Der Flounder

Seldom updated, occasionally insightful.

- Home
- About
- Contact
-

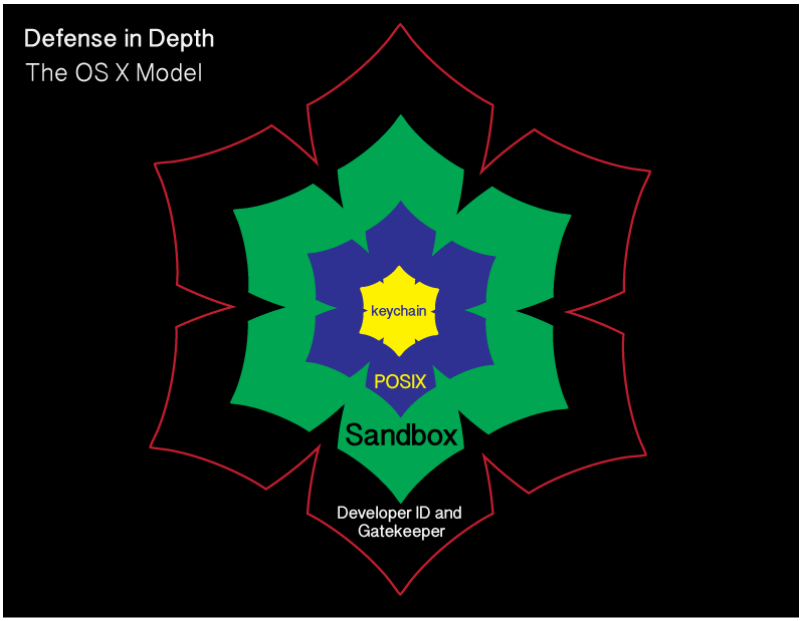
Type text to search here...

Home > Mac administration, Mac OS X, System Integrity Protection > System Integrity Protection – Adding another layer to Apple's security model

System Integrity Protection – Adding another layer to Apple's security model

October 1, 2015 rtrouton Leave a comment Go to comments

As part of the release of OS X El Capitan, Apple has added a new layer named System Integrity Protection (SIP) to its security model. To understand how System Integrity Protection fits in, let's first take a look at Apple's security model as it existed as of OS X Yosemite.



Gatekeeper

Gatekeeper is one of the outer lines of defense. It allows users to restrict which sources they can install applications from, with the general idea being that malware will not be from an allowed source.

Sandboxing

OS X also uses sandboxing extensively. A sandbox typically provides a tightly controlled set of resources for programs to run in. Network access, the ability to inspect the host system, or reading from input devices is usually disallowed or heavily restricted.

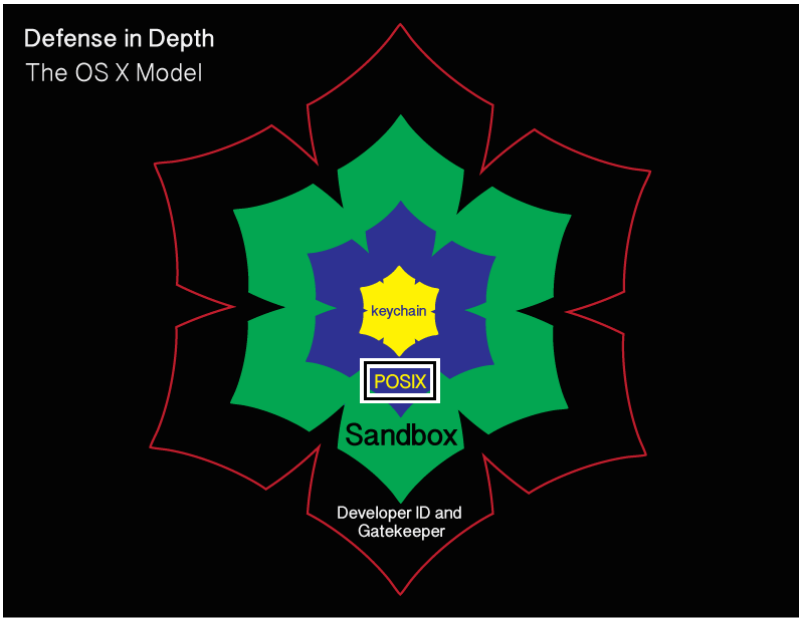
POSIX permissions

OS X uses the Unix permissions model as defined by POSIX, which governs which users and groups can access which files and directories. If a particular user account requests access to a particular file or directory and does not have the necessary rights, that account is refused access.

Keychains

The innermost layer of defense are keychains. Keychains are very specialized databases which are designed for the storing of secrets, like passwords, private keys, PIN numbers, and then controlling access to those secrets. To help protect these secrets, keychains are encrypted.

There's an issue with this model though and it's been there for decades. It pre-exists OS X and even pre-exists Apple as a company. That issue is found in the POSIX permissions layer.



Root

```
bash-3.2# whoami
root
bash-3.2#
```

Root is the superuser for a Unix system and the Unix permissions model is designed around the assumption that **root** has access to everything. Apple has not ignored this issue and has put some controls in place to limit the actual **root** user. These controls include disabling the **root** user account, discouraging its use, and providing ways to access elevated or root privileges using other means.

However, the **root** user account is still present and still can do anything on the system.

System Integrity Protection

To limit what the superuser can do and add another layer to OS X's security model, Apple has developed SIP and deployed it as part of OS X El Capitan. SIP is designed to limit the power of **root** and to protect the system even from the superuser. For more details, see below the jump.

SIP is an overall security policy with the goal of preventing system files and processes from being modified by third parties. To achieve this, it has the following concepts:

- File system protection
- Runtime protection
- Kernel extension protection

File system protection

SIP prevents parties other than Apple from adding, deleting or modifying directories and files stored in certain directories:

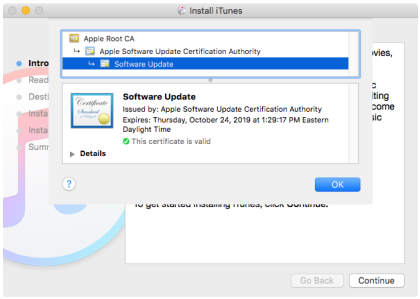
- **/bin**
- **/sbin**
- **/usr**
- **/System**

Apple has indicated that the following directories are available for developers to access:

- **/usr/local**
- **/Applications**
- **/Library**
- **~/Library**

All directories in **/usr** except for **/usr/local** are protected by SIP.

It is possible to add, remove or change SIP-protected files and directories via an installer package which is signed by Apple's own certificate authority. This allows Apple to make changes to SIP-protected parts of the OS without needing to change the existing SIP protections.



The certificate authority in question is reserved by Apple for their own use; Developer ID-signed installer packages are not able to alter SIP-protected files or directories.

To define which directories are protected, Apple has currently defined two configuration files on the filesystem. The primary one is found at the location below:

```
/System/Library/Sandbox/rootless.conf
```

The **rootless.conf** file lists all the applications and the top-level of directories which SIP is protecting.

```
                                /Applications/App Store.app
                                /Applications/Automator.app
                                /Applications/Calculator.app
                                /Applications/Calendar.app
                                /Applications/Chess.app
                                /Applications/Contacts.app
                                /Applications/Dashboard.app
                                /Applications/Dictionary.app
                                /Applications/DVD Player.app
                                /Applications/FaceTime.app
                                /Applications/Font Book.app
                                /Applications/Game Center.app
                                /Applications/Image Capture.app
                                /Applications/Launchpad.app
                                /Applications/Mail.app
                                /Applications/Maps.app
                                /Applications/Messages.app
                                /Applications/Mission Control.app
                                /Applications/Notes.app
                                /Applications/Photo Booth.app
                                /Applications/Photos.app
                                /Applications/Preview.app
                                /Applications/QuickTime Player.app
                                /Applications/Reminders.app
                                /Applications/Safari.app
                                /Applications/Stickies.app
                                /Applications/System Preferences.app
                                /Applications/TextEdit.app
                                /Applications/Time Machine.app
                                /Applications/Utilities/Activity Monitor.app
                                /Applications/Utilities/AirPort Utility.app
                                /Applications/Utilities/Audio MIDI Setup.app
                                /Applications/Utilities/Bluetooth File Exchange.app
                                /Applications/Utilities/Boot Camp Assistant.app
                                /Applications/Utilities/ColorSync Utility.app
                                /Applications/Utilities/Console.app
                                /Applications/Utilities/Digital Color Meter.app
                                /Applications/Utilities/Disk Utility.app
                                /Applications/Utilities/Feedback Assistant.app
                                /Applications/Utilities/Grab.app
                                /Applications/Utilities/Grapher.app
                                /Applications/Utilities/Keychain Access.app
                                /Applications/Utilities/Migration Assistant.app
                                /Applications/Utilities/Script Editor.app
                                /Applications/Utilities/System Information.app
                                /Applications/Utilities/Terminal.app
                                /Applications/Utilities/VoiceOver Utility.app
                                /Library/Preferences/SystemConfiguration/com.apple.Boot.plist
                                /System
*                               /System/Library/Caches
booter                          /System/Library/CoreServices
*                               /System/Library/CoreServices/Photo Library Migration Utility.app
                                /System/Library/CoreServices/RawCamera.bundle
*                               /System/Library/Extensions
                                /System/Library/Extensions/*
UpdateSettings                  /System/Library/LaunchDaemons/com.apple.UpdateSettings.plist
*                               /System/Library/Speech
*                               /System/Library/User Template
                                /bin
dyld                            /private/var/db/dyld
                                /sbin
                                /usr
*                               /usr/libexec/cups
*                               /usr/local
*                               /usr/share/man
# symlinks
                                /etc
                                /tmp
                                /var
```

Applications

SIP is protecting the core apps which OS X installs into **/Applications** and **/Applications/Utilities**.

```
/Applications/App Store.app
/Applications/Automator.app
/Applications/Calculator.app
/Applications/Calendar.app
/Applications/Chess.app
/Applications/Contacts.app
/Applications/Dashboard.app
/Applications/Dictionary.app
/Applications/DVD Player.app
/Applications/FaceTime.app
/Applications/Font Book.app
/Applications/Game Center.app
/Applications/Image Capture.app
/Applications/Launchpad.app
/Applications/Mail.app
/Applications/Maps.app
/Applications/Messages.app
/Applications/Mission Control.app
/Applications/Notes.app
/Applications/Photo Booth.app
/Applications/Photos.app
/Applications/Preview.app
/Applications/QuickTime Player.app
/Applications/Reminders.app
/Applications/Safari.app
/Applications/Stickies.app
/Applications/System Preferences.app
/Applications/TextEdit.app
/Applications/Time Machine.app

/Applications/Utilities/Activity Monitor.app
/Applications/Utilities/AirPort Utility.app
/Applications/Utilities/Audio MIDI Setup.app
/Applications/Utilities/Bluetooth File Exchange.app
/Applications/Utilities/Boot Camp Assistant.app
/Applications/Utilities/ColorSync Utility.app
/Applications/Utilities/Console.app
/Applications/Utilities/Digital Color Meter.app
/Applications/Utilities/Disk Utility.app
/Applications/Utilities/Feedback Assistant.app
/Applications/Utilities/Grab.app
/Applications/Utilities/Grapher.app
/Applications/Utilities/Keychain Access.app
/Applications/Utilities/Migration Assistant.app
/Applications/Utilities/Script Editor.app
/Applications/Utilities/System Information.app
/Applications/Utilities/Terminal.app
/Applications/Utilities/VoiceOver Utility.app
```

This means it will no longer be possible to delete the applications which OS X installs, even from the command line when using root privileges.

Directories

SIP is also protecting a number of directories and symlinks outside of **/Applications** and the top level of those directories are also listed in the **rootless.conf** file. In addition to protections, Apple has also defined some exceptions to SIP's protection in the **rootless.conf** file, and those exceptions are marked with asterixes. These exemptions from SIP's protection mean that it is possible to add, remove or change files and directories within those locations.

```
                        /Library/Preferences/SystemConfiguration/com.apple.Boot.plist
                        /System
*                       /System/Library/Caches
booter                  /System/Library/CoreServices
*                       /System/Library/CoreServices/Photo Library Migration Utility.app
                        /System/Library/CoreServices/RawCamera.bundle
*                       /System/Library/Extensions
                        /System/Library/Extensions/*
UpdateSettings          /System/Library/LaunchDaemons/com.apple.UpdateSettings.plist
*                       /System/Library/Speech
*                       /System/Library/User Template
                        /bin
dyld                    /private/var/db/dyld
                        /sbin
                        /usr
*                       /usr/libexec/cups
*                       /usr/local
*                       /usr/share/man
# symlinks
                        /etc
                        /tmp
                        /var
```

Among those exceptions are the following:

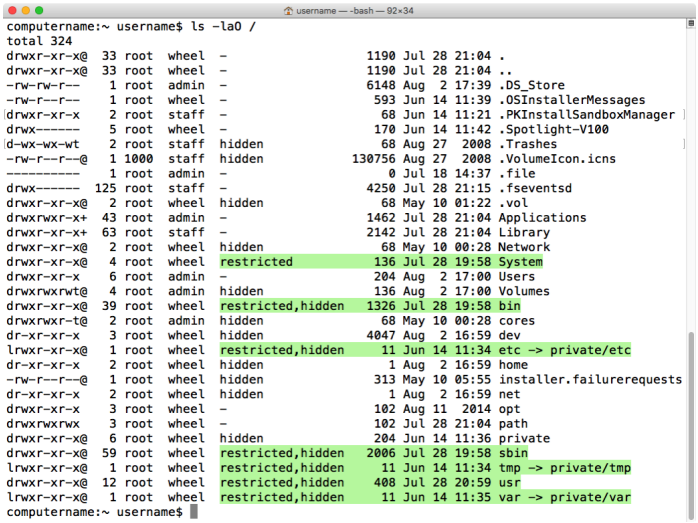
/System/Library/User Template – where OS X stores the template directories it uses when creating home folders for new accounts.
/usr/libexec/cups – where OS X stores printer configuration information

When I've spoken with Apple engineers about how this configuration file was updated and if third parties could add their own exceptions to it, it was made clear that Apple considers this file theirs and that any third parties' changes to it would be overwritten by Apple.

To see which files have been protected by SIP, use the ls command with the capital O flag in Terminal:

```
ls -O
```

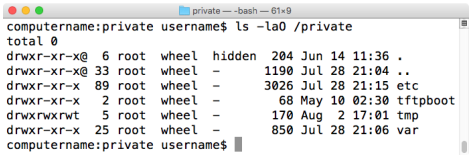
SIP-protected files will be labeled as restricted.



One important think to know is that even if a symlink is protected by SIP, that does not necessarily mean that the directory they're linking to is being protected by SIP. At the root level of an OS X El Capitan boot drive, there are several SIP-protected symlinks pointing to directories stored inside the root-level directory named **private**.

However, when the contents of the directory named **private** are examined, the directories which those symlinks point to are not protected by SIP and both they and their contents can be moved, edited or changed

by processes using root privileges.



In addition to the list of SIP exceptions which Apple has set in **rootless.conf**, there is a second list of SIP exceptions. This list includes a number of directories and application names for third-party products. Similar to **rootless.conf**, this exclusion list is Apple's and any third parties' changes to it will be overwritten by Apple.

```
1 /System/Library/Sandbox/Compatibility.bundle/Contents/Resources/paths
```

```
1  /System/Library/CFMSupport
2  /System/Library/CoreServices/Applications/Directory Utility.app/Contents/PlugIns/ADmitMac.d
3  /System/Library/CoreServices/CoreTypes.bundle/Contents/Library/iLifeSlideshowTypes.bundle
4  /System/Library/CoreServices/SecurityAgentPlugins/CentrifyPAM.bundle
5  /System/Library/CoreServices/SecurityAgentPlugins/CentrifySmartCard.bundle
6  /System/Library/CyborgRAT.kext
7  /System/Library/Extensions/IONetworkingFamily.kext/Contents/PlugIns/AppleRTL815XComposite10
8  /System/Library/Extensions/IONetworkingFamily.kext/Contents/PlugIns/AppleRTL815XEthernet109
9  /System/Library/Filesystems/DAVE
10 /System/Library/Filesystems/fusefs_txantfs.fs
11 /System/Library/Filesystems/ufsd_NTFS.fs
12 /System/Library/Fonts/encodings.dir
13 /System/Library/Fonts/fonts.dir
14 /System/Library/Fonts/fonts.list
15 /System/Library/Fonts/fonts.scale
16 /System/Library/HuaweiDataCardDriver.kext
17 /System/Library/LaunchAgents/com.paragon.NTFS.notify.plist
18 /System/Library/LaunchDaemons/com.absolute.rpcnet.plist
19 /System/Library/LaunchDaemons/com.intel.haxm.plist
20 /System/Library/LaunchDaemons/com.seagate.TBDecorator.plist
21 /System/Library/LaunchDaemons/de.novamedia.nmnetmgrd.plist
22 /System/Library/PrivateFrameworks/BrowserKit.framework
23 /System/Library/PrivateFrameworks/Helium.framework
24 /System/Library/PrivateFrameworks/LiveType.framework
25 /System/Library/PrivateFrameworks/ProKit.framework
26 /System/Library/PrivateFrameworks/iLifeSlideshow.framework
27 /System/Library/QuickTime/QuickTimeMPEG2.component
28 /System/Library/QuickTime/WiretapDataHandler.component
29 /System/Library/Services/KAVService.service
30 /System/Library/Services/Send to Kindle.workflow
31 /System/Library/StartupItems
32 /System/Library/USBExpressCardCantWake_Huawei.kext
33 /sbin/amconfig
34 /sbin/fsck_ufsd_NTFS
35 /sbin/mount_cifs
```

```
/sbin/mount_fusefs_txantfs
/sbin/mount_ufsd_NTFS
/sbin/mount_vmhgfs
/sbin/newfs_fusefs_txantfs
/sbin/newfs_ufsd_NTFS
/sbin/rpctool
/usr/X11
/usr/bin/FAHClient
/usr/bin/FAHCoreWrapper
/usr/bin/FAHViewer
/usr/bin/VBoxAutostart
/usr/bin/VBoxBalloonCtrl
/usr/bin/VBoxHeadless
/usr/bin/VBoxManage
/usr/bin/VBoxVRDP
/usr/bin/VirtualBox
/usr/bin/cups-calibrate
/usr/bin/escputil
/usr/bin/extlookup2hiera
/usr/bin/facter
/usr/bin/gnutar
/usr/bin/kashell
/usr/bin/kav
/usr/bin/nortonscanner
/usr/bin/nortonsettings
/usr/bin/nvconfigurator
/usr/bin/nvpmgr
/usr/bin/phidgetwebservice21
/usr/bin/puppet
/usr/bin/shake
/usr/bin/stkLaunchAgent.sh
/usr/bin/testpattern
/usr/bin/vagrant
/usr/bin/vboxwebsrv
/usr/discreet
/usr/include/gutenprint
/usr/lib/cshost
/usr/lib/gutenprint
/usr/lib/libMatroxMpeg2IFrameCodec.dylib
/usr/lib/libUFSDNTFS.dylib
/usr/lib/libgutenprint.2.0.3.dylib
/usr/lib/libgutenprint.2.dylib
/usr/lib/libgutenprint.a
/usr/lib/libgutenprint.dylib
/usr/lib/libgutenprint.la
/usr/lib/libnv6.dylib
/usr/lib/libnv6audit.dylib
/usr/lib/libnv6cli.dylib
/usr/lib/libnv6clit.dylib
```

```
/usr/lib/libnv6foreignras.dylib
/usr/lib/libnv6foreignrast.dylib
/usr/lib/libnv6gui.dylib
/usr/lib/libnv6guit.dylib
/usr/lib/libnv6http.dylib
/usr/lib/libnv6jobs.dylib
/usr/lib/libnv6jobst.dylib
/usr/lib/libnv6json.dylib
/usr/lib/libnv6jsont.dylib
/usr/lib/libnv6ndmp.dylib
/usr/lib/libnv6plugin.dylib
/usr/lib/libnv6plugint.dylib
/usr/lib/libnv6reports.dylib
/usr/lib/libnv6reportst.dylib
/usr/lib/libnv6scsi.dylib
/usr/lib/libnv6stats.dylib
/usr/lib/libnv6statst.dylib
/usr/lib/libnv6t.dylib
/usr/lib/libnv6xctl.dylib
/usr/lib/libnv6xpm.dylib
/usr/lib/libphidget21.jnilib
/usr/lib/libwkextmac.dylib
/usr/lib/pam/pam_centrifydc.so
/usr/lib/pkgconfig/gutenprint.pc
/usr/libexec/aksusbd
/usr/libexec/com.matrox.vpg.Agent
/usr/libexec/com.matrox.vpg.MaxAgent
/usr/libexec/cups/backend/cifs
/usr/libexec/hasplmd
/usr/local
/usr/netvault
/usr/sbin/AELWriter
/usr/sbin/cups-genppd.5.2
/usr/sbin/cups-genppdupdate
/usr/sbin/fsctl_ufsd
/usr/sbin/jamf
/usr/sbin/jamfAgent
/usr/sbin/m_agent
/usr/sbin/m_agent_upgrade
/usr/sbin/nipalsm
/usr/sbin/nmnetmgrd
/usr/sbin/nmnetmgrd_launchd
/usr/sbin/nmnetmgrd_launchd_MT
/usr/sbin/palModuleMgr.sh
/usr/sbin/proxyhelper
/usr/sbin/qmasterca
/usr/sbin/qmasterd
/usr/sbin/qmasterprefs
/usr/sbin/qmasterqd
```

```
/usr/sbin/rpc.net
/usr/sbin/rpcset
/usr/sbin/rpcstartup
/usr/sbin/setbufsize
/usr/share/centrifydc
/usr/share/cshost
/usr/share/cups/calibrate.ppm
/usr/share/cups/mime/pharos.convs
/usr/share/cups/usb
/usr/share/doc/facter
/usr/share/doc/puppet
/usr/share/gutenprint
/usr/share/locale/ca/gutenprint_ca.po
/usr/share/locale/cs/gutenprint_cs.po
/usr/share/locale/da/gutenprint_da.po
/usr/share/locale/de/gutenprint_de.po
/usr/share/locale/el/gutenprint_el.po
/usr/share/locale/en_GB/gutenprint_en_GB.po
/usr/share/locale/es/gutenprint_es.po
/usr/share/locale/fi/gutenprint_fi.po
/usr/share/locale/fr/gutenprint_fr.po
/usr/share/locale/gl/gutenprint_gl.po
/usr/share/locale/hu/gutenprint_hu.po
/usr/share/locale/it/gutenprint_it.po
/usr/share/locale/ja/gutenprint_ja.po
/usr/share/locale/nb/gutenprint_nb.po
/usr/share/locale/nl/gutenprint_nl.po
/usr/share/locale/pl/gutenprint_pl.po
/usr/share/locale/pt/gutenprint_pt.po
/usr/share/locale/ru/gutenprint_ru.po
/usr/share/locale/sk/gutenprint_sk.po
/usr/share/locale/sl/gutenprint_sl.po
/usr/share/locale/sv/gutenprint_sv.po
/usr/share/locale/tr/gutenprint_tr.po
/usr/share/locale/uk/gutenprint_uk.po
/usr/share/locale/vi/gutenprint_vi.po
/usr/share/locale/zh_CN/gutenprint_zh_CN.po
/usr/share/locale/zh_TW/gutenprint_zh_TW.po
```

view raw

gistfile1.txt
hosted with ❤ by GitHub

Runtime protection

SIP's protections are not limited to protecting the system from filesystem changes. There are also system calls which are now restricted in their functionality.

- task_for_pid() / processor_set_tasks() fail with EPERM
- Mach special ports are reset on exec(2)
- dyld environment variables are ignored
- DTrace probes unavailable

However, SIP does not block inspection by the developer of their own applications while they're being developed. Xcode's tools will continue to allow apps to be inspected and debugged during the development process.

For more details on this, I recommend taking a look at Apple's developer documentation for SIP.

Kernel extension protection

SIP blocks installation of unsigned kernel extensions. In order to install a kernel extension on OS X El Capitan with SIP enabled, a kernel extension must:

1. Be signed with a **Developer ID for Signing Kexts** certificate
2. Install into **/Library/Extensions**

If installing an unsigned kernel extension, SIP will need to be disabled first.

Managing SIP

To help ensure that third parties will not be able to disable these protections, SIP's configuration is stored in NVRAM rather than in the file system itself and is only configurable if the Mac is booted into one of two environments:

- The OS X Installer environment
- The OS X Recovery environment

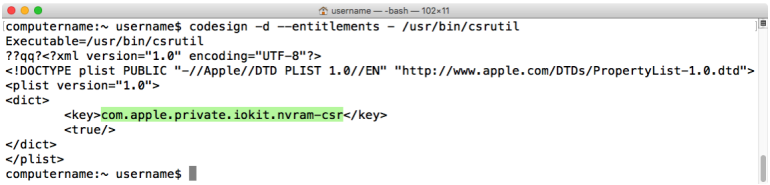
Note: *The OS X Installer and OS X Recovery environments are in fact the same environment from OS X's perspective, with the main difference being that the OS X Installer environment contains a copy of the installation files for OS X and the Recovery environment does not.*

Because SIP's configuration is stored in NVRAM, SIP's protection settings will apply to the entire machine and will persist even if the OS is reinstalled.

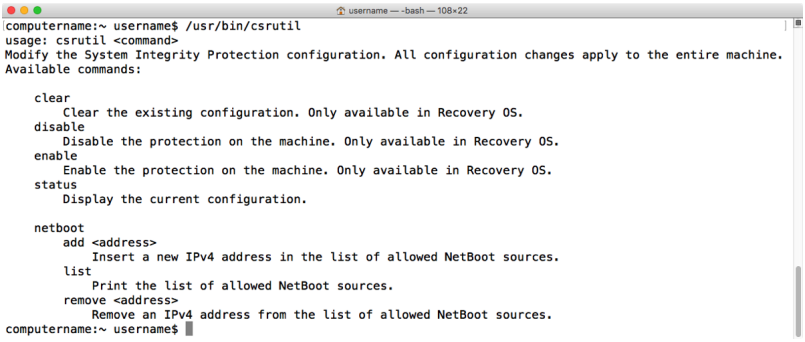
SIP can be managed to the extent of turning it on, turning it off, adding and removing IP addresses into a NetBoot whitelist and reporting on whether SIP is enabled or disabled. All changes to SIP's configuration also require a reboot before they take effect.

The tool used to manage SIP is **/usr/bin/csrutil**. **csrutil** is able to work with SIP because it has a unique application entitlement assigned to it by Apple. This entitlement is viewable using the codesign command shown below:

```
codesign -d --entitlements - /usr/bin/csrutil
```



When you run **csrutil** without any associated commands, it will pull up the help page.



When booted from Recovery, the command used to enable SIP is **csrutil enable**:

```
csrutil enable
```

When booted from Recovery, the command used to turn SIP off is **csrutil disable**:

```
csrutil disable
```

When booted from Recovery, the command used to reset SIP's configuration is **csrutil clear**:

```
csrutil clear
```

When **csrutil clear** is run, SIP goes back to its factory-default settings. That means SIP is enabled if it was disabled previously and any custom configuration is cleared out.

SIP and NetBoot

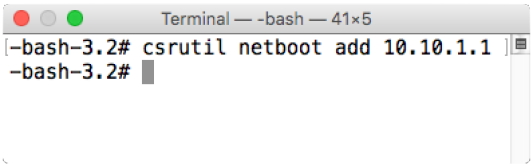
One of the custom configuration options available in SIP is the ability to set a whitelist for approved NetBoot servers. This whitelist is needed because the bless command in El Capitan is restricted by SIP from writing to NVRAM. This affects **bless**'s ability to set Macs to boot from NetBoot sets because it needs to write that information to NVRAM.

This whitelist defines by IP address which NetBoot servers are trusted in your environment. Once those IP addresses are part of the whitelist, the bless command can set a Mac to NetBoot from a NetBoot set on a trusted NetBoot server. For more information about whether or not you need to whitelist your NetBoot server(s), please see the link below:

https://derflounder.wordpress.com/2015/09/05/netbooting-and-system-integrity-protection/

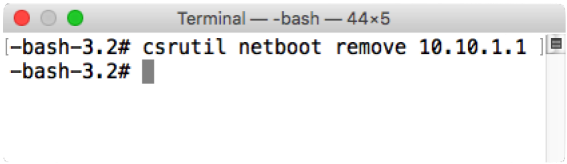
To help folks who need to use bless to set a NetBoot set as a startup drive, the **csrutil** tool includes functionality to add NetBoot servers to the whitelist. While booted from Recovery, use **csrutil netboot add** followed by an IP address to set the IP as being that of a NetBoot server approved for use by the bless command:

```
csrutil netboot add ip.address.here
```



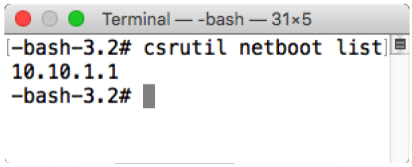
While booted from Recovery, you can also remove NetBoot servers from the whitelist. To do this, use **csrutil netboot remove** followed by the IP address that you want to remove from the whitelist.

```
csrutil netboot remove ip.address.here
```



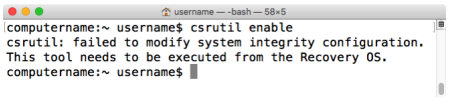
To see which NetBoot servers have been added to the whitelist, run csrutil netboot list.

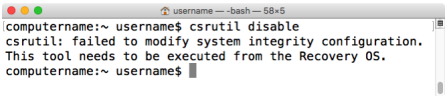
```
csrutil netboot list
```



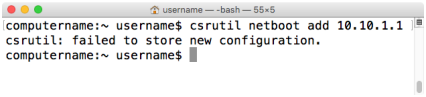
Running csrutil outside Recovery

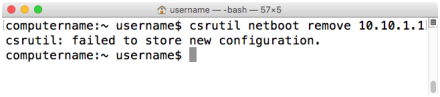
If you try to run the **csrutil enable** and **csrutil disable** commands while booted from a regular boot drive, you will receive a message that these commands need to be run from Recovery. The current SIP configuration will remain unchanged.





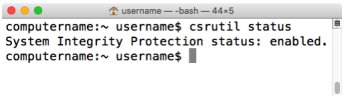
Likewise, if you try to run the **csrutil netboot add** and **csrutil netboot remove** commands while booted from a regular boot drive, you will receive the message that **csrutil** was unable to save the configuration and the status of the NetBoot whitelist will remain unchanged.





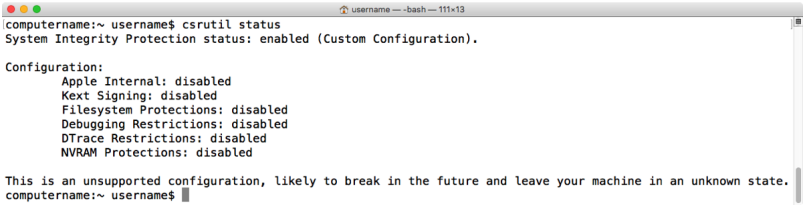
What can be run while booted from a regular boot drive is csrutil's reporting functions. For example, to learn if SIP is enabled or disabled, run **csrutil status**.

```
1 csrutil status
```



This command can be run without root privileges and will tell you if SIP is on or off.

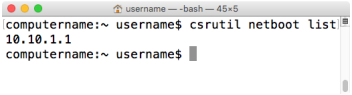
If SIP is off, you may receive a confusing message which indicates that SIP is enabled, followed by a list of individual SIP functions which are disabled. If all functions listed are showing as being disabled, SIP is actually completely disabled; it's just confusingly worded.



I actually have a bug report on this message. For those who wish to dupe it, it is bug ID **22361698** and is cross-posted to Open Radar here:

https://openradar.appspot.com/radar?id=4932475130216448

Likewise, you can run **csrutil netboot list** and it will report on which IPs have been set as allowed NetBoot sources when using the **bless** command.

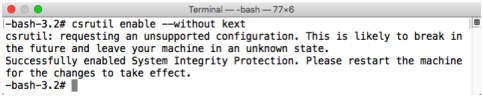


Other custom SIP configuration options

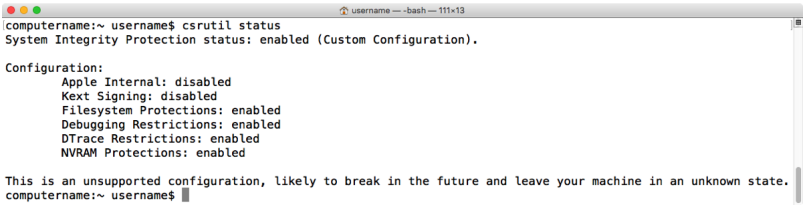
It is also possible to enable SIP protections and selectively disable aspects of it, by adding one or more flags to the **csrutil enable** command. All require being booted from Recovery in order to set them:

Enable SIP and allow installation of unsigned kernel extensions

```
1 csrutil enable --without kext
```

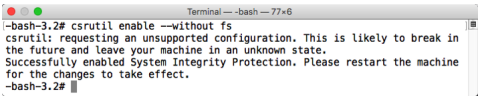


When this option is enabled, running **csrutil status** should produce output similar to this.

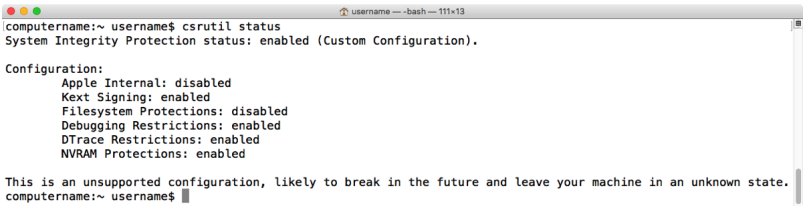


Enable SIP and disable filesystem protections

```
1 csrutil enable --without fs
```



When this option is enabled, running **csrutil status** should produce output similar to this.



Enable SIP and disable debugging restrictions

```
1 csrutil enable --without debug
```