



# Ledger Nano X Security Target

*Release 1.2*

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### Security Target Identification

Identification	Ledger Nano X Security Target
Release	1.2
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### Security Target History

Release	Date	Author	Role	Comments
1.0	2019-05-20	Alain DESTRES	Security Certification Engineer	Initial Release
1.1	2019-06-07	Alain DESTRES	Security Certification Engineer	Add clarifications
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### Security Target Review

Date	Release	Reviewer	Role
2019-05-27	1.0	Charles GUILLEMET	Chief Security Officer
2019-06-10	1.1	Charles GUILLEMET	Chief Security Officer



## INTRODUCTION

### 1.1 Acronym

<b>AES</b>	<b>A</b> dvanced <b>E</b> ncryption <b>S</b> tandard
<b>API</b>	<b>A</b> pplication <b>P</b> rogramming <b>I</b> nterface
<b>ANSSI</b>	<b>A</b> gence <b>N</b> ationale de la <b>S</b> écurité des <b>S</b> ystèmes d' <b>I</b> nformation
<b>BIP</b>	<b>B</b> itcoin <b>I</b> mprovement <b>P</b> roposal
<b>BOLOS</b>	<b>B</b> lockchain <b>O</b> pen <b>L</b> edger <b>O</b> perating <b>S</b> ystem
<b>BLE</b>	<b>B</b> luetooth <b>L</b> ow <b>E</b> nergy
<b>BSI</b>	<b>B</b> undesamt für <b>S</b> icherheit in der <b>I</b> nformationstechnik
<b>CC</b>	<b>C</b> ommon <b>C</b> riteria
<b>DES</b>	<b>D</b> ata <b>E</b> ncryption <b>S</b> tandard
<b>EC</b>	<b>E</b> lliptic <b>C</b> urve
<b>ECDSA</b>	<b>E</b> lliptic <b>C</b> urve <b>D</b> igital <b>S</b> ignature <b>A</b> lgorithm
<b>ECDH</b>	<b>E</b> lliptic- <b>C</b> urve <b>D</b> iffie- <b>H</b> ellman
<b>FIDO</b>	<b>F</b> ast <b>I</b> Dentity <b>O</b> nline
<b>GPIO</b>	<b>G</b> eneral <b>P</b> urpose <b>I</b> nput <b>O</b> utput
<b>GUI</b>	<b>G</b> raphical <b>U</b> ser <b>I</b> nterface
<b>HSM</b>	<b>H</b> ardware <b>S</b> ecurity <b>M</b> odule
<b>HTTPS</b>	<b>H</b> yper <b>T</b> ext <b>T</b> ransfert <b>P</b> rotocol <b>S</b> ecure
<b>IC</b>	<b>I</b> ntegrated <b>C</b> ircuit
<b>MCU</b>	<b>M</b> icro <b>C</b> ontroller <b>U</b> nit
<b>Nonce</b>	<b>N</b> umber used <b>once</b>
<b>OLED</b>	<b>O</b> rganic <b>L</b> ight <b>E</b> mitting <b>D</b> iode
<b>PIN</b>	<b>P</b> ersonnal <b>I</b> dentification <b>N</b> umber
<b>PKI</b>	<b>P</b> ublic <b>K</b> ey <b>I</b> nfrastucture
<b>PSD</b>	<b>P</b> ersonnal <b>S</b> ecurity <b>D</b> evice (synonym for the Ledger Nano X)
<b>RGS</b>	<b>R</b> éférentiel <b>G</b> énéral de <b>S</b> écurité
<b>RSA</b>	<b>R</b> ivest <b>S</b> hamir <b>A</b> delman
<b>SE</b>	<b>S</b> ecure <b>E</b> lement
<b>SEPROXYHAL</b>	<b>S</b> ecure <b>E</b> lement <b>PROXY</b> <b>H</b> ardware <b>A</b> btract <b>L</b> ayer
<b>SEC</b>	<b>S</b> tandards for <b>E</b> fficient <b>C</b> ryptography
<b>SF</b>	<b>S</b> ecurity <b>F</b> unctions
<b>SHA</b>	<b>S</b> ecure <b>H</b> ash <b>A</b> lgorithm
<b>SPI</b>	<b>S</b> erial <b>P</b> eripheral <b>I</b> nterface
<b>ToE</b>	<b>T</b> arget <b>of</b> <b>E</b> valuation
<b>TRNG</b>	<b>T</b> rue <b>R</b> andom <b>N</b> umber <b>G</b> enerator
<b>U2F</b>	<b>U</b> niversal <b>2</b> ( <b>S</b> econd) <b>F</b> actor

Continued on next page

Table 1 – continued from previous page

<b>UM</b>	<b>User Manual</b>
<b>USB</b>	<b>Universal Serial Bus</b>
<b>UX</b>	<b>User eXperience</b>



## 1.2 Terminology

Adversary	Person trying to compromise the Ledger Nano X
Attestation	One of the core security features developed by Ledger to prove by cryptographic means the Ledger Nano X is genuine. The attestation mechanism implementation relies on a set of cryptographic protocols based on Elliptic Curve.
BOLOS	The open native Operating System developed by Ledger. One of BOLOS's features is to manage Apps (delete, install) after issuance on the field. This capability offering flexibility allows to enrich the Ledger Nano X experience.
Blockchain	A list of blocks which are all linked together and validated via a consensus mechanism
Companion App	Ledger Live (or third-party like Mycelium, MyEtherWallet, Coinomi) running in the Host to support the Ledger Nano X services. The Companion Apps can be either desktop/laptop/tablet/smartphone-oriented.
Command/Response	The Host and the Ledger Nano X exchanges through a set of commands/responses (e.g. VALIDATE_TARGET_ID, INITIALIZE_AUTHENTICATION, VALIDATE_CERTIFICATE_LAST)
Consent	The Ledger Nano X security design is strengthened by the End-User. As soon as a sensitive operation is required, the End-User must confirm the operation via the 2 buttons
Crypto Asset	One of the digital asset whose value is saved on the blockchain
Crypto Asset address	It is a public address provided by the End-User to transfer crypto assets. This address is derived from the Public Key.
Device App	Software running in the SE on top of the BOLOS. These device Apps can be either developed by Ledger or a third-party. A Device App offers a service.
End-User	Owner of a Ledger Nano X. End-User is defined by general public.
Firmware	Software running on top of an hardware (both MCU -SEPROXYHAL- and SE -BOLOS-)
Hardware Wallet	Physical wallet leveraging an hardware to secure sensitive assets and sensitive operations
Host	End-User machine (desktop/laptop/tablet/smartphone) running a Companion App
Key Pair	Includes both a Private Key and a Public Key
Nano X	State-of-the-art device designed, developed and manufactured by Ledger offering a set of secure services. In this Security Target, <b>Personal Security Device (PSD)</b> means Nano X.
NESCRYPT	Coprocessor for public key cryptography algorithm embedded in [ST33J2M0]. For instance, Ledger leverages NESCRYPT to perform some operations on the elliptic curve.
On boarding	Set of operations (seed generation, PIN configuration. . . ) performed during the initialization of the Ledger Nano X
Private Key	Set of secret data involved for signing a transaction under the End-User Control
Public Key	Set of data, generated from the private key, distributed and used to verify the signature
SE Firmware	The SE firmware is composed of: BOLOS OS & BOLOS UX Dashboard Device App
secp256k1	Elliptic Curve defined by Certicom Research in Standards for Efficient Cryptography ([SEC_2])
Secure Element	A Secure Element is composed of a secure IC and a Secure Software
Secure IC	It is an hardware embedding a set of physical security countermeasures. The Secure IC included in the Ledger Nano X is Common Criteria certified [ST33J2M0CCCertificate].
Secure Software	It is a software embedding a set of logical security countermeasures. In the Ledger Nano X, Ledger has developed BOLOS and a set of Device Apps for the Ledger Nano X.
Seed	Set of data located at the top of a hierarchical tree
SEPROXYHAL	Firmware name running on top of [STM32WB55CG]
Service	Crypto asset management, Password Manager, Second Factor Authentication are typical services offered by the Ledger Nano X
Wallet	Solution to manage your crypto assets (hardware wallet, software wallet, paper wallet. . . )
Wallet Type	There are 2 types of wallet: non-deterministic wallet and deterministic wallet

## 1.3 References

### 1.3.1 ANSSI

References	Title	Version	Date
[RGS_B1]	Règles et recommandations concernant le choix et le dimensionnement des mécanismes cryptographiques	2.03	2014-02-21
[RGS_B2]	Règles et recommandations concernant la gestion des clés utilisées dans les mécanismes cryptographiques	2.0	2012-06-08
[RGS_B3]	Règles et recommandations concernant les mécanismes d'authentification	1.0	2010-01-13
[ST33_CC]	Rapport de maintenance ST33J2M0 Référence: ANSSI-CC-2017/50-M01 Evaluation Assurance Level: 5+ [ST33J2M0CCCertificate]		2019-04-18

### 1.3.2 Bitcoin Improvement Proposal

References	Title	Date
[BIP32]	Hierarchical Deterministic wallets	2012-02-11
[BIP39]	Mnemonic code for generating deterministic keys	2013-09-10
[BIP44]	Multi-Account Hierarchy for deterministic Wallets	2014-04-24

### 1.3.3 Ledger

References	Title	Version	Date
[UM]	User Manual - Ledger Nano X [Ledger_Nano_X_User_Manual]	1.3	2019-06-06

### 1.3.4 Certicom Research

References	Title	Version	Date
[SEC_2]	Certicom Research Standards for Efficient Cryptography SEC 2: Recommended Elliptic Curve Domain Parameters	2.0	2010-01-27

### 1.3.5 Federal Office for Information Security (BSI)

References	Title	Version	Date
[AIS31]	Functionality classes and evaluation methodology for physical random number generators	1	2001-09-25

### 1.3.6 STMicroelectronics Main Hardware

Type	Reference	Role
SE	[ST33J2M0]	Main Hardware offering an EAL 5+ security level as stated in [ST33J2M0CCCertificate]
MCU	[STM32WB55CG]	Supporting Hardware

## 1.4 BOLOS Python Loader

Ledger has developed a dedicated tool, called BOLOS Python Loader, to communicate with the Ledger Nano X. This tool allows to perform a set of functions. Some of them are:

1. checkGenuine

This script, which can be performed offline, achieves a mutual authentication between the Ledger HSM and the PSD. Firstly, the PSD ensures that the HSM is genuine, then the HSM ensures that the PSD is genuine.

2. genCAPair

This script generates a Certification Authority key pair (elliptic curve secp256k1) that will be used to perform a mutual authentication.

3. deleteApp / listApps / signApp

As Ledger offers the opportunity to develop some Device Apps, these scripts aim at managing the Apps developed by a third-party.

All the functions and further details regarding the BOLOS Python Loader can be found:

1. [Python\_Loader\_Installation]
2. [Python\_Loader\_Exploitation]

Note Ledger has also developed another tool, labelled [LedgerCtl], addressing the same set of features.

## 1.5 Ledger Technology Details

Some additional technical details regarding the technology created by Ledger can be found in the following list:

1. [Ledger]
2. [Readthedocs]
3. [GitHubLedgerHQ]



## LEDGER NANO X

### 2.1 Operational Environment

Ledger offers a full ecosystem to interface with the dedicated web services, offering a smooth User Experience:

1. The Ledger's secure servers (based on HSM technology) ensure the Ledger Nano X is a genuine one, proving that the Ledger Nano X is issued by Ledger
2. The Companion App, optional according to the use case, shares the account details and connects to the corresponding blockchain network
3. The Ledger Nano X device is leveraged to perform sensitive operations (e.g. generating the seed, signing transactions, submitting passwords)

The diagram below illustrates the main interactions between elements when the Companion App is required:

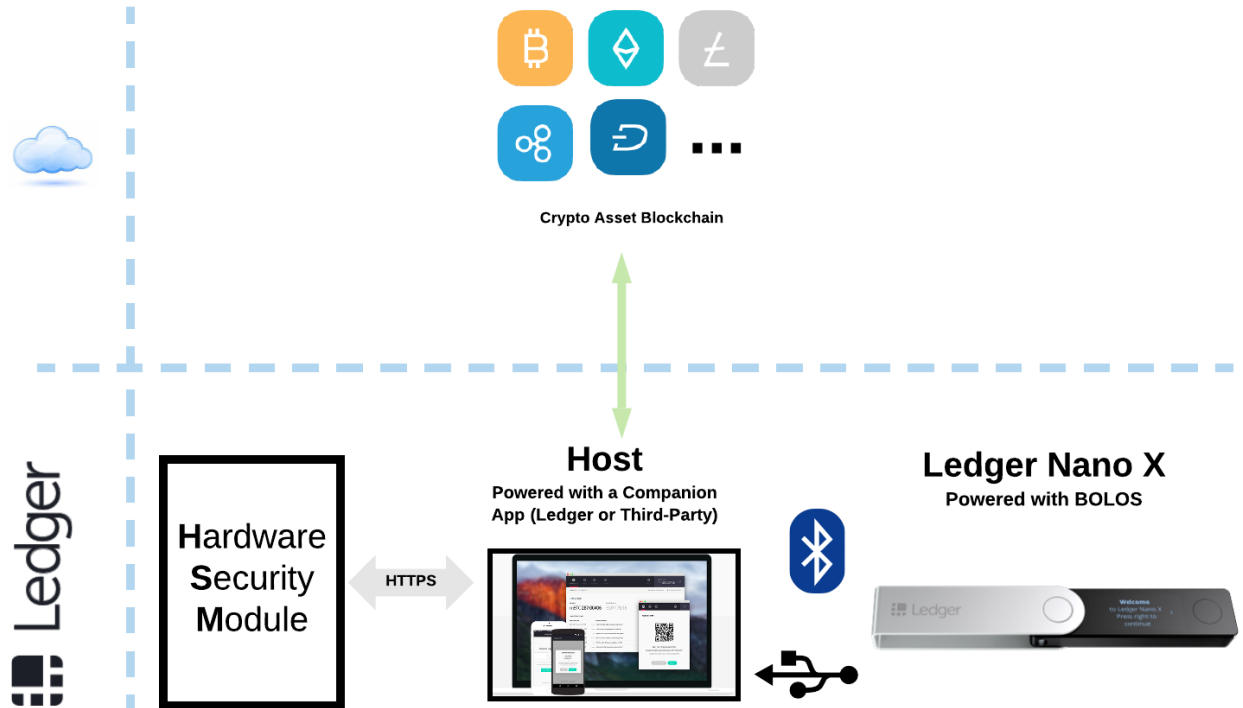


Fig. 1: Environment WITH a Companion App

The following diagram illustrates the main interactions between elements when the Companion App is not required:

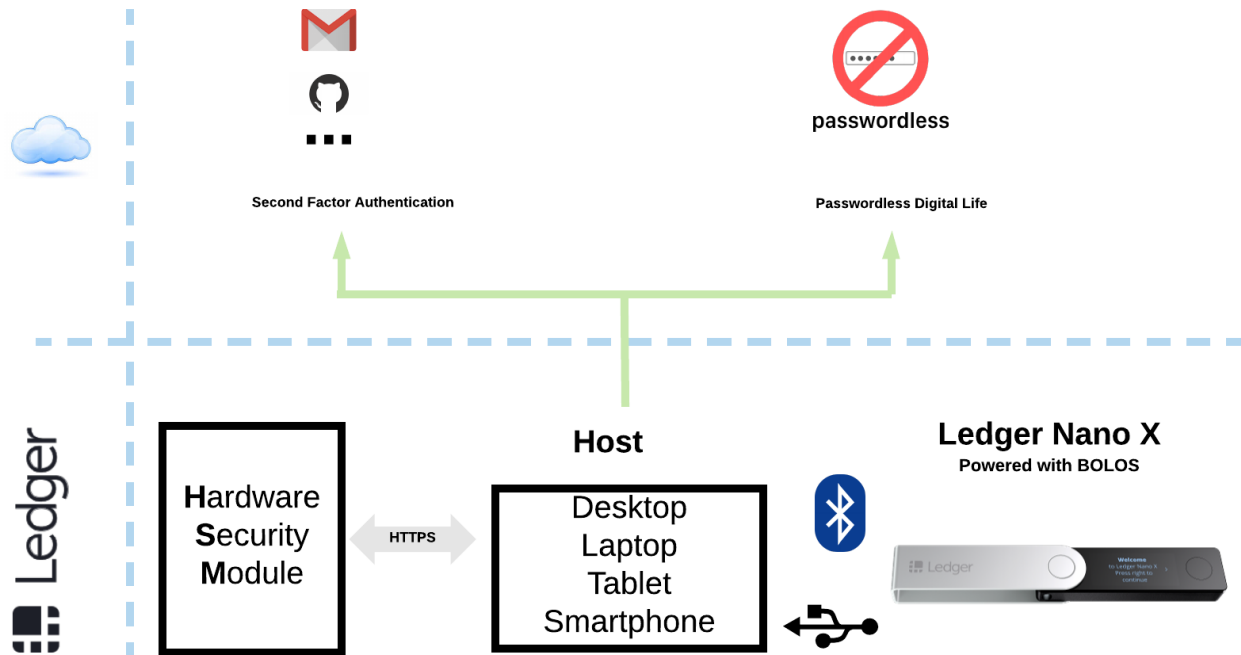


Fig. 2: Environment WITHOUT a Companion App

Thus, according to the use case, the End-User interacts with the:

1. Ledger Nano X (managing sensitive operations)
2. Companion App (processing non-sensitive operations) if required

## 2.2 Features

The Ledger Nano X supports the following features:

1. Multi-services: Hardware Wallet, Cryptographic Platform, Password Manager, Second Factor authenticator (FIDO)
2. Comply with several cryptocurrencies: Bitcoin, Bitcoin Cash, Bitcoin Gold, Ethereum, Ethereum Classic, Ethereum tokens...
3. USB connectivity
4. BLE v5.0 connectivity
5. Open Source Device App: all Device Apps developed by Ledger can be reviewed and verified by End-Users (e.g. Bitcoin, Ethereum)
6. Developer friendly: develop a Device App and then install it on the Ledger Nano X
7. Comply with the main BIP standards: [BIP32], [BIP39] and [BIP44]
8. Multi-platform: Windows (7+), Mac (10.9+), Linux or Chrome OS
9. **OLED screen: to verify the transaction data (amount, address)**
10. **Buttons: used to get the End-User's consent relative to sensitive operations like unlocking the device or processing a transaction**

11. **PIN: to unlock the Ledger Nano X**
12. **Plausible deniability: an additional PIN linked to a passphrase can be defined to create an hidden account**
13. **Genuine PSD: cryptographic attestation mechanisms ensuring that the Ledger Nano X is a genuine one**
14. **Post-issuance capability: all piece of software (MCU Firmware, SE Firmware, Device Apps) can be securely updated**

Bold features are included in the security scope and addressed by dedicated security functions. The Ledger's security model is based on the Secure Element technology and the embedded software developed by Ledger. In other words, the compromission of the connectivity (either USB or BLE) does not compromise the PSD.

## 2.3 Services

Services are not included in the security scope. These services are not addressed in the scope because they are all protected by the End-User's PIN. Indeed, the Ledger Nano X requires the End-User's PIN unlocking then all services listed in the following sections. Thus, even if the services are out of scope, the secret data belonging to services are properly protected through the PIN.

### 2.3.1 Hardware Wallet Service

The wallet is the main service.

It is the combination of the following two elements that creates an operational wallet:

1. Companion App executed on the Host
2. Ledger Nano X with the dedicated crypto asset application installed and currently selected. The Ledger Nano X acts as a secure gateway to the blockchain technology.

This wallet service managing crypto assets is in charge of:

1. Managing the balance (Companion App)
2. Handling one or several accounts (Companion App)
3. Supporting one or several crypto assets: Bitcoin, Bitcoin Cash, Bitcoin Gold, Ethereum, Ethereum Classic... (Companion App & Ledger Nano X)
4. Processing transactions: receive & perform payments (Companion App & Ledger Nano X)

If one of these elements is removed, no transaction can be processed. The Host performs no security operations. All sensitive operations (for instance signing a transaction, confirming the amount of the transaction, confirming the recipient's address) are directly performed with the Ledger Nano X based on the Secure Element technology. The security model designed by Ledger relies on the Ledger Nano X including not only a certified secure IC [ST33J2M0CCCertificate] but also a secure software developed by Ledger.

### 2.3.2 Cryptographic Platform Service

The Ledger Nano X, considered as a cryptographic embedded platform, supports several cryptographic primitives as listed below (not limited to):

1. Symmetric cryptography: DES/3DES, AES
2. Asymmetric cryptography: RSA (key size: 1024, 2048, 3072, 4096 bits), EC (brainpool, SECP and ANSSI)
3. Secure Hash: SHA224, SHA256, SHA384, SHA512, SHA3, Blake, Grøstl

### 2.3.3 Password Manager Service

A Device App manages all your passwords making the connection step easier for the End-User.

### 2.3.4 FIDO Service

The FIDO U2F Device App is a two-factor authentication method specified by the FIDO Alliance. It is compliant with several web services, like Facebook, Dashlane, Gmail, Dropbox, GitHub, etc.

For each of these web services, the End-User needs to set up the security parameters of the account to register the Ledger Nano X as a second factor security key to authenticate on it. This second factor of verification will improve the security of your log in processes, as the End-User will be first required the credentials (login/password) followed by the second factor via the Ledger Nano X.

### 2.3.5 Additional Innovative Services

As the Ledger's ecosystem is developer-friendly, a third-party can develop a Device App to build an innovative and useful service. This flexible approach is possible thanks to BOLOS acting as an Open Platform.

## 2.4 Dual-Chip Architecture

The Ledger Nano X is based on an architecture leveraging two hardware:

1. a generic MCU: [STM32WB55CG]
2. a Secure Element: [ST33J2M0]

The [STM32WB55CG] can be considered as a supporting hardware and is in charge of:

1. Communicating with the Host via either USB or BLE v5.0
2. Monitoring the battery state
3. Handling the battery management
4. Communicating with the SE

The [ST33J2M0], as it belongs to the Secure Element Technology and is Common Criteria certified (refer to [ST33J2M0CCCertificate] to get further details), ensures all sensitive operations and is in charge of (but not limited to):

1. Generating the seed
2. Deriving the corresponding Key Pair
3. Signing transactions
4. Communicating with the MCU
5. Driving the screen
6. Receiving the notifications from the buttons

Note that Ledger Nano X can be used without a Companion App. Indeed, both Password Manager and FIDO Device Apps directly connect to the web service without a Companion App.

The Ledger Nano X relies on the Secure Element technology addressing the security issues linked to the storage and manipulation of secret keys. The Secure Element technology is leveraged in sensitive applications: for instance



banking card, passport, driving licence. The PSD also uses this Secure Element technology to protect properly the End-User’s assets.

The Ledger Nano X is a secure hardware wallet thanks to the proper exploitation of the Secure Element technology. It can be used for instance in relation with a Companion App running on top of the Host as illustrated by the following diagram:

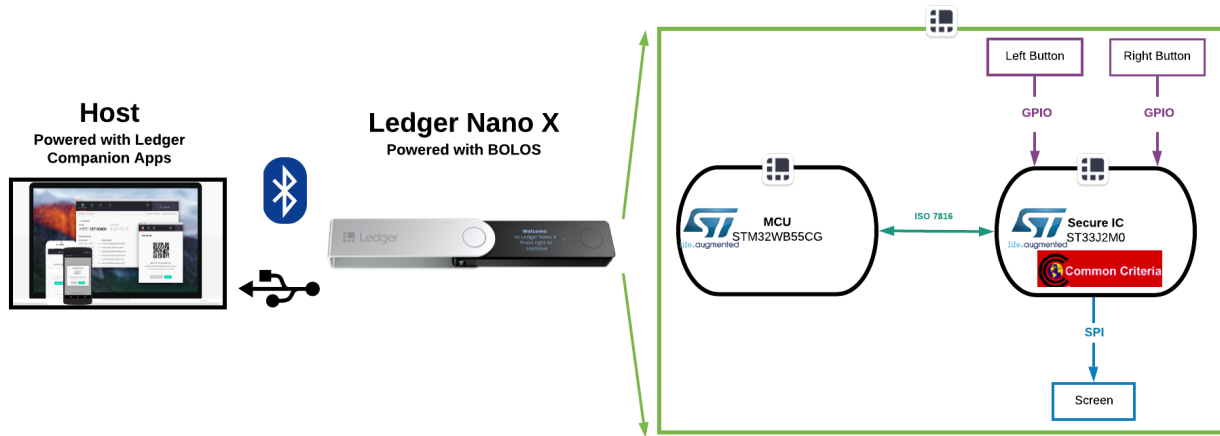


Fig. 3: Zoom on the Ledger Nano X

Besides, the End-User actively participates in the security: all sensitive operations must get the End-User’s consent (PIN validation, transaction confirmation) achieved via the screen and buttons.

One of the main advantages of the dual-chip architecture is the fact that the environment interacting with the Ledger Nano X can be hacked without compromising the overall security. For instance, if the Host is compromised, it cannot introduce a security breach in the Ledger Nano X. The security model defined by Ledger is that only the Ledger Nano X can be trusted. Thus, this solution is resistant against threats like malware proof.

## 2.5 Identification

The following table identifies the Ledger Nano X:

<b>Developer name</b>	Ledger, 1 rue du Mail, 75002 Paris
<b>Visit our website</b>	<a href="http://www.ledger.com">www.ledger.com</a>
<b>Product Type</b>	Personal Security Device
<b>Product Category</b>	Hardware and Embedded Software
<b>Product name</b>	Ledger Nano X
<b>Reference</b>	2C970004
<b>SE Firmware Version (BOLOS)</b>	1.2.5-1 [ST33J2M0]
<b>MCU Firmware Version (SEPROXYHAL)</b>	2.8 [STM32WB55CG]

The product identification can be directly processed by the End-User on the Ledger Nano X. The following steps must be performed:

1. Power on the Ledger Nano X
2. Enter and validate the PIN
3. Access to the **Control Center** menu by holding both buttons during 3 seconds
4. Select **Settings** and press both buttons

5. Select **General** and press both buttons
6. Select **Firmware version** and press both buttons
7. Retrieve SE Firmware version
8. Retrieve MCU Firmware version
9. Verify that two versions (Secure Element and MCU) displayed on the screen are identical to the ones identified in the previous table

## 2.6 Target of Evaluation

The Personal Security Device is an embedded platform processing securely sensitive services. The PSD includes a set of core security mechanisms (TRNG, End-User verification via the enrolled PIN, attestation mechanism, post-issuance capability). These security mechanisms combined with a simplified User Experience makes the PSD usage secured and simple.

The security model created by Ledger is based on the Secure Element technology. This Secure Element embeds a set of hardware security countermeasures (for instance active shield, monitoring of environmental parameters, True Random Number Generator [AIS-31] compliant).

Nevertheless, in order to get a product resistant against high attack potential, Ledger has also implemented a set of software security countermeasures. It is the composition of hardware security mechanisms (provided by the Secure IC) and the software security mechanisms (provided by Ledger) which make the Ledger Nano X resistant against sophisticated attacks.

The Target of Evaluation, focused on the Ledger Nano X, is identified in the following diagram:

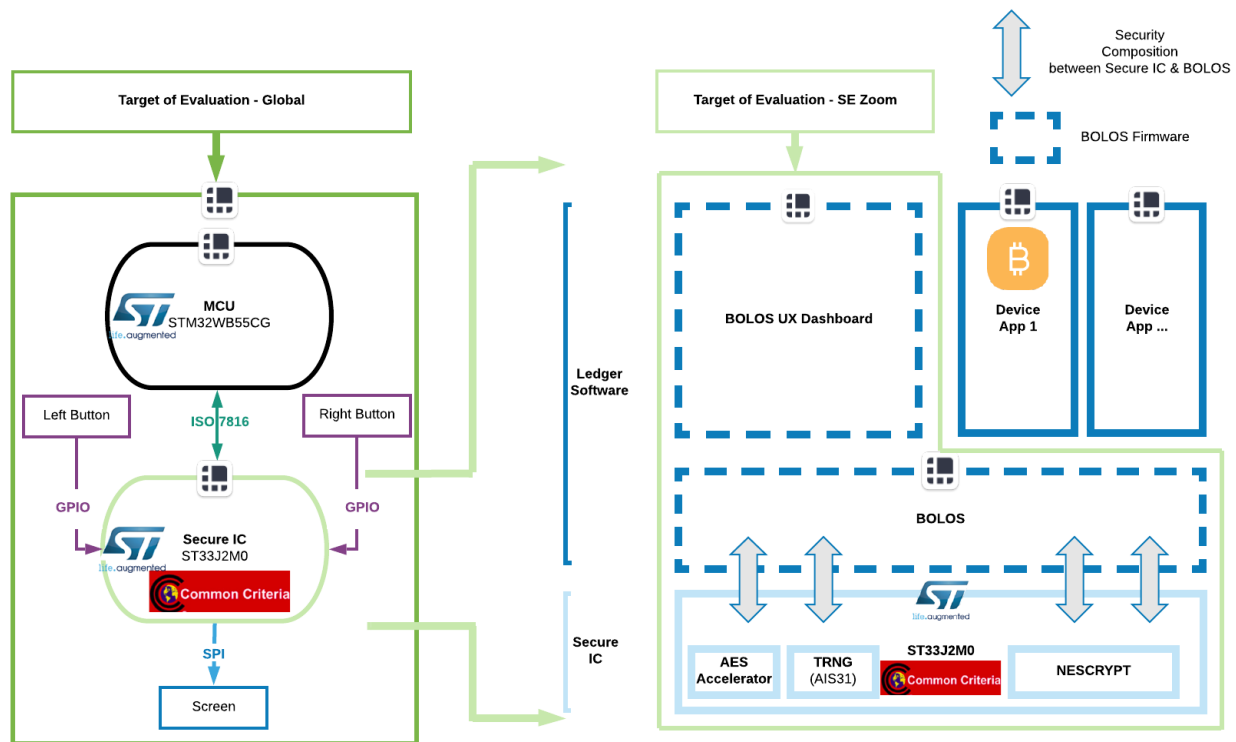


Fig. 4: Target of Evaluation including a zoom on the SE

The ToE includes:

1. **Physical elements**
  - (a) Two buttons
  - (b) One screen
2. **Hardware (provided by STMicroelectronics)**
  - (a) MCU: [STM32WB55CG]
  - (b) Secure IC: [ST33J2M0] (Common Criteria certified)
3. **Software (developed and secured by Ledger)**
  - (a) SEPROXYHAL firmware running on top of [STM32WB55CG]
  - (b) **BOLOS firmware running on top of [ST33J2M0] contains:**
    - i. an OS labelled BOLOS
    - ii. a Device App labelled BOLOS UX Dashboard

BOLOS is in charge of:

1. Communicating with the outside world
2. Managing trusted peripherals (both buttons & screen)
3. Performing cryptographic computation
4. Storing secret data (seed, PIN)
5. Offering a set of API (communication, cryptographic primitives, seed) accessible to all Device Apps

The BOLOS UX Dashboard Device App, default Device App active as soon as the PIN is successfully verified, is:

1. the entry point to select another Device App
2. in charge of the on boarding phase: seed generation and PIN enrollment
3. involved in the other Device App management (delete, install)

The BOLOS UX Dashboard Device App ensures a consistency UX whatever the running Device App. This Device App manages for instance buttons and the screen. Thus, this Device App also supports a third-party developer to create his own Device App.

All Device Apps (developed by Ledger or a third-party), except the BOLOS UX Dashboard Device App, are not included in the ToE.

## 2.7 Assumptions

Below is the list of assumptions:

1. The Ledger Nano X is acquired from an official Ledger reseller (Ledger, Amazon stores)
2. The HSM is properly operated by Ledger
3. The End-User has verified that the Ledger Nano X has not been tampered ([CheckHardwareIntegrity])
4. The End-User only installs non-malicious Device Apps
5. The Ledger Nano X is either powered off or locked (i.e. an End-User verification is required) when the PSD is either stolen or found

6. Techniques consisting in spying the End-User's interactions with the PSD (e.g. a CCTV focused on the Ledger Nano X during a transaction) are out of the scope

## 2.8 Environment Measures

Even if the Ledger Nano X can be used within a strict environment (for instance storing the device inside a vault, signing a transaction inside a secure building), the security design developed by Ledger allows the End-User to experience the PSD in a public area. The device is architected to provide an high assurance level to the End-User whatever the environment.

Nevertheless, with the Ledger Nano X security model, the security is shared between the Ledger Nano X device and the End-User. The following security rules must be fulfilled:

1. The End-User **must** maintain the PIN secret
2. The End-User **must** keep the recovery sheet secret
3. The End-User **must** ensure that no one has access to the recovery sheet
4. The End-User **must** verify transactions' details and address displayed on the screen are valid

## 2.9 End-User

One of Ledger's ambitions is to ensure the blockchain technology can be appropriated by all. While the solution is sophisticated, the Ledger Nano X offers a simple and natural User Experience. The Ledger Nano X being designed to be a mainstream technology, it is user-friendly and can be easily manipulated by End-Users with no technical background.

## ASSETS

As the PSD processes sensitive operations (i.e. sign transactions, manage passwords, achieve U2F authentication, ...) and stores confidential data, the following assets must be secured:

1. Random number - data
2. Secret seed - data
3. Secret Data (protected by the PIN) - data
4. PSD Access Control - operation
5. SE Firmware - data

All the assets listed above is worth of interest to an adversary and are subject to a set of threats as mentioned in *Threats*.



## 4.1 Threat Agent

The Ledger Nano X can be considered as a sensitive device: for instance, it can be used to process some sensitive operations related to the management of the corresponding crypto assets belonging to the End-User.

One of the Ledger Nano X features is to sign digital transactions. This signature operation, used to unlock the cryptocurrency funds located on the blockchain, involves the manipulation of the private key. The owner of this private key (the End-User) is the owner of the corresponding cryptocurrency funds.

Additionally, the Ledger Nano X is not only an hardware wallet but also provides a set of added-value services. The Password Manager and FIDO are typical Device Apps making the digital End-User life frictionless and more secured.

Several threats are applicable to the Ledger Nano X and can be divided into two classes:

1. Physical threats
2. Remote threats

The physical threats indicates the adversary has a physical access to the Ledger Nano X. This occurs when the Ledger Nano X has been either stolen or found. The PSD's state is either powered off or locked when the PSD is either stolen or found. This PSD's state requires the PIN to get access to the sensitive services.

As the Ledger Nano X is a device supporting sensitive online services (blockchain, second factor authentication, passwordless), the remote threats class is also applicable. With this class, the adversary has no physical access. This remote threats class is considered when the End-User's Host has been compromised. It is through this infected machine (desktop/laptop/smartphone/tablet) that an adversary will launch his attacks (i.e. signing a transaction, getting passwords).

The following section describes the main threats linked to the Ledger Nano X related to the two threat classes.

## 4.2 Threat #1: Generating a biased or a deterministic random number

### 4.2.1 Context

The Random Number Generator included in the Ledger Nano X is used to:

1. Generate a Random Number exploited as a seed
2. Participate in establishing a secure channel between the Ledger Nano X and the the Ledger's HSM

The Ledger Nano X, compliant with [BIP32], is a deterministic hardware wallet. This feature indicates that a seed is generated by the device during the initialization. From this seed, the End-User has the capability to derive all Key Pairs required to manage the crypto assets accounts.

Note that this feature allows to recover the crypto assets funds if the Ledger Nano X is lost, stolen or destroyed as long as the seed is correctly backed up (via the Recovery Sheet).

The Ledger Nano X uses the Random Number Generator not only for generating the seed but also for creating a Secure Channel between the Ledger's Secure Server and the Ledger Nano X avoiding replay attacks.

### 4.2.2 Threat

The entropy is the key element regarding a Random Number feature. The entropy must be ensured by a true random number. The main threat is to reduce the entropy so that it reduces dramatically the seed space. This seed's space size is  $2^{256}$ .

Another threat is to generate a number under the control of an adversary. This number is leveraged to set-up the End-User's account by creating the crypto address. Then, the End-User's account can be provisionned.

If the sensitive number generation operation is controlled by the adversary, it is then possible to recreate the End-User's account and perform a crypto asset transfer from the End-User's account to the adversary's account.

## 4.3 Threat #2: Using a not genuine Ledger Nano X

### 4.3.1 Context

Ledger is the unique manufacturer of the Ledger Nano X device. The authenticity proves the Ledger Nano X is only issued by Ledger avoiding some security holes related for instance to supply chain attacks. Besides, as the Ledger Nano X is a sensitive device, it must only work as specified by Ledger. For instance, the Ledger embedded software, including not only BOLOS and but also a set of Device Apps, must be executed as expected.

In other words, both authenticity and integrity of the Ledger Nano X must be ensured.

### 4.3.2 Threat

The main threats are:

1. Manufacturing a fake Ledger Nano X

As an adversary manufactures a fake Ledger Nano X, it has the full control on the device and can create malicious Ledger Nano X.

2. Modifying the Ledger Nano X produced by Ledger

An adversary adds malicious software to dump out sensitive data.

## 4.4 Threat #3: Bypassing the Access Control to Sensitive Services

### 4.4.1 Context

The Ledger Nano X embeds a set of sensitive services. One of them is related to the management of crypto assets. For instance, an End-User can create through his Ledger Nano X a set of accounts (e.g. a professional account, an individual account, a family account) linked to several cryptocurrencies (e.g. Bitcoin, Ethereum, Ripple). The Device Apps installed on the Ledger Nano X can sign transactions to unlock the funds.

Note that the Ledger Nano X offers several sensitive services (FIDO, Password Manager) interesting for an adversary as well.



### 4.4.2 Threat

The main threat is related to a stolen Ledger Nano X. As soon as the Ledger Nano X is stolen, a physical access to the hardware wallet is available. This stolen Ledger Nano X is not exploitable by the adversary. The PIN, defined by the genuine End-User during the on boarding phase, is required to get a full control over the device. Sensitive operations can be processed only if the candidate PIN matches with the reference PIN.

This threat is also applicable remotely when the End-User's Host has been previously compromised.

## 4.5 Threat #4: Compromising the Post-Issuance Capability

### 4.5.1 Context

The Ledger Nano X includes a post-issuance capability making possible to update not only Device Apps but also firmwares (both BOLOS and SEPROXYHAL). This feature, giving Ledger an incredible flexibility, can be exploited to:

1. add new services
2. fix some functional and protocol issues
3. reinforce the security of the Ledger Nano X

### 4.5.2 Threat

The main threat is to inject a malicious firmware (either SE or MCU) so that an adversary can take the full control of the Ledger Nano X.



## SECURITY FUNCTIONS

As raised in the previous section, the Ledger Nano X can be targeted with four main threats. These threats are critical because they can compromise the Ledger Nano X: deterministic random number, access to the device without End-User verification, fake or malicious Ledger Nano X.

Ledger has developed appropriate security functions explained in this section to properly block each threat. It is worth highlighting that the implementation of these security functions relies on a set of security mechanisms. This security methodology of adding several security layers (defense-in-depth concept) counteracts not only straightforward but also sophisticated attacks.

The diagram below illustrates the relationship between the threats and the security functions:

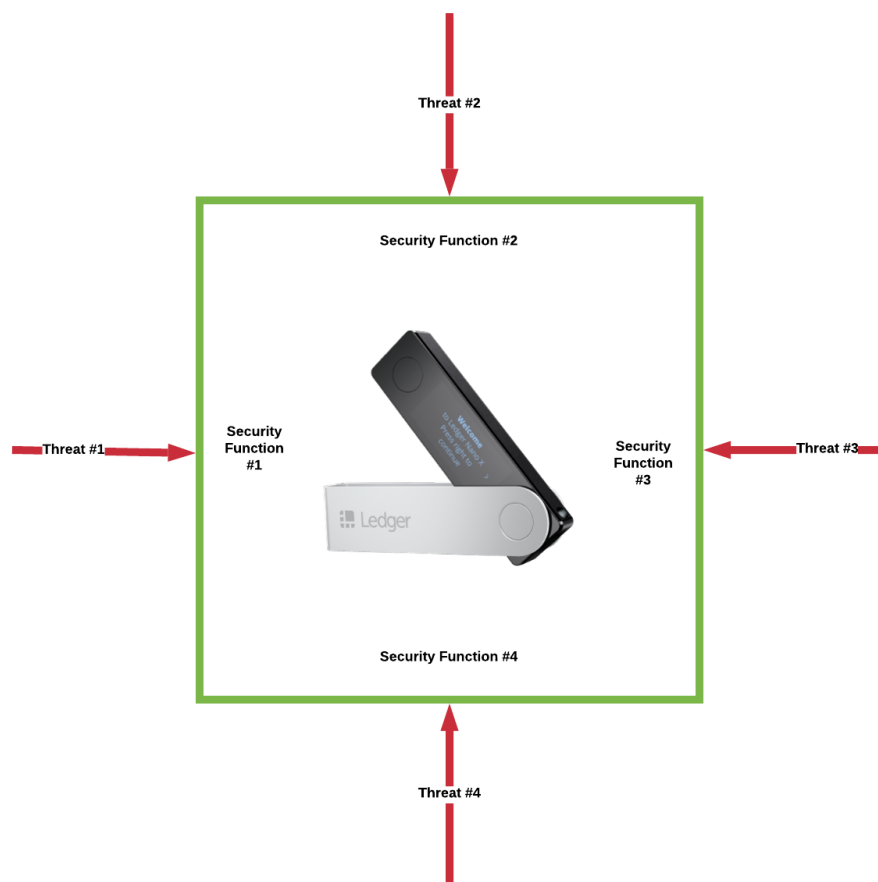


Fig. 1: Threats Vs Security Functions

## 5.1 Security Function #1: True Random Number Generator

### 5.1.1 Description

This security function #1, labelled True Random Number Generator, aims at counteracting threat #1.

This security function is based on the TRNG embedded in [ST33J2M0]. This TRNG, evaluated according to [AIS31] methodology, has been successfully certified Class PTG.2.

To reinforce the entropy of the generated Random Number, Ledger has also implemented an additional software post-processing countermeasure.

#### 5.1.1.1 Assets

The assets related to security function #1 are:

1. True Random Number Generator - non-deterministic and non-predictability properties - (operation)
2. Random Number - entropy - (data)
3. Secret Seed (data)

## 5.2 Security Function #2: Attestation Mechanism

### 5.2.1 Description

This security function #2, labelled Attestation Mechanism, aims at blocking threat #2.

Ledger has implemented a solution to ensure that the Ledger Nano X belonging to the End-User is a genuine one. To comply with this requirement, a Public Key Infrastructure (based on secp256k1 elliptic curve) has been set up: Ledger is the Certification Authority. This dedicated infrastructure, based on Hardware Security Module, is not only administrated but also operated by Ledger.

During the manufacturing process, each Ledger Nano X initializes itself with:

1. an individual key pair generation
2. the corresponding certificate (provided by the Ledger's HSM)

Then, when the Ledger Nano X is connected to the Host and under some circumstances (for instance a Device App, SE firmware download or MCU firmware installation), a mutual authentication between the Ledger's HSM and the Ledger Nano X is performed.

This security function #2 relies on the following commands:

1. VALIDATE\_TARGET\_ID
2. INITIALIZE\_AUTHENTICATION
3. VALIDATE\_CERTIFICATE\_LAST
4. GET\_CERTIFICATE\_LAST

The VALIDATE\_TARGET\_ID and INITIALIZE\_AUTHENTICATION commands initiate the mutual authentication. The VALIDATE\_CERTIFICATE\_LAST command is used by the PSD to authenticate the HSM while the GET\_CERTIFICATE\_LAST command is used by the HSM to authenticate the PSD.

At the end of this command/response sequence, a mutual authentication is achieved. Besides, both HSM and PSD have generated ephemeral keys leveraged during an ECDH to share a common secret between the HSM and the PSD.

This attestation mechanism is performed through a set of ECDSA operations as illustrated in the following diagram:

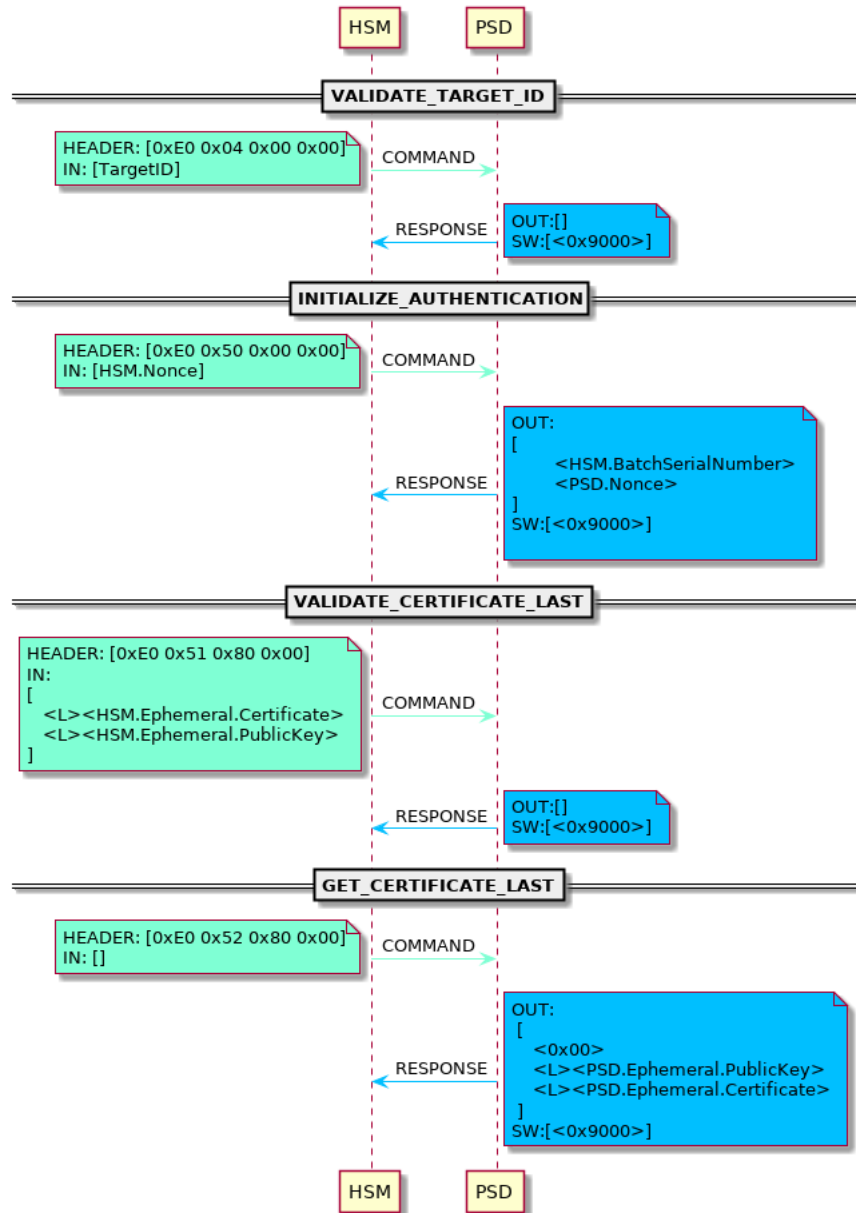


Fig. 2: Security Function #2 - Attestation Mechanism -

### 5.2.2 Assets

The assets related to security function #2 are:

1. True Random Number Generator (Operation)
2. Random Number (Data)
3. PSD Genuineness (Data)
4. PSD.PublicKey (Data)

5. PSD.Ephemeral.PrivateKey (Data)
6. PSD.PrivateKey (Data)
7. HSM.Ephemeral.PublicKey (Data)
8. HSM.Ephemeral.Certificate verification (Operation)
9. HSM.PublicKey (Data)

## 5.3 Security Function #3: End-User Verification

### 5.3.1 Description

This security function #3, labelled End-User Verification, aims at counteracting threat #3.

As soon as the Ledger Nano X is connected to a Host, the End-User must prove that he is the owner of this Ledger Nano X. This security function #3 is the first interaction between the End-User and the Ledger Nano X. This security function is critical because it gives access to all services supported by the Ledger Nano X.

The End-User verification is performed through a PIN verification. The length of the PIN, defined by the End-User during the on boarding stage, must be in the following range: minimum 4 digits, maximum 8 digits.

The End-User directly enters the PIN value using the 2 buttons. This candidate PIN is then compared to the Reference PIN stored in the SE. A correct verification allows the End-User to use all services provided by the Ledger Nano X. For instance, all cryptocurrency Device Apps are available meaning cryptocurrency transfer is available. Note that all other Device Apps (for instance Password Manager, FIDO) are also available as soon as the PIN verification is successfully performed.

The PIN Try Counter, whose default value is set to 3, counteracts brute-force attacks revealing the value of the PIN. As soon as the PTC exceeds its limit, the Ledger Nano X wipes the following sensitive assets:

1. PIN
2. Seed
3. Secret Data protected by the PIN

Thanks to this security action of wiping, the Ledger Nano X cannot be used because the current state is not operational anymore. An initialization (either normal mode or restore mode) is then required.

A correct End-User verification unlocks all the Ledger Nano X services and resets the PTC to 3.

### 5.3.2 Assets

Several sensitive assets are used to ensure the End-User verification:

1. PSD Access Control (Data)
2. Secret data protected by the PIN (Data)
3. Reference PIN (Data)
4. PIN Try Counter (Data)
5. PIN verification (Operation)
6. PIN Try Limit (Data)
7. PIN Result (Data)

## 5.4 Security Function #4: Post-Issuance Capability over a Secure Channel

### 5.4.1 Description

This security function #4, labelled Post-Issuance Capability over a Secure Channel, aims at counteracting threat #4.

This security function use security assets generated during security function #2 execution (mutual authentication between the HSM and the PSD).

The Post-Issuance Capability over a Secure Channel is illustrated in the following diagram:

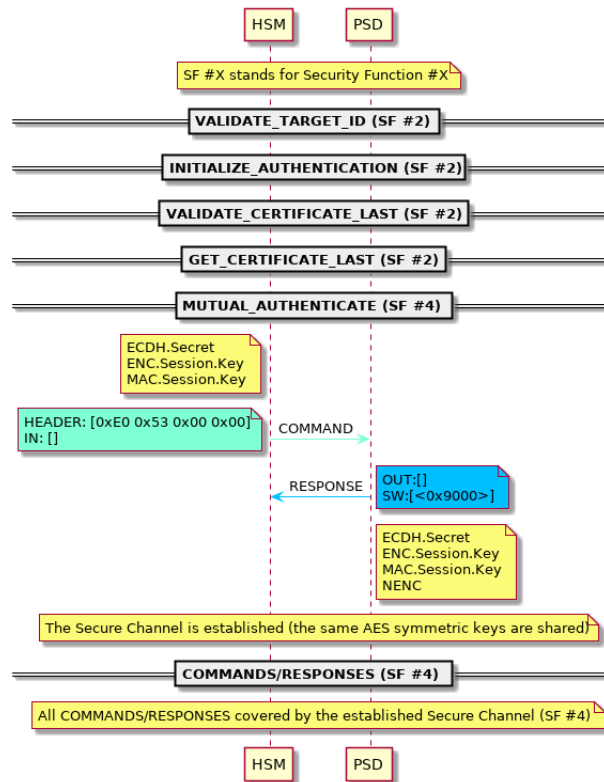


Fig. 3: Security Function #4 - Secure Channel -

The first commands (VALIDATE\_TARGET\_ID, INITIALIZE\_AUTHENTICATION, VALIDATE\_CERTIFICATE\_LAST, GET\_CERTIFICATE\_LAST) performs a mutual authentication (security function #2) to ensure the HSM and PSD are genuine. Note that during the execution of the previous commands, both HSM and PSD have generated ephemeral EC key pairs. These ephemeral key pairs are leveraged to process an ECDH so that both HSM and PSD share a common secret labelled ECDH.Secret.

This ECDH.Secret is then derived to get 2 session keys:

1. ENC.Session.Key
2. MAC.Session.Key

These 2 session keys ensure the confidentiality and the integrity of messages (command/response) over the secure channel.

There is an additional key, labelled NENC, used to only encrypt the SE firmware. In this case, the SE firmware is encrypted twice: the first encryption is achieved through NENC while the second encryption is processed with

ENC.Session.Key. NENC (an AES symmetric key initially stored during the manufacturing phase) is provisioned to the PSD during the previous SE firmware update.

After the successful processing of the MUTUAL\_AUTHENTICATE command, all following commands (secured in confidentiality and integrity) are managed inside the Secure Channel.

The secure channel is designed to block typical attacks. For instance, the secure channel does not accept the same set of commands twice making replay attacks not operational anymore. Additionally, thanks to the NENC's use, the software installation is always an upgrade. It is not possible to downgrade the software version already installed on the Ledger Nano X. This anti-rollback security protection discards all attack vectors related to install a previous software version containing a set of vulnerabilities already identified.

### 5.4.2 Assets

1. SE Firmware (Data)
2. ECDH.Secret (Data)
3. ENC.Session.Key (Data)
4. MAC.Session.Key (Data)
5. NENC (Data)



## SUMMARY: THREATS - ASSETS - SECURITY FUNCTIONS

### 6.1 Mapping Between Assets and Security Functions

The following table gives the relationship between assets and security functions.

#	Asset Name	Asset Type	Security Function	Memory Type	Property
1	True Random Number Generator	Operation	#1 and #2	Not applicable	I
2	Random Number	Data	#1 and #2	Volatile	
3	Secret Data (seed)	Data	#1	Persistent	I&C
4	PSD Access Control	Data	#3	Not applicable	AU
5	Secret Data protected by the PIN	Data	#3	Persistent	I&C
6	Reference PIN	Data	#3	Persistent	I&C
7	PIN Try Counter	Data	#3	Persistent	I
8	PIN Verification	Operation	#3	Not applicable	I
9	PIN Try Limit	Data	#3	Persistent	I
10	PIN Result	Data	#3	Volatile	I
11	PSD Genuineness	Data	#2	Not applicable	AU
12	PSD.PublicKey	Data	#2	Not applicable	I&C
13	PSD.Ephemeral.PrivateKey	Data	#2	Volatile	C
14	PSD.PrivateKey	Data	#2	Persistent	I&C
15	HSM.Ephemeral.PublicKey	Data	#2	Volatile	C
16	HSM.Ephemeral.Certificate Verification	Operation	#2	Not applicable	I
17	HSM.PublicKey	Data	#2	Volatile	I&C
18	SE Firmware	Data	#4	Volatile	I
19	ECDH.Secret	Data	#4	Volatile	I&C
20	ENC.Session.key	Data	#4	Volatile	C
21	MAC.Session.key	Data	#4	Volatile	C
22	NENC	Data	#4	Persistent	C

I = Integrity C = Confidentiality A = Availability AU = AUthenticity

### 6.2 Mapping Between Security Functions and Threats

The following table gives the full relationship between the security functions and the threats.

	<b>Threat #1</b>	<b>Threat #2</b>	<b>Threat #3</b>	<b>Threat #4</b>
True Random Number Generator	X			
Attestation Mechanism	X	X		
End-User Verification (PIN)			X	
Post-Issuance Capability over a Secure Channel		X		X

Threat #1 is also applicable to security function #2 because a Nonce is required during the attestation mechanism. Besides, as security function #4 is based on security function #2, Threat #2 is also applicable to security function #4.

## USE CASES

### 7.1 On Boarding

The on boarding use case is leveraged to properly initialize the Ledger Nano X. As soon as the Ledger Nano X is received by the End-User, this on boarding is:

1. a mandatory step: the on boarding is required to perform transactions
2. the first step which must be completely performed before using the Ledger Nano X

To initialize the device, the End-User has to select one of the following modes:

1. Normal mode (“Initialize as new device”)
2. Restore mode (“Restore a configuration”)

The restore mode is performed when the End-User has already a wallet and wants to use the Ledger Nano X (compliant with [BIP32]) to get access of his assets again. The normal mode is used when the End-User wants to create a seed.

Whatever the selected mode, the End-User has to choose a PIN code (from 4 to 8 digits long). Within the normal mode, the 24-word recovery phrase is displayed word by word and must be written down on the recovery sheet. With the restore mode, the End-User must enter the 12/18/24-word recovery phrase saved during the initialization phase. Note that during the on boarding phase, the Ledger Nano X only generates a recovery phrase composed of 24 words.

Refer to *On boarding Flow*, to get the diagram describing the on boarding process making the Ledger Nano X operational.

As soon as the initialization is completed by the End-User, the Ledger Nano X switches to the operational state.

### 7.2 Typical scenarios

As the Ledger Nano X is a generic personal secure device offering a comprehensive set of security features, there are as well a lot of scenario. For instance, The Ledger Nano X can be used within the following scenarios (but not limited to):

1. Install the official Bitcoin Device App (in other words, signed by Ledger)
2. Perform a Bitcoin transaction
3. Perform a FIDO transaction
4. Install the latest SE firmware
5. Install a third-party Device App

All these typical scenarios are sensitive because they are manipulating sensitive assets. The Ledger Nano X embeds 4 security functions implemented to secure the Ledger Nano X assets.

The following table maps some scenarios with the corresponding security functions. Note that the security functions are listed in a chronological order meaning that Security Functions #3 (End-User verification) is the first step, Security Function #1 is the second step and so on for the remaining security functions.

Typical Scenario	Security Functions			
	SF #3	SF #1	SF2 #2	SF #4
Install the official Bitcoin Device App	X	X	X	X
Perform a Bitcoin transaction	X			
Perform a FIDO transaction	X			
Install the SE firmware	X	X	X	X
Install a third-party device App	X			

As illustrated by the table above, Security Function #3 (End-User verification) is always performed whatever the scenario. It is even the first security action that the End-User's must process before using the Ledger Nano X.

As this Security Function #3 is crucial to the Ledger Nano X, all data are wiped (including PIN, Seed and all other Secret Data) as soon as the PTC exceeds its limit. Note that the End-User has then the possibility to restore the Ledger Nano X through the set of words written down the recovery sheet.

Depending on the use case, other Security Functions (#1, #2 and #4) may be invoked.

## 8.1 On boarding Flow

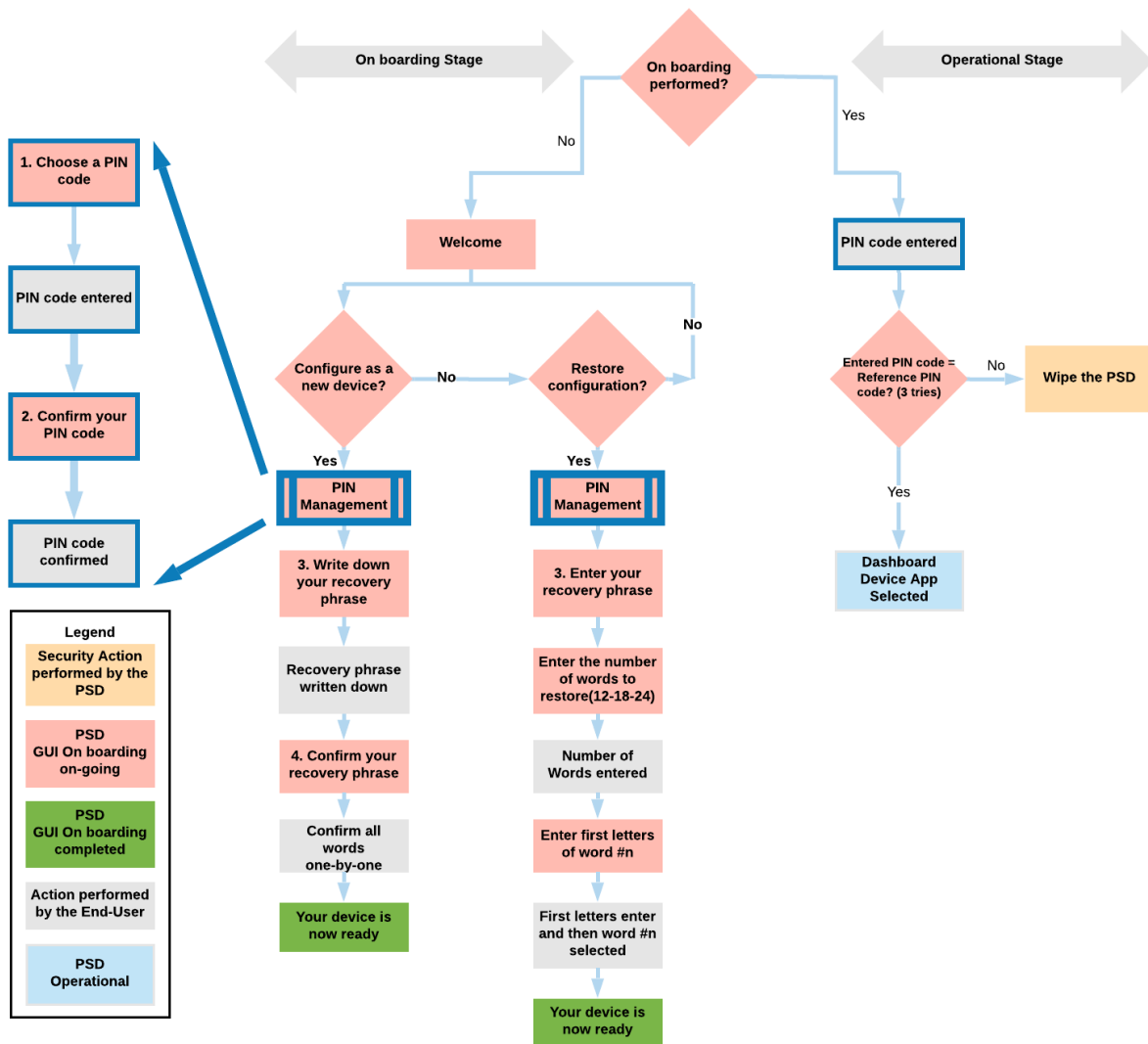


Fig. 1: On Boarding Flow

## 8.2 External References

[ST33J2M0CCertificate]	<a href="https://www.ssi.gouv.fr/uploads/2017/08/anssi-cc-2017_50-m01fr.pdf">https://www.ssi.gouv.fr/uploads/2017/08/anssi-cc-2017_50-m01fr.pdf</a>
[Python_Loader_Installation]	<a href="https://github.com/LedgerHQ/blue-loader-python">https://github.com/LedgerHQ/blue-loader-python</a>
[Python_loader_Exploitation]	<a href="https://ledger.readthedocs.io/projects/blue-loader-python/en/0.1.18/script_reference.html">https://ledger.readthedocs.io/projects/blue-loader-python/en/0.1.18/script_reference.html</a>
[LedgerCtl]	<a href="https://github.com/LedgerHQ/ledgerctl">https://github.com/LedgerHQ/ledgerctl</a>
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[GitHubLedgerHQ]	<a href="https://github.com/LedgerHQ">https://github.com/LedgerHQ</a>
[CheckHardwareIntegrity]	<a href="https://support.ledger.com/hc/en-us/articles/360019352834-Check-hardware-integrity">https://support.ledger.com/hc/en-us/articles/360019352834-Check-hardware-integrity</a>
[Ledger_Nano_X_User_Manual]	<a href="https://support.ledger.com/hc/en-us/articles/360019514333-User-manual">https://support.ledger.com/hc/en-us/articles/360019514333-User-manual</a>