

Securing SUSE Linux Micro Using Keylime

WHAT?

Keylime is a TPM-based remote boot attestation and runtime integrity measurement.

WHY?

The article describes how to configure and run Keylime on SUSE Linux Micro.

EFFORT

It takes approximately 25 minutes to read the article.

GOAL

You will know more about Keylime—how it works, how you should configure it and how it is run.

REQUIREMENTS

- A running instance of SUSE Linux Micro

Publication Date: 30 Jan 2025

Contents

- 1 Remote attestation using Keylime 3
- 2 Running the Keylime workload using Podman 6

- 3 Installing the Keylime agent 8
- 4 Registering the Keylime agent 10
- 5 Keylime secure payloads 10
- 6 Enabling IMA tracking for Keylime 11
- 7 For more information 12
- 8 Legal Notice 12
- A GNU Free Documentation License 13

1 Remote attestation using Keylime

With the growing demand on securing devices against unauthorized changes, the use of the security mechanism called *remote attestation (RA)* has been experiencing significant growth. Using RA, a host (client) can authenticate its boot chain status and running software on a remote host (verifier). RA is often combined with public-key encryption (using TPM2), thus the sent information can only be read by the services that requested the attestation, and the validity of the data can be verified. Remote attestation on SUSE Linux Micro is implemented by *Keylime*.

1.1 Terminology

Remote attestation technology uses the following terms:

Attestation key (AK)

A data signing key that proves that the data comes from a real TPM and has not been tampered with.

Core root of trust for measurement

Calculates its own hash and the hash of the next step in the boot process, initiating the chain of measurements.

Endorsement key (EK)

An encryption key that is permanently embedded in the TPM when it is manufactured. The public part of the key and the certification stored in the TPM are used to recognize a genuine TPM.

Integrity management architecture (IMA)

A kernel integrity subsystem that provides a means of detecting malicious changes to files.

Measured boot

A method with which each component in the booting sequence calculates a hash of the next one before delegating the execution of the next component. The hash extends one or several PCRs of the TPM. An event is created with the information about where the measurement took place and what was measured. Such events are collected in an event log, and, along with the extended PCR values, the events can be compared with the expected values representing a healthy system.

Platform Configuration Register (PCR)

A memory location in TPM that, for example, stores hashes of booting layers. PCR can be updated only by using the non-reversible operation: extend. A signed list of current PCR values can be obtained by the quote command on TPM, and this quote can be verified by a third party during the attestation process.

Secure boot

Each step of the booting process checks a cryptographic signature on the executable of the next step before launching it.

Trusted Platform Module (TPM)

A self-contained security cryptographic processor present in the system as hardware or implemented in the firmware that serves as a root of trust. TPM provides a PCR for storing the hashes of booting layers. A typical TPM provides several functions, like a random number generator, counters or a local clock. It also stores 24 PCRs grouped by banks per each supported cryptographic hash function (SHA1, SHA256, SHA384 or SHA512).



Note

By default, TPM usage is disabled. Therefore, the measured boot does not take place. To enable the remote attestation, enable TPM in the EFI/BIOS menu.

Secure payload

A mechanism to deliver encrypted data to healthy agents. Payloads are used to provide keys, passwords, certificates, configurations or scripts that are further used by the agent.

1.2 What is Keylime?

Keylime is a remote attestation solution that enables you to monitor the health of remote nodes using a TPM as a root of trust for measurement. With Keylime, you can perform multiple tasks, for example:

- Validate of the PCRs extended during the measured boot.
- Create analysis and make assertions of the event log.
- Make assertion of the value of any PCR in the remote system.
- Monitor the validity of open or executed files.

- Deliver encrypted data to verified nodes via *secure payloads*.
- Execute custom scripts that are triggered when a machine fails the attested measurements.

1.3 Architecture

Keylime consists of an agent, a verifier, a registrar and a command-line tool (tenant). Agents are on those systems that need to be attested. The verifier and registrar are on remote systems that perform the registration and attestation of agents. Keep in mind that only the agent role is available on SUSE Linux Micro. For details about each component, refer to the following sections.

1.3.1 Keylime agent

The agent is a service that runs on the system that needs to be attested. The agent sends the event log, IMA hashes, and information about the measured boot to the verifier, using the local TPM as a certifier of the data validity.

When a new agent is started, it needs to register itself in the registrar first. To do so, the agent needs a TLS certificate to establish the connection. The TLS certificate is generated by the registrar, but it needs to be installed manually to the agent. After the registration, the agent sends its attestation key and the public part of the endorsement key to the registrar. The registrar responds to the agent with a challenge in a process called credential activation, which validates the TPM of the agent. Once the agent has been registered, it is ready to be enrolled for attestation.

1.3.2 Keylime registrar

The registrar is used to register agents that should be attested. The registrar collects the agent's attestation key, the public part of the endorsement key and the endorsement key certification, and verifies that the agent attestation key belongs to the endorsement key.

1.3.3 Keylime verifier

The verifier performs the actual attestation of agents and continuously pulls the required attestation data from agents (among others, the PCR values, IMA logs, and UEFI event logs).

2 Running the Keylime workload using Podman

Keylime is a remote attestation solution that enables you to monitor the health of remote nodes. The *verifier* and *registrar* are essential components of Keylime on remote systems to perform the registration and attestation of Keylime agents.



Note

The container described in this article delivers control plane services *verifier* and *registrar* and a *tenant* command-line tool (CLI) that are part of the Keylime project.

Before you start installing and registering agents, prepare the verifier and the registrar on remote hosts, as described in the following procedure.

1. Identify the Keylime workload image.

```
# podman search keylime
[...]  
registry.opensuse.org/devel/microos/containers/containerfile/opensuse/keylime-  
control-plane
```

2. Pull the image from the registry.

```
# podman pull \  
registry.opensuse.org/devel/microos/containers/containerfile/opensuse/keylime-  
control-plane:latest
```

3. Create the keylime-control-plane volume to persist the database and certificates required during the attestation process.

```
# podman container runlabel install \  
registry.opensuse.org/devel/microos/containers/containerfile/opensuse/keylime-  
control-plane:latest
```

4. Start the container and related services.

```
# podman container runlabel run \  
registry.opensuse.org/devel/microos/containers/containerfile/opensuse/keylime-  
control-plane:latest
```

The `keylime-control-plane` container is created. It includes configured and running registrar and verifier services. Internally, the container exposes ports 8881, 8890 and 8891 to the host using the default values. Validate the firewall configuration to allow access to the ports and to allow communication between containers, because the tenant CLI requires it.



Tip

If you need to stop Keylime services, run the following command:

```
# podman kill keylime-control-plane-container
```

2.1 Monitoring Keylime services

To get the status of running containers on the host, run the following command:

```
# podman ps
```

To view the logs of Keylime services, run the following command:

```
# podman logs keylime-control-plane-container
```

2.2 Executing the tenant CLI

The tenant CLI tool is included in the container, and if the host firewall does not interfere with the ports exposed by Keylime services, you can execute it using the same image, for example:

```
# podman run --rm \  
-v keylime-control-plane-volume:/var/lib/keylime/ \  
keylime-control-plane:latest \  
keylime_tenant -v 10.88.0.1 -r 10.88.0.1 --cert default -c reglist
```

2.3 Extracting the Keylime certificate

The first time that the Keylime container is executed, its services create a certificate required by several agents. You need to extract the certificate from the container and copy it to the agent's `/var/lib/keylime/cv_ca/` directory.

```
# podman cp \  
keylime-control-plane-container:/var/lib/keylime/cv_ca/cacert.crt  
.  
# scp cacert.crt  
AGENT_HOST:/var/lib/keylime/cv_ca/
```



Tip

Find more details about installing the agent in [Section 3, "Installing the Keylime agent"](#).

3 Installing the Keylime agent

Keylime is a remote attestation solution that enables you to monitor the health of remote nodes. The Keylime agent is a service that runs on the system that needs to be attested and sends the event log, IMA hashes, and information about the measured boot to the verifier.

The Keylime agent is not present on SUSE Linux Micro by default, and you need to install it manually. To install the agent, proceed as follows:

1. Install the `rust-keylime` package as follows:

```
# transactional-update pkg in rust-keylime
```

Then reboot the system.

2. Adjust the default agent's configuration.

- a. Create a directory to store a new configuration file for your changes in `/etc/keylime/agent.conf.d/`. The default configuration is stored in `/usr/etc/keylime/agent.conf`, but we do not recommend editing this file because it may be overwritten in upcoming system updates.

```
# mkdir -p /etc/keylime/agent.conf.d
```


b. Create a new file `/etc/keylime/agent.conf.d/agent.conf`:

```
# cat << EOF > /etc/keylime/agent.conf.d/agent.conf
[agent]

uuid = "d111ec46-34d8-41af-ad56-d560bc97b2e8" ❶
registrar_ip = "<REMOTE_IP>" ❷
revocation_notification_ip = "<REMOTE_IP>" ❸
EOF
```

- ❶ The unique identifier is generated each time the agent is run. However, you can define a specific value by this option.
- ❷ IP address of the registrar.
- ❸ IP address of the verifier.

c. Change the owner of the `/etc/keylime/` directory to `keylime:tss`:

```
# chown -R keylime:tss /etc/keylime
```

d. Change permissions on the `/etc/keylime/` directory:

```
# chmod -R 600 /etc/keylime
```

3. Copy the certificates generated by the CA to the agent node. On the agent node, do the following:

a. Prepare a directory for the certificate:

```
# mkdir -p /var/lib/keylime/cv_ca
```

b. Copy the certificate to the agent:

```
# scp CERT_SERVER_ADDRESS:/var/lib/keylime/cv_ca/cacert.crt /var/lib/keylime/
cv_ca
```

c. Change the owner of the certificate to `keylime:tss`:

```
# chown -R keylime:tss /var/lib/keylime/cv_ca
```

4. Start and enable the `keylime_agent.service`:

```
# systemctl enable --now keylime_agent.service
```

4 Registering the Keylime agent

Keylime is a remote attestation solution that enables you to monitor the health of remote nodes. The Keylime agent is a service that runs on the system that needs to be attested and sends the event log, IMA hashes, and information about the measured boot to the verifier.

You can register a new agent either by using the CLI tenant or by editing the configuration of the verifier. Using the tenant on the verifier host, run the following:

```
# keylime_tenant -v 127.0.0.1 \  
-t AGENT \❶  
-u UUID \❷  
--cert default \  
-c add  
[--include PATH_TO_ZIP_FILE]❸
```

- ❶ `AGENT` is an IP address of the agent to be registered.
- ❷ `UUID` is the agent's unique identifier.
- ❸ The file passed by the `include` option is used to deliver secret payload data to the agent. For details, refer to [Section 5, "Keylime secure payloads"](#).

You can list registered agents by using the `reglist` command on the verifier host as follows:

```
# keylime_tenant -v 127.0.0.1 \  
--cert default \  
-c reglist
```

To remove a registered agent, specify the agent using the `-t` and `-u` options and the `delete` command as follows:

```
# keylime_tenant -v 127.0.0.1 \  
-t AGENT \  
-u UUID \  
-c delete
```

5 Keylime secure payloads

Keylime is a remote attestation solution that enables you to monitor the health of remote nodes.

5.1 What is a secure payload?

A Keylime secure payload enables you to deliver encrypted data to healthy agents. Payloads are used to provide keys, passwords, certificates, configurations or scripts that are used by the Keylime agent at a later stage.

5.2 How does a secure payload work?

A secure payload is delivered to the agent in a `zip` file that must contain a shell script named `autorun.sh`. The script is executed only if the agent has been properly registered and verified. To deliver the `zip` file, use the `--include` option of the `keylime_tenant` command.

For example, the following `autorun.sh` script creates a directory structure and copies SSH keys there. The related `zip` archive must include these SSH keys.

```
> cat autorun.sh
#!/bin/bash

mkdir -p /root/.ssh/
cp id_rsa* /root/.ssh/
chmod 600 /root/.ssh/id_rsa*
cp /root/.ssh/id_rsa.pub /root/.ssh/authorized_keys
```

6 Enabling IMA tracking for Keylime

Keylime is a remote attestation solution that enables you to monitor the health of remote nodes. *Integrity management architecture* (IMA) is a kernel integrity subsystem that provides a means of detecting malicious changes to files.

When using IMA, the kernel calculates a hash of accessed files. The hash is then used to extend the PCR 10 in the TPM and also log a list of accessed files. The verifier can request a signed quote to the agent for PCR 10 to get the logs of all accessed files including the file hashes. Verifiers then compare the accessed files with a local allowlist of approved files. If any of the hashes are not recognized, the system is considered unsafe, and a revocation event is triggered.

Before Keylime can collect information, IMA/EVM needs to be enabled. To enable the process, boot a kernel of the agent with the `ima_appraise=log` and `ima_policy=tcb` parameters:

1. Update the `GRUB_CMDLINE_LINUX_DEFAULT` option with the parameters in `/etc/default/grub`:

```
GRUB_CMDLINE_LINUX_DEFAULT="ima_appraise=log ima_policy=tcb"
```

2. Regenerate `grub.cfg` by running:

```
# transactional-update grub.cfg
```

3. Reboot your system.

The procedure above uses the default kernel IMA policy. To avoid monitoring too many files and therefore creating long logs, create a new custom policy. Find more details in the [Keylime documentation \(https://keylime-docs.readthedocs.io/en/latest/user_guide/runtime_ima.html\)](https://keylime-docs.readthedocs.io/en/latest/user_guide/runtime_ima.html).

To indicate the expected hashes, use the `--allowlist` option of the `keylime_tenant` command when registering the agent. To view the excluded or ignored files, use the `--exclude` option of the `keylime_tenant` command:

```
# keylime_tenant --allowlist  
-v 127.0.0.1 \  
-u UUID
```

7 For more information

- Keylime home page is at <https://keylime.dev>.
- Latest Keylime documentation is at <https://keylime.readthedocs.io/en/latest/>.
- For a high-level overview of IMA/EVM, refer to https://en.opensuse.org/SDB:Ima_evm#Introduction.
- Find more details about creating a new kernel IMA policy in https://keylime-docs.readthedocs.io/en/latest/user_guide/runtime_ima.html.

8 Legal Notice

Copyright© 2006–2025 SUSE LLC and contributors. All rights reserved.

Permission is granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License, Version 1.2 or (at your option) version 1.3; with the Invariant Section being this copyright notice and license. A copy of the license version 1.2 is included in the section entitled “GNU Free Documentation License”.

For SUSE trademarks, see <https://www.suse.com/company/legal/>. All other third-party trademarks are the property of their respective owners. Trademark symbols (®, ™ etc.) denote trademarks of SUSE and its affiliates. Asterisks (*) denote third-party trademarks.

All information found in this book has been compiled with utmost attention to detail. However, this does not guarantee complete accuracy. Neither SUSE LLC, its affiliates, the authors, nor the translators shall be held liable for possible errors or the consequences thereof.

A GNU Free Documentation License

Copyright (C) 2000, 2001, 2002 Free Software Foundation, Inc. 51 Franklin St, Fifth Floor, Boston, MA 02110-1301 USA. Everyone is permitted to copy and distribute verbatim copies of this license document, but changing it is not allowed.

0. PREAMBLE

The purpose of this License is to make a manual, textbook, or other functional and useful document "free" in the sense of freedom: to assure everyone the effective freedom to copy and redistribute it, with or without modifying it, either commercially or non-commercially. Secondly, this License preserves for the author and publisher a way to get credit for their work, while not being considered responsible for modifications made by others.

This License is a kind of "copyleft", which means that derivative works of the document must themselves be free in the same sense. It complements the GNU General Public License, which is a copyleft license designed for free software.

We have designed this License to use it for manuals for free software, because free software needs free documentation: a free program should come with manuals providing the same freedoms that the software does. But this License is not limited to software manuals; it can be used for any textual work, regardless of subject matter or whether it is published as a printed book. We recommend this License principally for works whose purpose is instruction or reference.

1. APPLICABILITY AND DEFINITIONS

This License applies to any manual or other work, in any medium, that contains a notice placed by the copyright holder saying it can be distributed under the terms of this License. Such a notice grants a world-wide, royalty-free license, unlimited in duration, to use that work under the conditions stated herein. The "Document", below, refers to any such manual or work. Any member of the public is a licensee, and is addressed as "you". You accept the license if you copy, modify or distribute the work in a way requiring permission under copyright law.

A "Modified Version" of the Document means any work containing the Document or a portion of it, either copied verbatim, or with modifications and/or translated into another language.

A "Secondary Section" is a named appendix or a front-matter section of the Document that deals exclusively with the relationship of the publishers or authors of the Document to the Document's overall subject (or to related matters) and contains nothing that could fall directly within that overall subject. (Thus, if the Document is in part a textbook of mathematics, a Secondary Section may not explain any mathematics.) The relationship could be a matter of historical connection with the subject or with related matters, or of legal, commercial, philosophical, ethical or political position regarding them.

The "Invariant Sections" are certain Secondary Sections whose titles are designated, as being those of Invariant Sections, in the notice that says that the Document is released under this License. If a section does not fit the above definition of Secondary then it is not allowed to be designated as Invariant. The Document may contain zero Invariant Sections. If the Document does not identify any Invariant Sections then there are none.

The "Cover Texts" are certain short passages of text that are listed, as Front-Cover Texts or Back-Cover Texts, in the notice that says that the Document is released under this License. A Front-Cover Text may be at most 5 words, and a Back-Cover Text may be at most 25 words.

A "Transparent" copy of the Document means a machine-readable copy, represented in a format whose specification is available to the general public, that is suitable for revising the document straightforwardly with generic text editors or (for images composed of pixels) generic paint programs or (for drawings) some widely available drawing editor, and that is suitable for input to text formatters or for automatic translation to a variety of formats suitable for input to text formatters. A copy made in an otherwise Transparent file format whose markup, or absence of markup, has been arranged to thwart or discourage subsequent modification by readers is not Transparent. An image format is not Transparent if used for any substantial amount of text. A copy that is not "Transparent" is called "Opaque".

Examples of suitable formats for Transparent copies include plain ASCII without markup, Texinfo input format, LaTeX input format, SGML or XML using a publicly available DTD, and standard-conforming simple HTML, PostScript or PDF designed for human modification. Examples of transparent image formats include PNG, XCF and JPG. Opaque formats include proprietary formats that can be read and edited only by proprietary word processors, SGML or XML for which the DTD and/or processing tools are not generally available, and the machine-generated HTML, PostScript or PDF produced by some word processors for output purposes only.

The "Title Page" means, for a printed book, the title page itself, plus such following pages as are needed to hold, legibly, the material this License requires to appear in the title page. For works in formats which do not have any title page as such, "Title Page" means the text near the most prominent appearance of the work's title, preceding the beginning of the body of the text.

A section "Entitled XYZ" means a named subunit of the Document whose title either is precisely XYZ or contains XYZ in parentheses following text that translates XYZ in another language. (Here XYZ stands for a specific section name mentioned below, such as "Acknowledgements", "Dedications", "Endorsements", or "History".) To "Preserve the Title" of such a section when you modify the Document means that it remains a section "Entitled XYZ" according to this definition.

The Document may include Warranty Disclaimers next to the notice which states that this License applies to the Document. These Warranty Disclaimers are considered to be included by reference in this License, but only as regards disclaiming warranties: any other implication that these Warranty Disclaimers may have is void and has no effect on the meaning of this License.

2. VERBATIM COPYING

You may copy and distribute the Document in any medium, either commercially or non-commercially, provided that this License, the copyright notices, and the license notice saying this License applies to the Document are reproduced in all copies, and that you add no other conditions whatsoever to those of this License. You may not use technical measures to obstruct or control the reading or further copying of the copies you make or distribute. However, you may accept compensation in exchange for copies. If you distribute a large enough number of copies you must also follow the conditions in section 3.

You may also lend copies, under the same conditions stated above, and you may publicly display copies.

3. COPYING IN QUANTITY

If you publish printed copies (or copies in media that commonly have printed covers) of the Document, numbering more than 100, and the Document's license notice requires Cover Texts, you must enclose the copies in covers that carry, clearly and legibly, all these Cover Texts: Front-Cover Texts on the front cover, and Back-Cover Texts on the back cover. Both covers must also clearly and legibly identify you as the publisher of these copies. The front cover must present the full title with all words of the title equally prominent and visible. You may add other material on the covers in addition. Copying with changes limited to the covers, as long as they preserve the title of the Document and satisfy these conditions, can be treated as verbatim copying in other respects.

If the required texts for either cover are too voluminous to fit legibly, you should put the first ones listed (as many as fit reasonably) on the actual cover, and continue the rest onto adjacent pages.

If you publish or distribute Opaque copies of the Document numbering more than 100, you must either include a machine-readable Transparent copy along with each Opaque copy, or state in or with each Opaque copy a computer-network location from which the general network-using public has access to download using public-standard network protocols a complete Transparent copy of the Document, free of added material. If you use the latter option, you must take reasonably prudent steps, when you begin distribution of Opaque copies in quantity, to ensure that this Transparent copy will remain thus accessible at the stated location until at least one year after the last time you distribute an Opaque copy (directly or through your agents or retailers) of that edition to the public.

It is requested, but not required, that you contact the authors of the Document well before redistributing any large number of copies, to give them a chance to provide you with an updated version of the Document.

4. MODIFICATIONS

You may copy and distribute a Modified Version of the Document under the conditions of sections 2 and 3 above, provided that you release the Modified Version under precisely this License, with the Modified Version filling the role of the Document, thus licensing distribution and modification of the Modified Version to whoever possesses a copy of it. In addition, you must do these things in the Modified Version:

- A. Use in the Title Page (and on the covers, if any) a title distinct from that of the Document, and from those of previous versions (which should, if there were any, be listed in the History section of the Document). You may use the same title as a previous version if the original publisher of that version gives permission.
- B. List on the Title Page, as authors, one or more persons or entities responsible for authorship of the modifications in the Modified Version, together with at least five of the principal authors of the Document (all of its principal authors, if it has fewer than five), unless they release you from this requirement.
- C. State on the Title page the name of the publisher of the Modified Version, as the publisher.
- D. Preserve all the copyright notices of the Document.
- E. Add an appropriate copyright notice for your modifications adjacent to the other copyright notices.
- F. Include, immediately after the copyright notices, a license notice giving the public permission to use the Modified Version under the terms of this License, in the form shown in the Addendum below.
- G. Preserve in that license notice the full lists of Invariant Sections and required Cover Texts given in the Document's license notice.
- H. Include an unaltered copy of this License.
- I. Preserve the section Entitled "History", Preserve its Title, and add to it an item stating at least the title, year, new authors, and publisher of the Modified Version as given on the Title Page. If there is no section Entitled "History" in the Document, create one stating the title, year, authors, and publisher of the Document as given on its Title Page, then add an item describing the Modified Version as stated in the previous sentence.

- J. Preserve the network location, if any, given in the Document for public access to a Transparent copy of the Document, and likewise the network locations given in the Document for previous versions it was based on. These may be placed in the "History" section. You may omit a network location for a work that was published at least four years before the Document itself, or if the original publisher of the version it refers to gives permission.
- K. For any section Entitled "Acknowledgements" or "Dedications", Preserve the Title of the section, and preserve in the section all the substance and tone of each of the contributor acknowledgements and/or dedications given therein.
- L. Preserve all the Invariant Sections of the Document, unaltered in their text and in their titles. Section numbers or the equivalent are not considered part of the section titles.
- M. Delete any section Entitled "Endorsements". Such a section may not be included in the Modified Version.
- N. Do not retitle any existing section to be Entitled "Endorsements" or to conflict in title with any Invariant Section.
- O. Preserve any Warranty Disclaimers.

If the Modified Version includes new front-matter sections or appendices that qualify as Secondary Sections and contain no material copied from the Document, you may at your option designate some or all of these sections as invariant. To do this, add their titles to the list of Invariant Sections in the Modified Version's license notice. These titles must be distinct from any other section titles.

You may add a section Entitled "Endorsements", provided it contains nothing but endorsements of your Modified Version by various parties--for example, statements of peer review or that the text has been approved by an organization as the authoritative definition of a standard.

You may add a passage of up to five words as a Front-Cover Text, and a passage of up to 25 words as a Back-Cover Text, to the end of the list of Cover Texts in the Modified Version. Only one passage of Front-Cover Text and one of Back-Cover Text may be added by (or through arrangements made by) any one entity. If the Document already includes a cover text for the same cover, previously added by you or by arrangement made by the same entity you are acting on behalf of, you may not add another; but you may replace the old one, on explicit permission from the previous publisher that added the old one.

The author(s) and publisher(s) of the Document do not by this License give permission to use their names for publicity for or to assert or imply endorsement of any Modified Version.

5. COMBINING DOCUMENTS

You may combine the Document with other documents released under this License, under the terms defined in section 4 above for modified versions, provided that you include in the combination all of the Invariant Sections of all of the original documents, unmodified, and list them all as Invariant Sections of your combined work in its license notice, and that you preserve all their Warranty Disclaimers.

The combined work need only contain one copy of this License, and multiple identical Invariant Sections may be replaced with a single copy. If there are multiple Invariant Sections with the same name but different contents, make the title of each such section unique by adding at the end of it, in parentheses, the name of the original author or publisher of that section if known, or else a unique number. Make the same adjustment to the section titles in the list of Invariant Sections in the license notice of the combined work.

In the combination, you must combine any sections Entitled "History" in the various original documents, forming one section Entitled "History"; likewise combine any sections Entitled "Acknowledgements", and any sections Entitled "Dedications". You must delete all sections Entitled "Endorsements".

6. COLLECTIONS OF DOCUMENTS

You may make a collection consisting of the Document and other documents released under this License, and replace the individual copies of this License in the various documents with a single copy that is included in the collection, provided that you follow the rules of this License for verbatim copying of each of the documents in all other respects.

You may extract a single document from such a collection, and distribute it individually under this License, provided you insert a copy of this License into the extracted document, and follow this License in all other respects regarding verbatim copying of that document.

7. AGGREGATION WITH INDEPENDENT WORKS

A compilation of the Document or its derivatives with other separate and independent documents or works, in or on a volume of a storage or distribution medium, is called an "aggregate" if the copyright resulting from the compilation is not used to limit the legal rights of the compilation's users beyond what the individual works permit. When the Document is included in an aggregate, this License does not apply to the other works in the aggregate which are not themselves derivative works of the Document.

If the Cover Text requirement of section 3 is applicable to these copies of the Document, then if the Document is less than one half of the entire aggregate, the Document's Cover Texts may be placed on covers that bracket the Document within the aggregate, or the electronic equivalent of covers if the Document is in electronic form. Otherwise they must appear on printed covers that bracket the whole aggregate.

8. TRANSLATION

Translation is considered a kind of modification, so you may distribute translations of the Document under the terms of section 4. Replacing Invariant Sections with translations requires special permission from their copyright holders, but you may include translations of some or all Invariant Sections in addition to the original versions of these Invariant Sections. You may include a translation of this License, and all the license notices in the Document, and any Warranty Disclaimers, provided that you also include the original English version of this License and the original versions of those notices and disclaimers. In case of a disagreement between the translation and the original version of this License or a notice or disclaimer, the original version will prevail.

If a section in the Document is Entitled "Acknowledgements", "Dedications", or "History", the requirement (section 4) to Preserve its Title (section 1) will typically require changing the actual title.

9. TERMINATION

You may not copy, modify, sublicense, or distribute the Document except as expressly provided for under this License. Any other attempt to copy, modify, sublicense or distribute the Document is void, and will automatically terminate your rights under this License. However, parties who have received copies, or rights, from you under this License will not have their licenses terminated so long as such parties remain in full compliance.

10. FUTURE REVISIONS OF THIS LICENSE

The Free Software Foundation may publish new, revised versions of the GNU Free Documentation License from time to time. Such new versions will be similar in spirit to the present version, but may differ in detail to address new problems or concerns. See <https://www.gnu.org/copyleft/>.

Each version of the License is given a distinguishing version number. If the Document specifies that a particular numbered version of this License "or any later version" applies to it, you have the option of following the terms and conditions either of that specified version or of any later version that has been published (not as a draft) by the Free Software Foundation. If the Document does not specify a version number of this License, you may choose any version ever published (not as a draft) by the Free Software Foundation.

ADDENDUM: How to use this License for your documents

```
Copyright (c) YEAR YOUR NAME.  
Permission is granted to copy, distribute and/or modify this document  
under the terms of the GNU Free Documentation License, Version 1.2  
or any later version published by the Free Software Foundation;  
with no Invariant Sections, no Front-Cover Texts, and no Back-Cover Texts.  
A copy of the license is included in the section entitled "GNU  
Free Documentation License".
```

If you have Invariant Sections, Front-Cover Texts and Back-Cover Texts, replace the "with...Texts." line with this:

```
with the Invariant Sections being LIST THEIR TITLES, with the  
Front-Cover Texts being LIST, and with the Back-Cover Texts being LIST.
```

If you have Invariant Sections without Cover Texts, or some other combination of the three, merge those two alternatives to suit the situation.

If your document contains nontrivial examples of program code, we recommend releasing these examples in parallel under your choice of free software license, such as the GNU General Public License, to permit their use in free software.