Managing EFI Boot Loaders for Linux: Controlling Secure Boot

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This page is part of my Managing EFI Boot Loaders for Linux document. If a Web search has brought you to this page, you may want to start at the beginning.

Contents

This page is the second of two covering Secure Boot as part of my EFI Boot Loaders for Linux document. If you're a beginner to intermediate user who wants to get Secure Boot working quickly with a popular distribution such as Ubuntu, Fedora, or OpenSuse, I recommend you begin with my first Secure Boot page, Dealing with Secure Boot. This page is written for more advanced users who want to take *full* control of their Secure Boot features. Reasons to take this type of control are covered in the Why Read This Page? section of this page. The Contents section to the left shows other sections, in case you know enough to know what you want to read.

Why Read This Page?

If you boot nothing but Windows, chances are this page won't do you any good, except perhaps to help satisfy your curiosity about the inner workings of Secure Boot. If you dual-boot Windows and a single popular Linux distribution such as Fedora or Ubuntu, you probably don't need this page, either; such distributions ship with Secure Boot solutions that work reasonably well for such dual-boot configurations. If your needs are more complex, though, you may find this page of interest.

Secure Boot works by installing a set of keys in the computer's firmware. These keys (or more precisely, their private counterparts) are used to sign boot loaders, drivers, option ROMs, and other software that the firmware runs. Most commodity PCs (desktops, laptops, many tablets, and some servers) sold today include keys that Microsoft controls. In fact, Microsoft's keys are the *only* ones that are more-or-less guaranteed to be installed in your firmware, at least on desktop and laptop computers. Thus, to install your favorite Linux distribution, you must disable Secure Boot, find a Linux boot loader that's signed with Microsoft's keys, or replace your computer's standard keys with ones that you control. This page is about this final option, but both of the other options have their merits. Disabling Secure Boot is quick and enables you to easily run any EFI tool you like—but it also leaves you vulnerable to any pre-boot malware that might crop up. Using a pre-signed boot loader, such as the popular Shim program, can be even easier than disabling Secure Boot—*if* your distribution provides such a program. If not, you'll need to jump through hoops. Also, using a pre-signed boot loader with the default key set means that your computer will accept as valid Microsoft's boot loaders and any others that Microsoft decides to sign.

Taking control of your computer's Secure Boot keys offers several advantages over these approaches:

- **Locking out threats from the standard keys**—In theory, Secure Boot should prevent malware from running. On the other hand, it's always possible that an attacker could trick Microsoft into signing malware. If you use Shim with the default keys, your computer will remain vulnerable to these threats, at least until they're discovered and your blacklist database is updated.
- **Locking out threats from your distribution's keys**—Similar to the preceding, it's also possible that your distribution's keys could be compromised, in which case an attacker could distribute malware signed with the compromised keys. Depending on how you manage your keys, you can greatly reduce this vulnerability—but the greatest level of protection will require extra effort on your part.
- **Eliminating the need for MOKs**—The Shim and PreLoader tools both rely on Machine Owner Keys (MOKs), which are similar to Secure Boot keys but easier to install. Because they can be more easily installed, it's conceivable that they could be more readily abused by social engineering or other means. Eliminating MOKs may therefore slightly increase your security, particularly if you're managing a collection of desktop computers used by other people.
- **Taking philosophical control**—Relying on a third party's keys strikes some people as being wrong. Partly this is because of the preceding reasons, but some people object to the dependency on a more philosophical level. If you fall into this category, generating and using your own keys may give you a sense of satisfaction.
- **Testing and development**—If you want to develop your own boot manager, you may need to be able to test a signed version of your software in an environment that mimics a "stock" computer. The process for signing binaries with Microsoft's Secure Boot keys is tedious and time-consuming, though, so you may need to set your computer up with your own keys so that you can sign the binaries yourself. When the software works as you expect, you can send it to Microsoft to be signed.
- **Enabling Secure Boot on systems without keys**—Some servers ship without Microsoft's Secure Boot keys installed. Using Secure Boot with such a server requires adding keys as described on this page. Note that Linux distributions for exotic platforms, such as ARM64, do not currently (in mid-2018) ship with signed Shim implementations, so you'll need to sign the boot loader (or add whatever public key matches the private key used to sign the boot loader) and boot it directly.
- **Overcoming default boot-hogs**—This one is admittedly speculative. Some people have reported difficulty getting their computers to boot anything but Windows by default; they can boot to Linux temporarily, use `efibootmgr` to set Linux as the default boot loader, but then find themselves booting back to Windows because the firmware keeps setting Windows as the default. *If* the Linux boot entry remains in place but is "demoted," setting your own boot keys might enable you to control this problem by removing Microsoft's key from the regular Secure Boot list and adding it to your MOK list. You'd need to use Shim or PreLoader for this to work. Note, however, that some computers hang upon encountering the first Secure Boot error; and if the problem is caused by a computer "forgetting" its entire boot list, this solution will do no good whatsoever.

Of course, there are drawbacks to this approach, too. Some of these disadvantages are fairly obvious, but others may hide out and bite you unexpectedly:

- **Extra setup effort**—The length of this page is a hint of the lengths to which you'll have to go to make this approach work. I've tried to be as thorough as possible in writing this page, but nonetheless, you'll almost certainly find it easier to disable Secure Boot or use Shim or PreLoader, at least if your needs are modest.
- **Lack of support for option ROMs**—Some plug-in cards have firmware that's signed by Microsoft's keys. Such a card will not work (at least, not from the firmware) if you enable Secure Boot without the matching public key. (The card should still work once you've booted an OS. The biggest concern is for cards that must work in a pre-boot environment, such as a video card or for PXE-booting a network card.) You can add Microsoft's keys back to the environment to make such cards work, but this eliminates the advantages of not having those keys, if that's a significant factor for you.
- **Greater potential for future problems**—OS installation utilities and system upgrade tools may

not run or may replace your working custom-signed boot programs with versions that are signed improperly for your system. You'll have to be alert to such potential problems and keep suitable backups for restoration purposes. Disabling Secure Boot may be necessary to install a new OS.

- **Broken Secure Boot authentication**—Some of my Secure Boot computers reject a significant fraction of EFI programs that are signed as described on this page. Other computers accept the same binaries just fine, and they work fine on the affected machines when launched via Shim, so it appears that either some computers' Secure Boot implementations are overly strict or there's a subtle problem in the way the binaries are signed that affects only some Secure Boot implementations. Binaries built with recent versions of GNU-EFI seem to be particularly prone to these problems. Of course, you might not run into such difficulties, but if you do, you may need to use Shim or PreLoader to overcome them.

If any of these advantages sounds compelling to you, read on. If the drawbacks sound like too much hassle, you may be interested in simpler ways of handling Secure Boot, as described on my Dealing with Secure Boot page.

Knowing Secure Boot Key Types

Before delving into the nitty-gritty of setting things up, you should be aware of the fact that there are four types of Secure Boot keys built into your firmware, and a fifth that you may encounter if you use Shim or PreLoader:

- **Database Key (db)**—This is the key type that you're most likely to think of with respect to Secure Boot, because it's used to sign or verify the binaries (boot loaders, boot managers, shells, drivers, etc.) that you run. Most computers come with two Microsoft keys installed. Microsoft uses one of these itself and uses the other to sign third-party software, such as Shim. Some computers also come with keys created by the computer manufacturer or other parties. Canonical (the creator of the Ubuntu Linux distribution) has managed to get its key embedded in some computers' firmwares, for instance, although it's not nearly ubiquitous enough that you can count on its being present. As this description implies, the db can hold multiple keys—an important fact for some purposes. Note that the db can contain both public keys (which are matched to private keys that can be used to sign multiple binaries) and hashes (which describe individual binaries). For the most part, this document focuses on the db as a carrier for keys, but you can add hashes to your db if you like. (The KeyTool program is useful for this purpose.)
- **Database Blacklist Key (dbx)**—The dbx is a sort of anti-db; it contains keys and hashes that correspond to known malware or otherwise undesirable software. I don't describe setting up the dbx on this page, although you could install keys or hashes to it just as you would to the db. If a binary matches a key or hash that's in both the db and the dbx, the dbx should take precedence. This enables blacklisting a single binary (via its hash) even if that binary is signed by a key that you don't want to revoke because it's been used to sign lots of legitimate binaries.
- **Key Exchange Key (KEK)**—The KEK is used to sign keys so that the firmware accepts them as valid when entering them into the database (either the db or the dbx). Without the KEK, the firmware would have no way of knowing whether a new key was valid or was being fed by malware. Thus, in the absence of the KEK, Secure Boot would either be a joke or require that the databases remain static. Since a critical point of Secure Boot is the dbx, a static database would be unworkable. Computers often ship with two KEKs, one from Microsoft and one from the motherboard manufacturer. This enables either party to issue updates.

> **Note:** If you want to accept Microsoft's or your computer manufacturer's dbx updates, you must retain their KEKs. If you install only your own KEK, you'll have to manually update your dbx or leave it alone. If you don't install Microsoft's keys in your db, chances are you'll never need the dbx, since Microsoft's dbx entries should be for binaries signed by Microsoft that are later found to be malware, and such binaries won't run without Microsoft's db key.

- **Platform Key (PK)**—The PK is the top-level key in Secure Boot, and it serves a function relative to the KEK similar to that of the KEK to the db and dbx. UEFI Secure Boot supports a single PK, which is generally provided by the motherboard manufacturer. Thus, only the motherboard manufacturer has full control over the computer. An important part of controlling the Secure Boot process yourself is to replace the PK with your own version.

- **Machine Owner Key (MOK)**—A MOK is equivalent to a db key; it's used to sign boot loaders and other EFI executables or to store hashes corresponding to individual programs. MOKs are not a standard part of Secure Boot, though; they're used by the Shim and PreLoader programs to store keys and hashes. As such, this page doesn't cover them in any detail.

All of these key types are similar; they're examples of Public Key Infrastructure (PKI), in which two long numbers are used for encryption or (in the case of Secure Boot) authentication of data. In Secure Boot, one key, known as the *private key,* is used to "sign" a file (an EFI program). This signature is appended to the program. The other key, known as the *public key,* must be publicly available—in the case of Secure Boot, it's embedded in firmware or stored in NVRAM. The public key can be used, in conjunction with the signature, to verify that the file has not been modified and to verify that it was signed with the key matched to the public key in use.

Obviously, the public key is not particularly sensitive; it needn't be hidden away or kept secret. The private key, however, is sensitive; if it were to fall into the hands of a malware author, that person could sign malware that would then be accepted as valid by computers using the matching public key.

When you replace your computer's set of public keys with your own, you'll also create a set of private keys. You must keep these keys secure. Ideally, you should store them on an encrypted external medium locked in a safe. Of course, you must balance security of your keys with access; if you need to sign binaries every five minutes, keeping your keys in an off-site safe will be impractical.

The keys are stored in computer files, and each of the key types just described takes an identical form; in fact, you could use a PK as a MOK if you liked. Keep in mind also that each key is really two paired keys. Sometimes writers (myself included) get a little sloppy and write something like "the binary was signed by the key in the firmware," when in fact the binary was signed by the private key matched to the public key in the firmware.

Creating Secure Boot Keys

> **Note:** It's possible to generate keys and sign binaries using tools other than `efitools` and `sbsigntool`; however, these are the tools with which I'm most familiar, so I describe the process using them.

Now to action! The first step to replacing your computer's standard set of keys is to generate your own keys. To do this, you'll need several packages installed on your Linux computer. In particular, you need `openssl` and `efitools`. The former is available in a package of that name on most distributions, but `efitools` is less common. It's available in Ubuntu's repository, and builds for several distributions are available at the OpenSUSE Build Service (OBS). If necessary, you can compile it from source code; check here for source. Note that `efitools` is dependent upon `sbsigntool` (aka `sbsigntools`), so you may need to install it, too. See here for `sbsigntool` source code.

> Thanks to Vishnu V. Krishnan for some improvements to the `mkkeys.sh` script.

You must create three Secure Boot key sets (public and private), and for greatest flexibility, you'll need several file formats—annoyingly, different programs require different file formats. Generating all these keys requires running a number of commands. To help out, I've written a short script for this purpose; you can download it here, or copy-and-paste it from the following listing into a file (I call it `mkkeys.sh`):

```
#!/bin/bash
# Copyright (c) 2015 by Roderick W. Smith
# Licensed under the terms of the GPL v3

echo -n "Enter a Common Name to embed in the keys: "
read NAME

openssl req -new -x509 -newkey rsa:2048 -subj "/CN=$NAME PK/" -keyout PK.key \
        -out PK.crt -days 3650 -nodes -sha256
openssl req -new -x509 -newkey rsa:2048 -subj "/CN=$NAME KEK/" -keyout KEK.key \
        -out KEK.crt -days 3650 -nodes -sha256
openssl req -new -x509 -newkey rsa:2048 -subj "/CN=$NAME DB/" -keyout DB.key \
        -out DB.crt -days 3650 -nodes -sha256
openssl x509 -in PK.crt -out PK.cer -outform DER
openssl x509 -in KEK.crt -out KEK.cer -outform DER
openssl x509 -in DB.crt -out DB.cer -outform DER
```

```
GUID=`python -c 'import uuid; print(str(uuid.uuid1()))'`
echo $GUID > myGUID.txt

cert-to-efi-sig-list -g $GUID PK.crt PK.esl
cert-to-efi-sig-list -g $GUID KEK.crt KEK.esl
cert-to-efi-sig-list -g $GUID DB.crt DB.esl
rm -f noPK.esl
touch noPK.esl

sign-efi-sig-list -t "$(date --date='1 second' +'%Y-%m-%d %H:%M:%S')" \
                  -k PK.key -c PK.crt PK PK.esl PK.auth
sign-efi-sig-list -t "$(date --date='1 second' +'%Y-%m-%d %H:%M:%S')" \
                  -k PK.key -c PK.crt PK noPK.esl noPK.auth
sign-efi-sig-list -t "$(date --date='1 second' +'%Y-%m-%d %H:%M:%S')" \
                  -k PK.key -c PK.crt KEK KEK.esl KEK.auth
sign-efi-sig-list -t "$(date --date='1 second' +'%Y-%m-%d %H:%M:%S')" \
                  -k KEK.key -c KEK.crt db DB.esl DB.auth

chmod 0600 *.key

echo ""
echo ""
echo "For use with KeyTool, copy the *.auth and *.esl files to a FAT USB"
echo "flash drive or to your EFI System Partition (ESP)."
echo "For use with most UEFIs' built-in key managers, copy the *.cer files."
echo ""
```

Be sure to set the executable bit on the program file (as in **`chmod a+x mkkeys.sh`**). Running this program creates output similar to the following:

```
$ ./mkkeys.sh
Enter a Common Name to embed in the keys: Foo, Inc. Secure Boot key set
Generating a 2048 bit RSA private key
.......+++
...................................+++
writing new private key to 'PK.key'
-----
Generating a 2048 bit RSA private key
....+++
.......................................+++
writing new private key to 'KEK.key'
-----
Generating a 2048 bit RSA private key
.............................+++
.....................................................+++
writing new private key to 'DB.key'
-----
Authentication Payload size 897
Signature of size 1463
Authentication Payload size 40
Signature of size 1463
Authentication Payload size 901
Signature of size 1463
Authentication Payload size 897
Signature of size 1466


For use with KeyTool, copy the *.auth and *.esl files to a FAT USB
flash drive or to your EFI System Partition (ESP).
For use with most UEFIs' built-in key managers, copy the *.cer files;
but some UEFIs require the *.auth files.
```

This script prompts you for a common name to embed in your keys. You can leave this blank if you like, but providing a name will help you identify your keys and differentiate them from other keys.

Be aware that you might not need to run this command, though; the procedure described for Securing Multiple Computers, which uses a program called LockDown, will build a new set of keys. By default there will be no common name in the keys created for LockDown, though. It's possible to embed the keys generated with the `mkkeys.sh` script in LockDown, if you prefer to use one key set for multiple procedures.

After running `mkkeys.sh`, you'll have a total of seventeen key files for PK, KEK, and DB. Filename extensions are `.crt`, `.cer`, `.esl`, and `.auth` for public keys and `.key` for private keys. The `myGUID.txt` file holds a GUID that's embedded in the `.esl` and `.auth` files. As the script's message notes, you should copy the `.cer`, `.esl`, and `.auth` files to a FAT partition or USB flash drive that your target computer's EFI can read.

At this point, it's worth considering precisely how you intend to lock down your computer. Broadly speaking, you have two options: You can rely exclusively on your own keys, which means you must sign every program your firmware runs, and probably sign every Linux kernel you boot; or you can add third-party keys to your database, which will enable binaries signed by that party to run without re-signing them. You might do the latter to simplify maintenance of a distribution such as Fedora, OpenSUSE, or Ubuntu, all of which distribute signed copies of GRUB and of their Linux kernels. On the other hand, relying on these keys will render your computer at least theoretically vulnerable to attack should their private keys be compromised. Similarly, you might add one or both of Microsoft's public keys if you want to run Windows or third-party programs signed by Microsoft's key. (Note that plug-in cards may have firmware that's been signed by Microsoft's third-party key.)

> **Warning:** KeyTool's file browser doesn't show files with `.der` extensions. This extension and `.cer` both refer to the same file format, so you should rename your `.der` files to end in `.cer` if you plan to use KeyTool.

If you decide to use outside keys, you should obtain them from their maintainer. For convenience, my rEFInd boot manager comes with a number of keys; see its git repository for easy access to individual keys. For better security, though, track down the original key and obtain it from a secure site. You'll need `.cer`, `.der`, or `.esl` files to add the key to your database. Copy any additional keys you obtain to the same FAT partition or USB flash drive to which you copied your own keys.

As noted earlier, the private keys are highly sensitive, so you should guard them carefully. Before locking them up, though, you'll want to use them to sign your binaries. This topic is up next....

Signing EFI Binaries

> **Note:** For the following steps, I assume that the Secure Boot keys you prepared are available in `~/efitools`. You must adjust this path as necessary on your system.

Once you lock down your computer with a new set of keys, it won't be able to run any programs that were not signed by one of the keys corresponding to the public db keys you've installed. Therefore, you'll probably want to sign your most important EFI programs before proceeding. (This won't be necessary if your EFI binaries and kernels are all signed by your distribution's maintainer and if you add the distribution's public key to your db.) Depending on your boot loader, you may need to sign your Linux kernels, too. (If you run into problems, you can always disable Secure Boot temporarily to sign more binaries, or use another computer to sign `EFI/BOOT/bootx64.efi` on a USB flash drive.)

In any event, the procedure to sign an EFI binary is fairly straightforward, once you've installed the `sbsigntool` package and created keys:

```
$ sbsign --key ~/efitools/DB.key --cert ~/efitools/DB.crt \
        --output vmlinuz-signed.efi vmlinuz.efi
warning: file-aligned section .text extends beyond end of file
warning: checksum areas are greater than image size. Invalid section table?
```

This example signs the `vmlinuz.efi` binary, located in the current directory, writing the signed binary to `vmlinuz-signed.efi`. Of course, you must change the names of the binaries to suit your needs, as well as adjust the path to the keys (`DB.key` and `DB.crt`). The `DB.key` and `DB.crt` filenames correspond to the database keys, described earlier. If you're signing a binary that should be recognized by Shim through MOK, you must change the key files appropriately.

This example shows two warnings. I don't claim to fully understand them, but they don't seem to do any harm—at least, the Linux kernel binaries I've signed that have produced these warnings have worked fine. (Such warnings seem to be less common in 2015 and later than they were a couple of before then.) Another warning I've seen on binaries produced with GNU-EFI also seems harmless:

```
warning: data remaining[1231832 vs 1357089]: gaps between PE/COFF sections?
```

On the other hand, the `ChangeLog` file for GNU-EFI indicates that binaries created with GNU-EFI versions earlier than 3.0q may not boot in a Secure Boot environment when signed, and signing such binaries produces another warning:

```
warning: gap in section table:
    .text   : 0x00000400 - 0x00019c00,
    .reloc  : 0x00019c91 - 0x0001a091,
warning: gap in section table:
    .reloc  : 0x00019c91 - 0x0001a091,
    .data   : 0x0001a000 - 0x00035000,
gaps in the section table may result in different checksums
```

If you see a warning like this, you may need to recompile your binary using a more recent version of GNU-EFI.

If you're using rEFIt, rEFInd, or gummiboot/systemd-boot, you must sign not just those boot manager binaries, but also the programs that they launch, such as Linux kernels, ELILO binaries, and filesystem drivers. If you fail to do this, you'll be unable to launch the boot loaders that the boot managers are intended to launch. Stock versions of ELILO, GRUB Legacy, and older builds of GRUB 2 don't check Secure Boot status or use EFI system calls to load kernels, so even signed versions of these programs will launch any kernel you feed them. This defeats the purpose of Secure Boot, though, at least when launching Linux. Most recent versions of GRUB 2 communicate with Shim or the Secure Boot subsystem for authenticating Linux kernels and so will refuse to launch a Linux kernel that's not been signed.

Once you've signed your binaries, you should install them to your ESP as you would an unsigned EFI binary. Signed binaries should work fine even on systems on which you've disabled Secure Boot. If your computer is already booting through an existing boot program such as GRUB or rEFInd, you must sign the binary with your own key and then either replace the original file or create a new boot entry by using `efibootmgr` or a similar tool. If you're currently booting in Secure Boot mode via Shim, you can either sign the Shim binary (leaving the follow-on boot loader untouched, at least initially) or sign the follow-on boot loader and register it to boot directly via `efibootmgr`. Similar comments apply if you're using PreLoader—but be aware that if you sign the follow-on boot loader, that will change its hash, so PreLoader will no longer recognize it as valid.

Securing One Computer

You can lock down a single computer with your new Secure Boot keys in any of three ways: You can use your firmware's built-in setup utility, you can use the KeyTool program that's part of the `efitools` package, or you can create a version of the LockDown program with an embedded key. The first of these methods is not possible on some computers, since many lack the necessary user interface options. Thus, using KeyTool is the most general-purpose method. Using LockDown also works, but it requires compiling the software from source. As this method can greatly simplify the setup of multiple computers, I describe it in more detail in that context.

Conceptually, replacing your default Secure Boot keys requires entering *setup mode.* In this mode, you may replace all of the keys, including the PK. Setup mode may be entered only from the firmware setup utility; you cannot enter setup mode from within an OS. Thus, you must deal with your computer's setup utility. Unfortunately, there is no standardization of UEFI user interfaces, so it's impossible to describe precisely how to enter setup mode in a way that applies to all computers. In fact, many UEFIs don't even refer to setup mode as such—they use some other term!

Replacing Keys Using Your Firmware's Setup Utility

Some UEFIs provide the means to install your own keys using their own built-in user interfaces. This method of doing the job is likely to be slightly easier than using a separate utility, because you won't need to use an EFI shell or otherwise configure such a tool to run; but all four of the interfaces I've seen employ confusing terminology and are unintuitive in certain key respects. They're all similar to one another, so for the sake of simplicity I'll describe only one: The ASUS P8H77-I. Some details differ between computers, but with any luck yours won't differ greatly from this one.

To begin, you must find a way to enter the firmware setup utility. You can do this by hitting the Delete or F2 key on many computers just after you power them on, but this detail varies greatly between machines. Check your manual or watch the screen for prompts. Many Linux boot managers, including my own rEFInd, offer options to launch the firmware setup tool, so you may be able to use that method, too—but this feature relies on firmware support that's not universal, so it might not work for you. This same firmware support can be accessed from within an OS. In Linux systems that use systemd, typing `systemctl reboot --firmware` will do the job.

Once you've entered the firmware setup utility, you must find the Secure Boot options. In the case of the ASUS P8H77, you may need to hit F7 to enter *Advanced Mode,* select the *Boot* screen, and then scroll down to the *Secure Boot* option, as shown here:

Entering the *Secure Boot* menu, set *OS Type* to *Windows UEFI mode.* This will activate another submenu called *Key Management.* As you can see from the following screen shot, this menu provides options to clear keys, save keys, and modify the PK, KEK, db, and dbx individually. (The dbx options require scrolling down on this computer.)

Before proceeding, you might want to select the *Save Secure Boot keys* option, which saves your keys to disk files. The ASUS permits to you restore the default keys, so this isn't really vital if you're starting from the factory defaults with this model; but if yours doesn't offer such a reset-to-defaults option or if you've modified the keys, saving them may be prudent.

In the case of the ASUS P8H77-I, you enter setup mode by selecting the *Clear Secure Boot keys* option. As the name implies, this option also erases all your Secure Boot keys. (It does *not* erase your MOKs, though.) You can then use the *Load... from File* and *Append... from File* options to load the files you prepared earlier. I recommend starting with the db, then installing your KEK, and finishing with the PK. The reason is that some systems exit setup mode the moment you enter a new PK, so doing the PK last is necessary. (The ASUS isn't so finicky, though.) If you want to load multiple keys (say, your own and the key for your Linux distribution), be sure to select the *Append db from File* option for the second and subsequent keys.

The ASUS P8H77-I's prompts are confusing once you opt to load or append a key from a file. The first prompt is *Append the additional db,* with a yes/no option. What the firmware is *really* asking is whether you want to load the default keys. If you respond *yes,* you won't be prompted to access a file and the default keys will be added to the db. Making this mistake after you've loaded two or three keys from files can be quite frustrating! When you respond *no* to the query, you'll be shown a primitive file selection dialog box, with which you can navigate your disks to locate a suitable key file.

In this case, a "suitable key file" is a `.cer`/`.der` or `.esl` file. (I've seen reports of UEFIs that require `.auth` files for this purpose.) The ASUS will ask whether the file is a *key certificate blob* or a *Uefi secure variable.* The former refers to `.cer`/`.der` files and the latter refers to `.esl` files.

Warning: My ASUS P8H77-I will accept *anything* as a key file, but only a properly formatted file will actually work! If you mistakenly add a `.crt` file or something else, you might be confused when it doesn't work. I don't know how many other implementations suffer from this same problem.

After you've loaded one or more db keys, one or more KEKs, and your PK, you can hit F10 to exit and save your changes. If you prepared your keys properly, signed your boot loader properly, and (if applicable) registered your boot loader via `efibootmgr`, you should see your boot loader appear. It should continue to launch anything that you've signed with your key and fail to launch anything that's not signed. An exception is boot loaders such as ELILO, GRUB Legacy, and early versions of GRUB 2, which don't check Secure Boot signatures on kernels. Also, if you signed a Shim or PreLoader binary and boot through it, anything authenticated by Shim or PreLoader should launch.

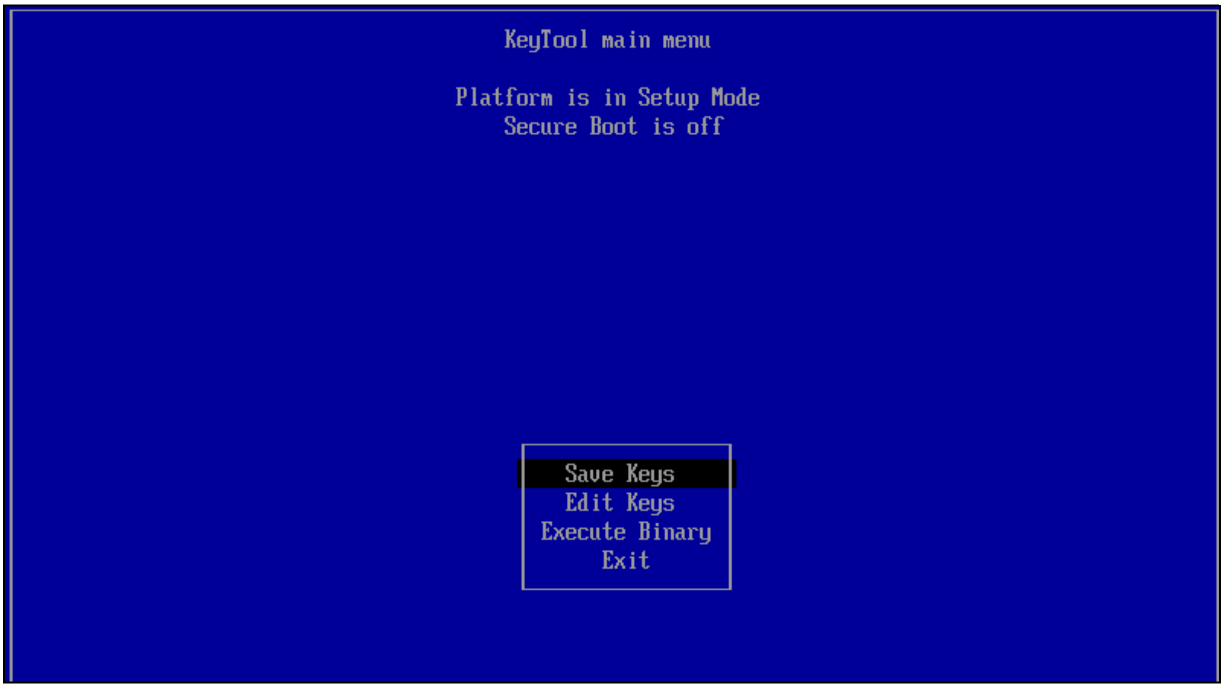
Replacing Keys Using KeyTool

Even if you can't find a Secure Boot key management screen like the one I've just described, you can perform similar tasks by using the KeyTool binary that comes with `efitools`. The procedure is as follows:

1. **Configure KeyTool to launch**—You can launch KeyTool in any number of ways. Examples include:

   > **Note:** I refer to `KeyTool-signed.efi` rather than `KeyTool.efi` because the former should run after you've locked your platform down, but the latter won't. Either binary will work before you register your keys.

   - Copy `KeyTool-signed.efi` to a FAT USB flash drive under the filename `EFI/BOOT/bootx64.efi`. You'll then be able to boot from the USB flash drive as you would from an OS installation medium.
   - Configure your system to boot an EFI shell, and then launch KeyTool from it. If you can already launch a shell from your firmware or from a boot manager, this is a simple solution, since you need only copy `KeyTool-signed.efi` to your ESP.
   - Copy `KeyTool-signed.efi` to your ESP and register it as a boot option with `efibootmgr`; or create an entry for it in your rEFInd, GRUB, gummiboot/systemd-boot, or other boot manager menu.
2. **Launch KeyTool**—Using whatever method you chose in step #1, launch KeyTool. The result should resemble the following:



3. **Save keys**—Using the *Save Keys* menu option, save your existing keys. As with the method that uses the firmware's user interface exclusively, this step is a precaution that may not be necessary with your computer; but it's better to be safe than sorry.
4. **Enter setup mode**—Reboot and enter your firmware's setup utility, as described earlier, in [Replacing Keys Using Your Firmware's Setup Utility,](#) and peruse the options to locate one to enter setup mode. Unfortunately, the name and location of this option is likely to be variable. It

may be described as an option to remove the Secure Boot keys. The option may also be inactive or even invisible until you've activated Secure Boot. After you've selected the setup mode option, save your changes and reboot.

5. **Launch KeyTool**—Launch KeyTool again.
6. **Verify setup mode**—In the preceding screen shot, note that KeyTool is reporting that the computer is running in setup mode. If KeyTool reports something else, go back into your firmware's setup utility and try again to locate the correct option.
7. **Delete unwanted keys**—If your firmware did not delete all your keys, you can use the *Edit Keys* menu to delete the ones you don't want. You should almost certainly delete the PK, and you may want to delete your KEKs and db entries. If you want to continue booting Windows, though, you can leave the Microsoft production PCA key intact; and if you want to continue booting programs other than the Windows boot loader that were signed by Microsoft, leave the Microsoft UEFI third-party marketplace key intact. Note that you can delete MOKs with KeyTool. If you're switching from a Secure Boot setup that used Shim or PreLoader, you might consider doing this—or you can save it until after you've tested your new configuration.
8. **Add new keys**—The *Add New Key* item in the *Edit Keys* menu, unsurprisingly, enables you to add new keys. You'll have to browse your disks (identified by long and awkward EFI identifier strings) to locate your keys and add them one at a time. Be sure to enter the PK *last;* once it's entered, KeyTool will prevent additional changes except from `.auth` files. (I describe them in more detail shortly.) You can use `.esl` or `.cer` files for db and KEK entries. The `.esl` files will appear in the KeyTool menu with the GUID associated with them; but `.cer` files will show up with an ID of `G0`. (Note that KeyTool ignores `.der` files, so if you have keys with this filename extension, you must rename them to end in `.cer`.) When you enter the PK, you must select the `PK.auth` file. The `mkkeys.sh` script saves the GUID embedded in the `.esl` and `.auth` files it generates so that you can use them in the future, should the need arise. The GUID is stored in the `myGUID.txt` file. Note also that if you use your firmware's setup utility to enter your keys, it will use its own GUID.

   > **Note:** If KeyTool is not run in setup mode, the menu options to add keys will be present but the only files the file selector will show will be `.auth` files.

9. **Exit and reboot**—Use the Esc key to back out to the main menu, exit the program, and then reboot the computer.

With any luck, Secure Boot will now work with your new set of keys. Test it by launching programs or kernels that you have and have not signed. If it doesn't work as you expect, you can go back in and change your keys. To make changes, you must either use `.auth` files for the keys you want to load or load the `noPK.auth` file into the PK position, as described shortly. You might also want to check that Secure Boot is active in your firmware; some computers may drop back to leaving Secure Boot disabled after you're done with KeyTool.

After you've locked down your platform with KeyTool, it won't permit you to make any additional changes from the `.esl` or `.cer` files in which the original keys were stored. It should, however, permit you to use `.auth` files to make changes. These files are basically `.esl` files that have been signed by the next-higher-level key—db files are signed with the KEK and KEK files are signed with the PK. The PK can sign itself, though. The command to sign a file looks something like this:

```
$ sign-efi-sig-list -t "$(date --date='1 second' +'%Y-%m-%d %H:%M:%S')" \
                    -k KEK.key -c KEK.crt db mykey.esl mykey.auth
```

This example signs the `mykey.esl` db file with the KEK, saving the result as `mykey.auth`. You should then be able to load `mykey.auth` into the db using KeyTool, even when not in setup mode.

A particularly useful special `.auth` file is `noPK.auth`. Both the `efitools` build process and my `mkkeys.sh` script create this file, which removes the PK from your computer, returning it to setup mode. The file must be matched to the original PK; you can't use the `noPK.auth` file you generate to remove the computer's original PK, or a different PK you generated some other time. Returning to setup mode in this way might be helpful if you must load keys that aren't already signed and turned into `.auth` files themselves. Remember to load the original `PK.auth` file after you've made your changes.

Be aware that KeyTool is very finicky about its `.auth` files. In part, this is because it checks not only the keys, but the GUIDs that are embedded in `.esl` (and hence `.auth`) files. If the GUID of the KEK used to sign a db key (or of the PK used to sign a KEK or PK) doesn't match that of the current KEK (or PK), KeyTool will refuse to make a change.

I've found that KeyTool can work differently on different computers. The instructions presented here for use of `.auth` files work fine on some machines, but fail completely on others. If you run into problems, I recommend saving your key files, using the firmware's own user interface to enter setup mode, restoring the db and KEK files you just saved, making whatever changes you intended, and then restoring the PK. This workaround is awkward, but it should do the trick. (Note that when you save existing keys, all the db keys will be stored in a single `.esl` file, even if you've entered several keys manually to start. This fact can greatly speed up recovery or replication of a configuration.)

One of the advantages of KeyTool, at least over the built-in setup utilities I've seen, is that it enables you to view and delete individual keys. This can be handy if you want to fine-tune your system without ripping everything out and starting from scratch.

Securing Multiple Computers

If you've read the preceding two sections, and if you need to replace the keys on a large number of computers, you may be groaning inwardly right now. Both of the preceding procedures involve a lot of tedious manual operations, so you'll end up spending several minutes per computer—and the possibility of error when selecting keys is significant.

Fortunately, there is an alternative that can help remove some (but not all) of the tedium and reduce the risk of making a mistake. The `efitools` package ships with an EFI program called LockDown, which automates the process of installing keys. Unfortunately, the keys it installs are stored in the binary itself, which means that you must compile the program yourself for it to do you any good. If you're unfamiliar with building software in Linux, you may run into significant stumbling blocks in the following procedure; describing every possible problem and solution is beyond the scope of this page. The procedure to build the program is as follows:

1. Prepare a Linux computer for building software, and especially for building EFI software. Some distributions provide a meta-package that can help, such as `build-essential` in Ubuntu. You'll also need the `gnu-efi` and `git` packages, and perhaps some others.
2. Download the `efitools` source code. Typing **`git clone git://git.kernel.org/pub/scm/linux/kernel/git/jejb/efitools.git`** in a scratch directory should do the trick.
3. Change into the `efitools` directory.
4. Type **`make`**. After a few seconds, this process should complete. The last few lines look like this:

```
Signature of size 1145
Signature at: 40
rm UpdateVars.o DB1.crt PK-hash-blacklist.esl SetNull.so ReadVars.o PK-blacklist.esl
 DB2.crt ms-kek-hash-blacklist.esl ms-uefi-hash-blacklist.esl ms-kek-blacklist.esl
 ms-uefi-blacklist.esl KEK-hash-blacklist.esl DB-hash-blacklist.esl HelloWorld.o
 DB-blacklist.esl Loader.o HashTool.o KEK-blacklist.esl DB1-hash-blacklist.esl
 DB1-blacklist.esl ms-kek.esl ms-uefi.esl DB2-hash-blacklist.esl DB2-blacklist.esl
 SetNull.o DB1.esl DB2.esl KeyTool.o
```

   If you see an error message instead, you'll have to debug the problem. It may be caused by a missing tool, and in most such cases an error message will contain a clue about what's missing, although such clues are seldom explicit—that is, they don't usually read "install the gnu-efi package to continue," although they may refer to missing header files that, if you Google their name, will point you to `gnu-efi`.

Assuming no errors, you should now have a number of files, including public and private keys and the `LockDown.efi` binary. There is, however, one potential complication: The build process for the program generated its own keys. This may be fine; if you want to simply use your own keys and no others, or if you're happy to sign a version of Shim or PreLoader and use MOKs to launch other EFI programs, you can store the PK, KEK, and db files that the build process generated and use the db files to sign your own binaries.

On the other hand, if you want to include keys for your Linux distribution, for Microsoft products, or for some other party, using the LockDown binary generated at this point will be inadequate.

Fortunately, there is a way to include additional keys in the binary:

1. If you haven't already built `efitools`, do so by typing **`make`** in the `efitools` directory.
2. If you want to use keys you've built with `mkkeys.sh`, copy *all* of the files that `mkkeys.sh` created to the `efitools` source code directory (the same directory that holds `LockDown.c` and other `.c` files for the EFI binaries).
3. Copy any third-party public keys you want to include, such as Microsoft's or your distribution's public keys, to the `efitools` source code directory.
4. Convert all the additional keys you want `LockDown` to install into `.esl` format. If you have `.crt` files, they can be converted as follows:
```
$ cert-to-efi-sig-list -g `python -c 'import uuid; print str(uuid.uuid1())'` \
  mykey.crt mykey.esl
```
Change `mykey.crt` to the original key's filename and `mykey.esl` into a matching `.esl` filename. If you have `.cer` or `.der` files, they must first be converted to `.crt` form:
```
$ openssl x509 -in mykey.cer -inform der -out mykey.crt
```
5. If you haven't already done so, concatenate all the `.esl` files that are destined for the db:
```
$ mv DB.esl DB-orig.esl
$ cat DB-orig.esl mykey.esl otherkey.esl > DB.esl
```
6. If you want multiple KEKs in your final system, repeat the previous two steps for the KEKs.
7. Remove the version of LockDown that's already been built, including its intermediate files:
```
$ rm LockDown*efi LockDown.so LockDown.o
```
8. Type **`make`** to build a copy of LockDown that includes all the keys you've placed in `DB.esl` (and in `KEK.esl`, if you've added keys to it).

With your `LockDown.efi` binary in hand, you can use it to (relatively) quickly install your custom set of keys on a computer. The procedure bears some similarities to that used to set up a computer using the built-in setup utility or KeyTool; however, you must enter setup mode and then run `LockDown.efi`. (Installing it to run from a USB flash drive can be a good way to move it around efficiently to set up many machines.) When you run `LockDown.efi`, it should report something like the following:

```
2.0 FS0:\> LockDown.efi
Platform is in Setup Mode
Created KEK Cert
Created db Cert
Created PK Cert
Platform is in User Mode
Platform is set to boot securely
```

Some computers don't switch immediately to Secure Boot mode when LockDown runs, in which case the final line will report that the computer is *not* set to boot securely. This is not necessarily cause for concern; when you reboot, the computer may activate Secure Boot, and if it doesn't, you should be able to use the firmware's own user interface to do so.

The build process for `efitools` creates both signed and unsigned versions of several other programs. You can use one matched pair of them, such as `HelloWorld.efi` and `HelloWorld-signed.efi`, to test that LockDown did what it should. If you replaced the keys with your own, though, you may need to rebuild this program just as you did LockDown.

Managing Keys from Linux

In principle, you can manage your Secure Boot keys from within Linux. The `efitools` package provides two utilities to help with this task: `efi-readvar` and `efi-updatevar`. As their names imply, they're used to read and write, respectively. Unfortunately, writing is tricky to do, at best.

To get an overview of your Secure Boot keys, you can simply type `efi-readvar`:

```
$ efi-readvar
Variable PK, length 837
PK: List 0, type X509
    Signature 0, size 809, owner 177d2c80-b6e5-11e4-a0f7-d050994678c5
        Subject:
            CN=Ringworld 2015-2-17 PK
        Issuer:
            CN=Ringworld 2015-2-17 PK
Variable KEK, length 839
KEK: List 0, type X509
    Signature 0, size 811, owner 177d2c80-b6e5-11e4-a0f7-d050994678c5
        Subject:
            CN=Ringworld 2015-2-17 KEK
        Issuer:
            CN=Ringworld 2015-2-17 KEK
Variable db, length 7064
db: List 0, type X509
    Signature 0, size 809, owner 177d2c80-b6e5-11e4-a0f7-d050994678c5
        Subject:
            CN=Ringworld 2015-2-17 DB
        Issuer:
            CN=Ringworld 2015-2-17 DB
db: List 1, type X509
    Signature 0, size 847, owner 0b807420-b6e3-11e4-b7b5-d050994678c5
        Subject:
            CN=Roderick W. Smith, rodsmith@rodsbooks.com
        Issuer:
            CN=Roderick W. Smith, rodsmith@rodsbooks.com
db: List 2, type X509
    Signature 0, size 1096, owner 0b807420-b6e3-11e4-b7b5-d050994678c5
        Subject:
            C=GB, ST=Isle of Man, L=Douglas, O=Canonical Ltd., CN=Canonical Ltd. Mas
        Issuer:
            C=GB, ST=Isle of Man, L=Douglas, O=Canonical Ltd., CN=Canonical Ltd. Mas
Variable dbx has no entries
Variable MokList has no entries
```

As you can see, this computer has one PK, one KEK, and three db entries. The PK, KEK, and first db entry were built with my `mkkeys.sh` script using the name `Ringworld 2015-2-17`. The second db entry is the public key associated with my rEFInd project, and the third is Canonical's public key. Although several of my computers have MOKs, they haven't shown up in `efi-readvar` output for me.

You can limit `efi-readvar`'s output by applying the `-v` and `-s` options; see the program's man page for details. The `-o` option redirect's output to a file.

The `efi-updatevar` command is more complex. In theory, you can use it to update your db or KEK database, but *only* if you have the *private key* for the next-higher database—that is, to add a db entry, you need the KEK private key, and to add a KEK, you need the PK private key. The command to add a db key would look like this:

```
# efi-updatevar -a -c newkey.crt -k KEK.key db
```

Unfortunately, this command has never worked for me; `efi-updatevar` reports `Failed to update db: Operation not permitted` or `Cannot write to db, wrong filesystem permissions`, even when run as `root`. In some cases, immediately thereafter `efi-readvar` reports that the database is empty (although a reboot fixes that problem). Perhaps this bug will be fixed by the time you read this, though. If so, be sure to read the `efi-updatevar` man pages and [its author's blog posts] on the tool. [This Gentoo wiki page] provides more detailed step-by-step procedures for setting up Secure Boot using this tool. A mistake when using this tool could be quite damaging. In particular, note the `-a` option in the preceding example, which causes a key to be added to the list. Omitting that option causes the new key to *replace all existing keys.*

Conclusions

Taking full control of your computer's Secure Boot keys is not for everybody; the process is tedious and error-prone. It has the potential, though, to improve your computer's security by ensuring that only boot loaders and kernels *you* have explicitly approved can run.

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