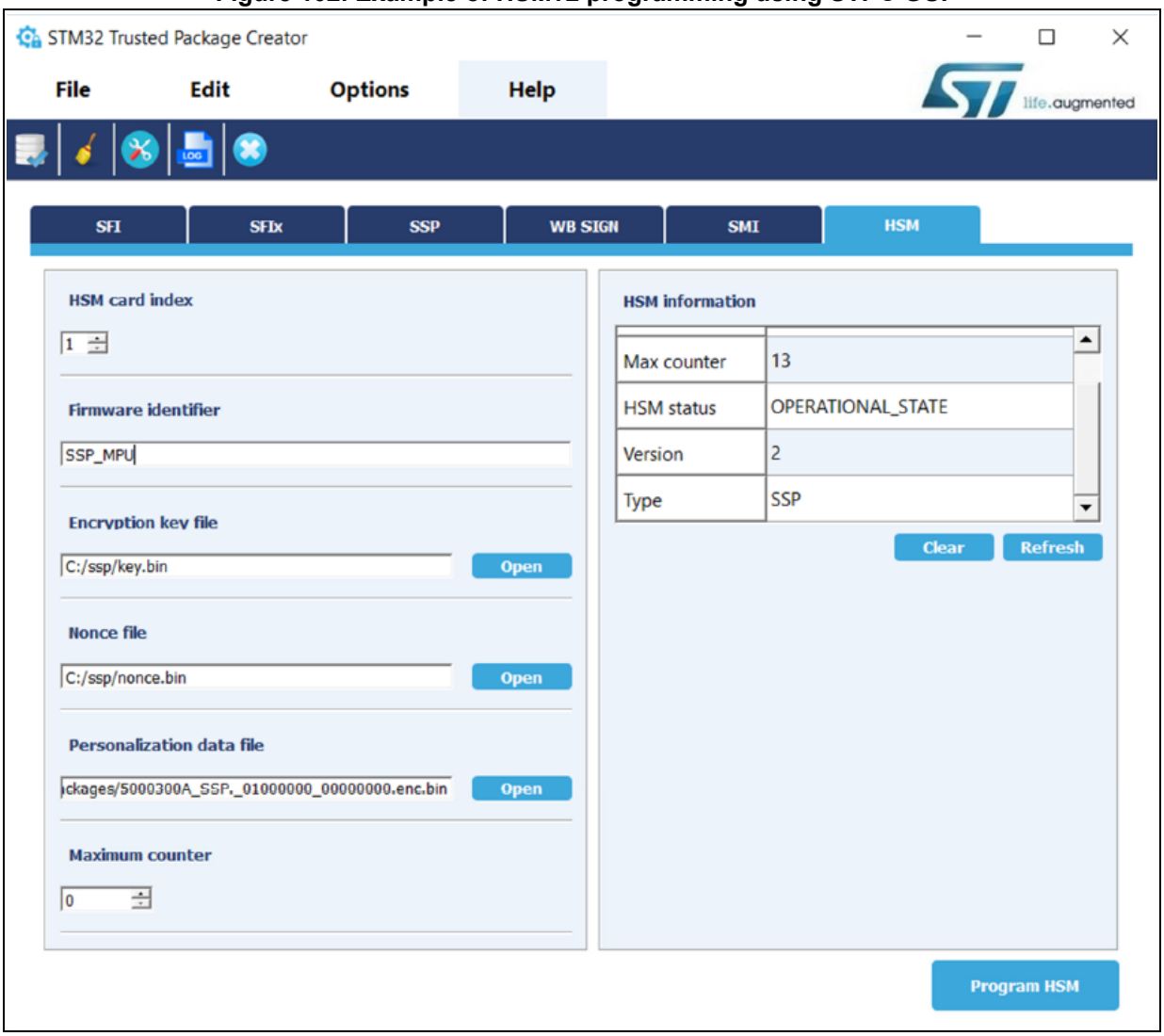
The OEM must provide a license generation tool to the programming house, to be used for license generation during the SSP install process. In this example, HSMs are used as license generation tools in the field.

See *Section 4.1.2: License mechanism* for HSM use and programming details.

This example uses HSM version 2. The HSM version can be identified before performing the programming operation by clicking the **Refresh** button to make the version number appear in the version field.

Note: HSM version 2 must be used for STM32 MPU devices.

Figure 102. Example of HSMv2 programming using STPC GUI



The STM32 Trusted Package Creator tool provides all personalization package files, ready to be used on SSP flow. To obtain all the supported packages, go to the “PersoPackages” directory residing in the tool’s install path. Each file name starts

with a number, which is the product ID of the device. The correct one must be selected.

17.3.4 SSP programming conditions

Before performing an SSP flow make sure that:

- only DFU or UART interfaces are used
- the chip supports security
- the SSP image is encrypted by the same key/nonce as used in the HSM provisioning step.
- There is an adequate Trusted Firmware-A file, which is previously signed and ready for SSP use via USB or UART interface.

17.3.5 Perform the SSP installation using STM32CubeProgrammer

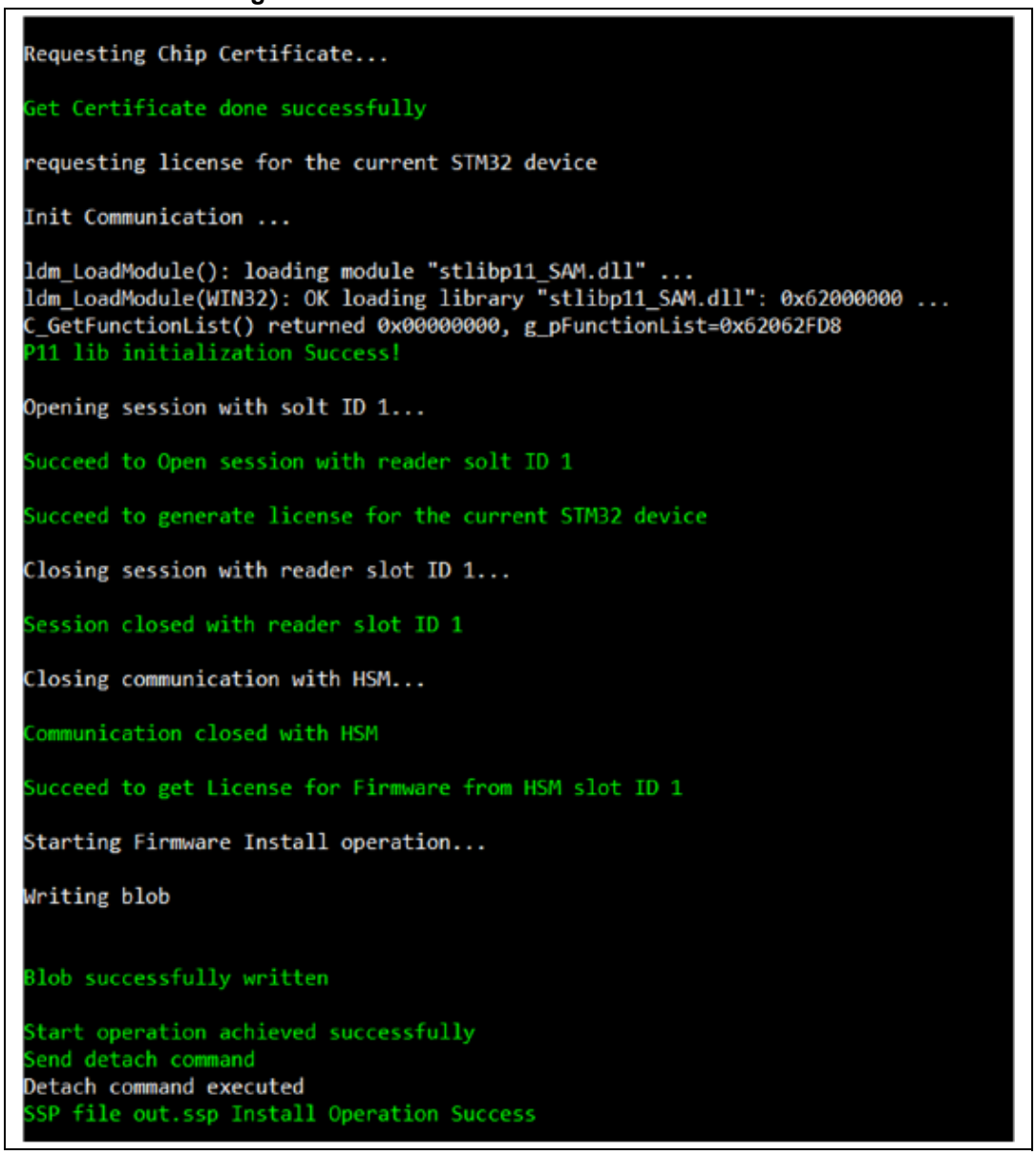
In this step, the STM32CubeProgrammer tool is used in CLI mode (the only mode available so far for secure programming) to program the SSP image already created with STM32 Trusted Package Creator. STM32CubeProgrammer supports communication with STMicroelectronics HSMs (hardware secure modules based on a smartcard) to generate a license for the connected STM32 MPU device during SSP install.

Example using USB DFU bootloader interface:

```
STM32_Programmer_CLI.exe -c port=usb1 -ssp "out.ssp" "tf-a-
ssp-stm32mp157f-dk2-trusted.stm32" hsm=1 slot=1
```

All SSP traces are shown on the output console (*Figure 103*).

Figure 103. STM32MP1 SSP installation success



18 Example of SSP-SFI programming scenario for STM32MP2

18.1 Scenario overview

On each SSP-SFI installation step, the STM32 ecosystem tools are used to manage the secure programming and the SSP flow.

Five main steps are done using SSP tools:

- Secrets generation with STM32 Trusted Package Creator
- Backup memory generation with STM32 Trusted Package Creator (optional)
- SSP-SFI file generation with STM32 Trusted Package Creator
- HSM provisioning with STM32 Trusted Package Creator
- SSP-SFI procedure with STM32CubeProgrammer.

18.2 Hardware and software environment

The following prerequisites are needed for a successful SSP-SFI programming:

- An STM32MP2 board
- A USB-C cable for DFU connection
- A PC running on either Windows®, Linux® or macOS®
- The STM32 Trusted Package Creator v2.17.0 (or greater) package available from *www.st.com*
- STM32CubeProgrammer v2.17.0 (or greater) package available from *www.st.com*
- An HSMv2 card

Note: Refer to [4] or [5] for the supported operating systems and architectures.

18.3 Step-by-step execution

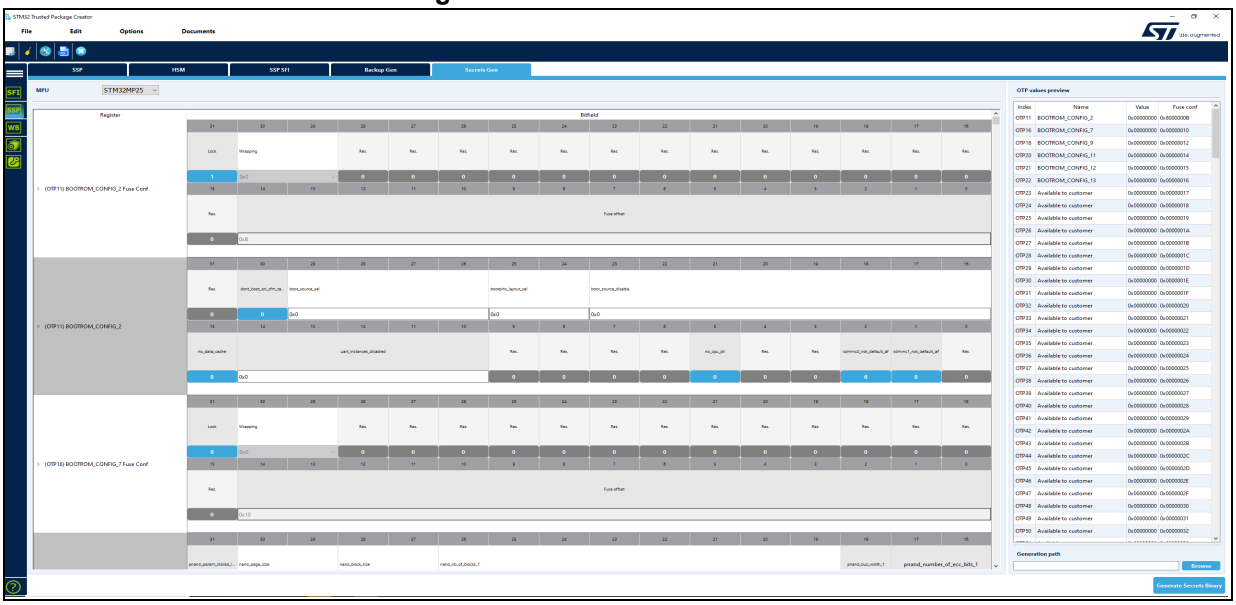
18.3.1 Building a secret file

A secret file must be created before the SSP processing. This secret file must fit into the OTP area reserved for the customer. OTP memory is organized as 32-bit words.

The STM32Trusted Package Creator offers a graphical interface to edit and customize the secrets binary.

From the SSP panel, select the "*Secrets Gen*" tab and start the editing.

Figure 104. Secrets Gen Window



18.3.2 Building a backup memory file

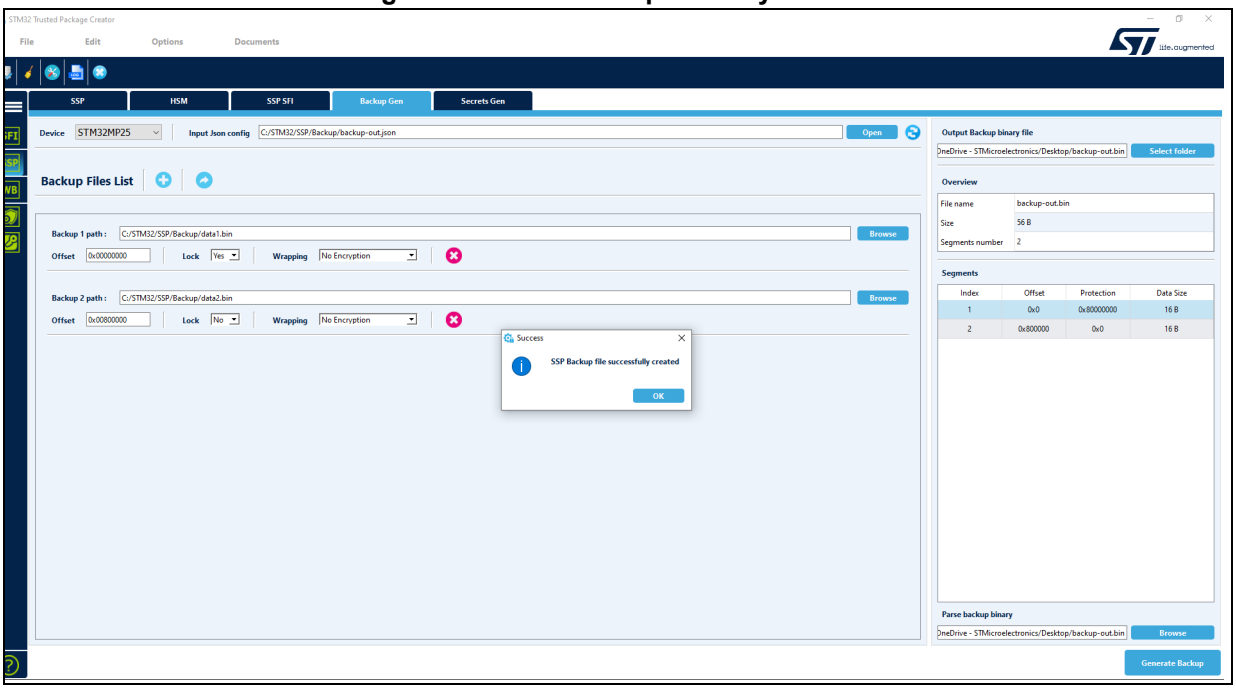
It is optional to integrate a backup file into an SSP-SFI image by specifying the backup input file.

The STM32Trusted Package Creator offers a graphical interface to edit and customize the secrets of the backup memory file.

From the SSP panel, select the "*Backup Gen"* tab and start the editing.

If all necessary elements are present,pressing the "*Generate Backup*" button initiates the preparation of the image. The resulting image is saved into a binary file, which is specified in the "*Output Backup binary file*" field.

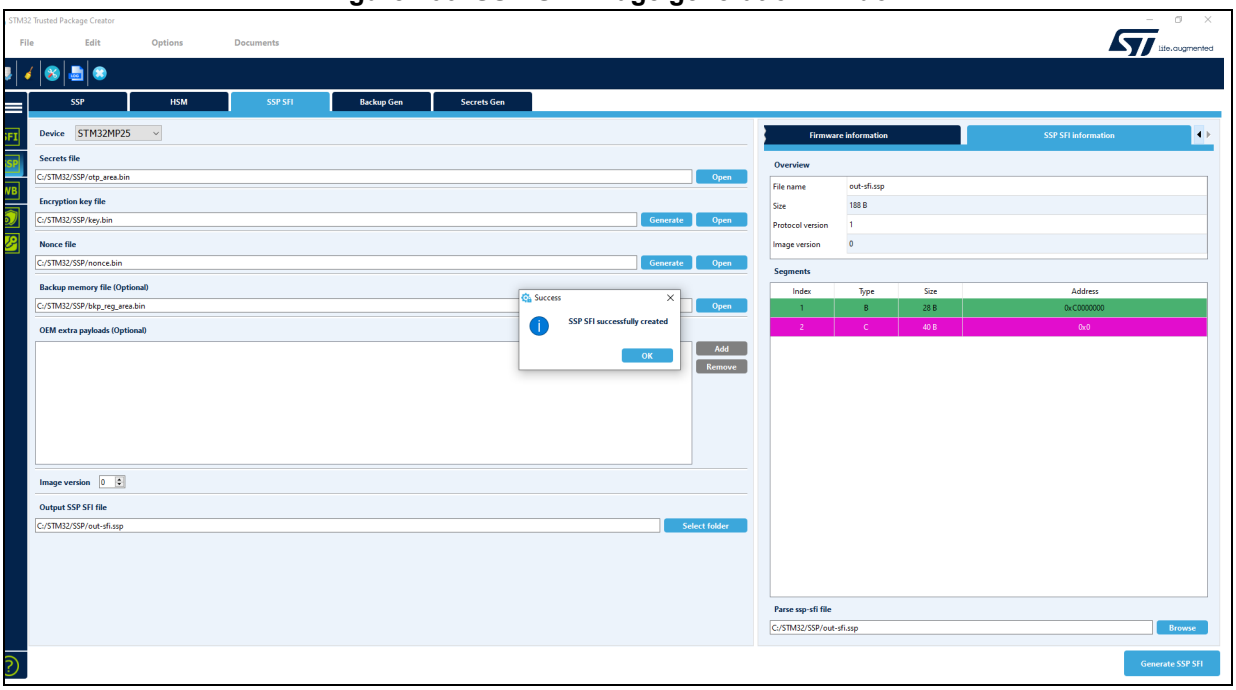
Figure 105. SSP Backup memory window



18.3.3 Performing the SSP-SFI generation (GUI mode)

The STM32Trusted Package Creator tool GUI presents an SSP-SFI tab located in the SSP panel to generate an SSP image in SFI format. The user must fill in the input fields with valid values.

Figure 106. SSP-SFI image generation window



18.3.4 Performing HSM programming (GUI mode)

Refer to *Section 17.3.3: Performing HSM programming for license generation using STPC (GUI mode)*.

18.3.5 SSP-SFI programming conditions

Before performing an SSP flow make sure that:

- Only DFU or UART interfaces are used.
- The chip supports security to deploy the SSP flow.
- The SSP image is encrypted by the same key/nonce that is used in the HSM provisioning step.
- A trusted RSSe SSP binary provided by STMicroelectronics is used.

18.3.6 Perform the SSP installation using STM32CubeProgrammer

In this step, the STM32CubeProgrammer tool is used in CLI mode (in a similar way the GUI mode with the Security window can be used) to program the SSP-SFI image already created with STM32 Trusted Package Creator.

The STM32CubeProgrammer supports the communication with STMicroelectronics HSMs (hardware secure modules based on a smartcard) to generate a license for the connected STM32MP2 device during the SSP installation.

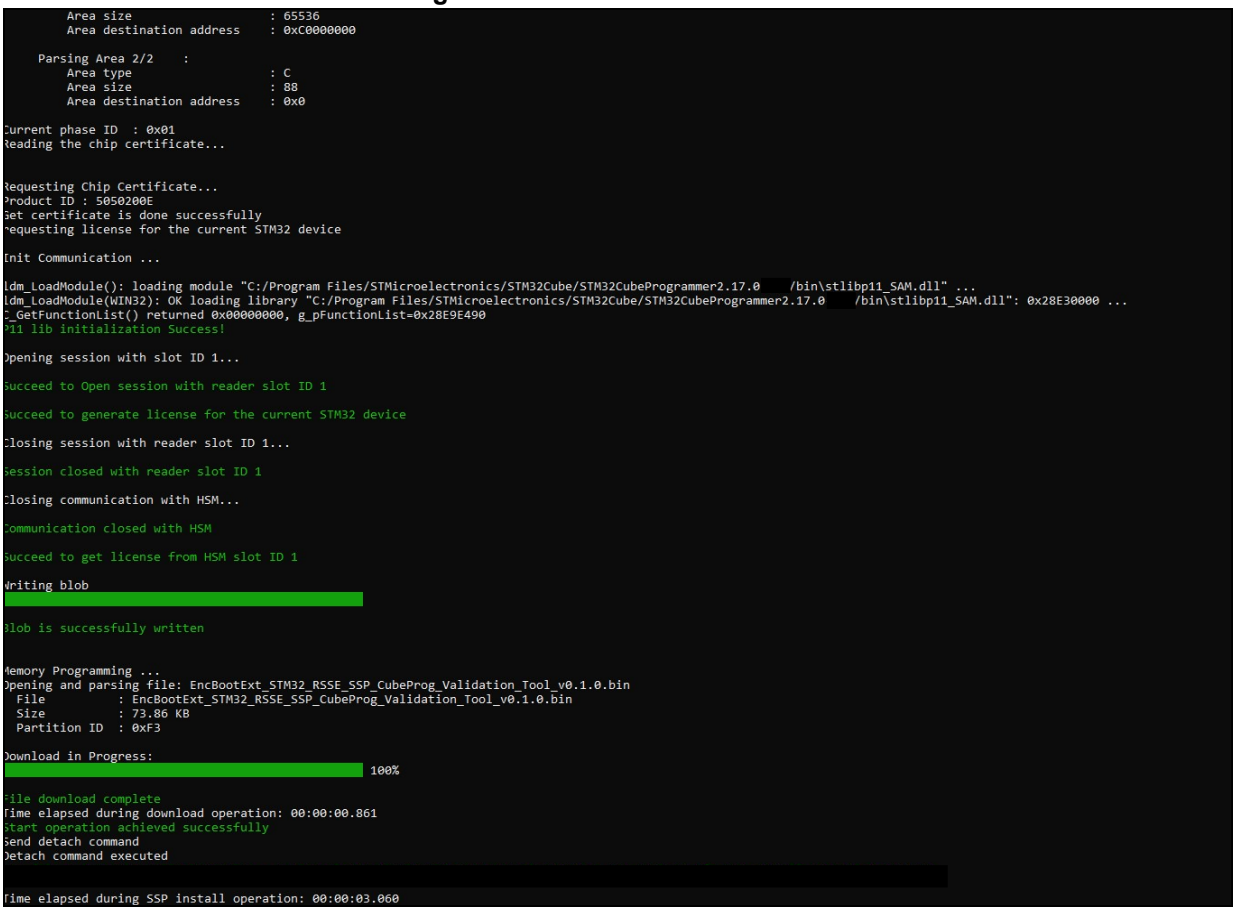
Example using USB DFU bootloader interface:

```
STM32_Programmer_CLI.exe -c port=usb1 -ssp "image.ssp"
"EncBootExt_STM32_RSSE_SSP.bin" hsm=1 slot=1
```

The file **EncBootExt_STM32_RSSE_SSP.bin** is located in the STM32CubeProgrammer install path under the /bin/RSSe/MP25 folder.

All the SSP traces are shown on the output console.

Figure 107. SSSP-SFI installation



19 Reference documents

Table 3. Document references

Reference	Document title
[1]	Application note *STM32 MCUs secure firmware install (SFI) overview* (AN4992), STMicroelectronics.
[2]	User manual *Hardware secure module (HSM) for STM32CubeProgrammer secure firmware install (SFI)* (UM2428), STMicroelectronics.
[3]	Application note *Overview of the secure secret provisioning (SSP) on STM32MP1 series* (AN5510), STMicroelectronics.
[4]	Release note *STM32CubeProgrammer release vx.y.z* (RN0109), STMicroelectronics.
[5]	User manual *STM32 Trusted Package Creator tool software description* (UM2238), STMicroelectronics.

20 Revision history

Table 4. Document revision history

Date	Revision	Changes
03-Aug-2018	1	Initial release.
18-Apr-2019	2	Updated publication scope from ‘ST restricted’ to ‘Public’.
16-Oct-2019	3	Updated: Section 4.1.2: License mechanism Section 5.3.4: Performing HSM programming for license generation using STPC (GUI mode) Figure 44: HSM programming GUI in the STPC tool (title caption) – Figure 54: Example of HSM programming using STPC GUI.
03-Feb-2020	4	Replaced occurrences of STM32L451CE with STM32L462CE in Section 4.2.1: Secure firmware installation using a bootloader interface flow. Updated document to cover secure programming with SFIx.
26-Feb-2020	5	Updated: Section 4.3.1: SFI/SFIx programming using JTAG/SWD flow Section 5.3.4: Performing HSM programming for license generation using STPC (GUI mode) Section 5.3.5: Performing HSM programming for license generation using STPC (CLI mode) Figure 72: SFIx installation success using SWD connection (1) Figure 75: SFIx installation success using SWD connection (4).
27-Jul-2020	6	Updated: Introduction Section 3.1: System requirements Added: Section 3.5: SSP generation process Section 3.6.3: Steps for SSP generation (CLI) Section 3.7.4: SSP generation using STPC in GUI mode Section 4.2.5: STM32CubeProgrammer for SSP via a bootloader interface – Section 12: Example of SSP programming scenario for STM32MP1.

Table 4. Document revision history (continued)

Date	Revision	Changes
19-Nov-2020	7	Updated: Introduction on cover page License mechanism general scheme HSM programming by OEM for license distribution Section 5.3.5: Performing HSM programming for license generation using STPC (CLI mode). Added: Section 4.4: Secure programming using bootloader interface (UART/I2C/SPI/USB) – Section 6: Example of SFI programming scenario for STM32WL.
29-Jun-2021	8	Updated: In the whole document, replaced STM32H7A/B by STM32H7A3/7B3 and STM32H7B0, STM32H72/3 by STM32H723/333 and STM32H725/335, STM32H7B board by STM32H7B3I-EVAL Replaced BL by bootloader. Section 3.2: SFI generation process: removed references to RSS. Section 4.1.2: License mechanism: removed Figure HSM programming toolchain. Section 4.2: Secure programming using a bootloader interface, Section 4.2.2: Secure module installation using a bootloader interface flow, Section 4.2.3: STM32CubeProgrammer for SFI using a bootloader interface Section 4.3.1: SFI/SFIx programming using JTAG/SWD flow and Section 4.3.2: SMI programming through JTAG/SWD flow. Section 4.4: Secure programming using bootloader interface (UART/I2C/SPI/USB) Example of SFI programming scenario/ Section 5.2: Hardware and software environment and Example of SFI programming scenario for STM32WL/ Section 6.2: Hardware and software environment: removed bootloader and RSS versions Section 5.3.5: Performing HSM programming for license generation using STPC (CLI mode): removed STM32L4 from the list of devices that support SFI via debug interface. Added: Support for STM32U5 Series. – Section 7: Example of SFI programming scenario for STM32U5.

Table 4. Document revision history (continued)

Date	Revision	Changes
02-Aug-2021	9	Added note about CSV file in Section 3.6.1: Steps for SFI generation (CLI) and Figure 27: Option bytes file example. Corrected binary file names in Section 4.4: Secure programming using bootloader interface (UART/I2C/SPI/USB). Section 3.6.1: Steps for SFI generation (CLI) Added note about option byte file example in: Section 3.7.1: SFI generation using STPC in GUI mode Section 5.3.3: Perform the SFI generation (GUI mode) Section 6.3.2: Perform the SFI generation (GUI mode) Section 7.3.2: Perform the SFI generation (GUI mode) Section 9.3.2: Perform the SFIx generation (GUI mode) Section 10.3.2: Perform the SFIx generation (GUI mode) Section 11.3: Step-by-step execution. Updated Corrected board name in Section 4.2: Secure programming using a bootloader interface. Corrected board name in Section 7.2: Hardware and software environment.
04-Mar-2022	10	Updated Section 3.3: SFIx generation process. Added: Section 5.3.2: Performing the option bytes file generation (GUI mode) – Section 5.3.8: SFI with Integrity check (for STM32H73).
29-Jun-2022	11	Updated: – Section 3.3: SFIx generation process – Section 4.2.3: STM32CubeProgrammer for SFI using a bootloader interface – Section 10.1: Scenario overview – Section 10.2: Hardware and software environment – Section 10.3.2: Perform the SFIx generation (GUI mode) STM32CubeProgrammer version, use cases 1 and 2 scope STM32L5, and added subsections for use cases 3 and 4 for STM32U5, listed below. – Figure 67: STPC GUI during SMI generation – Figure 88: STM32 Trusted Package Creator SSP GUI tab – Section 12.3.4: SSP programming conditions Added: – Use case 3: generation of SFIx without key area for STM32U5 – Figure : Use case 4: generation of SFIx with key area for STM32U5
25-Nov-2022	12	Updated Section 3.2: SFI generation process. Removed “multi install” from document.

Table 4. Document revision history (continued)

Date	Revision	Changes
24-Feb-2023	13	Updated: – Section 3.6: STM32 Trusted Package Creator tool in the command line interface – Section 3.6.1: Steps for SFI generation (CLI)
04-Aug-2023	14	Global document update, and compatibility with the STM32H5 series and extended STM32U5 series. Updated: – Figure 28: SFI generation example using an ELF file and the related command line example – Figure 60: STPC GUI showing the STPC GUI during the SFI generation – Figure 63: SFI installation via SWD execution command-line output – Figure 86: Successful SFIx generation use case 1 – Figure 87: Successful SFIx generation use case 2 – Figure 92: SFIx installation success using SWD connection (1) – Figure 93: SFIx installation success using SWD connection (2) – Figure 94: SFIx installation success using SWD connection (3) Removed: – Figure 83. SFIx installation success using SWD connection (4) – Figure 84. SFIx installation success using SWD connection (5) Added: – Chapter 9: Example of SFI programming scenario for STM32H5 – Chapter 14: Example of SFIx programming scenario for STM32H5 – Figure 89: Successful SFIx generation use case 3 for STM32U59xxx, STM32U5Axxx, STM32U5Fxxx, and STM32U5Gxxx – Figure 91: Successful SFIx generation use case 4 for STM32U59xxx, STM32U5Axxx, STM32U5Fxxx, and STM32U5Gxxx Minor text edits across the document.

Table 4. Document revision history (continued)

Date	Revision	Changes
22-Mar-2024	15	Added: – *Example of SFI programming scenario for STM32WBA5* – *Example of SFI programming scenario for STM32H7RS* Updated: – Updated the document title – *License mechanism* – *Perform the SFI generation (GUI mode)* – *Performing the SFI install using STM32CubeProgrammer*
24-Jun-2024	16	Added: – *Section 9: Example of SFIA programming scenario for STM32WBA5* – *Section 18: Example of SSP-SFI programming scenario for STM32MP2*