



OpenCore

Reference Manual (0.6.~~7~~.8)

[2021.04.03]

1 Introduction

This document provides information on the [format of the](#) OpenCore user configuration file ~~format~~ used to set up the correct functioning of the macOS operating system. It is to be read as the official clarification of expected OpenCore behaviour. All deviations, if found in published OpenCore releases, shall be considered to be documentation or implementation issues which should be reported via the Acidanthera Bugtracker. An errata sheet is available in OpenCorePkg repository.

This document is structured as a specification and is not meant to provide a step-by-step guide to configuring an end-user Board Support Package (BSP). The intended audience of the document is anticipated to be programmers and engineers with a basic understanding of macOS internals and UEFI functionality. For these reasons, this document is available exclusively in English, and all other sources or translations of this document are unofficial and may contain errors.

Third-party articles, utilities, books, and similar, may be more useful for a wider audience as they could provide guide-like material. However, they are subject to their authors' preferences, ~~tastes~~, misinterpretations of this document, and unavoidable obsolescence. In cases of using such sources, such as Dortania's OpenCore Install Guide and related material, please refer back to this document on every decision made and re-evaluate potential ~~consequences~~[implications](#).

Please note that regardless of the sources used, users are required to fully understand every OpenCore configuration option, and the principles behind them, before posting issues to the Acidanthera Bugtracker.

Note: Creating this document would not have been possible without the invaluable contributions from other people: Andrey1970, Goldfish64, dakanji, PMheart, and several others, with the full list available in OpenCorePkg history.

1.1 Generic Terms

- **plist** — Subset of ASCII Property List format written in XML, also known as XML plist format version 1. Uniform Type Identifier (UTI): `com.apple.property-list`. Plists consist of **plist objects**, which are combined to form a hierarchical structure. Due to plist format not being well-defined, all the definitions of this document may only be applied after plist is considered valid by running `plutil -lint`. External references: <https://www.apple.com/DTDs/PropertyList-1.0.dtd>, `man plutil`.
- **plist type** — plist collections (**plist array**, **plist dictionary**, **plist key**) and primitives (**plist string**, **plist data**, **plist date**, **plist boolean**, **plist integer**, **plist real**).
- **plist object** — definite realisation of **plist type**, which may be interpreted as value.
- **plist array** — array-like collection, conforms to `array`. Consists of zero or more **plist objects**.
- **plist dictionary** — map-like (associative array) collection, conforms to `dict`. Consists of zero or more **plist keys**.
- **plist key** — contains one **plist object** going by the name of **plist key**, conforms to `key`. Consists of printable 7-bit ASCII characters.
- **plist string** — printable 7-bit ASCII string, conforms to `string`.
- **plist data** — base64-encoded blob, conforms to `data`.
- **plist date** — ISO-8601 date, conforms to `date`, unsupported.
- **plist boolean** — logical state object, which is either true (1) or false (0), conforms to `true` and `false`.
- **plist integer** — possibly signed integer number in base 10, conforms to `integer`. Fits in 64-bit unsigned integer in two's complement representation, unless a smaller signed or unsigned integral type is explicitly mentioned in specific **plist object** description.
- **plist real** — floating point number, conforms to `real`, unsupported.
- **plist multidata** — value cast to data by the implementation. Permits passing **plist string**, in which case the result is represented by a null-terminated sequence of bytes (C string), **plist integer**, in which case the result is represented by 32-bit little endian sequence of bytes in two's complement representation, **plist boolean**, in which case the value is one byte: 01 for `true` and 00 for `false`, and **plist data** itself. All other types or larger integers invoke undefined behaviour.

2 Configuration

2.1 Configuration Terms

- **OC config** — OpenCore Configuration file in **plist** format named **config.plist**. It provides an extensible way to configure OpenCore and is structured to be separated into multiple named sections situated under the root **plist** dictionary. These sections may have **plist array** or **plist dictionary** types and are described in corresponding sections of this document.
- **valid key** — **plist key** object of **OC config** described in this document or its future revisions. Besides explicitly described **valid keys**, keys starting with the **#** symbol (e.g. **#Hello**) are also considered **valid keys** and while they behave as comments, effectively discarding their values, they are still required to be valid **plist objects**. All other **plist keys** are not valid, and their presence results in **undefined behaviour**.
- **valid value** — valid **plist object** of **OC config** described in this document that matches all the additional requirements in specific **plist object** descriptions if any.
- **invalid value** — valid **plist object** of **OC config** described in this document that is of other **plist type**, does not conform to additional requirements found in specific **plist object** descriptions (e.g. value range), or missing from the corresponding collection. **Invalid values** are read with or without an error message as any possible value of this **plist object** in an undetermined manner (i.e. the values may not be same across the reboots). Whilst reading an **invalid value** is equivalent to reading certain defined **valid values**, applying incompatible values to the host system may result in **undefined behaviour**.
- **optional value** — **valid value** of **OC config** described in this document that reads in a certain defined manner provided in specific **plist object** description (instead of **invalid value**) when not present in **OC config**. All other cases of **invalid value** do still apply. Unless explicitly marked as **optional value**, any other value is required to be present and reads to **invalid value** if missing.
- **fatal behaviour** — behaviour leading to boot termination. Implementations shall prevent the boot process from continuing until the host system is restarted. It is permitted, but not required, to execute cold reboots or to show warning messages in such cases.
- **undefined behaviour** — behaviour not prescribed by this document. Implementations may take any measures including, but not limited to, measures associated with **fatal behaviour**, assumptions of any state or value, or disregarding any associated states or values. This is however subject to such measures not negatively impacting upon system integrity.

2.2 Configuration Processing

The **OC config** file is guaranteed to be processed at least once if found. ~~Depending on~~ Subject to the OpenCore bootstrapping mechanism, the presence of multiple **OC config** files may lead to the reading of any of them. It is permissible for no **OC Config** file to be present on disk. In such cases, if the implementation does not abort the boot process, all values shall follow the rules of **invalid values** and **optional values**.

The **OC config** file has restrictions on size, nesting levels, and number of keys:

- The **OC config** file size shall not exceed **32 MBs**.
- The **OC config** file shall not have more than **32** nesting levels.
- The **OC config** file may have up to **32,768** XML nodes within each **plist object**.
 - One **plist dictionary** item is counted as a pair of nodes

Reading malformed **OC config** files results in **undefined behaviour**. Examples of malformed **OC config** files include the following:

- **OC config** files that do not conform to DTD **PLIST 1.0**.
- **OC config** files with unsupported or non-conformant **plist objects** found in this document.
- **OC config** files violating restrictions on size, nesting levels, and number of keys.

It is recommended, but not required, to abort loading malformed **OC config** files and to continue as if an **OC config** file is not present. For forward compatibility, it is recommended, but not required, for the implementation to warn about the use of **invalid values**.

3 Setup

3.1 Directory Structure

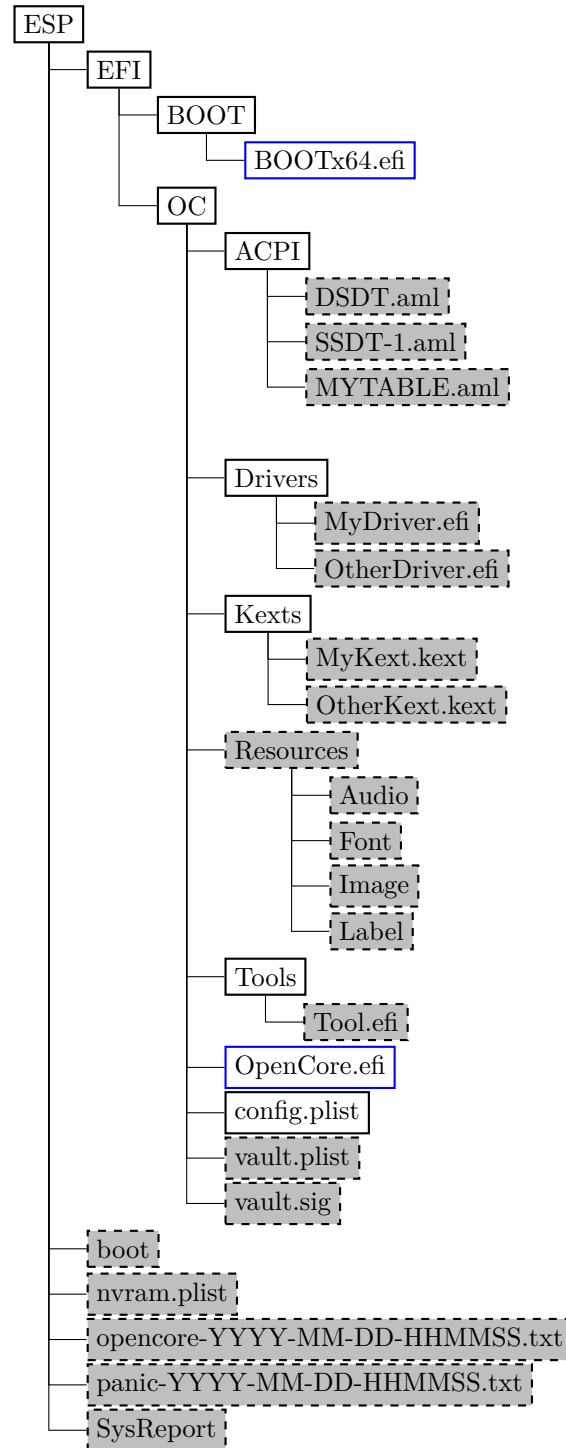


Figure 1. Directory Structure

When directory boot is used, the directory structure used should follow the descriptions in the Directory Structure figure. Available entries include:

- **BOOTx64.efi** or **BOOTIa32.efi**
Initial bootstrap loaders, which load **OpenCore.efi**. **BOOTx64.efi** is loaded by the firmware by default consistent with the UEFI specification. However, it may also be renamed and put in a custom location to allow OpenCore coexist alongside operating systems, such as Windows, that use **BOOTx64.efi** files as their loaders. Refer to the

LauncherOption property for [more](#) details.

- **boot**
Duet bootstrap loader, which initialises the UEFI environment on legacy BIOS firmware and loads `OpenCore.efi` similarly to other bootstrap loaders. A modern Duet bootstrap loader will default to `OpenCore.efi` on the same partition when present.
- **ACPI**
Directory used for storing supplemental ACPI information for the ACPI section.
- **Drivers**
Directory used for storing supplemental UEFI drivers for UEFI section.
- **Kexts**
Directory used for storing supplemental kernel information for the Kernel section.
- **Resources**
Directory used for storing media resources such as audio files for screen reader support. [See-Refer to](#) the UEFI Audio Properties section for [more](#) details. This directory also contains image files for graphical user interface. [See-Refer to](#) the OpenCanopy section for [more](#) details.
- **Tools**
Directory used for storing supplemental tools.
- **OpenCore.efi**
Main booter application responsible for operating system loading. The directory `OpenCore.efi` resides in is called the **root directory**, which is set to `EFI\OC` by default. When launching `OpenCore.efi` directly or through a custom launcher however, other directories containing `OpenCore.efi` files are also supported.
- **config.plist**
OC Config.
- **vault.plist**
Hashes for all files potentially loadable by OC Config.
- **vault.sig**
Signature for `vault.plist`.
- **SysReport**
Directory containing system reports generated by `SysReport` option.
- **nvram.plist**
OpenCore variable import file.
- **opencore-YYYY-MM-DD-HHMMSS.txt**
OpenCore log file.
- **panic-YYYY-MM-DD-HHMMSS.txt**
Kernel panic log file.

Note: It is not guaranteed that paths longer than `OC_STORAGE_SAFE_PATH_MAX` (128 characters including the 0-terminator) will be accessible within OpenCore.

3.2 Installation and Upgrade

To install OpenCore, replicate the Configuration Structure described in the previous section in the EFI volume of a GPT partition. While corresponding sections of this document provide some information regarding external resources such as ACPI tables, UEFI drivers, or kernel extensions (kexts), completeness of the matter is out of the scope of this document. Information about kernel extensions may be found in a separate Kext List document available in the OpenCore repository. Vaulting information is provided in the Security Properties section of this document.

The `OC config` file, as with any property list file, can be edited with any text editor, such as nano or vim. However, specialised software may provide a better experience. On macOS, the preferred GUI application is Xcode. For a lightweight cross-platform and open-source alternative, the ProperTree editor can be utilised.

For BIOS booting, a third-party UEFI environment provider is required and `OpenDuetPkg` is one such UEFI environment provider for legacy systems. To run OpenCore on such a legacy system, `OpenDuetPkg` can be installed with a dedicated tool — `BootInstall` (bundled with OpenCore). Third-party utilities can be used to perform this on systems other than macOS.

For upgrade purposes, refer to the `Differences.pdf` document which provides information about changes to the configuration (as compared to the previous release) as well as to the `Changelog.md` document (which contains a list of modifications across all published updates).

3.3 Contribution

OpenCore can be compiled as a standard EDK II package and requires the EDK II Stable package. The currently supported EDK II release is hosted in acidanthera/audk. Required patches for this package can be found in the **Patches** directory.

The only officially supported toolchain is XCODE5. Other toolchains might work but are neither supported nor recommended. Contributions of clean patches are welcome. Please do follow EDK II C Codestyle.

To compile with XCODE5, besides Xcode, users should also install NASM and MTOC. The latest Xcode version is recommended for use despite the toolchain name. An example command sequence is as follows:

```
git clone --depth=1 https://github.com/acidanthera/audk UDK
cd UDK
git submodule update --init --recommend-shallow
git clone --depth=1 https://github.com/acidanthera/OpenCorePkg
source edksetup.sh
make -C BaseTools
build -a X64 -b RELEASE -t XCODE5 -p OpenCorePkg/OpenCorePkg.dsc
```

Listing 1: Compilation Commands

For IDE usage Xcode projects are available in the root of the repositories. Another approach could be Sublime Text with EasyClangComplete plugin. Add `.clang_complete` file with similar content to the UDK root:

```
-I/UefiPackages/MdePkg
-I/UefiPackages/MdePkg/Include
-I/UefiPackages/MdePkg/Include/X64
-I/UefiPackages/MdeModulePkg
-I/UefiPackages/MdeModulePkg/Include
-I/UefiPackages/MdeModulePkg/Include/X64
-I/UefiPackages/OpenCorePkg/Include/AMI
-I/UefiPackages/OpenCorePkg/Include/Acidanthera
-I/UefiPackages/OpenCorePkg/Include/Apple
-I/UefiPackages/OpenCorePkg/Include/Apple/X64
-I/UefiPackages/OpenCorePkg/Include/Duet
-I/UefiPackages/OpenCorePkg/Include/Generic
-I/UefiPackages/OpenCorePkg/Include/Intel
-I/UefiPackages/OpenCorePkg/Include/Microsoft
-I/UefiPackages/OpenCorePkg/Include/Nvidia
-I/UefiPackages/OpenCorePkg/Include/VMware
-I/UefiPackages/OvmfPkg/Include
-I/UefiPackages/UefiCpuPkg/Include
-IInclude
-include
/UefiPackages/MdePkg/Include/Uefi.h
-fshort-wchar
-Wall
-Wextra
-Wno-unused-parameter
-Wno-missing-braces
-Wno-missing-field-initializers
-Wno-tautological-compare
-Wno-sign-compare
-Wno-varargs
-Wno-unused-const-variable
-DOC_TARGET_NOOPT=1
-DNO_MSABI_VA_FUNCS=1
```

Listing 2: ECC Configuration

4 ACPI

4.1 Introduction

ACPI (Advanced Configuration and Power Interface) is an open standard to discover and configure computer hardware. The ACPI specification ~~define the~~ defines standard tables (e.g. DSDT, SSDT, FACS, DMAR) and various methods (e.g. _DSM, _PRW) for implementation. Modern hardware needs ~~little few~~ changes to maintain ACPI compatibility ~~yet some of those~~ and some options for such changes are provided as ~~a~~ part of OpenCore.

To compile and disassemble ACPI tables, the iASL compiler developed by ACPICA can be used. A GUI front-end to iASL compiler can be downloaded from Acidanthera/MaciASL.

ACPI changes apply globally (to every operating system) with the following effective order:

- Patch is processed.
- Delete is processed.
- Add is processed.
- Quirks are processed.

Applying the changes globally resolves the problems of incorrect operating system detection (consistent with the ACPI specification, not possible before the operating system boots), operating system chainloading, and difficult ACPI debugging. Hence, more attention may be required when writing changes to _OSI.

Applying the patches early makes it possible to write so called “proxy” patches, where the original method is patched in the original table and is implemented in the patched table.

There are several sources of ACPI tables and workarounds. Commonly used ACPI tables are provided with OpenCore, VirtualSMC, VoodooPS2, and WhateverGreen releases. Besides those, several third-party instructions may be found on the AppleLife Laboratory and DSDT subforums (e.g. Battery register splitting guide). A slightly more user-friendly explanation of some tables included with OpenCore can also be found in Dortania’s Getting started with ACPI guide. For more exotic cases, there are several alternatives such as daliansky’s ACPI sample collection (English Translation by 5T33Z0 et al. [may be outdated and contain typos](#)). Note however that the quality of the suggested solutions will be variable.

4.2 Properties

1. Add

Type: plist array

Failsafe: Empty

Description: Load selected tables from the OC/ACPI directory.

~~Designed to~~ To be filled with `plist dict` values, describing each add entry. ~~See~~ Refer to the Add Properties section below for details.

2. Delete

Type: plist array

Failsafe: Empty

Description: Remove selected tables from the ACPI stack.

~~Designed to~~ To be filled with `plist dict` values, describing each delete entry. ~~See~~ Refer to the Delete Properties section below for details.

3. Patch

Type: plist array

Failsafe: Empty

Description: Perform binary patches in ACPI tables before table addition or removal.

~~Designed to~~ To be filled with `plist dictionary` values describing each patch entry. ~~See~~ Refer to the Patch Properties section below for details.

4. Quirks

Type: plist dict

Description: Apply individual ACPI quirks described in the Quirks Properties section below.

4.3 Add Properties

1. **Comment**
Type: plist string
Failsafe: Empty
Description: Arbitrary ASCII string used to provide human readable reference for the entry. Whether this value is used is implementation defined.
2. **Enabled**
Type: plist boolean
Failsafe: false
Description: Set to **true** to add this ACPI table.
3. **Path**
Type: plist string
Failsafe: Empty
Description: File paths meant to be loaded as ACPI tables. Example values include `DSDT.aml`, `SubDir/SSDT-8.aml`, `SSDT-USBX.aml`, etc.

The ACPI table load order follows the item order in the array. ACPI tables are loaded from the `OC/ACPI` directory.

Note: All tables apart from tables with a DSDT table identifier (determined by parsing data, not by filename) insert new tables into the ACPI stack. DSDT tables perform a replacement of DSDT tables instead.

4.4 Delete Properties

1. **All**
Type: plist boolean
Failsafe: false (Only delete the first matched table)
Description: Set to **true** to delete all ACPI tables matching the condition.
2. **Comment**
Type: plist string
Failsafe: Empty
Description: Arbitrary ASCII string used to provide human readable reference for the entry. Whether this value is used is implementation defined.
3. **Enabled**
Type: plist boolean
Failsafe: false
Description: Set to **true** to remove this ACPI table.
4. **OemTableId**
Type: plist data, 8 bytes
Failsafe: All zero (Match any table OEM ID)
Description: Match table OEM ID equal to this value.
5. **TableLength**
Type: plist integer
Failsafe: 0 (Match any table size)
Description: Match table size equal to this value.
6. **TableSignature**
Type: plist data, 4 bytes
Failsafe: All zero (Match any table signature)
Description: Match table signature equal to this value.

Note: Do not use table signatures when the sequence must be replaced in multiple places. This is particularly relevant when performing different types of renames.

4.5 Patch Properties

1. Base
Type: plist string
Failsafe: Empty (Ignored)
Description: Selects ACPI path base for patch lookup (or immediate replacement) by obtaining the offset to the provided path.

Only fully-qualified absolute paths are supported (e.g. _SB.PCI0.LPCB.HPET). Currently supported object types are: Device, Field, Method.

Note: Use with care, not all OEM tables can be parsed. Use ACPIe utility to debug. ACPIe compiled with DEBUG=1 make command produces helpful ACPI lookup tracing.
2. BaseSkip
Type: plist integer
Failsafe: 0 (Do not skip any occurrences)
Description: Number of found Base occurrences to skip before finds and replacements are applied.
3. Comment
Type: plist string
Failsafe: Empty
Description: Arbitrary ASCII string used to provide human readable reference for the entry. Whether this value is used is implementation defined.
4. Count
Type: plist integer
Failsafe: 0 (Apply patch to all occurrences found)
Description: Number of occurrences to patch.
5. Enabled
Type: plist boolean
Failsafe: false
Description: Set to true to apply this ACPI patch.
6. Find
Type: plist data
Failsafe: Empty
Description: Data to find. Must be equal to Replace in size if set.

Note: Can be empty, when Base is specified, immediate replacement after Base lookup happens in this case.
7. Limit
Type: plist integer
Failsafe: 0 (Search entire ACPI table)
Description: Maximum number of bytes to search for.
8. Mask
Type: plist data
Failsafe: Empty (Ignored)
Description: Data bitwise mask used during find comparison. Allows fuzzy search by ignoring not masked (set to zero) bits. Must be equal to Replace in size if set.
9. OemTableId
Type: plist data, 8 bytes
Failsafe: All zero (Match any table OEM ID)
Description: Match table OEM ID equal to this value.
10. Replace
Type: plist data
Failsafe: Empty
Description: Replacement data of one or more bytes.

11. **ReplaceMask**
Type: plist data
Failsafe: Empty (Ignored)
Description: Data bitwise mask used during replacement. Allows fuzzy replacement by updating masked (set to non-zero) bits. Must be equal to **Replace** in size if set.
12. **Skip**
Type: plist integer
Failsafe: 0 (Do not skip any occurrences)
Description: Number of found occurrences to skip before replacements are applied.
13. **TableLength**
Type: plist integer
Failsafe: 0 (Match any table size)
Description: Match table size equal to this value.
14. **TableSignature**
Type: plist data, 4 bytes
Failsafe: All zero (Match any table signature)
Description: Match table signature equal to this value.

In most cases, ACPI patches are not useful and are harmful:

- Avoid renaming devices with ACPI patches. This may fail or perform improper renaming of unrelated devices (e.g. EC and ECO), be unnecessary, or even fail to rename devices in certain tables. For ACPI consistency it is much safer to rename devices at the I/O Registry level, as done by WhateverGreen.
- Avoid patching `_OSI` to support a higher feature set level whenever possible. While this enables a number of workarounds on APTIO firmware, it typically results in a need for additional patches. ~~Modern firmware generally does not need this~~ These are not usually needed on modern firmware and smaller patches work well on firmware that does. However, laptop vendors often rely on this method to determine the availability of functions such as modern I2C input support, thermal adjustment and custom feature additions.
- Avoid patching embedded controller event `_Qxx` just to enable brightness keys. The conventional process to find these keys typically involves significant modifications to DSDT and SSDT files and in addition, the debug kext is not stable on newer systems. Please use the built-in brightness key discovery in BrightnessKeys instead.
- Avoid making ad hoc changes such as renaming `_PRW` or `_DSM` whenever possible.

Some cases where patching is actually useful include:

- Refreshing HPET (or another device) method header to avoid compatibility checks by `_OSI` on legacy hardware. `_STA` method with `if ((OSFL () == Zero)) { If (HPTE) ... Return (Zero)` content may be forced to always return 0xF by replacing `A0 10 93 4F 53 46 4C 00` with `A4 0A 0F A3 A3 A3 A3`.
- To provide a custom method implementation within an SSDT, to inject shutdown fixes on certain computers for instance, the original method can be replaced with a dummy name by patching `_PTS` with `ZPTS` and adding a callback to the original method.

The Tianocore AcpiAml.h source file may help with better understanding ACPI opcodes.

Note: Patches of different **Find** and **Replace** lengths are unsupported as they may corrupt ACPI tables and make the system unstable due to area relocation. If such changes are needed, the utilisation of “proxy” patching or the padding of NOP to the remaining area could be considered.

4.6 Quirks Properties

1. **FadtEnableReset**
Type: plist boolean
Failsafe: false
Description: Provide reset register and flag in FADT table to enable reboot and shutdown.

Mainly required on legacy hardware and a few newer laptops. Can also fix power-button shortcuts. Not recommended unless required.

5 Booter

5.1 Introduction

This section allows the application of different types of UEFI modifications to operating system bootloaders, primarily the Apple bootloader (`boot.efi`). The modifications currently provide various patches and environment alterations for different firmware types. Some of these features were originally implemented as part of `AptioMemoryFix.efi`, which is no longer maintained. Refer to the Tips and Tricks section for instructions on migration.

If this is used for the first time on customised firmware, the following requirements should be met before starting:

- Most up-to-date UEFI firmware (check the motherboard vendor website).
- **Fast Boot** and **Hardware Fast Boot** disabled in firmware settings if present.
- **Above 4G Decoding** or similar enabled in firmware settings if present. Note that on some motherboards, notably the ASUS WS-X299-PRO, this option results in adverse effects and must be disabled. While no other motherboards with the same issue are known, this option should be checked first whenever erratic boot failures are encountered.
- **DisableIoMapper** quirk enabled, or **VT-d** disabled in firmware settings if present, or **ACPI DMAR** table deleted.
- **No ‘slide’** boot argument present in NVRAM or anywhere else. It is not necessary unless the system cannot be booted at all or **No slide values are usable! Use custom slide!** message can be seen in the log.
- **CFG Lock** (MSR 0xE2 write protection) disabled in firmware settings if present. ~~Consider if no option is available (for advanced users only).~~ ~~See notes for more~~ [Refer to the](#) [ControlMsrE2](#) [notes for](#) details.
- **CSM** (Compatibility Support Module) disabled in firmware settings if present. On NVIDIA 6xx/AMD 2xx or older, **GOP ROM** may have to be flashed first. Use `GopUpdate` (see the second post) or **AMD UEFI GOP MAKER** in case of any potential confusion.
- **EHCI/XHCI Hand-off** enabled in firmware settings **only** if boot stalls unless USB devices are disconnected.
- **VT-x, Hyper Threading, Execute Disable Bit** enabled in firmware settings if present.
- While it may not be required, sometimes **Thunderbolt support**, **Intel SGX**, and **Intel Platform Trust** may have to be disabled in firmware settings present.

When debugging sleep issues, **Power Nap** and **automatic power off** (which appear to sometimes cause wake to black screen or boot loop issues on older platforms) may be temporarily disabled. The specific issues may vary, but ~~generally~~ [ACPI tables](#) should [typically](#) be looked at first.

Here is an example of a defect found ~~in-on~~ [some](#) Z68 motherboards. To turn **Power Nap** and the others off, run the following commands in Terminal:

```
sudo pmset autopoweroff 0
sudo pmset powernap 0
sudo pmset standby 0
```

Note: These settings may be reset by hardware changes and in certain other circumstances. To view their current state, use the `pmset -g` command in Terminal.

5.2 Properties

1. MmioWhitelist

Type: plist array

Description: ~~Designed to~~ [To](#) be filled with `plist dict` values, describing addresses critical for particular firmware functioning when `DevirtualiseMmio` quirk is in use. ~~See~~ [Refer to](#) the `MmioWhitelist` Properties section below [for details](#).

2. Patch

Type: plist array

Failsafe: Empty

Description: Perform binary patches in booter.

~~Designed to~~ [To](#) be filled with `plist dictionary` values, describing each patch. ~~See~~ [Refer to](#) the `Patch` Properties section below [for details](#).

3. Quirks

Type: plist dict

Description: Apply individual booter quirks described in the `Quirks` Properties section below.

5.3 MmioWhitelist Properties

1. Address

Type: plist integer

Failsafe: 0

Description: Exceptional MMIO address, which memory descriptor should be left virtualised (unchanged) by DevirtualiseMmio. This means that the firmware will be able to directly communicate with this memory region during operating system functioning, because the region this value is in will be assigned a virtual address.

The addresses written here must be part of the memory map, have EfiMemoryMappedIO type and EFI_MEMORY_RUNTIME attribute (highest bit) set. The debug log can be used to find the list of the candidates.

2. Comment

Type: plist string

Failsafe: Empty

Description: Arbitrary ASCII string used to provide human readable reference for the entry. Whether this value is used is implementation defined.

3. Enabled

Type: plist boolean

Failsafe: false

Description: Exclude MMIO address from the devirtualisation procedure.

5.4 Patch Properties

1. Arch

Type: plist string

Failsafe: Any (Apply to any supported architecture)

Description: Booter patch architecture (i386, x86_64).

2. Comment

Type: plist string

Failsafe: Empty

Description: Arbitrary ASCII string used to provide human readable reference for the entry. Whether this value is used is implementation defined.

3. Count

Type: plist integer

Failsafe: 0 (Apply to all occurrences found)

Description: Number of patch occurrences to apply.

4. Enabled

Type: plist boolean

Failsafe: false

Description: Set to true to activate this booter patch.

5. Find

Type: plist data

Failsafe: Empty

Description: Data to find. Must be equal to Replace in size if set.

6. Identifier

Type: plist string

Failsafe: Any (Match any booter)

Description: Apple for macOS booter (~~generally~~ typically boot.efi); or a name with a suffix, such as bootmgfw.efi, for a specific booter.

7. Limit

Type: plist integer

Failsafe: 0 (Search the entire booter)

Description: Maximum number of bytes to search for.

Note: This quirk may potentially weaken firmware security. Please use `RebuildAppleMemoryMap` if the firmware supports memory attributes table (MAT). Refer to the `OCABC: MAT support is 1/0` log entry to determine whether MAT is supported.

9. `ForceBooterSignature`

Type: plist boolean

Failsafe: false

Description: Set macOS boot-signature to OpenCore launcher.

Booter signature, essentially a SHA-1 hash of the loaded image, is used by Mac EFI to verify the authenticity of the bootloader when waking from hibernation. This option forces macOS to use OpenCore launcher SHA-1 hash as a booter signature to let OpenCore shim hibernation wake on Mac EFI firmware.

Note: OpenCore launcher path is determined from `LauncherPath` property.

10. `ForceExitBootServices`

Type: plist boolean

Failsafe: false

Description: Retry `ExitBootServices` with new memory map on failure.

Try to ensure that the `ExitBootServices` call succeeds. If required, an outdated `MemoryMap` key argument can be used by obtaining the current memory map and retrying the `ExitBootServices` call.

Note: The need for this quirk is determined by early boot crashes of the firmware. Do not use this option without a full understanding of the implications.

11. `ProtectMemoryRegions`

Type: plist boolean

Failsafe: false

Description: Protect memory regions from incorrect access.

Some types of firmware incorrectly map certain memory regions:

- The CSM region can be marked as boot services code, or data, which leaves it as free memory for the XNU kernel.
- MMIO regions can be marked as reserved memory and stay unmapped. They may however be required to be accessible at runtime for NVRAM support.

This quirk attempts to fix the types of these regions, e.g. ACPI NVS for CSM or MMIO for MMIO.

Note: The need for this quirk is determined by artifacts, sleep wake issues, and boot failures. This quirk is typically only required by very old firmware.

12. `ProtectSecureBoot`

Type: plist boolean

Failsafe: false

Description: Protect UEFI Secure Boot variables from being written.

Reports security violation during attempts to write to `db`, `dbx`, `PK`, and `KEK` variables from the operating system.

Note: This quirk attempts to avoid issues with NVRAM implementations with fragmentation issues, such as on the `MacPro5,1` as well as on certain Insyde firmware without garbage collection or with defective garbage collection.

13. `ProtectUefiServices`

Type: plist boolean

Failsafe: false

Description: Protect UEFI services from being overridden by the firmware.

Some modern firmware, including on virtual machines such as VMware, may update pointers to UEFI services during driver loading and related actions. Consequently, this directly obstructs other quirks that affect memory management, such as `DevirtualiseMmio`, `ProtectMemoryRegions`, or `RebuildAppleMemoryMap`, and may also obstruct other quirks depending on the scope of such.

Note: On VMware, the need for this quirk may be determined by the appearance of the “Your Mac OS guest might run unreliably with more than one virtual core.” message.

Note: The need for this quirk is determined by early boot failures.

18. **SignalAppleOS**

Type: plist boolean

Failsafe: false

Description: Report macOS being loaded through OS Info for any OS.

This quirk is useful on Mac firmware, which loads different operating systems with different hardware configurations. For example, it is supposed to enable Intel GPU in Windows and Linux in some dual-GPU MacBook models.

19. **SyncRuntimePermissions**

Type: plist boolean

Failsafe: false

Description: Update memory permissions for the runtime environment.

Some types of firmware fail to properly handle runtime permissions:

- They incorrectly mark **OpenRuntime** as not executable in the memory map.
- They incorrectly mark **OpenRuntime** as not executable in the memory attributes table.
- They lose entries from the memory attributes table after **OpenRuntime** is loaded.
- They mark items in the memory attributes table as read-write-execute.

This quirk ~~tries to update~~ attempts to update the memory map and memory attributes table to correct this.

Note: The need for this quirk is indicated by early boot failures. Only firmware released after 2017 is typically affected.

6 DeviceProperties

6.1 Introduction

Device configuration is provided to macOS with a dedicated buffer, called `EfiDevicePathPropertyDatabase`. This buffer is a serialised map of DevicePaths to a map of property names and their values.

Property data can be debugged with `gfxutil`. To obtain current property data, use the following command in macOS:

```
ioreg -lw0 -p IODeviceTree -n efi -r -x | grep device-properties |  
sed 's/.*<///;s/>.*///' > /tmp/device-properties.hex &&  
gfxutil /tmp/device-properties.hex /tmp/device-properties.plist &&  
cat /tmp/device-properties.plist
```

Device properties are part of the `IODeviceTree` (`gIODT`) plane of the macOS I/O Registry. This plane has several construction stages relevant for the platform initialisation. While the early construction stage is performed by the XNU kernel in the `IODeviceTreeAlloc` method, the majority of the construction is performed by the platform expert, implemented in `AppleACPIPlatformExpert.kext`.

`AppleACPIPlatformExpert` incorporates two stages of `IODeviceTree` construction implemented by calling `AppleACPIPlatformExpert::mergeDeviceProperties`:

1. During ACPI table initialisation through the recursive ACPI namespace scanning by the calls to `AppleACPIPlatformExpert::createDTNubs`.
2. During IOService registration (`IOServices::registerService`) callbacks implemented as a part of `AppleACPIPlatformExpert::platformAdjustService` function and its private worker method `AppleACPIPlatformExpert::platformAdjustPCIDevice` specific to the PCI devices.

The application of the stages depends on the device presence in ACPI tables. The first stage applies very early but exclusively to the devices present in ACPI tables. The second stage applies to all devices much later after the PCI configuration and may repeat the first stage if the device was not present in ACPI.

For all kernel ~~drivers~~ [extensions](#) that may inspect the `IODeviceTree` plane without probing, such as `Lilu` and its plugins (e.g. `WhateverGreen`), it is especially important to ensure device presence in the ACPI tables. A failure to do so may result in **erratic behaviour** caused by ignoring the injected device properties as they were not constructed at the first stage. See `SSDT-IMEI.dsl` and `SSDT-BRGO.dsl` for an example.

6.2 Properties

1. Add

Type: `plist dict`

Description: Sets device properties from a map (`plist dict`) of device paths to a map (`plist dict`) of variable names and their values in `plist multidata` format.

[Note 1:](#) Device paths must be provided in canonic string format (e.g. `PciRoot(0x0)/Pci(0x1,0x0)/Pci(0x0,0x0)`).
~~Properties will only be set if not present and not deleted.~~

~~[Note 2:](#) Currently properties may only be (formerly) added by the original driver, so unless a separate driver was installed, there is no reason to delete the variables~~
Existing properties will not be changed unless deleted in the [DeviceProperties Delete](#) section.

2. Delete

Type: `plist dict`

Description: Removes device properties from a map (`plist dict`) of device paths to an array (`plist array`) of variable names in `plist string` format.

[Note:](#) ~~Currently, existing properties may only exist on firmware with DeviceProperties drivers (e.g. Apple).~~
Hence, there is typically no reason to delete variables unless a new driver has been installed.

6.3 Common Properties

Some known properties include:

7 Kernel

7.1 Introduction

This section allows the application of different kinds of kernelspace modifications on Apple Kernel (XNU). The modifications currently provide driver (kext) injection, kernel and driver patching, and driver blocking.

7.2 Properties

1. Add

Type: plist array

Failsafe: Empty

Description: Load selected kernel ~~drivers from extensions (kexts) from the~~ OC/Kexts directory.

~~Designed to~~ To be filled with `plist` dict values, describing each ~~driver. See kext. Refer to~~ the Add Properties section below for details.

Note 1: The load order is based on the order in which the kexts appear in the array. Hence, dependencies must appear before kexts that depend on them. ~~Kernel driver load order follows the item order in the array, thus the dependencies should be written prior to their consumers.~~

Note 2: To track the dependency order, inspect the `OSBundleLibraries` key in the `Info.plist` file of the kext being added. Any kext ~~mentioned in the OSBundleLibraries of the other kext must precede this kext included under the key is a dependency that must appear before the kext being added.~~

Note 3: Kexts may have inner kexts (~~Plug-Ins~~Plugins) ~~in their bundle. Each inner kext included in the bundle. Such Plugins~~ must be added separately and follow the same global ordering rules as other kexts.

2. Block

Type: plist array

Failsafe: Empty

Description: Remove selected kernel ~~drivers from extensions (kexts) from the~~ prelinked kernel.

~~Designed to~~ To be filled with `plist` dictionary values, describing each blocked ~~driver. See kext. Refer to~~ the Block Properties section below for details.

3. Emulate

Type: plist dict

Description: Emulate certain hardware in kernelspace via parameters described in the Emulate Properties section below.

4. Force

Type: plist array

Failsafe: Empty

Description: Load kernel ~~drivers from extensions (kexts) from the~~ system volume if they are not cached.

~~Designed to~~ To be filled with `plist` dict values, describing each ~~driver. See kext. Refer to~~ the Force Properties section below for details. This section resolves the problem of injecting ~~drivers kexts~~ that depend on other ~~drivers kexts~~, which are not ~~cached otherwise otherwise cached.~~ The issue ~~normally typically~~ affects older operating systems, where various dependency kexts, such as `IOAudioFamily` or `IONetworkingFamily` may not be present in the kernel cache by default. ~~The kernel driver load order follows the item order in the array, thus the dependencies should be written prior to their consumers.~~

Note 1: The load order is based on the order in which the kexts appear in the array. Hence, dependencies must appear before kexts that depend on them.

Note 2: Force happens before Add.

Note 3: The signature of the “forced” ~~kernel drivers kext~~ is not checked ~~anyhow, making the use of in any way.~~ This makes using this feature extremely dangerous and ~~undesired undesirable~~ for secure boot.

Note 4: This feature may not work on encrypted partitions in newer operating systems.

5. Patch

Type: plist array

Failsafe: Empty

Description: Perform binary patches in kernel and drivers prior to driver addition and removal.

~~Designed to~~ To be filled with `plist` dictionary values, describing each patch. ~~See~~ Refer to the Patch Properties section below for details.

6. Quirks

Type: `plist dict`

Description: Apply individual kernel and driver quirks described in the Quirks Properties section below.

7. Scheme

Type: `plist dict`

Description: Define kernelspace operation mode via parameters described in the Scheme Properties section below.

7.3 Add Properties

1. Arch

Type: `plist string`

Failsafe: Any (Apply to any supported architecture)

Description: Kext architecture (`i386`, `x86_64`).

2. BundlePath

Type: `plist string`

Failsafe: Empty

Description: Kext bundle path (e.g. `Lilu.kext` or `MyKext.kext/Contents/PlugIns/MySubKext.kext`).

3. Comment

Type: `plist string`

Failsafe: Empty

Description: Arbitrary ASCII string used to provide human readable reference for the entry. Whether this value is used is implementation defined.

4. Enabled

Type: `plist boolean`

Failsafe: `false`

Description: ~~This kernel driver will not be added unless set~~ Set to `true` to add this kernel extension.

5. ExecutablePath

Type: `plist string`

Failsafe: Empty

Description: Kext executable path relative to bundle (e.g. `Contents/MacOS/Lilu`).

6. MaxKernel

Type: `plist string`

Failsafe: Empty

Description: Adds kernel ~~driver-extension~~ on specified macOS version or older.

Kernel version can be obtained with `uname -r` command, and should look like 3 numbers separated by dots, for example `18.7.0` is the kernel version for `10.14.6`. Kernel version interpretation is implemented as follows:

$$\begin{aligned} \text{ParseDarwinVersion}(\kappa, \lambda, \mu) &= \kappa \cdot 10000 && \text{Where } \kappa \in (0, 99) \text{ is kernel version major} \\ &+ \lambda \cdot 100 && \text{Where } \lambda \in (0, 99) \text{ is kernel version minor} \\ &+ \mu && \text{Where } \mu \in (0, 99) \text{ is kernel version patch} \end{aligned}$$

Kernel version comparison is implemented as follows:

$$\alpha = \begin{cases} \text{ParseDarwinVersion}(\text{MinKernel}), & \text{If MinKernel is valid} \\ 0 & \text{Otherwise} \end{cases}$$

$$\beta = \begin{cases} \text{ParseDarwinVersion}(\text{MaxKernel}), & \text{If MaxKernel is valid} \\ \infty & \text{Otherwise} \end{cases}$$

$$\gamma = \begin{cases} \text{ParseDarwinVersion}(\text{FindDarwinVersion}()), & \text{If valid "Darwin Kernel Version" is found} \\ \infty & \text{Otherwise} \end{cases}$$

$$f(\alpha, \beta, \gamma) = \alpha \leq \gamma \leq \beta$$

Here *ParseDarwinVersion* argument is assumed to be 3 integers obtained by splitting Darwin kernel version string from left to right by the . symbol. *FindDarwinVersion* function looks up Darwin kernel version by locating "Darwin Kernel Version $\kappa.\lambda.\mu$ " string in the kernel image.

7. MinKernel

Type: plist string

Failsafe: Empty

Description: Adds kernel ~~driver~~-extension on specified macOS version or newer.

Note: Refer to the Add MaxKernel description for matching logic.

8. PlistPath

Type: plist string

Failsafe: Empty

Description: Kext Info.plist path relative to bundle (e.g. Contents/Info.plist).

7.4 Block Properties

1. Arch

Type: plist string

Failsafe: Any (Apply to any supported architecture)

Description: Kext block architecture (i386, x86_64).

2. Comment

Type: plist string

Failsafe: Empty

Description: Arbitrary ASCII string used to provide human readable reference for the entry. Whether this value is used is implementation defined.

3. Enabled

Type: plist boolean

Failsafe: false

Description: ~~This kernel driver will not be blocked unless set~~ Set to true to block this kernel extension.

4. Identifier

Type: plist string

Failsafe: Empty

Description: Kext bundle identifier (e.g. com.apple.driver.AppleTyMCEDriver).

5. MaxKernel

Type: plist string

Failsafe: Empty

Description: Blocks kernel ~~driver~~-extension on specified macOS version or older.

Note: Refer to the Add MaxKernel description for matching logic.

6. MinKernel

Type: plist string

Failsafe: Empty

Description: Blocks kernel ~~driver~~-extension on specified macOS version or newer.

Note: Refer to the `Add MaxKernel` description for matching logic.

7.5 Emulate Properties

1. `Cpuid1Data`

Type: plist data, 16 bytes

Failsafe: All zero

Description: Sequence of `EAX`, `EBX`, `ECX`, `EDX` values to replace `CPUID` (1) call in XNU kernel.

This property primarily meets three requirements:

- Enabling support for an unsupported CPU model (e.g. Intel Pentium).
- Enabling support for a CPU model not yet supported by a specific version of macOS (typically old versions).
- Enabling XCPM support for an unsupported CPU variant.

Note 1: It may also be the case that the CPU model is supported but there is no power management supported (e.g. virtual machines). In this case, `MinKernel` and `MaxKernel` can be set to restrict CPU virtualisation and dummy power management patches to the particular macOS kernel version.

Note 2: ~~Normally it is only~~ Only the value of `EAX` ~~that needs to be taken care of, since it,~~ which represents the full `CPUID`. ~~The remaining bytes are to,~~ typically needs to be accounted for and remaining bytes should be left as zeroes. ~~Byte~~ The byte order is Little Endian, ~~so for.~~ For example, `C3 06 03 00` stands for `CPUID 0x0306C3` (Haswell).

Note 3: For XCPM support it is recommended to use the following combinations.

- Haswell-E (0x0306F2) to Haswell (0x0306C3):
`Cpuid1Data:` `C3 06 03 00 00 00 00 00 00 00 00 00 00 00 00 00`
`Cpuid1Mask:` `FF FF FF FF 00 00 00 00 00 00 00 00 00 00 00 00`
- Broadwell-E (0x0406F1) to Broadwell (0x0306D4):
`Cpuid1Data:` `D4 06 03 00 00 00 00 00 00 00 00 00 00 00 00 00`
`Cpuid1Mask:` `FF FF FF FF 00 00 00 00 00 00 00 00 00 00 00 00`
- Rocket Lake (0x0A0670) to Comet Lake (0x0906EB):
`Cpuid1Data:` `EB 06 09 00 00 00 00 00 00 00 00 00 00 00 00 00`
`Cpuid1Mask:` `FF FF FF FF 00 00 00 00 00 00 00 00 00 00 00 00`

Note 4: Be aware that the following configurations are unsupported by XCPM (at least out of the box):

- Consumer Ivy Bridge (0x0306A9) as Apple disabled XCPM for Ivy Bridge and recommends legacy power management for these CPUs. `_xcpm_bootstrap` should manually be patched to enforce XCPM on these CPUs instead of this option.
- Low-end CPUs (e.g. Haswell+ Pentium) as they are not supported properly by macOS. Legacy workarounds for older models can be found in the `Special NOTES` section of `acidanthera/bugtracker#365`.

2. `Cpuid1Mask`

Type: plist data, 16 bytes

Failsafe: All zero

Description: Bit mask of active bits in `Cpuid1Data`.

When each `Cpuid1Mask` bit is set to 0, the original CPU bit is used, otherwise set bits take the value of `Cpuid1Data`.

3. `DummyPowerManagement`

Type: plist boolean

Failsafe: false

Requirement: 10.4

Description: Disables `AppleIntelCpuPowerManagement`.

Note 1: This option is a preferred alternative to `NullCpuPowerManagement.kext` for CPUs without native power management driver in macOS.

Note 2: While this option is typically needed to disable `AppleIntelCpuPowerManagement` on unsupported platforms, it can also be used to disable this `kext` in other situations (e.g. with `Cpuid1Data` left blank).

4. `MaxKernel`

Type: plist string

Failsafe: Empty

Description: Emulates CPUID and applies DummyPowerManagement on specified macOS version or older.

Note: Refer to the Add MaxKernel description for matching logic.

5. MinKernel

Type: plist string

Failsafe: Empty

Description: Emulates CPUID and applies DummyPowerManagement on specified macOS version or newer.

Note: Refer to the Add MaxKernel description for matching logic.

7.6 Force Properties

1. Arch

Type: plist string

Failsafe: Any (Apply to any supported architecture)

Description: Kext architecture (i386, x86_64).

2. BundlePath

Type: plist string

Failsafe: Empty

Description: Kext bundle path (e.g. System/Library/Extensions/IONetworkingFamily.kext).

3. Comment

Type: plist string

Failsafe: Empty

Description: Arbitrary ASCII string used to provide human readable reference for the entry. Whether this value is used is implementation defined.

4. Enabled

Type: plist boolean

Failsafe: false

Description: ~~This kernel driver will not be added~~ Set to true to load this kernel extension from the system volume when not present unless set to true in the kernel cache.

5. ExecutablePath

Type: plist string

Failsafe: Empty

Description: Kext executable path relative to bundle (e.g. Contents/MacOS/IONetworkingFamily).

6. Identifier

Type: plist string

Failsafe: Empty

Description: Kext identifier to perform presence checking before adding (e.g. com.apple.iokit.IONetworkingFamily). Only drivers which identifiers are not be found in the cache will be added.

7. MaxKernel

Type: plist string

Failsafe: Empty

Description: Adds kernel ~~driver~~ extension on specified macOS version or older.

Note: Refer to the Add MaxKernel description for matching logic.

8. MinKernel

Type: plist string

Failsafe: Empty

Description: Adds kernel ~~driver~~ extension on specified macOS version or newer.

Note: Refer to the Add MaxKernel description for matching logic.

9. PlistPath

Type: plist string

Failsafe: Empty

Description: Patches data on specified macOS version or newer.

Note: Refer to the `Add MaxKernel` description for matching logic.

12. `Replace`

Type: plist data

Failsafe: Empty

Description: Replacement data of one or more bytes.

13. `ReplaceMask`

Type: plist data

Failsafe: Empty (Ignored)

Description: Data bitwise mask used during replacement. Allows fuzzy replacement by updating masked (set to non-zero) bits. Must be equal to `Replace` in size if set.

14. `Skip`

Type: plist integer

Failsafe: 0 (Do not skip any occurrences)

Description: Number of found occurrences to skip before replacements are applied.

7.8 Quirks Properties

1. `AppleCpuPmCfgLock`

Type: plist boolean

Failsafe: false

Requirement: 10.4

Description: Disables `PKG_CST_CONFIG_CONTROL` (0xE2) MSR modification in `AppleIntelCPUPowerManagement.kext`, commonly causing early kernel panic, when it is locked from writing.

Some types of firmware lock the `PKG_CST_CONFIG_CONTROL` MSR register and the bundled [VerifyMsrE2ControlMsrE2](#) tool can be used to check its state. Note that some types of firmware only have this register locked on some cores.

As modern firmware provide a `CFG Lock` setting that allows configuring the `PKG_CST_CONFIG_CONTROL` MSR register lock, this option should be avoided whenever possible.

On APTIO firmware that do not provide a `CFG Lock` setting in the GUI, it is possible to access the option directly:

- Download UEFITool and IFR-Extractor.
- Open the firmware image in UEFITool and find `CFG Lock` unicode string. If it is not present, the firmware may not have this option and the process should therefore be discontinued.
- Extract the `Setup.bin` PE32 Image Section (the UEFITool found) through the `Extract Body` menu option.
- Run IFR-Extractor on the extracted file (e.g. `./ifrexpact Setup.bin Setup.txt`).
- Find `CFG Lock, VarStoreInfo (VarOffset/VarName):` in `Setup.txt` and remember the offset right after it (e.g. `0x123`).
- Download and run Modified GRUB Shell compiled by brainsucker or use a newer version by datasone.
- Enter `setup_var 0x123 0x00` command, where `0x123` should be replaced by the actual offset, and reboot.

Warning: Variable offsets are unique not only to each motherboard but even to its firmware version. Never ever try to use an offset without checking.

On selected platforms, the `ControlMsre2` tool can also change such hidden options. Pass desired argument: `lock`, `unlock` for `CFG Lock`. Or pass `interactive` to find and modify other hidden options.

As a last resort, consider patching the BIOS (for advanced users only).

2. `AppleXcpmCfgLock`

Type: plist boolean

Failsafe: false

Requirement: 10.8 (not required for older)

Description: Disables `PKG_CST_CONFIG_CONTROL` (0xE2) MSR modification in XNU kernel, commonly causing early kernel panic, when it is locked from writing (XCPM power management).

Note: This option should be avoided whenever possible. ~~See~~ [Refer to the](#) `AppleCpuPmCfgLock` description for ~~more~~ details.

3. `AppleXcpmExtraMsrs`

Type: plist boolean

Failsafe: false

Requirement: 10.8 (not required for older)

Description: Disables multiple MSR access critical for certain CPUs, which have no native XCPM support.

This is ~~normally~~ [typically](#) used in conjunction with [the](#) `Emulate` section on Haswell-E, Broadwell-E, Skylake-SP, and similar CPUs. More details on the XCPM patches are outlined in `acidanthera/bugtracker#365`.

Note: Additional not provided patches will be required for Ivy Bridge or Pentium CPUs. It is recommended to use `AppleIntelCpuPowerManagement.kext` for the former.

4. `AppleXcpmForceBoost`

Type: plist boolean

Failsafe: false

Requirement: 10.8 (not required for older)

Description: Forces maximum performance in XCPM mode.

This patch writes `0xFF00` to `MSR_IA32_PERF_CONTROL` (`0x199`), effectively setting maximum multiplier for all the time.

Note: While this may increase the performance, this patch is strongly discouraged on all systems but those explicitly dedicated to scientific or media calculations. Only certain Xeon models typically benefit from the patch.

5. `CustomSMBIOSGuid`

Type: plist boolean

Failsafe: false

Requirement: 10.4

Description: Performs GUID patching for `UpdateSMBIOSMode Custom` mode. Usually relevant for Dell laptops.

6. `DisableIoMapper`

Type: plist boolean

Failsafe: false

Requirement: 10.8 (not required for older)

Description: Disables `IoMapper` support in XNU (VT-d), which may conflict with the firmware implementation.

Note: This option is a preferred alternative to deleting `DMAR` ACPI table and disabling VT-d in firmware preferences, which does not obstruct VT-d support in other systems in case they need this.

7. `DisableLinkeditJettison`

Type: plist boolean

Failsafe: false

Requirement: 11

Description: Disables `__LINKEDIT` jettison code.

This option lets `Lilu.kext`, and possibly other kexts, function in macOS Big Sur at their best performance levels without requiring the `keepsyms=1` boot argument.

8. `DisableRtcChecksum`

Type: plist boolean

Failsafe: false

Requirement: 10.4

Description: Disables primary checksum (`0x58-0x59`) writing in `AppleRTC`.

Note 1: This option will not protect other areas from being overwritten, see `RTCMemoryFixup` kernel extension if this is desired.

Note 2: This option will not protect areas from being overwritten at firmware stage (e.g. macOS bootloader), see `AppleRtcRam` protocol description if this is desired.

9. `ExtendBTFeatureFlags`

Type: plist boolean

sometimes fails to wake up. For debug kernels `setpowerstate_panic=0` boot argument should be used, which is otherwise equivalent to this quirk.

17. SetApfsTrimTimeout

Type: plist integer

Failsafe: -1

Requirement: 10.14 (not required for older)

Description: Set trim timeout in microseconds for APFS filesystems on SSDs.

The APFS filesystem is designed in a way that the space controlled via the spaceman structure is either used or free. This may be different in other filesystems where the areas can be marked as used, free, and *unmapped*. All free space is trimmed (unmapped/deallocated) at macOS startup. The trimming procedure for NVMe drives happens in LBA ranges due to the nature of the DSM command with up to 256 ranges per command. The more fragmented the memory on the drive is, the more commands are necessary to trim all the free space.

Depending on the SSD controller and the level of drive fragmentation, the trim procedure may take a considerable amount of time, causing noticeable boot slowdown. The APFS driver explicitly ignores previously unmapped areas and repeatedly trims them on boot. To mitigate against such boot slowdowns, the macOS driver introduced a timeout (9.999999 seconds) that stops the trim operation when not finished in time.

On several controllers, such as Samsung, where the deallocation process is relatively slow, this timeout can be reached very quickly. Essentially, it means that the level of fragmentation is high, thus macOS will attempt to trim the same lower blocks that have previously been deallocated, but never have enough time to deallocate higher blocks. The outcome is that trimming on such SSDs will be non-functional soon after installation, resulting in additional wear on the flash.

One way to workaround the problem is to increase the timeout to an extremely high value, which at the cost of slow boot times (extra minutes) will ensure that all the blocks are trimmed. Set this option to a high value, such as 4294967295, to ensure that all blocks are trimmed. Alternatively, use over-provisioning, if supported, or create a dedicated unmapped partition where the reserve blocks can be found by the controller. Conversely, the trim operation can be disabled by setting a very low timeout value. e.g. 999. Refer to this article for ~~more~~ details.

18. ThirdPartyDrives

Type: plist boolean

Failsafe: false

Requirement: 10.6 (not required for older)

Description: Apply vendor patches to IOAHCIBlockStorage.kext to enable native features for third-party drives, such as TRIM on SSDs or hibernation support on 10.15 and newer.

Note: This option may be avoided on user preference. NVMe SSDs are compatible without the change. For AHCI SSDs on modern macOS version there is a dedicated built-in utility called `trimforce`. Starting from 10.15 this utility creates `EnableTRIM` variable in `APPLE_BOOT_VARIABLE_GUID` namespace with 01 00 00 00 value.

19. XhciPortLimit

Type: plist boolean

Failsafe: false

Requirement: 10.11 (not required for older)

Description: Patch various kexts (AppleUSBXHCI.kext, AppleUSBXHCIPCI.kext, IOUSBHostFamily.kext) to remove USB port count limit of 15 ports.

Note: This option should be avoided whenever possible ~~and may no longer in macOS 11.~~ USB port limit is imposed by the amount of used bits in locationID format and there is no possible way to workaround this without heavy OS modification. The only valid solution is to limit the amount of used ports to 15 (discarding some). More details can be found on AppleLife.ru.

7.9 Scheme Properties

These properties are particularly relevant for older macOS operating systems. Refer to the Legacy Apple OS section for details on how to install and troubleshoot such macOS installations.

1. FuzzyMatch

Type: plist boolean

Failsafe: `false`

Description: Use `kernelcache` with different checksums when available.

On macOS 10.6 and earlier, `kernelcache` filename has a checksum, which essentially is `adler32` from SMBIOS product name and EfiBoot device path. On certain firmware, the EfiBoot device path differs between UEFI and macOS due to ACPI or hardware specifics, rendering `kernelcache` checksum as always different.

This setting allows matching the latest `kernelcache` with a suitable architecture when the `kernelcache` without suffix is unavailable, improving macOS 10.6 boot performance on several platforms.

2. KernelArch

Type: `plist string`

Failsafe: `Auto` (Choose the preferred architecture automatically)

Description: Prefer specified kernel architecture (`i386`, `i386-user32`, `x86_64`) when available.

On macOS 10.7 and earlier, the XNU kernel can boot with architectures different from the usual `x86_64`. This setting will use the specified architecture to boot macOS when it is supported by the macOS and the configuration:

- `i386` — Use `i386` (32-bit) kernel when available.
- `i386-user32` — Use `i386` (32-bit) kernel when available and force the use of 32-bit userspace on 64-bit capable processors if supported by the operating system.
 - On macOS, 64-bit capable processors are assumed to support `SSSE3`. This is not the case for older 64-bit capable Pentium processors, which cause some applications to crash on macOS 10.6. This behaviour corresponds to the `-legacy` kernel boot argument.
 - This option is unavailable on macOS 10.4 and 10.5 when running on 64-bit firmware due to an uninitialised 64-bit segment in the XNU kernel, which causes AppleEFIRuntime to incorrectly execute 64-bit code as 16-bit code.
- `x86_64` — Use `x86_64` (64-bit) kernel when available.

The algorithm used to determine the preferred kernel architecture is set out below.

- (a) `arch` argument in image arguments (e.g. when launched via UEFI Shell) or in `boot-args` variable overrides any compatibility checks and forces the specified architecture, completing this algorithm.
- (b) OpenCore build architecture restricts capabilities to `i386` and `i386-user32` mode for the 32-bit firmware variant.
- (c) Determined EfiBoot version restricts architecture choice:
 - 10.4-10.5 — `i386` or `i386-user32` (only on 32-bit firmware)
 - 10.6 — `i386`, `i386-user32`, or `x86_64`
 - 10.7 — `i386` or `x86_64`
 - 10.8 or newer — `x86_64`
- (d) If `KernelArch` is set to `Auto` and `SSSE3` is not supported by the CPU, capabilities are restricted to `i386-user32` if supported by EfiBoot.
- (e) Board identifier (from SMBIOS) based on EfiBoot version disables `x86_64` support on an unsupported model if any `i386` variant is supported. `Auto` is not consulted here as the list is not overridable in EfiBoot.
- (f) `KernelArch` restricts the support to the explicitly specified architecture (when not set to `Auto`) if the architecture remains present in the capabilities.
- (g) The best supported architecture is chosen in this order: `x86_64`, `i386`, `i386-user32`.

Unlike macOS 10.7 (where certain board identifiers are treated as the `i386` only machines), and macOS 10.5 or earlier (where `x86_64` is not supported by the macOS kernel), macOS 10.6 is very special. The architecture choice on macOS 10.6 depends on many factors including not only the board identifier, but also the macOS product type (client vs server), macOS point release, and amount of RAM. The detection of all these is complicated and impractical, as several point releases had implementation ~~defects~~-flaws resulting in a failure to properly execute the server detection in the first place. For this reason, OpenCore on macOS 10.6 falls back on the `x86_64` architecture whenever it is supported by the board, as it is on macOS 10.7.

A 64-bit Mac model compatibility matrix corresponding to actual EfiBoot behaviour on macOS 10.6.8 and 10.7.5 is outlined below.

Model	10.6 (minimal)	10.6 (client)	10.6 (server)	10.7 (any)
Macmini	4,x (Mid 2010)	5,x (Mid 2011)	4,x (Mid 2010)	3,x (Early 2009)
MacBook	Unsupported	Unsupported	Unsupported	5,x (2009/09)
MacBookAir	Unsupported	Unsupported	Unsupported	2,x (Late 2008)
MacBookPro	4,x (Early 2008)	8,x (Early 2011)	8,x (Early 2011)	3,x (Mid 2007)
iMac	8,x (Early 2008)	12,x (Mid 2011)	12,x (Mid 2011)	7,x (Mid 2007)
MacPro	3,x (Early 2008)	5,x (Mid 2010)	3,x (Early 2008)	3,x (Early 2008)
Xserve	2,x (Early 2008)	2,x (Early 2008)	2,x (Early 2008)	2,x (Early 2008)

Note: 3+2 and 6+4 hotkeys to choose the preferred architecture are unsupported as they are handled by EfiBoot and hence, difficult to detect.

3. KernelCache

Type: plist string

Failsafe: Auto

Description: Prefer specified kernel cache type (Auto, Cacheless, Mkext, Prelinked) when available.

Different variants of macOS support different kernel caching variants designed to improve boot performance. This setting prevents the use of faster kernel caching variants if slower variants are available for debugging and stability reasons. I.e. That is, by specifying Mkext, Prelinked will be disabled for e.g. 10.6 but not for 10.7.

The list of available kernel caching types and its current support in OpenCore is listed below.

macOS	i386 NC	i386 MK	i386 PK	x86_64 NC	x86_64 MK	x86_64 PK	x86_64 KC
10.4	YES	YES (V1)	NO (V1)	—	—	—	—
10.5	YES	YES (V1)	NO (V1)	—	—	—	—
10.6	YES	YES (V2)	YES (V2)	YES	YES (V2)	YES (V2)	—
10.7	YES	—	YES (V3)	YES	—	YES (V3)	—
10.8-10.9	—	—	—	YES	—	YES (V3)	—
10.10-10.15	—	—	—	—	—	YES (V3)	—
11+	—	—	—	—	—	YES (V3)	YES

Note: The first version (V1) of the 32-bit **prelinkedkernel** is unsupported due to the corruption of kext symbol tables by the tools. On this version, the Auto setting will block **prelinkedkernel** booting. This also results in the **keepsyms=1** boot argument being non-functional for kext frames on these systems.

8 Misc

8.1 Introduction

This section contains miscellaneous configuration options affecting OpenCore operating system loading behaviour in addition to other options that do not readily fit into other sections.

OpenCore broadly follows the “bless” model, also known as the “Apple Boot Policy”. The primary purpose of the “bless” model is to allow embedding boot options within the file system (and be accessible through a specialised driver) as well as supporting a broader range of predefined boot paths as compared to the removable media list set out in the UEFI specification.

Partitions can only be booted by OpenCore when they meet the requirements of a predefined **Scan policy**. This policy sets out which specific file systems a partition must have, and which specific device types a partition must be located on, to be made available by OpenCore as a boot option. Refer to the **ScanPolicy** property for ~~more~~ details.

The scan process starts with enumerating all available partitions, filtered based on the **Scan policy**. Each partition may generate multiple primary and alternate options. Primary options represent operating systems installed on the media, while alternate options represent recovery options for the operating systems on the media.

- Alternate options may exist without primary options and vice versa.
- Options may not necessarily represent operating systems on the same partition.
- Each primary and alternate option can be an auxiliary option or not.
 - Refer to the **HideAuxiliary** section for ~~more~~ details.

The algorithm to determine boot options behaves as follows:

1. Obtain all available partition handles filtered based on the **Scan policy** (and driver availability).
2. Obtain all available boot options from the **BootOrder** UEFI variable.
3. For each boot option found:
 - Retrieve the device path of the boot option.
 - Perform fixups (e.g. NVMe subtype correction) and expansion (e.g. for Boot Camp) of the device path.
 - On failure, if it is an OpenCore custom entry device path, pre-construct the corresponding custom entry and succeed.
 - Obtain the device handle by locating the device path of the resulting device path (ignore it on failure).
 - Locate the device handle in the list of partition handles (ignore it if missing).
 - For disk device paths (not specifying a bootloader), execute “bless” (may return > 1 entry).
 - For file device paths, check for presence on the file system directly.
 - On the OpenCore boot partition, exclude all OpenCore bootstrap files by file header checks.
 - Mark device handle as *used* in the list of partition handles if any.
 - Register the resulting entries as primary options and determine their types.
The option will become auxiliary for some types (e.g. Apple HFS recovery).
4. For each partition handle:
 - If the partition handle is marked as *unused*, execute “bless” primary option list retrieval.
In case a **BlessOverride** list is set, both standard and custom “bless” paths will be found.
 - On the OpenCore boot partition, exclude OpenCore bootstrap files using header checks.
 - Register the resulting entries as primary options and determine their types if found.
The option will become auxiliary for some types (e.g. Apple HFS recovery).
 - If a partition already has any primary options of the “Apple Recovery” type, proceed to the next handle.
 - Lookup alternate entries by “bless” recovery option list retrieval and predefined paths.
 - Register the resulting entries as alternate auxiliary options and determine their types if found.
5. Custom entries and tools, except such pre-constructed previously, are added as primary options without any checks with respect to **Auxiliary**.
6. System entries, such as **Reset NVRAM**, are added as primary auxiliary options.

The display order of the boot options in the OpenCore picker and the boot process are determined separately from the scanning algorithm.

The display order as follows:

- Alternate options follow corresponding primary options. That is, Apple recovery options will follow the relevant macOS option whenever possible.

- Options will be listed in file system handle firmware order to maintain an established order across reboots regardless of the operating system chosen for loading.
- Custom entries, tools, and system entries will be added after all other options.
- Auxiliary options will only be displayed upon entering “Extended Mode” in the OpenCore picker (typically by pressing the **Space** key).

The boot process is as follows:

- Look up the first valid primary option in the **BootNext** UEFI variable.
- On failure, look up the first valid primary option in the **BootOrder** UEFI variable.
- Mark the option as the default option to boot.
- Boot option through the picker or without it depending on the **ShowPicker** option.
- Show picker on failure otherwise.

Note 1: This process will only work reliably when the **RequestBootVarRouting** option is enabled or the firmware does not control UEFI boot options (**OpenDuetPkg** or custom BDS). When **LauncherOption** is not enabled, other operating systems may overwrite OpenCore settings and this property should therefore be enabled when planning to use other operating systems.

Note 2: UEFI variable boot options boot arguments will be removed, if present, as they may contain arguments that can compromise the operating system, which is undesirable when secure boot is enabled.

Note 3: Some operating systems, such as Windows, may create a boot option and mark it as the topmost option upon first boot or after NVRAM resets from within OpenCore. When this happens, the default boot entry choice will remain changed until the next manual reconfiguration.

8.2 Properties

1. Boot

Type: plist dict

Description: Apply the boot configuration described in the Boot Properties section below.

2. BlessOverride

Type: plist array

Description: Add custom scanning paths through the bless model.

~~Designed to~~ To be filled with **plist string** entries containing absolute UEFI paths to customised bootloaders such as `\EFI\debian\grubx64.efi` for the Debian bootloader. This allows non-standard boot paths to be automatically discovered by the OpenCore picker. Designwise, they are equivalent to predefined blessed paths, such as `\System\Library\CoreServices\boot.efi` or `\EFI\Microsoft\Boot\bootmgfw.efi`, but unlike predefined bless paths, they have the highest priority.

3. Debug

Type: plist dict

Description: Apply debug configuration described in the Debug Properties section below.

4. Entries

Type: plist array

Description: Add boot entries to OpenCore picker.

~~Designed to~~ To be filled with **plist dict** values, describing each load entry. ~~See Refer to~~ the Entry Properties section below for details.

5. Security

Type: plist dict

Description: Apply the security configuration described in the Security Properties section below.

6. Tools

Type: plist array

Description: Add tool entries to the OpenCore picker.

~~Designed to~~ To be filled with **plist dict** values, describing each load entry. ~~See Refer to~~ the Entry Properties section below for details.

Note: Certain UEFI tools, such as UEFI Shell, can be very dangerous and **MUST NOT** appear in production configurations, particularly in vaulted configurations as well as those protected by secure boot, as such tools can be used to bypass the secure boot chain. Refer to the UEFI section for examples of UEFI tools.

8.3 Boot Properties

1. ConsoleAttributes

Type: plist integer

Failsafe: 0

Description: Sets specific attributes for the console.

The text renderer supports colour arguments as a sum of foreground and background colours based on the UEFI specification. The value for black background and for black foreground, 0, is reserved.

List of colour values and names:

- 0x00 — EFI_BLACK
- 0x01 — EFI_BLUE
- 0x02 — EFI_GREEN
- 0x03 — EFI_CYAN
- 0x04 — EFI_RED
- 0x05 — EFI_MAGENTA
- 0x06 — EFI_BROWN
- 0x07 — EFI_LIGHTGRAY
- 0x08 — EFI_DARKGRAY
- 0x09 — EFI_LIGHTBLUE
- 0x0A — EFI_LIGHTGREEN
- 0x0B — EFI_LIGHTCYAN
- 0x0C — EFI_LIGHTRED
- 0x0D — EFI_LIGHTMAGENTA
- 0x0E — EFI_YELLOW
- 0x0F — EFI_WHITE
- 0x10 — EFI_BACKGROUND_BLACK
- 0x11 — EFI_BACKGROUND_BLUE
- 0x12 — EFI_BACKGROUND_GREEN
- 0x13 — EFI_BACKGROUND_CYAN
- 0x14 — EFI_BACKGROUND_RED
- 0x15 — EFI_BACKGROUND_MAGENTA
- 0x16 — EFI_BACKGROUND_BROWN
- 0x17 — EFI_BACKGROUND_LIGHTGRAY

Note: This option may not work well with the **System** text renderer. Setting a background different from black could help with testing GOP functionality.

2. HibernateMode

Type: plist string

Failsafe: None

Description: Hibernation detection mode. The following modes are supported:

- None — ~~Avoid hibernation (Recommended)~~[Ignore hibernation state.](#)
- Auto — Use RTC and NVRAM detection.
- RTC — Use RTC detection.
- NVRAM — Use NVRAM detection.

Note: If the firmware can handle hibernation itself (valid for Mac EFI firmware), then None should be specified to hand-off hibernation state as is to OpenCore.

3. HideAuxiliary

Type: plist boolean

Failsafe: false

Description: Set to **true** to hide auxiliary entries from the picker menu.

An entry is considered auxiliary when at least one of the following applies:

- Entry is macOS recovery.
- Entry is macOS Time Machine.
- Entry is explicitly marked as **Auxiliary**.
- Entry is system (e.g. **Reset NVRAM**).

To display all entries, the picker menu can be reloaded into “Extended Mode” by pressing the **Spacebar** key. Hiding auxiliary entries may increase boot performance on multi-disk systems.

4. LauncherOption

Type: plist string

Failsafe: Disabled

Description: Register the launcher option in the firmware preferences for persistence.

Valid values:

- **Disabled** — do nothing.
- **Full** — create or update the top priority boot option in UEFI variable storage at bootloader startup.
 - For this option to work, **RequestBootVarRouting** is required to be enabled.
- **Short** — create a short boot option instead of a complete one.
 - This variant is useful for some older types of firmware, typically from Insyde, that are unable to manage full device paths.
- **System** — create no boot option but assume specified custom option is blessed.
 - This variant is useful when relying on **ForceBooterSignature** quirk and **OpenCore** launcher path management happens through **bless** utilities without involving **OpenCore**.

This option allows integration with third-party operating system installation and upgrades (which may overwrite the `\EFI\BOOT\BOOTx64.efi` file). The `BOOTx64.efi` file is no longer used for bootstrapping **OpenCore** if a custom option is created. The custom path used for bootstrapping can be specified by using the **LauncherPath** option.

Note 1: Some types of firmware may have ~~defective NVRAM implementation~~ NVRAM implementation flaws, no boot option support, or other incompatibilities. While unlikely, the use of this option may ~~cause result in~~ boot failures and should only be used exclusively on ~~the~~ boards known to be compatible. Refer to [acidanthera/bug-tracker#1222](#) for some known issues ~~with affecting~~ Haswell and other boards.

Note 2: While NVRAM resets executed from **OpenCore** would not typically erase the boot option created in **Bootstrap**, executing NVRAM resets prior to loading **OpenCore** will erase the boot option. Therefore, for significant implementation updates ~~(e.g. in, such as was the case with~~ OpenCore 0.6.4), an NVRAM reset should be ~~performed-executed~~ with **Bootstrap** disabled, after which it can be ~~reenabled~~ re-enabled.

5. LauncherPath

Type: plist string

Failsafe: Default

Description: Launch path for the **LauncherOption** property.

Default points to `OpenCore.efi`. User specified paths, e.g. `\EFI\SomeLauncher.efi`, can be used to provide custom loaders, which are supposed to load `OpenCore.efi` themselves.

6. PickerAttributes

Type: plist integer

Failsafe: 0

Description: Sets specific attributes for the **OpenCore** picker.

Different **OpenCore** pickers may be configured through the attribute mask containing **OpenCore**-reserved (BIT0~BIT15) and OEM-specific (BIT16~BIT31) values.

Current **OpenCore** values include:

- 0x0001 — `OC_ATTR_USE_VOLUME_ICON`, provides custom icons for boot entries:
 - For **Tools**, **OpenCore** will attempt loading a custom icon and fallback to a default icon on failure:
 - **ResetNVRAM** — `Resources\Image\ResetNVRAM.icns` — `ResetNVRAM.icns` from icons directory.
 - `Tools\<TOOL_RELATIVE_PATH>.icns` — icon near the tool file with appended `.icns` extension.

For custom boot **Entries**, OpenCore will attempt loading a custom icon and fallback to the volume icon or the default icon on failure:

- `<ENTRY_PATH>.icns` — icon near the entry file with appended `.icns` extension.

For all other entries, OpenCore will attempt loading a volume icon by searching as follows, and will fallback to the default icon on failure:

- `.VolumeIcon.icns` file at **Preboot** volume in per-volume directory (`/System/Volumes/Preboot/{GUID}/` when mounted at the default location within macOS) for APFS (if present).
- `.VolumeIcon.icns` file at the **Preboot** volume root (`/System/Volumes/Preboot/`, when mounted at the default location within macOS) for APFS (otherwise).
- `.VolumeIcon.icns` file at the volume root for other filesystems.

Note 1: The Apple picker partially supports placing a volume icon file at the operating system’s **Data** volume root, `/System/Volumes/Data/`, when mounted at the default location within macOS. This approach is flawed: the file is neither accessible to OpenCanopy nor to the Apple picker when FileVault 2, which is meant to be the default choice, is enabled. Therefore, OpenCanopy does not attempt supporting Apple’s approach. A volume icon file may be placed at the root of the **Preboot** volume for compatibility with both OpenCanopy and the Apple picker, or use the **Preboot** per-volume location as above with OpenCanopy as a preferred alternative to Apple’s approach.

Note 2: Be aware that using a volume icon on any drive overrides the normal OpenCore picker behaviour for that drive of selecting the appropriate icon depending on whether the drive is internal or external.

- `0x0002` — `OC_ATTR_USE_DISK_LABEL_FILE`, provides custom rendered titles for boot entries:
 - `.disk_label` (`.disk_label_2x`) file near bootloader for all filesystems.
 - `<TOOL_NAME>.lbl` (`<TOOL_NAME>.l2x`) file near tool for Tools.

Prerendered labels can be generated via the `disklabel` utility or the `bless` command. When disabled or missing text labels, (`.contentDetails` or `.disk_label.contentDetails`) are to be rendered instead.

- `0x0004` — `OC_ATTR_USE_GENERIC_LABEL_IMAGE`, provides predefined label images for boot entries without custom entries. This may however give less detail for the actual boot entry.
- `0x0008` — `OC_ATTR_HIDE_THEMED_ICONS`, prefers builtin icons for certain icon categories to match the theme style. For example, this could force displaying the builtin Time Machine icon. Requires `OC_ATTR_USE_VOLUME_ICON`.
- `0x0010` — `OC_ATTR_USE_POINTER_CONTROL`, enables pointer control in the OpenCore picker when available. For example, this could make use of mouse or trackpad to control UI elements.
- [0x0020 — OC_ATTR_DEBUG_DISPLAY, enable display of additional timing and debug information, in Builtin picker in DEBUG and NOOPT builds only.](#)

7. PickerAudioAssist

Type: plist boolean

Failsafe: false

Description: Enable screen reader by default in the OpenCore picker.

For the macOS bootloader, screen reader preference is set in the `preferences.efires` archive in the `isV0Enabled.int32` file and is controlled by the operating system. For OpenCore screen reader support, this option is an independent equivalent. Toggling screen reader support in both the OpenCore picker and the macOS bootloader FileVault 2 login window can also be done by using the `Command + F5` key combination.

Note: The screen reader requires working audio support. Refer to the **UEFI Audio Properties** section for ~~more~~ details.

8. PollAppleHotKeys

Type: plist boolean

Failsafe: false

Description: Enable modifier hotkey handling in the OpenCore picker.

In addition to **action hotkeys**, which are partially described in [the PickerMode](#) section and are ~~normally typically~~ handled by Apple BDS, modifier keys handled by the operating system bootloader (`boot.efi`) also exist. These keys allow changing the behaviour of the operating system by providing different boot modes.

On certain firmware, using modifier keys may be problematic due to driver incompatibilities. To workaround this problem, this option allows registering certain hotkeys in a more permissive manner from within the OpenCore picker. Such extensions include support for tapping on ~~keys in addition to holding and pressing Shift along with other keys instead of only pressing~~ [key combinations before selecting the boot item, and for reliable detection](#)

of the Shift key ~~, which is not detectable~~ when selecting the boot item, in order to work around the fact that hotkeys which are continuously held during boot cannot be reliably detected on many PS/2 keyboards.

This list of known modifier hotkeys includes:

- **CMD+C+MINUS** — disable board compatibility checking.
- **CMD+K** — boot release kernel, similar to **kcsuffix=release**.
- **CMD+S** — single user mode.
- **CMD+S+MINUS** — disable KASLR slide, requires disabled SIP.
- **CMD+V** — verbose mode.
- **Shift+Enter, Shift+Index** — safe mode, may be used in combination with CTRL+Enter, CTRL+Index.

9. **ShowPicker**

Type: plist boolean

Failsafe: false

Description: Show a simple picker to allow boot entry selection.

10. **TakeoffDelay**

Type: plist integer, 32 bit

Failsafe: 0

Description: Delay in microseconds executed before handling the OpenCore picker startup and **action hotkeys**.

Introducing a delay may give extra time to hold the right **action hotkey** sequence to, for instance, boot into recovery mode. On some platforms, setting this option to a minimum of 5000–10000 microseconds may be required to access **action hotkeys** due to the nature of the keyboard driver.

11. **Timeout**

Type: plist integer, 32 bit

Failsafe: 0

Description: Timeout in seconds in the OpenCore picker before automatic booting of the default boot entry. Set to 0 to disable.

12. **PickerMode**

Type: plist string

Failsafe: Builtin

Description: Choose picker used for boot management.

PickerMode describes the underlying boot management with an optional user interface responsible for handling boot options.

The following values are supported:

- **Builtin** — boot management is handled by OpenCore, a simple text-only user interface is used.
- **External** — an external boot management protocol is used if available. Otherwise, the **Builtin** mode is used.
- **Apple** — Apple boot management is used if available. Otherwise, the **Builtin** mode is used.

Upon success, the **External** mode may entirely disable all boot management in OpenCore except for policy enforcement. In the **Apple** mode, it may additionally bypass policy enforcement. Refer to the OpenCanopy plugin for an example of a custom user interface.

The OpenCore built-in picker contains a set of actions chosen during the boot process. The list of supported actions is similar to Apple BDS and typically can be accessed by holding **action hotkeys** during the boot process.

The following actions are currently considered:

- **Default** — this is the default option, and it lets the built-in OpenCore picker load the default boot option as specified in the Startup Disk preference pane.
- **ShowPicker** — this option forces the OpenCore picker to be displayed. This can typically be achieved by holding the OPT key during boot. Setting **ShowPicker** to **true** will make **ShowPicker** the default option.
- **ResetNvram** — this option erases certain UEFI variables and is normally executed by holding down the **CMD+OPT+P+R** key combination during boot. Another way to erase UEFI variables is to choose **Reset NVRAM** in the OpenCore picker. This option requires **AllowNvramReset** to be set to **true**.

- **BootApple** — this options performs booting to the first Apple operating system found unless the chosen default operating system is one from Apple. Hold the **X** key down to choose this option.
- **BootAppleRecovery** — this option performs booting into the Apple operating system recovery partition. This is either that related to the default chosen operating system, or first one found when the chosen default operating system is not from Apple or does not have a recovery partition. Hold the **CMD+R** key combination down to choose this option.

Note 1: The **KeySupport**, **OpenUsbKbDxe**, or similar drivers are required for key handling. However, not all of the key handling functions can be implemented on several types of firmware.

Note 2: In addition to **OPT**, **OpenCore** supports using both the **Escape** key to display and **Zero** keys to enter the **OpenCore** picker when **ShowPicker** is disabled. ~~This key exists for the **Escape** exists to support co-existence with the **Apple** picker (including **OpenCore** Apple picker mode as well as for firmware that fail-) and to support firmware that fails to report held **OPT** keys on key, as on some PS/2 keyboards, requiring multiple presses of the-.~~ In addition, **Zero** is provided to support systems on which **Escape** is already assigned to some other pre-boot firmware feature. In systems which do not require **KeySupport**, pressing and holding one of these keys from after power on until the picker appears should always be successful. The same should apply when using ~~Escape key to access the **OpenCore** picker~~ **KeySupport** mode if it is correctly configured for the system, i.e. with a long enough **KeyForgetThreshold**. If pressing and holding the key is not successful to reliably enter the picker, multiple repeated keypresses may be tried instead.

Note 3: On Macs with problematic **GOP**, it may be difficult to access the **Apple** picker. The **BootKicker** utility can be blessed to workaround this problem even without loading **OpenCore**. On some Macs however, the **BootKicker** utility cannot be run from **OpenCore**.

13. PickerVariant

Type: plist string

Failsafe: Auto

Description: Choose specific icon set to be used for boot management.

The following values are supported:

- **Auto** — Automatically select one set of icons based on the **DefaultBackground** colour.
- **Default** — Normal icon set (without prefix).
- **Old** — Vintage icon set (**Old** filename prefix).
- **Modern** — Nouveau icon set (**Modern** filename prefix).
- Other value — Custom icon set if supported by installed resources.

8.4 Debug Properties

1. AppleDebug

Type: plist boolean

Failsafe: false

Description: Enable writing the **boot.efi** debug log to the **OpenCore** log.

Note: This option only applies to 10.15.4 and newer.

2. ApplePanic

Type: plist boolean

Failsafe: false

Description: Save macOS kernel panic output to the **OpenCore** root partition.

The file is saved as **panic-YYYY-MM-DD-HHMMSS.txt**. It is strongly recommended to set the **keepsyms=1** boot argument to see debug symbols in the panic log. In cases where it is not present, the **kpddescribe.sh** utility (bundled with **OpenCore**) may be used to partially recover the stacktrace.

Development and debug kernels produce more useful kernel panic logs. Consider downloading and installing the **KernelDebugKit** from developer.apple.com when debugging a problem. To activate a development kernel, the boot argument **kcsuffix=development** should be added. Use the **uname -a** command to ensure that the current loaded kernel is a development (or a debug) kernel.

In cases where the **OpenCore** kernel panic saving mechanism is not used, kernel panic logs may still be found in the **/Library/Logs/DiagnosticReports** directory.

Starting with macOS Catalina, kernel panics are stored in JSON format and thus need to be preprocessed before passing to `kpdescribe.sh`:

```
cat Kernel.panic | grep macOSProcessedStackshotData |  
python -c 'import json,sys;print(json.load(sys.stdin)["macOSPanicString"]'
```

3. DisableWatchDog

Type: plist boolean

Failsafe: false

Description: Some types of firmware may not succeed in booting the operating system quickly, especially in debug mode. This results in the watchdog timer aborting the process. This option turns off the watchdog timer.

4. DisplayDelay

Type: plist integer

Failsafe: 0

Description: Delay in microseconds executed after every printed line visible onscreen (i.e. console).

5. DisplayLevel

Type: plist integer, 64 bit

Failsafe: 0

Description: EDK II debug level bitmask (sum) showed onscreen. Unless **Target** enables console (onscreen) printing, onscreen debug output will not be visible.

The following levels are supported (discover more in `DebugLib.h`):

- 0x00000002 (bit 1) — `DEBUG_WARN` in `DEBUG`, `NOOPT`, `RELEASE`.
- 0x00000040 (bit 6) — `DEBUG_INFO` in `DEBUG`, `NOOPT`.
- 0x00400000 (bit 22) — `DEBUG_VERBOSE` in custom builds.
- 0x80000000 (bit 31) — `DEBUG_ERROR` in `DEBUG`, `NOOPT`, `RELEASE`.

6. SerialInit

Type: plist boolean

Failsafe: false

Description: Perform serial port initialisation.

This option will perform serial port initialisation within OpenCore prior to enabling (any) debug logging. Serial port configuration is defined via PCDs at compile time in `gEfiMdeModulePkgTokenSpaceGuid` GUID.

Default values as found in `MdeModulePkg.dec` are as follows:

- `PcdSerialBaudRate` — Baud rate: 115200.
- `PcdSerialLineControl` — Line control: no parity, 8 data bits, 1 stop bit.

Refer to the [Debugging](#) section for ~~more~~ details.

7. SysReport

Type: plist boolean

Failsafe: false

Description: Produce system report on ESP folder.

This option will create a **SysReport** directory in the ESP partition unless already present. The directory will contain ACPI, SMBIOS, and audio codec dumps. Audio codec dumps require an audio backend driver to be loaded.

Note: To maintain system integrity, the **SysReport** option is **not** available in **RELEASE** builds. Use a **DEBUG** build if this option is required.

8. Target

Type: plist integer

Failsafe: 0

Description: A bitmask (sum) of enabled logging targets. Logging output is hidden by default and this option must be set when such output is required, such as when debugging.

The following logging targets are supported:

- OCAE — OcAppleEventLib
- OCAK — OcAppleKernelLib
- OCAU — OcAudioLib
- OCA — OcAcpiLib
- OCBP — OcAppleBootPolicyLib
- OCB — OcBootManagementLib
- OCCL — OcAppleChunkListLib
- OCCPU — OcCpuLib
- OCC — OcConsoleLib
- OCDL — OcDriverConnectionLib
- OCDH — OcDataHubLib
- OCDD — OcAppleDiskImageLib
- OCDM — OcDeviceMiscLib
- OCFS — OcFileLib
- OCFV — OcFirmwareVolumeLib
- OCHS — OcHashServicesLib
- OCIA — OcAppleImg4Lib
- OCIC — OcImageConversionLib
- OCII — OcInputLib
- OCJS — OcApfsLib
- OCKM — OcAppleKeyMapLib
- OCL — OcDebugLogLib
- OCM — OcMiscLib
- OCMCO — OcMachoLib
- OCME — OcHeciLib
- OCMM — OcMemoryLib
- OCPE — OcPeCoffLib, OcPeCoffExtLib
- OCPI — OcFileLib, partition info
- OCPNG — OcPngLib
- OCRAM — OcAppleRamDiskLib
- OCRTC — OcRtcLib
- OCSB — OcAppleSecureBootLib
- OCSMB — OcSmbiosLib
- OCSMC — OcSmcLib
- OCST — OcStorageLib
- OCS — OcSerializedLib
- OCTPL — OcTemplateLib
- OCUC — OcUnicodeCollationLib
- OCUT — OcAppleUserInterfaceThemeLib
- OCXML — OcXmlLib

8.5 Security Properties

1. AllowNvramReset

Type: plist boolean

Failsafe: false

Description: Allow CMD+OPT+P+R handling and enable showing NVRAM **Reset** entry in OpenCore picker.

Note 1: It is known that some Lenovo laptops have a firmware bug, which makes them unbootable after performing NVRAM reset. [See Refer to acidanthera/bugtracker#995](#) for ~~more~~ details.

Note 2: Resetting NVRAM will also erase any boot options not backed up using the bless command. For example, Linux installations to custom locations not specified in BlessOverride

2. AllowSetDefault

Type: plist boolean

Failsafe: false

Description: Allow CTRL+Enter and CTRL+Index handling to set the default boot option in the OpenCore picker.

Note 1: May be used in combination with `Shift+Enter` or `Shift+Index` when `PollAppleHotKeys` is enabled.

Note 2: In order to support systems with unresponsive modifiers during preboot (which includes V1 and V2 KeySupport mode on some firmware) OpenCore also allows holding the `=/+` key in order to trigger 'set default' mode.

3. ApECID

Type: plist integer, 64 bit

Failsafe: 0

Description: Apple Enclave Identifier.

Setting this value to any non-zero 64-bit integer will allow using personalised Apple Secure Boot identifiers. To use this setting, generate a random 64-bit number with a cryptographically secure random number generator. As an alternative, the first 8 bytes of `SystemUUID` can be used for `ApECID`, this is found in macOS 11 for Macs without the T2 chip.

With this value set and `SecureBootModel` valid (and not `Disabled`), it is possible to achieve **Full Security** of Apple Secure Boot.

To start using personalised Apple Secure Boot, the operating system must be reinstalled or personalised. Unless the operating system is personalised, macOS DMG recovery cannot be loaded. In cases where DMG recovery is missing, it can be downloaded by using the `macrecovery` utility and saved in `com.apple.recovery.boot` as explained in the Tips and Tricks section. Note that DMG loading needs to be set to `Signed` to use any DMG with Apple Secure Boot.

To personalise an existing operating system, use the `bless` command after loading to macOS DMG recovery. Mount the system volume partition, unless it has already been mounted, and execute the following command:

```
bless bless --folder "/Volumes/Macintosh HD/System/Library/CoreServices" \  
--bootefi --personalize
```

On macOS versions before macOS 11, which introduced a dedicated `x86legacy` model for models without the T2 chip, personalised Apple Secure Boot may not work as expected. When reinstalling the operating system, the macOS Installer from macOS 10.15 and older will often run out of free memory on the `/var/tmp` partition when trying to install macOS with the personalised Apple Secure Boot. Soon after downloading the macOS installer image, an `Unable to verify macOS` error message will appear.

To workaround this issue, allocate a dedicated RAM disk of 2 MBs for macOS personalisation by entering the following commands in the macOS recovery terminal before starting the installation:

```
disk=$(hdiutil attach -nomount ram://4096)  
diskutil erasevolume HFS+ SecureBoot $disk  
diskutil unmount $disk  
mkdir /var/tmp/OSPersonalizationTemp  
diskutil mount -mountpoint /var/tmp/OSPersonalizationTemp $disk
```

4. AuthRestart

Type: plist boolean

Failsafe: false

Description: Enable `VirtualSMC`-compatible authenticated restart.

Authenticated restart is a way to reboot FileVault 2 enabled macOS without entering the password. A dedicated terminal command can be used to perform authenticated restarts: `sudo fdsetup authrestart`. It is also used when installing operating system updates.

`VirtualSMC` performs authenticated restarts by splitting and saving disk encryption keys between NVRAM and RTC, which despite being removed as soon as OpenCore starts, may be considered a security risk and thus is optional.

5. BlacklistAppleUpdate

Type: plist boolean

Failsafe: false

Description: Ignore boot options trying to update Apple peripheral firmware (e.g. `MultiUpdater.efi`).

Failsafe: Default

Description: Apple Secure Boot hardware model.

Sets Apple Secure Boot hardware model and policy. Specifying this value defines which operating systems will be bootable. Operating systems shipped before the specified model was released will not boot.

Valid values:

- **Default** — Recent available model, currently set to j137.
- **Disabled** — No model, Secure Boot will be disabled.
- **j137** — iMacPro1,1 (December 2017). Minimum macOS 10.13.2 (17C2111)
- **j680** — MacBookPro15,1 (July 2018). Minimum macOS 10.13.6 (17G2112)
- **j132** — MacBookPro15,2 (July 2018). Minimum macOS 10.13.6 (17G2112)
- **j174** — Macmini8,1 (October 2018). Minimum macOS 10.14 (18A2063)
- **j140k** — MacBookAir8,1 (October 2018). Minimum macOS 10.14.1 (18B2084)
- **j780** — MacBookPro15,3 (May 2019). Minimum macOS 10.14.5 (18F132)
- **j213** — MacBookPro15,4 (July 2019). Minimum macOS 10.14.5 (18F2058)
- **j140a** — MacBookAir8,2 (July 2019). Minimum macOS 10.14.5 (18F2058)
- **j152f** — MacBookPro16,1 (November 2019). Minimum macOS 10.15.1 (19B2093)
- **j160** — MacPro7,1 (December 2019). Minimum macOS 10.15.1 (19B88)
- **j230k** — MacBookAir9,1 (March 2020). Minimum macOS 10.15.3 (19D2064)
- **j214k** — MacBookPro16,2 (May 2020). Minimum macOS 10.15.4 (19E2269)
- **j223** — MacBookPro16,3 (May 2020). Minimum macOS 10.15.4 (19E2265)
- **j215** — MacBookPro16,4 (June 2020). Minimum macOS 10.15.5 (19F96)
- **j185** — iMac20,1 (August 2020). Minimum macOS 10.15.6 (19G2005)
- **j185f** — iMac20,2 (August 2020). Minimum macOS 10.15.6 (19G2005)
- **x86legacy** — Macs without T2 chip and VMs. Minimum macOS 11.0.1 (20B29)

Apple Secure Boot appeared in macOS 10.13 on models with T2 chips. Since **PlatformInfo** and **SecureBootModel** are independent, Apple Secure Boot can be used with any SMBIOS with and without T2. Setting **SecureBootModel** to any valid value but **Disabled** is equivalent to **Medium Security** of Apple Secure Boot. The **ApECID** value must also be specified to achieve **Full Security**. Check **ForceSecureBootScheme** when using Apple Secure Boot on a virtual machine.

Note that enabling Apple Secure Boot is demanding on invalid configurations, faulty macOS installations, and on unsupported setups.

Things to consider:

- As with T2 Macs, ~~unsigned kernel drivers and all unsigned kernel extensions as well as~~ driver extensions, including NVIDIA Web Drivers, cannot be installed.
- The list of cached ~~drivers kernel extensions~~ driver extensions may be different, resulting in a need to change the list of **Added** or **Forced** kernel ~~drivers~~ driver extensions. For example, **I080211Family** cannot be injected in this case.
- System volume alterations on operating systems with sealing, such as macOS 11, may result in the operating system being unbootable. Do not try to disable system volume encryption unless Apple Secure Boot is disabled.
- Boot failures might occur when the platform requires certain settings, but they have not been enabled because the associated issues were not discovered earlier. Be extra careful with **IgnoreInvalidFlexRatio** or **HashServices**.
- Operating systems released before Apple Secure Boot was released (e.g. macOS 10.12 or earlier), will still boot until UEFI Secure Boot is enabled. This is so because Apple Secure Boot treats these as incompatible and they are then handled by the firmware (as Microsoft Windows is).
- On older CPUs (e.g. before Sandy Bridge), enabling Apple Secure Boot might cause slightly slower loading (by up to 1 second).
- As the **Default** value will increase with time to support the latest major released operating system, it is not recommended to use the **ApECID** and the **Default** settings together.
- Installing macOS with Apple Secure Boot enabled is not possible while using HFS+ target volumes. This may include HFS+ formatted drives when no spare APFS drive is available.

The installed operating system may have sometimes outdated Apple Secure Boot manifests on the **Preboot** partition, resulting in boot failures. This is likely to be the case when an “OCB: Apple Secure Boot prohibits this

9 NVRAM

9.1 Introduction

~~Has plist dict type and allows to set volatile~~ This section allows setting non-volatile UEFI variables commonly referred ~~described~~ as NVRAM variables. Refer to `man nvram` for ~~more details. macOS details.~~ The macOS operating system extensively uses NVRAM variables for OS — Bootloader — Firmware intercommunication, ~~and thus supplying several NVRAM.~~ Hence, the supply of several NVRAM variables is required for ~~proper macOS functioning~~ the proper functioning of macOS.

Each NVRAM variable consists of its name, value, attributes (refer to UEFI specification), and its GUID, representing which ‘section’ the NVRAM variable belongs to. ~~macOS uses~~ The macOS operating system makes use of several GUIDs, including but not limited to:

- 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14 (APPLE_VENDOR_VARIABLE_GUID)
- 7C436110-AB2A-4BBB-A880-FE41995C9F82 (APPLE_BOOT_VARIABLE_GUID)
- 8BE4DF61-93CA-11D2-AA0D-00E098032B8C (EFI_GLOBAL_VARIABLE_GUID)
- 4D1FDA02-38C7-4A6A-9CC6-4BCCA8B30102 (OC_VENDOR_VARIABLE_GUID)

Note: Some of the variables may be added by the PlatformNVRAM or Generic subsections of the PlatformInfo section. Please ensure that variables ~~of this section never collide with them, as set in this section do not conflict with items in those subsections as the implementation~~ behaviour is undefined otherwise.

~~For proper macOS functioning it is often required to use~~ The OC_FIRMWARE_RUNTIME protocol implementation, currently offered as a part of the OpenRuntime driver. ~~While it brings any, is often required for macOS to function properly. While this brings many~~ benefits, there are ~~certain limitations which arise depending on the use~~ some limitations that should be considered for certain use cases.

1. Not all tools may be aware of protected namespaces.
When RequestBootVarRouting is used, Boot-prefixed variable access is restricted and protected in a separate namespace. To access the original variables ~~tools have to,~~ tools must be aware of the OC_FIRMWARE_RUNTIME logic.

9.2 Properties

1. Add
Type: plist dict
Description: Sets NVRAM variables from a map (plist dict) of GUIDs to a map (plist dict) of variable names and their values in plist multidata format. GUIDs must be provided in canonic string format in upper or lower case (e.g. 8BE4DF61-93CA-11D2-AA0D-00E098032B8C).

~~Created variables get~~ The EFI_VARIABLE_BOOTSERVICE_ACCESS and EFI_VARIABLE_RUNTIME_ACCESS attributes of created variables are set. Variables will only be set if not present or deleted. ~~I.e. That is,~~ to overwrite an existing variable value, add the variable name to the Delete section. This approach enables ~~to provide default values till the provision of default values until~~ the operating system takes the lead.

Note: ~~If The implementation behaviour is undefined when the~~ plist key does not conform to ~~GUID format, behaviour is undefined~~ the GUID format.

2. Delete
Type: plist dict
Description: Removes NVRAM variables from a map (plist dict) of GUIDs to an array (plist array) of variable names in plist string format.
3. LegacyEnable
Type: plist boolean
Failsafe: false
Description: Enables loading ~~of a~~ NVRAM variable file named nvram.plist from EFI volume root.

This file must have a root plist dictionary type and contain two fields:

- Version — plist integer, file version, must be set to 1.
- Add — plist dictionary, equivalent to Add from config.plist.

Variable loading happens prior to [the](#) Delete (and Add) phases. Unless LegacyOverwrite is enabled, it will not overwrite any existing variable. Variables allowed to be set must be specified in LegacySchema.

Third-party scripts may be used to create nvram.plist file. An example of such script can be found in Utilities. The use of third-party scripts may require ExposeSensitiveData set to 0x3 to provide boot-path variable with [the](#) OpenCore EFI partition UUID.

Warning: This feature ~~is very dangerous~~[can be dangerous](#), as it passes unprotected data to firmware variable services. ~~Use it only~~ [Only use](#) when no hardware NVRAM implementation is provided by the firmware or ~~it when~~ [the NVRAM implementation](#) is incompatible.

4. LegacyOverwrite

Type: plist boolean

Failsafe: false

Description: Permits overwriting firmware variables from nvram.plist.

Note: Only variables accessible from the operating system will be overwritten.

5. LegacySchema

Type: plist dict

Description: Allows setting certain NVRAM variables from a map (plist dict) of GUIDs to an array (plist array) of variable names in plist string format.

* value can be used to accept all variables for certain GUID.

WARNING: Choose variables ~~very~~ carefully, as [the](#) nvram.plist [file](#) is not vaulted. For instance, do not ~~put~~ [include](#) boot-args or csr-active-config, as ~~this can~~ [these can be used to](#) bypass SIP.

6. WriteFlash

Type: plist boolean

Failsafe: false

Description: Enables writing to flash memory for all added variables.

Note: ~~It is recommended to have this value~~ [This value should be](#) enabled on most types of firmware but ~~it~~ is left configurable [to account](#) for firmware that may have issues with NVRAM variable storage garbage collection or similar.

~~To~~ [The nvram command can be used to](#) read NVRAM variable ~~value from macOS~~, ~~nvram could be used by concatenating values from macOS by concatenating the~~ GUID and name variables separated by a : symbol. For example, nvram 7C436110-AB2A-4BBB-A880-FE41995C9F82:boot-args.

A continuously updated variable list can be found in a corresponding document: NVRAM Variables.

9.3 Mandatory Variables

Warning: These variables may be added by [the](#) PlatformNVRAM or Generic subsections of [the](#) PlatformInfo section. Using PlatformInfo is the recommended way of setting these variables.

The following variables are mandatory for macOS functioning:

- 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:FirmwareFeatures
32-bit FirmwareFeatures. Present on all Macs to avoid extra parsing of SMBIOS tables.
- 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:FirmwareFeaturesMask
32-bit FirmwareFeaturesMask. Present on all Macs to avoid extra parsing of SMBIOS tables.
- 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:MLB
BoardSerialNumber. Present on newer Macs (2013+ at least) to avoid extra parsing of SMBIOS tables, especially in boot.efi.
- 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:ROM
Primary network adapter MAC address or replacement value. Present on newer Macs (2013+ at least) to avoid accessing special memory region, especially in boot.efi.

9.4 Recommended Variables

The following variables are recommended for faster startup or other improvements:

- `log-level=VALUE` — log level bitmask.
 - * `0x01` — enables trace logging (default).
- `serial=VALUE` — enables serial logging.
 - * `0` — disables serial logging (default).
 - * `1` — enables serial logging for `EXITBS:END` onwards.
 - * `2` — enables serial logging for `EXITBS:START` onwards.
 - * `3` — enables serial logging when debug protocol is missing.
 - * `4` — enables serial logging unconditionally.
- `timestamps=VALUE` — enables timestamp logging.
 - * `0` — disables timestamp logging.
 - * `1` — enables timestamp logging (default).
- `log=VALUE` — deprecated starting from 10.15.
 - * `1` — `AppleLoggingConOutOrErrSet/AppleLoggingConOutOrErrPrint` (classical `ConOut/StdErr`)
 - * `2` — `AppleLoggingStdErrSet/AppleLoggingStdErrPrint` (`StdErr` or serial?)
 - * `4` — `AppleLoggingFileSet/AppleLoggingFilePrint` (`BOOTER.LOG/BOOTER.OLD` file on EFI partition)
- `debug=VALUE` — deprecated starting from 10.15.
 - * `1` — enables print something to `BOOTER.LOG` (stripped code implies there may be a crash)
 - * `2` — enables perf logging to `/efi/debug-log` in the device three
 - * `4` — enables timestamp printing for styled printf calls
- `level=VALUE` — deprecated starting from 10.15. Verbosity level of `DEBUG` output. Everything but `0x80000000` is stripped from the binary, and this is the default value.

Note: ~~To see~~ [Enable the AppleDebug option to display](#) verbose output from `boot.efi` on modern macOS versions ~~enable AppleDebug option~~. This will save the log to [the](#) general OpenCore log [file](#). For versions before 10.15.4, set `bootercfg` to `log=1`. This will print verbose output onscreen.

- `7C436110-AB2A-4BBB-A880-FE41995C9F82:bootercfg-once`
Booter arguments override removed after first launch. Otherwise equivalent to `bootercfg`.
- `7C436110-AB2A-4BBB-A880-FE41995C9F82:efiboot-perf-record`
Enable performance log saving in `boot.efi`. Performance log is saved to physical memory and is pointed ~~by to by the~~ `efiboot-perf-record-data` and `efiboot-perf-record-size` variables. Starting from 10.15.4, it can also be saved to [the](#) OpenCore log by [setting the](#) `AppleDebug` option.
- `7C436110-AB2A-4BBB-A880-FE41995C9F82:fmm-computer-name`
Current saved host name. ASCII string.
- `7C436110-AB2A-4BBB-A880-FE41995C9F82:nvda_drv`
NVIDIA Web Driver control variable. Takes ASCII digit 1 or 0 to enable or disable installed driver.
- `7C436110-AB2A-4BBB-A880-FE41995C9F82:run-efi-updater`
Override EFI firmware updating support in macOS (MultiUpdater, ThorUtil, and so on). Setting this to `No` or alternative boolean-castable value will prevent any firmware updates in macOS starting with 10.10 at least.
- `7C436110-AB2A-4BBB-A880-FE41995C9F82:StartupMute`
Mute startup chime sound in firmware audio support. 8-bit integer. The value of `0x00` means unmuted. Missing variable or any other value means muted.
- `7C436110-AB2A-4BBB-A880-FE41995C9F82:SystemAudioVolume`
System audio volume level for firmware audio support. 8-bit integer. The bit of `0x80` means muted. Lower bits are used to encode volume range specific to installed audio codec. The value is capped by `MaximumBootBeepVolume` AppleHDA layout value to avoid too loud audio playback in the firmware.

10 PlatformInfo

Platform information ~~is comprised~~ consists of several identification fields generated or filled manually to be compatible with macOS services. The base part of the configuration may be obtained from `AppleModels`, which itself generates a set of interfaces based on a database in YAML format. These fields are written to three destinations:

- SMBIOS
- Data Hub
- NVRAM

Most of the fields specify the overrides in SMBIOS, and their field names conform to EDK2 `SmBios.h` header file. However, several important fields reside in Data Hub and NVRAM. Some of the values can be found in more than one field and/or destination, so there are two ways to control their update process: manual, where all the values are specified (the default), and semi-automatic, where (`Automatic`) only certain values are specified, and later used for system configuration.

~~To inspect SMBIOS contents~~ The `dmidecode` utility can be used ~~Version~~ to inspect SMBIOS contents and a version with macOS specific enhancements can be downloaded from `Acidanthera/dmidecode`.

10.1 Properties

1. `Automatic`

Type: plist boolean

Failsafe: false

Description: Generate PlatformInfo based on the `Generic` section instead of using values from the `DataHub`, `NVRAM`, and `SMBIOS` sections.

Enabling this option is useful when `Generic` section is flexible enough:

- When enabled `SMBIOS`, `DataHub`, and `PlatformNVRAM` data is unused.
- When disabled `Generic` section is unused.

Warning: ~~It is strongly discouraged to set~~ Setting this option to `false` is strongly discouraged when intending to update platform information. ~~The only reason to do so is if making~~ A false setting is typically only valid for minor corrections to `SMBIOS` values on legacy Apple hardware. In all other cases, setting `Automatic` to `false` may lead to ~~hard-to-debug errors~~ due to hard-to-debug errors resulting from inconsistent or invalid settings.

2. `CustomMemory`

Type: plist boolean

Failsafe: false

Description: Use custom memory configuration defined in the `Memory` section. This completely replaces any existing memory configuration in `SMBIOS`, and is only active when `UpdateSMBIOS` is set to `true`.

3. `UpdateDataHub`

Type: plist boolean

Failsafe: false

Description: Update Data Hub fields. These fields are read from the `Generic` or `DataHub` sections depending on the setting of the `Automatic` ~~value~~ property.

Note: The implementation of the Data Hub protocol in EFI firmware on ~~essentially-virtually~~ all systems, including Apple hardware, means that existing Data Hub entries cannot be overridden, ~~while new~~ New entries are added to the end of the Data Hub instead, with macOS ignoring ~~them~~ old entries. This can be worked around by ~~reinstalling-replacing~~ the Data Hub protocol using the `ProtocolOverrides` section. Refer to the `DataHub` protocol override description for details.

4. `UpdateNVRAM`

Type: plist boolean

Failsafe: false

Description: Update NVRAM fields related to platform information.

These fields are read from the `Generic` or `PlatformNVRAM` sections depending on the setting of the `Automatic` ~~value~~ property. All the other fields are to be specified with the `NVRAM` section.

If `UpdateNVRAM` is set to `false`, the aforementioned variables can be updated with [the NVRAM](#) section. If `UpdateNVRAM` is set to `true`, the behaviour is undefined when any of the fields are present in [the NVRAM](#) section.

5. `UpdateSMBIOS`

Type: plist boolean

Failsafe: false

Description: Update SMBIOS fields. These fields are read from [the Generic](#) or [SMBIOS](#) sections depending on [the setting of the Automatic value property](#).

6. `UpdateSMBIOSMode`

Type: plist string

Failsafe: Create

Description: Update SMBIOS fields approach:

- **TryOverwrite** — **Overwrite** if new size is \leq than the page-aligned original and there are no issues with legacy region unlock. **Create** otherwise. Has issues on some types of firmware.
- **Create** — Replace the tables with newly allocated `EfiReservedMemoryType` at `AllocateMaxAddress` without any fallbacks.
- **Overwrite** — Overwrite existing `gEfiSmbiosTableGuid` and `gEfiSmbiosTable3Guid` data if it fits new size. Abort with unspecified state otherwise.
- **Custom** — Write SMBIOS tables (`gEfiSmbios(3)TableGuid`) to `gOcCustomSmbios(3)TableGuid` to workaround firmware overwriting SMBIOS contents at `ExitBootServices`. Otherwise equivalent to **Create**. Requires patching `AppleSmbios.kext` and `AppleACPIPlatform.kext` to read from another GUID: "EB9D2D31" - "EB9D2D35" (in ASCII), done automatically by `CustomSMBIOSGuid` quirk.

Note: A side effect of using [the Custom](#) approach ~~is making that it makes~~ SMBIOS updates exclusive to macOS, avoiding a collision with existing Windows activation and custom OEM software but potentially obstructing the operation of Apple-specific tools.

7. `UseRawUuidEncoding`

Type: plist boolean

Failsafe: false

Description: Use raw encoding for SMBIOS UUIDs.

Each UUID AABBCDD-EEFF-GGHH-IIJJ-KKLLMMNNOO PP is essentially a hexadecimal 16-byte number. It can be encoded in two ways:

- **Big Endian** — by writing all the bytes as they are without making any order changes ({AA BB CC DD EE FF GG HH II JJ KK LL MM NN OO PP}). This method is also known as RFC 4122 encoding or **Raw** encoding.
- **Little Endian** — by interpreting the bytes as numbers and using Little Endian byte representation ({DD CC BB AA FF EE HH GG II JJ KK LL MM NN OO PP}).

[The](#) SMBIOS specification did not explicitly specify the encoding format for the UUID up to SMBIOS 2.6, where it stated that **Little Endian** encoding shall be used. This led to the confusion in both firmware implementations and system software as different vendors used different encodings prior to that.

- Apple uses [the Big Endian](#) format everywhere but it ignores SMBIOS UUID within macOS.
- `dmidecode` uses [the Big Endian](#) format for SMBIOS 2.5.x or lower and [the Little Endian format](#) for 2.6 and newer. Acidanthera `dmidecode` prints all ~~the~~ three.
- Windows uses [the Little Endian](#) format everywhere, but ~~it this~~ only affects the visual representation of the values.

OpenCore always sets a recent SMBIOS version (currently 3.2) when generating the modified DMI tables. If `UseRawUuidEncoding` is enabled, ~~then the~~ **Big Endian** format is used to store the `SystemUUID` data. Otherwise, [the Little Endian format](#) is used.

Note: ~~Since This preference does not affect~~ UUIDs used in DataHub and NVRAM [as they](#) are not standardised and are added by Apple, ~~this preference does not affect them~~. Unlike SMBIOS, [they](#) are always stored in the **Big Endian** format.

8. `Generic`

Type: plist dictionary

Description: Update all fields in `Automatic` mode.

Note: This section is ignored but may not be removed when `Automatic` is `false`.

9. DataHub

Type: plist dictionary

Description: Update Data Hub fields in non-Automatic mode.

Note: This section is ignored and may be removed when `Automatic` is `true`.

10. Memory

Type: plist dictionary

Description: Define custom memory configuration.

Note: This section is ignored and may be removed when `CustomMemory` is `false`.

11. PlatformNVRAM

Type: plist dictionary

Description: Update platform NVRAM fields in non-Automatic mode.

Note: This section is ignored and may be removed when `Automatic` is `true`.

12. SMBIOS

Type: plist dictionary

Description: Update SMBIOS fields in non-Automatic mode.

Note: This section is ignored and may be removed when `Automatic` is `true`.

10.2 Generic Properties

1. SpoofVendor

Type: plist boolean

Failsafe: false

Description: Sets SMBIOS vendor fields to `Acidanthera`.

It ~~is can be~~ dangerous to use ~~Apple~~ “Apple” in SMBIOS vendor fields for reasons ~~given~~ outlined in the `SystemManufacturer` description. However, certain firmware may not provide valid values otherwise, which could obstruct the operation of some software.

2. AdviseWindows

Type: plist boolean

Failsafe: false

Description: Forces Windows support in `FirmwareFeatures`.

Added bits to `FirmwareFeatures`:

- `FW_FEATURE_SUPPORTS_CSM_LEGACY_MODE` (0x1) - Without this bit, it is not possible to reboot to Windows installed on a drive with ~~EFI partition being an EFI partition that is~~ not the first partition on the disk.
- `FW_FEATURE_SUPPORTS_UEFI_WINDOWS_BOOT` (0x20000000) - Without this bit, it is not possible to reboot to Windows installed on a drive with ~~EFI partition being an EFI partition that is~~ the first partition on the disk.

3. MaxBIOSVersion

Type: plist boolean

Failsafe: false

Description: Sets `BIOSVersion` to `9999.999.999.999.999`, recommended for legacy Macs when using `Automatic PlatformInfo` to avoid BIOS updates in unofficially supported macOS versions.

4. SystemMemoryStatus

Type: plist string

Failsafe: Auto

Description: Indicates whether system memory is upgradable in `PlatformFeature`. This controls the visibility of the Memory tab in “About This Mac”.

Valid values:

- `Auto` — use the original `PlatformFeature` value.

Type: plist integer, 64-bit

Failsafe: 0 (Automatic)

Description: Sets ARTFrequency in gEfiProcessorSubClassGuid.

This value contains CPU ART frequency, also known as crystal clock frequency. Its existence is exclusive to the Skylake generation and newer. The value is specified in Hz, and is normally 24 MHz for [the](#) client Intel segment, 25 MHz for [the](#) server Intel segment, and 19.2 MHz for Intel Atom CPUs. macOS till 10.15 inclusive assumes 24 MHz by default.

Note: On Intel Skylake X ART frequency may be a little less (approx. 0.25%) than 24 or 25 MHz due to special EMI-reduction circuit as described in Acidanthera Bugtracker.

11. DevicePathsSupported

Type: plist integer, 32-bit

Failsafe: 0 (Not installed)

Description: Sets DevicePathsSupported in gEfiMiscSubClassGuid. Must be set to 1 for AppleACPIPlatform.kext to append SATA device paths to Boot#### and efi-boot-device-data variables. Set to 1 on all modern Macs.

12. SmcRevision

Type: plist data, 6 bytes

Failsafe: Empty (Not installed)

Description: Sets REV in gEfiMiscSubClassGuid. Custom property read by VirtualSMC or FakeSMC to generate SMC REV key.

13. SmcBranch

Type: plist data, 8 bytes

Failsafe: Empty (Not installed)

Description: Sets RBr in gEfiMiscSubClassGuid. Custom property read by VirtualSMC or FakeSMC to generate SMC RBr key.

14. SmcPlatform

Type: plist data, 8 bytes

Failsafe: Empty (Not installed)

Description: Sets RPlt in gEfiMiscSubClassGuid. Custom property read by VirtualSMC or FakeSMC to generate SMC RPlt key.

10.4 Memory Properties

1. DataWidth

Type: plist integer, 16-bit

Failsafe: 0xFFFF (unknown)

SMBIOS: Memory Device (Type 17) — Data Width

Description: Specifies the data width, in bits, of the memory. A DataWidth of 0 and a TotalWidth of 8 indicates that the device is being used solely to provide 8 error-correction bits.

2. Devices

Type: plist array

Failsafe: Empty

Description: Specifies the custom memory devices to be added.

Designed to [To](#) be filled with **plist** dictionary values, describing each memory device. **See** [Refer to](#) the Memory Devices Properties section below. This should include all memory slots, even if unpopulated.

3. ErrorCorrection

Type: plist integer, 8-bit

Failsafe: 0x03

SMBIOS: Physical Memory Array (Type 16) — Memory Error Correction

Description: Specifies the primary hardware error correction or detection method supported by the memory.

- 0x01 — Other
- 0x02 — Unknown
- 0x03 — None

- 0x04 — Parity
- 0x05 — Single-bit ECC
- 0x06 — Multi-bit ECC
- 0x07 — CRC

4. FormFactor

Type: plist integer, 8-bit

Failsafe: 0x02

SMBIOS: Memory Device (Type 17) — Form Factor

Description: Specifies the form factor of the memory. On Macs, this should typically be DIMM or SODIMM. Commonly used form factors are listed below.

When `CustomMemory` is `false`, this value is automatically set based on Mac product name.

When `Automatic` is `true`, the original value from the the corresponding Mac model will be set if available. Otherwise, the value from `OcMacInfoLib` will be set. When `Automatic` is `false`, a user-specified value will be set if available. Otherwise, the original value from the firmware will be set. If no value is provided, the failsafe value will be set.

- 0x01 — Other
- 0x02 — Unknown
- 0x09 — DIMM
- 0x0D — SODIMM
- 0x0F — FB-DIMM

5. MaxCapacity

Type: plist integer, 64-bit

Failsafe: 0

SMBIOS: Physical Memory Array (Type 16) — Maximum Capacity

Description: Specifies the maximum amount of memory, in bytes, supported by the system.

6. TotalWidth

Type: plist integer, 16-bit

Failsafe: 0xFFFF (unknown)

SMBIOS: Memory Device (Type 17) — Total Width

Description: Specifies the total width, in bits, of the memory, including any check or error-correction bits. If there are no error-correction bits, this value should be equal to `DataWidth`.

7. Type

Type: plist integer, 8-bit

Failsafe: 0x02

SMBIOS: Memory Device (Type 17) — Memory Type

Description: Specifies the memory type. Commonly used types are listed below.

- 0x01 — Other
- 0x02 — Unknown
- 0x0F — SDRAM
- 0x12 — DDR
- 0x13 — DDR2
- 0x14 — DDR2 FB-DIMM
- 0x18 — DDR3
- 0x1A — DDR4
- 0x1B — LPDDR
- 0x1C — LPDDR2
- 0x1D — LPDDR3
- 0x1E — LPDDR4

8. TypeDetail

Type: plist integer, 16-bit

Failsafe: 0x4

SMBIOS: Memory Device (Type 17) — Type Detail

Description: Specifies additional memory type information.

Description: Mac Board ID (board-id). May look like Mac-7BA5B2D9E42DDD94 or Mac-F221BEC8 in older models. Sometimes it can be just empty.

10. SystemFamily
Type: plist string
Failsafe: Empty (OEM specified)
SMBIOS: System Information (Type 1) — Family
Description: Family name. May look like iMac Pro.
11. BoardManufacturer
Type: plist string
Failsafe: Empty (OEM specified)
SMBIOS: Baseboard (or Module) Information (Type 2) - Manufacturer
Description: Board manufacturer. All rules of SystemManufacturer do apply.
12. BoardProduct
Type: plist string
Failsafe: Empty (OEM specified)
SMBIOS: Baseboard (or Module) Information (Type 2) - Product
Description: Mac Board ID (board-id). May look like Mac-7BA5B2D9E42DDD94 or Mac-F221BEC8 in older models.
13. BoardVersion
Type: plist string
Failsafe: Empty (OEM specified)
SMBIOS: Baseboard (or Module) Information (Type 2) - Version
Description: Board version number. Varies, may match SystemProductName or SystemProductVersion.
14. BoardSerialNumber
Type: plist string
Failsafe: Empty (OEM specified)
SMBIOS: Baseboard (or Module) Information (Type 2) — Serial Number
Description: Board serial number in defined format. Known formats are described in macserial.
15. BoardAssetTag
Type: plist string
Failsafe: Empty (OEM specified)
SMBIOS: Baseboard (or Module) Information (Type 2) — Asset Tag
Description: Asset tag number. Varies, may be empty or Type2 - Board Asset Tag.
16. BoardType
Type: plist integer
Failsafe: 0 (OEM specified)
SMBIOS: Baseboard (or Module) Information (Type 2) — Board Type
Description: Either 0xA (Motherboard (includes processor, memory, and I/O) or 0xB (Processor/Memory Module); ~~refer~~. [Refer](#) to Table 15 – Baseboard: Board Type for ~~more~~ details.
17. BoardLocationInChassis
Type: plist string
Failsafe: Empty (OEM specified)
SMBIOS: Baseboard (or Module) Information (Type 2) — Location in Chassis
Description: Varies, may be empty or Part Component.
18. ChassisManufacturer
Type: plist string
Failsafe: Empty (OEM specified)
SMBIOS: System Enclosure or Chassis (Type 3) — Manufacturer
Description: Board manufacturer. All rules of SystemManufacturer do apply.
19. ChassisType
Type: plist integer
Failsafe: 0 (OEM specified)

SMBIOS: System Enclosure or Chassis (Type 3) — Type

Description: Chassis type, ~~refer~~, [Refer](#) to Table 17 — System Enclosure or Chassis Types for ~~more~~ details.

20. ChassisVersion

Type: plist string

Failsafe: Empty (OEM specified)

SMBIOS: System Enclosure or Chassis (Type 3) — Version

Description: Should match BoardProduct.

21. ChassisSerialNumber

Type: plist string

Failsafe: Empty (OEM specified)

SMBIOS: System Enclosure or Chassis (Type 3) — Version

Description: Should match SystemSerialNumber.

22. ChassisAssetTag

Type: plist string

Failsafe: Empty (OEM specified)

SMBIOS: System Enclosure or Chassis (Type 3) — Asset Tag Number

Description: Chassis type name. Varies, could be empty or MacBook-Aluminum.

23. PlatformFeature

Type: plist integer, 32-bit

Failsafe: 0xFFFFFFFF (OEM specified on Apple hardware, do not provide the table otherwise)

SMBIOS: APPLE_SMBIOS_TABLE_TYPE133 - PlatformFeature

Description: Platform features bitmask ([Missing on older Macs](#)). Refer to AppleFeatures.h for ~~more details~~.
~~Missing on older Macs~~, [details](#).

24. SmcVersion

Type: plist data, 16 bytes

Failsafe: All zero (OEM specified on Apple hardware, do not provide the table otherwise)

SMBIOS: APPLE_SMBIOS_TABLE_TYPE134 - Version

Description: ASCII string containing SMC version in upper case. Missing on T2 based Macs.

25. FirmwareFeatures

Type: plist data, 8 bytes

Failsafe: 0 (OEM specified on Apple hardware, 0 otherwise)

SMBIOS: APPLE_SMBIOS_TABLE_TYPE128 - FirmwareFeatures and ExtendedFirmwareFeatures

Description: 64-bit firmware features bitmask. Refer to AppleFeatures.h for ~~more~~ details. Lower 32 bits match FirmwareFeatures. Upper 64 bits match ExtendedFirmwareFeatures.

26. FirmwareFeaturesMask

Type: plist data, 8 bytes

Failsafe: 0 (OEM specified on Apple hardware, 0 otherwise)

SMBIOS: APPLE_SMBIOS_TABLE_TYPE128 - FirmwareFeaturesMask and ExtendedFirmwareFeaturesMask

Description: Supported bits of extended firmware features bitmask. Refer to AppleFeatures.h for ~~more~~ details. Lower 32 bits match FirmwareFeaturesMask. Upper 64 bits match ExtendedFirmwareFeaturesMask.

27. ProcessorType

Type: plist integer, 16-bit

Failsafe: 0 (Automatic)

SMBIOS: APPLE_SMBIOS_TABLE_TYPE131 - ProcessorType

Description: Combined of Processor Major and Minor types.

Automatic value generation ~~tries to provide~~ [attempts to provide the](#) most accurate value for the currently installed CPU. When this fails ~~please make sure to create~~, [please raise](#) an issue and provide sysctl machdep.cpu and dmidecode output. For a full list of available values and their limitations (the value will only apply if the CPU core count matches) ~~refer to~~, [refer to the](#) Apple SMBIOS definitions header here.

11 UEFI

11.1 Introduction

UEFI (Unified Extensible Firmware Interface) is a specification that defines a software interface between an operating system and platform firmware. This section allows ~~to load~~ loading additional UEFI modules ~~and/or apply tweaks for~~ as well as applying tweaks to the onboard firmware. To inspect firmware contents, apply modifications and perform upgrades UEFITool and supplementary utilities can be used.

11.2 Drivers

Depending on the firmware, a different set of drivers may be required. Loading an incompatible driver may lead the system to unbootable state or even cause permanent firmware damage. Some of the known drivers are listed below:

AudioDxe*	HDA audio support driver in UEFI firmware for most Intel and some other analog audio controllers. Staging driver, refer to acidanthera/bugtracker#740 for known issues in AudioDxe.
CrScreenshotDxe*	Screenshot making driver saving images to the root of OpenCore partition (ESP) or any available writeable filesystem upon pressing F10. This is a modified version of CrScreenshotDxe driver by Nikolaj Schlej.
ExFatDxe	Proprietary ExFAT file system driver for Bootcamp support commonly found in Apple firmware. For Sandy Bridge and earlier CPUs, the ExFatDxeLegacy driver should be used due to the lack of RDRAND instruction support.
HfsPlus	Recommended. Proprietary HFS file system driver with bless support commonly found in Apple firmware. For Sandy Bridge and earlier CPUs, the HfsPlusLegacy driver should be used due to the lack of RDRAND instruction support.
HiiDatabase*	HII services support driver from MdeModulePkg. This driver is included in most types of firmware starting with the Ivy Bridge generation. Some applications with GUI, such as UEFI Shell, may need this driver to work properly.
EnhancedFatDxe	FAT filesystem driver from FatPkg. This driver is embedded in all UEFI firmware and cannot be used from OpenCore. Several types of firmware have defective FAT support implementation that may lead to corrupted filesystems on write attempts. Embedding this driver within the firmware may be required in case writing to the EFI partition is needed during the boot process.
NvmExpressDxe*	NVMe support driver from MdeModulePkg. This driver is included in most firmware starting with the Broadwell generation. For Haswell and earlier, embedding it within the firmware may be more favourable in case a NVMe SSD drive is installed.
OpenCanopy*	OpenCore plugin implementing graphical interface.
OpenRuntime*	OpenCore plugin implementing OC_FIRMWARE_RUNTIME protocol.
OpenUsbKbdDxe*	USB keyboard driver adding support for AppleKeyMapAggregator protocols on top of a custom USB keyboard driver implementation. This is an alternative to builtin KeySupport, which may work better or worse depending on the firmware.
OpenPartitionDxe*	Partition management driver with Apple Partitioning Scheme support. This driver can be used to support loading older DMG recoveries such as macOS 10.9 using Apple Partitioning Scheme. OpenDuet already includes this driver.
Ps2KeyboardDxe*	PS/2 keyboard driver from MdeModulePkg. OpenDuetPkg and some types of firmware may not include this driver, but it is necessary for PS/2 keyboard to work. Note, unlike OpenUsbKbdDxe this driver has no AppleKeyMapAggregator support and thus requires KeySupport to be enabled.
Ps2MouseDxe*	PS/2 mouse driver from MdeModulePkg. Some very old laptop firmware may not include this driver but it is necessary for the touchpad to work in UEFI graphical interfaces such as OpenCanopy.
OpenHfsPlus*	HFS file system driver with bless support. This driver is an alternative to a closed source HfsPlus driver commonly found in Apple firmware. While it is feature complete, it is approximately 3 times slower and is yet to undergo a security audit.
UsbMouseDxe*	USB mouse driver from MdeModulePkg. Some virtual machine firmware such as OVMF may not include this driver but it is necessary for the mouse to work in UEFI graphical interfaces such as OpenCanopy.
XhciDxe*	XHCI USB controller support driver from MdeModulePkg. This driver is included in most types of firmware starting with the Sandy Bridge generation. For earlier firmware or legacy systems, it may be used to support external USB 3.0 PCI cards.

Driver marked with * are bundled with OpenCore. To compile the drivers from UDK (EDK II) the same command used for OpenCore compilation can be taken, but choose a corresponding package:

```
git clone https://github.com/acidanthera/audk UDK
cd UDK
source edksetup.sh
make -C BaseTools
build -a X64 -b RELEASE -t XCODE5 -p FatPkg/FatPkg.dsc
build -a X64 -b RELEASE -t XCODE5 -p MdeModulePkg/MdeModulePkg.dsc
```

11.3 Tools and Applications

Standalone tools may help to debug firmware and hardware. Some of the known tools are listed below. While some tools can be launched from within OpenCore, ~~see more details in~~ [\(Refer to the Tools subsection of the configuration for more details\)](#), most should be run separately either directly or from Shell.

To boot into OpenShell or any other tool directly save `OpenShell.efi` under the name of `EFI\BOOT\BOOTX64.EFI` on a FAT32 partition. It is typically unimportant whether the partition scheme is GPT or MBR.

While the previous approach works both on Macs and other computers, an alternative Mac-only approach to bless the tool on an HFS+ or APFS volume:

```
sudo bless --verbose --file /Volumes/VOLNAME/DIR/OpenShell.efi \
--folder /Volumes/VOLNAME/DIR/ --setBoot
```

Listing 3: Blessing tool

Note 1: `/System/Library/CoreServices/BridgeVersion.bin` should be copied to `/Volumes/VOLNAME/DIR`.

Note 2: To be able to use the `bless` command, disabling System Integrity Protection is necessary.

Note 3: To be able to boot Secure Boot might be disabled if present.

Some of the known tools are listed below (builtin tools are marked with *):

<code>BootKicker*</code>	Enter Apple BootPicker menu (exclusive for Macs with compatible GPUs).
<code>ChipTune*</code>	Test BeepGen protocol and generate audio signals of different style and length.
<code>CleanNvram*</code>	Reset NVRAM alternative bundled as a standalone tool.
<code>GopStop*</code>	Test GraphicsOutput protocol with a simple scenario.
<code>KeyTester*</code>	Test keyboard input in <code>SimpleText</code> mode.
<code>MemTest86</code>	Memory testing utility.
<code>OpenControl*</code>	Unlock and lock back NVRAM protection for other tools to be able to get full NVRAM access when launching from OpenCore.
<code>OpenShell*</code>	OpenCore-configured UEFI Shell for compatibility with a broad range of firmware.
<code>PavpProvision</code>	Perform EPID provisioning (requires certificate data configuration).
<code>ResetSystem*</code>	Utility to perform system reset. Takes reset type as an argument: <code>ColdReset</code> , <code>Firmware</code> , <code>Shutdown</code> , <code>WarmReset</code> . Defaults to <code>ColdReset</code> .
<code>RtcRw*</code>	Utility to read and write RTC (CMOS) memory.
<code>ControlMsre2*</code>	Check CFG Lock (MSR 0xE2 write protection) consistency across all cores and change such hidden options on selected platforms .

11.4 OpenCanopy

OpenCanopy is a graphical OpenCore user interface that runs in `External PickerMode` and relies on `OpenCorePkg OcBootManagementLib` similar to the builtin text interface.

OpenCanopy requires graphical resources located in `Resources` directory to run. Sample resources (fonts and images) can be found in `OcBinaryData` repository. Customised icons can be found over the internet (e.g. [here](#) or [there](#)).

OpenCanopy provides full support for `PickerAttributes` and offers a configurable builtin icon set. The default chosen icon set depends on the `DefaultBackgroundColor` variable value. For `Light Gray Old` icon set will be used, for other colours — the one without a prefix.

Predefined icons are saved in the `\EFI\OC\Resources\Image` directory. A full list of supported icons (in `.icns` format) is provided below. When optional icons are missing, the closest available icon will be used. External entries will use `Ext`-prefixed icon if available (e.g. `OldExtHardDrive.icns`).

Note: In the following all dimensions are normative for the 1x scaling level and shall be scaled accordingly for other levels.

- `Cursor` — Mouse cursor (mandatory, up to 144x144).
- `Selected` — Selected item (mandatory, 144x144).
- `Selector` — Selecting item (mandatory, up to 144x40).
- `Left` — Scrolling left (mandatory, 40x40).
- `Right` — Scrolling right (mandatory, 40x40).

Audio support provides a way for upstream protocols to interact with the selected hardware and audio resources. All audio resources should reside in `\EFI\OC\Resources\Audio` directory. Currently the supported audio file formats are MP3 and WAVE PCM. While it is driver-dependent which audio stream format is supported, most common audio cards support 16-bit signed stereo audio at 44100 or 48000 Hz.

Audio file path is determined by audio type, audio localisation, and audio path. Each filename looks as follows: `[audio type]_[audio localisation]_[audio path].[audio ext]`. For unlocalised files filename does not include the language code and looks as follows: `[audio type]_[audio path].[audio ext]`. Audio extension can either be `mp3` or `wav`.

- Audio type can be `OCEFIAudio` for OpenCore audio files or `AXEFIAudio` for macOS bootloader audio files.
- Audio localisation is a two letter language code (e.g. `en`) with an exception for Chinese, Spanish, and Portuguese. Refer to `APPLE_VOICE_OVER_LANGUAGE_CODE` definition for the list of all supported localisations.
- Audio path is the base filename corresponding to a file identifier. For macOS bootloader audio paths refer to `APPLE_VOICE_OVER_AUDIO_FILE` definition. For OpenCore audio paths refer to `OC_VOICE_OVER_AUDIO_FILE` definition. The only exception is OpenCore boot chime file, which is `OCEFIAudio_VoiceOver_Boot.mp3`.

Audio localisation is determined separately for macOS bootloader and OpenCore. For macOS bootloader it is set in `preferences.efi` archive in `systemLanguage.utf8` file and is controlled by the operating system. For OpenCore the value of `prev-lang:kbd` variable is used. When native audio localisation of a particular file is missing, English language (`en`) localisation is used. Sample audio files can be found in OcBinaryData repository.

3. ConnectDrivers

Type: plist boolean

Failsafe: false

Description: Perform UEFI controller connection after driver loading.

This option is useful for loading drivers following UEFI driver model as they may not start by themselves. Examples of such drivers are filesystem or audio drivers. While effective, this option may not be necessary for drivers performing automatic connection, and may slightly slowdown the boot.

Note: Some types of firmware, particularly those made by Apple, only connect the boot drive to speed up the boot process. Enable this option to be able to see all the boot options when running multiple drives.

4. Drivers

Type: plist array

Failsafe: None

Description: Load selected drivers from `OC/Drivers` directory.

~~Designed to~~ To be filled with string filenames meant to be loaded as UEFI drivers.

5. Input

Type: plist dict

Failsafe: None

Description: Apply individual settings designed for input (keyboard and mouse) in the Input Properties section below.

6. Output

Type: plist dict

Failsafe: None

Description: Apply individual settings designed for output (text and graphics) in the Output Properties section below.

7. ProtocolOverrides

Type: plist dict

Failsafe: None

Description: Force builtin versions of certain protocols described in the ProtocolOverrides Properties section below.

Note: all protocol instances are installed prior to driver loading.

8. Quirks

Type: plist dict

Failsafe: None

Description: Apply individual firmware quirks described in the Quirks Properties section below.

9. ReservedMemory

Type: plist array

Description: ~~Designed to~~ To be filled with plist dict values, describing memory areas ~~exquisite to particular~~ exclusive to specific firmware and hardware functioning, which should not be used by the operating system. ~~An example~~ Examples of such memory ~~region could be~~ regions could be the second 256 MB corrupted by the Intel HD 3000 or an area with faulty RAM. ~~See~~ Refer to the ReservedMemory Properties section below for details.

11.7 APFS Properties

1. EnableJumpstart

Type: plist boolean

Failsafe: false

Description: Load embedded APFS drivers from APFS containers.

An APFS EFI driver is bundled in all bootable APFS containers. This option performs the loading of signed APFS drivers ~~with respect to~~ (consistent with the ScanPolicy. ~~See more details in~~). Refer to the “EFI Jumpstart” section of the Apple File System Reference for details.

2. GlobalConnect

Type: plist boolean

Failsafe: false

Description: Perform full device connection during APFS loading.

~~Instead of~~ Every handle is connected recursively instead of the partition handle connection ~~normally typically~~ used for APFS driver loading ~~every handle is connected recursively~~. This may ~~take more time than usual but~~ can result in additional time being taken but can sometimes be the only way to access APFS partitions on ~~some~~ certain firmware, such as those on older HP laptops.

3. HideVerbose

Type: plist boolean

Failsafe: false

Description: Hide verbose output from APFS driver.

APFS verbose output can be useful for debugging.

4. JumpstartHotPlug

Type: plist boolean

Failsafe: false

Description: Load APFS drivers for newly connected devices.

~~Performs APFS driver loading not only~~ Permits APFS USB hot plug which enables loading APFS drivers, both at OpenCore startup ~~but also during the OpenCore picker. This permits APFS USB hot plug, and during~~ OpenCore picker display. Disable if not required.

5. MinDate

Type: plist integer

Failsafe: 0

Description: Minimal allowed APFS driver date.

The APFS driver date connects the APFS driver with the calendar release date. ~~Older versions of APFS drivers may contain unpatched vulnerabilities, which Apple ultimately drops support for older macOS releases and APFS drivers from such releases may contain vulnerabilities that~~ can be used to ~~inflict harm to the computer~~ compromise a computer if such drivers are used after support ends. This option permits restricting APFS drivers to ~~only recent releases~~ current macOS versions.

- 0 — require the default supported release date of APFS in OpenCore. The default release date will increase with time and thus this setting is recommended. Currently set to 2018/06/21.
- -1 — permit any release date to load (strongly discouraged).
- Other — use custom minimal APFS release date, e.g. 20200401 for 2020/04/01. APFS release dates can be found in OpenCore boot log and `OcApfsLib`.

6. MinVersion

Type: plist integer

Failsafe: 0

Description: Minimal allowed APFS driver version.

The APFS driver version connects the APFS driver with the macOS release. ~~APFS drivers from Apple ultimately drops support for older macOS releases will become unsupported and thus may contain unpatched vulnerabilities, which and APFS drivers from such releases may contain vulnerabilities that~~ can be used to ~~inflict harm to the computer~~ compromise a computer if such drivers are used after support ends. This option permits restricting APFS drivers to ~~only modern current~~ macOS versions.

- 0 — require the default supported version of APFS in OpenCore. The default version will increase with time and thus this setting is recommended. Currently set to the latest point release from High Sierra from App Store (748077008000000).
- -1 — permit any version to load (strongly discouraged).
- Other — use custom minimal APFS version, e.g. 1412101001000000 from macOS Catalina 10.15.4. APFS versions can be found in OpenCore boot log and `0cApsLib`.

11.8 AppleInput Properties

1. AppleEvent

Type: plist string

Failsafe: Auto

Description: Determine whether OC builtin or OEM Apple Event protocol is used.

This option determines whether Apple's OEM Apple Event protocol is used (where available), or whether OpenCore's reversed engineered and updated re-implementation is used. In general OpenCore's re-implementation should be preferred, since it contains updates such as noticeably improved fine mouse cursor movement and configurable key repeat delays.

- **Auto** — Performs automatic choice of implementation. Because of optimisations used to achieve fast boot times, this actually means that the OpenCore re-implementation will be found and used except in the case that OpenCore was been explicitly selected and started (not just auto-booted) from Apple's boot picker (where present).
- **Builtin** — Use OpenCore's updated re-implementation of the Apple Event protocol. Recommended.
- **OEM** — Assume Apple's protocol will be available at driver connection. This results in Apple's implementation being reliably used on Apple systems. It results in no keyboard or mouse support otherwise.

2. CustomDelays

Type: plist string

Failsafe: Auto

Description: Enable custom key repeat delays.

- If **Auto** is treated as **Enabled** when **KeySupport** is **true** and **Disabled** otherwise.
- If **Enabled** the values **KeyInitialDelay** and **KeySubsequentDelay** are used.
- If **Disabled** Apple default values of 500ms (50) and 50ms (5) are used.

3. KeyInitialDelay

Type: plist integer

Failsafe: 0 (no initial delay, immediate repeat)

Description: Configure initial keyboard repeat delay in OpenCore implementation of Apple Event protocol, in units of 10ms.

When not using **KeySupport**, this option will configure the initial delay before key repeat as expected. The Apple OEM default value is 50 (500ms).

When using **KeySupport**, you may find that you get one additional slow key repeat before normal speed key repeat starts. If so, your initial key repeat delay is being driven by your BIOS firmware and cannot be overridden by OC. To avoid this minor undesired effect, set **KeyInitialDelay** to 0. If doing this, to avoid multiple reponses to single key presses, you should set **KeySubsequentDelay** to at least the value of your **KeyForgetThreshold** setting.

4. [KeySubsequentDelay](#)
Type: [plist integer](#)
Failsafe: 1
Description: [Configure subsequent keyboard repeat delay in OpenCore implementation of Apple Event protocol, in units of 10ms.](#)
[Configures the gap between key repeats. The Apple OEM default value is 5 \(50ms\). 0 is an invalid value for this option.](#)
[When using KeySupport, you may find that you get one additional slow key repeat before normal speed key repeat starts. If so, set KeyInitialDelay to 0 and set this option to at least the value of your KeyForgetThreshold setting. \(In the unlikely event that you still get frequent, or occasional, double key responses after doing this, proceed to set this value to one or two greater than KeyForgetThreshold - use the lowest value which works.\)](#)
5. [PointerSpeedDiv](#)
Type: [plist integer](#)
Failsafe: 1)
Description: [Configure pointer speed divisor in OpenCore implementation of Apple Event protocol.](#)
[Configures the divisor for pointer movements. The Apple OEM default value is 1. 0 is an invalid value for this option.](#)
6. [PointerSpeedMul](#)
Type: [plist integer](#)
Failsafe: 0)
Description: [Configure pointer speed multiplier in OpenCore implementation of Apple Event protocol.](#)
[Configures the multiplier for pointer movements. The Apple OEM default value is 1.](#)

11.9 Audio Properties

1. **AudioCodec**
Type: **plist integer**
Failsafe: 0
Description: Codec address on the specified audio controller for audio support.
~~Normally this contains~~ [This typically contains the](#) first audio codec address on the builtin analog audio controller (HDEF). Audio codec addresses, e.g. 2, can be found in the debug log (marked in bold-italic):

```
OCAU: 1/3 PciRoot(0x0)/Pci(0x1,0x0)/Pci(0x0,0x1)/VenMsg(<redacted>,00000000) (4 outputs)
OCAU: 2/3 PciRoot(0x0)/Pci(0x3,0x0)/VenMsg(<redacted>,00000000) (1 outputs)
OCAU: 3/3 PciRoot(0x0)/Pci(0x1B,0x0)/VenMsg(<redacted>,02000000) (7 outputs)
```

As an alternative, this value can be obtained from IOHDACodecDevice class in I/O Registry containing it in IOHDACodecAddress field.
2. **AudioDevice**
Type: **plist string**
Failsafe: Empty
Description: Device path of the specified audio controller for audio support.
~~Normally this~~ [This typically](#) contains builtin analog audio controller (HDEF) device path, e.g. PciRoot(0x0)/Pci(0x1b,0x0). The list of recognised audio controllers can be found in the debug log (marked in bold-italic):

```
OCAU: 1/3 PciRoot(0x0)/Pci(0x1,0x0)/Pci(0x0,0x1)/VenMsg(<redacted>,00000000) (4 outputs)
OCAU: 2/3 PciRoot(0x0)/Pci(0x3,0x0)/VenMsg(<redacted>,00000000) (1 outputs)
OCAU: 3/3 PciRoot(0x0)/Pci(0x1B,0x0)/VenMsg(<redacted>,02000000) (7 outputs)
```

As an alternative, `gfxutil -f HDEF` command can be used in macOS. Specifying [an](#) empty device path will result in the first available audio controller ~~to be~~ [being](#) used.
3. **AudioOut**
Type: **plist integer**
Failsafe: 0
Description: Index of the output port of the specified codec starting from 0.

~~Normally this~~ This typically contains the index of the green out of the builtin analog audio controller (HDEF). The number of output nodes (N) in the debug log (marked in bold-italic):

```
OCAU: 1/3 PciRoot(0x0)/Pci(0x1,0x0)/Pci(0x0,0x1)/VenMsg(<redacted>,00000000) (4 outputs)
OCAU: 2/3 PciRoot(0x0)/Pci(0x3,0x0)/VenMsg(<redacted>,00000000) (1 outputs)
OCAU: 3/3 PciRoot(0x0)/Pci(0x1B,0x0)/VenMsg(<redacted>,02000000) (7 outputs)
```

The quickest way to find the right port is to bruteforce the values from 0 to N - 1.

4. AudioSupport

Type: plist boolean

Failsafe: false

Description: Activate audio support by connecting to a backend driver.

Enabling this setting routes audio playback from builtin protocols to a dedicated audio port (**AudioOut**) of the specified codec (**AudioCodec**) located on the audio controller (**AudioDevice**).

5. MinimumVolume

Type: plist integer

Failsafe: 0

Description: Minimal heard volume level from 0 to 100.

~~Screen~~ The screen reader will use this volume level ~~;~~ when the calculated volume level is ~~less~~ lower than **MinimumVolume** ~~;~~ ~~Boot chime sound and the boot chime~~ will not play if the calculated volume level is ~~less~~ lower than **MinimumVolume**.

6. PlayChime

Type: plist string

Failsafe: Auto

Description: Play chime sound at startup.

Enabling this setting plays ~~boot chime through the boot chime using the~~ builtin audio support. ~~Volume~~ The volume level is determined by the **MinimumVolume** and **VolumeAmplifier** settings ~~and as well as the~~ SystemAudioVolume NVRAM variable. Possible values include:

- Auto — Enables chime when **StartupMute** NVRAM variable is not present or set to 00.
- Enabled — Enables chime unconditionally.
- Disabled — Disables chime unconditionally.

Note: Enabled can be used in separate from **StartupMute** NVRAM variable to avoid conflicts when the firmware is able to play the boot chime.

7. ResetTrafficClass

Type: plist boolean

Failsafe: false

Description: Set HDA Traffic Class Select Register to TC0.

AppleHDA kext will function correctly only if TCSEL register is configured to use TC0 traffic class. Refer to Intel I/O Controller Hub 9 (ICH9) Family Datasheet (or any other ICH datasheet) for more details about this register.

Note: This option is independent from **AudioSupport**. If AppleALC is used it is preferred to use AppleALC **alctsel** property instead.

8. SetupDelay

Type: plist integer

Failsafe: 0

Description: Audio codec reconfiguration delay in microseconds.

Some codecs require a vendor-specific delay after the reconfiguration (e.g. volume setting). This option makes it configurable. A typical delay can be up to 0.5 seconds.

9. VolumeAmplifier

Type: plist integer

Failsafe: 0

Description: Multiplication coefficient for system volume to raw volume linear translation from 0 to 1000.

Volume level range read from `SystemAudioVolume` varies depending on the codec. To transform read value in [0, 127] range into raw volume range [0, 100] the read value is scaled to `VolumeAmplifier` percents:

$$RawVolume = MIN(\frac{SystemAudioVolume * VolumeAmplifier}{100}, 100)$$

Note: the transformation used in macOS is not linear, but it is very close and this nuance is thus ignored.

11.10 Input Properties

1. KeyFiltering

Type: plist boolean

Failsafe: false

Description: Enable keyboard input sanity checking.

Apparently some boards such as the GA Z77P-D3 may return uninitialised data in `EFI_INPUT_KEY` with all input protocols. This option discards keys that are neither ASCII, nor are defined in the UEFI specification (see tables 107 and 108 in version 2.8).

2. KeyForgetThreshold

Type: plist integer

Failsafe: 0

Description: ~~Remove key unless it was submitted~~ Treat duplicate key presses as held keys if they arrive during this timeout~~in milliseconds, in 10 ms units. Only applies to systems using KeySupport.~~

AppleKeyMapAggregator protocol is supposed to contain a fixed length buffer of currently pressed keys. However, the majority of the drivers ~~only which require KeySupport~~ report key presses as interrupts~~and pressing and holding the key on the keyboard results in subsequent submissions of this key, with automatically generated key repeat behaviour~~ with some defined ~~time interval~~ initial and subsequent delay. As a result, to emulate the raw key behaviour required by several Apple boot systems, we use a timeout to ~~remove once pressed keys from the buffer once the timeout expires and no new submission of this key happened~~ merge multiple repeated keys which are submitted within a small timeout window.

This option allows ~~to set setting~~ this timeout based on the platform. The recommended value ~~that works on for~~ the majority of ~~the platforms is platforms is from 5 milliseconds(50 milliseconds) to 7 (70 milliseconds), although values up to 9 (90 milliseconds) have been observed to be required on some PS/2 systems~~. For reference, holding ~~one a~~ key on VMware will repeat ~~it roughly every roughly every 220 milliseconds~~ and the ~~same equivalent~~ value for APTIO V is ~~3-430-40 milliseconds~~. Thus KeyForgetThreshold should be configured to be longer than this. Thus, it is possible to set a slightly lower value on faster platforms and slightly configure a lower KeyForgetThreshold value on platforms with a faster native driver key repeat rate, for more responsive input, and it is required to set a higher value on slower platforms~~for more responsive input~~.

Pressing keys one after the other results in delays of at least ~~660~~ and ~~10100~~ milliseconds for the same platforms. Ideally, KeyForgetThreshold should remain lower than this value, to avoid merging real key presses.

Note: ~~Some platforms may require different values, higher or lower. For example, when detecting key misses in OpenCanopy try increasing this value (e.g. to 10), and when detecting keystall, try decreasing this value. Since every platform is different it may be reasonable to check every value from 1 to 25~~ If you wish to fine tune this value, a good heuristic is to use the 'set default' indicator within either OpenCanopy or the builtin picker. When KeyForgetThreshold is configured correctly, this indicator should flicker once, when first pressing and holding the CTRL or =/+ key, and then after a further very brief interval should go on and stay on. (The initial flicker is an unavoidable artefact of using KeySupport to emulate raw keyboard data.) If KeyForgetThreshold is configured too low for the system, then the 'set default' indicator will continue to flicker while CTRL or =/+ is held. Configure the lowest value which causes this indicator to go on and stay on after the first initial flicker.

3. KeySupport

Type: plist boolean

Failsafe: false

Description: Enable internal keyboard input translation to AppleKeyMapAggregator protocol.

This option activates the internal keyboard interceptor driver, based on `AppleGenericInput`, also known as `AptioInputFix`, to fill the AppleKeyMapAggregator database for input functioning. In ~~case cases where~~ a separate driver ~~is used,~~ such as `OpenUsbKbDxe` is used, this option should never be enabled.

4. KeySupportMode

Type: plist string

Failsafe: Auto

Description: Set internal keyboard input translation to `AppleKeyMapAggregator` protocol mode.

- **Auto** — Performs automatic choice as available with the following preference: `AMI`, `V2`, `V1`.
- **V1** — Uses UEFI standard legacy input protocol `EFI_SIMPLE_TEXT_INPUT_PROTOCOL`.
- **V2** — Uses UEFI standard modern input protocol `EFI_SIMPLE_TEXT_INPUT_EX_PROTOCOL`.
- **AMI** — Uses APTIO input protocol `AMI_EFIKEYCODE_PROTOCOL`.

Note: Currently `V1`, `V2`, and `AMI` unlike `Auto` only do filtering of the particular specified protocol. This may change in the future versions.

5. KeySwap

Type: plist boolean

Failsafe: false

Description: Swap `Command` and `Option` keys during submission.

This option may be useful for keyboard layouts with `Option` key situated to the right of `Command` key.

6. PointerSupport

Type: plist boolean

Failsafe: false

Description: Enable internal pointer driver.

This option implements standard UEFI pointer protocol (`EFI_SIMPLE_POINTER_PROTOCOL`) through certain OEM protocols. The option may be useful on Z87 ASUS boards, where `EFI_SIMPLE_POINTER_PROTOCOL` is defective.

7. PointerSupportMode

Type: plist string

Failsafe: Empty

Description: Set OEM protocol used for internal pointer driver.

Currently the only supported variant is `ASUS`, using specialised protocol available on certain Z87 and Z97 ASUS boards. More details can be found in `LongSoft/UefiTool#116`. The value of this property cannot be empty if `PointerSupport` is enabled.

8. TimerResolution

Type: plist integer

Failsafe: 0

Description: Set architecture timer resolution.

This option allows ~~to update~~ updating the firmware architecture timer period with the specified value in 100 nanosecond units. Setting a lower value ~~generally~~ typically improves performance and responsiveness of the interface and input handling.

The recommended value is 50000 (5 milliseconds) or slightly higher. Select ASUS Z87 boards use 60000 for the interface. Apple boards use 100000. In case of issues, this option can be left as 0.

11.11 Output Properties

1. TextRenderer

Type: plist string

Failsafe: `BuiltinGraphics`

Description: Chooses renderer for text going through standard console output.

Currently two renderers are supported: `Builtin` and `System`. `System` renderer uses firmware services for text rendering. `Builtin` bypassing firmware services and performs text rendering on its own. Different renderers support a different set of options. It is recommended to use `Builtin` renderer, as it supports HiDPI mode and uses full screen resolution.

UEFI firmware ~~generally~~ typically supports `ConsoleControl` with two rendering modes: `Graphics` and `Text`. Some types of firmware do not support `ConsoleControl` and rendering modes. OpenCore and macOS expect

text to only be shown in **Graphics** mode and graphics to be drawn in any mode. Since this is not required by UEFI specification, exact behaviour varies.

Valid values are combinations of text renderer and rendering mode:

- **BuiltinGraphics** — Switch to **Graphics** mode and use **Builtin** renderer with custom **ConsoleControl**.
- **BuiltinText** — Switch to **Text** mode and use **Builtin** renderer with custom **ConsoleControl**.
- **SystemGraphics** — Switch to **Graphics** mode and use **System** renderer with custom **ConsoleControl**.
- **SystemText** — Switch to **Text** mode and use **System** renderer with custom **ConsoleControl**.
- **SystemGeneric** — Use **System** renderer with system **ConsoleControl** assuming it behaves correctly.

The use of **BuiltinGraphics** is ~~generally~~ straightforward. For most platforms, it is necessary to enable **ProvideConsoleGop**, ~~and~~ set **Resolution** to **Max**. The **BuiltinText** variant is an alternative **BuiltinGraphics** for some very old and defective laptop firmware, which can only draw in **Text** mode.

The use of **System** protocols is more complicated. Typically, the preferred setting is **SystemGraphics** or **SystemText**. Enabling **ProvideConsoleGop**, setting **Resolution** to **Max**, enabling **ReplaceTabWithSpace** is useful on almost all platforms. **SanitiseClearScreen**, **IgnoreTextInGraphics**, and **ClearScreenOnModeSwitch** are more specific, and their use depends on the firmware.

Note: Some Macs, such as the **MacPro5,1**, may have incompatible console output when using modern GPUs, and thus only **BuiltinGraphics** may work for them in such cases. NVIDIA GPUs may require additional firmware upgrades.

2. ConsoleMode

Type: plist string

Failsafe: Empty (Maintain current console mode)

Description: Sets console output mode as specified with the WxH (e.g. 80x24) formatted string.

Set to **Max** to attempt using the largest available console mode. This option is currently ignored as the **Builtin** text renderer only supports one console mode.

Note: This field is best left empty on most types of firmware.

3. Resolution

Type: plist string

Failsafe: Empty (Maintain current screen resolution)

Description: Sets console output screen resolution.

- Set to WxH@Bpp (e.g. 1920x1080@32) or WxH (e.g. 1920x1080) formatted string to request custom resolution from GOP if available.
- Set to **Max** to attempt using the largest available screen resolution.

On HiDPI screens **APPLE_VENDOR_VARIABLE_GUID UIScale** NVRAM variable may need to be set to **02** to enable HiDPI scaling in **Builtin** text renderer, FileVault 2 UEFI password interface, and boot screen logo. Refer to the Recommended Variables section for ~~more~~ details.

Note: This will fail when console handle has no GOP protocol. When the firmware does not provide it, it can be added with **ProvideConsoleGop** set to **true**.

4. ForceResolution

Type: plist boolean

Failsafe: false

Description: Forces **Resolution** to be set in cases where the desired resolution is not available by default, such as on legacy Intel GMA and first generation Intel HD Graphics (Ironlake/Arrandale). Setting **Resolution** to **Max** will try to pull the largest available resolution from the connected display's EDID.

Note: This option depends on the **OC_FORCE_RESOLUTION_PROTOCOL** protocol being present. This protocol is currently only supported by **OpenDuetPkg**. The **OpenDuetPkg** implementation currently only supports Intel iGPUs.

5. ClearScreenOnModeSwitch

Type: plist boolean

Failsafe: false

Description: Some types of firmware only clear part of the screen when switching from graphics to text mode,

12. SanitiseClearScreen

Type: plist boolean

Failsafe: false

Description: Some types of firmware reset screen resolutions to a failsafe value (such as 1024x768) on the attempts to clear screen contents when large display (e.g. 2K or 4K) is used. This option attempts to apply a workaround.

Note: This option only applies to the **System** renderer. On all known affected systems, **ConsoleMode** must be set to an empty string for this option to work.

13. UgaPassThrough

Type: plist boolean

Failsafe: false

Description: Provide UGA protocol instances on top of GOP protocol instances.

Some types of firmware do not implement the legacy UGA protocol but this may be required for screen output by older EFI applications such as EfiBoot from 10.4.

11.12 ProtocolOverrides Properties

1. AppleAudio

Type: plist boolean

Failsafe: false

Description: Replaces Apple audio protocols with builtin versions.

Apple audio protocols allow ~~macOS bootloader and OpenCore~~ [OpenCore and the macOS bootloader](#) to play sounds and signals for screen reading or audible error reporting. Supported protocols are beep generation and VoiceOver. [The](#) VoiceOver protocol is specific to Gibraltar machines (T2) and is not supported before macOS High Sierra (10.13). ~~Instead older~~ [Older](#) macOS versions use ~~AppleHDA protocol, which is currently not implemented~~ [the AppleHDA protocol \(which is not currently implemented\) instead](#).

Only one set of audio protocols can be available at a time, so [this setting should be enabled](#) in order to ~~get enable~~ audio playback in [the](#) OpenCore user interface on Mac ~~system systems~~ implementing some of these protocols ~~this setting should be enabled~~.

Note: ~~Backend~~ [The backend](#) audio driver needs to be configured in UEFI Audio section for these protocols to be able to stream audio.

2. AppleBootPolicy

Type: plist boolean

Failsafe: false

Description: Replaces the Apple Boot Policy protocol with a builtin version. This may be used to ensure APFS compatibility on VMs and legacy Macs.

Note: This option is advisable on certain Macs, such as the **MacPro5,1**, that are APFS compatible but on which the Apple Boot Policy protocol has recovery detection issues.

3. AppleDebugLog

Type: plist boolean

Failsafe: false

Description: Replaces the Apple Debug Log protocol with a builtin version.

4. AppleEvent

Type: plist boolean

Failsafe: false

Description: Replaces the Apple Event protocol with a builtin version. This may be used to ensure FileVault 2 compatibility on VMs and legacy Macs.

5. AppleFramebufferInfo

Type: plist boolean

Failsafe: false

Description: Replaces the Apple Framebuffer Info protocol with a builtin version. This may be used to override

framebuffer information on VMs and legacy Macs to improve compatibility with legacy EfiBoot such as the one in macOS 10.4.

Note: The current implementation of this property results in it only being active when GOP is available (it is always equivalent to **false** otherwise).

6. AppleImageConversion

Type: plist boolean

Failsafe: false

Description: Replaces the Apple Image Conversion protocol with a builtin version.

7. AppleImg4Verification

Type: plist boolean

Failsafe: false

Description: Replaces the Apple IMG4 Verification protocol with a builtin version. This protocol is used to verify im4m manifest files used by Apple Secure Boot.

8. AppleKeyMap

Type: plist boolean

Failsafe: false

Description: Replaces Apple Key Map protocols with builtin versions.

9. AppleRtcRam

Type: plist boolean

Failsafe: false

Description: Replaces the Apple RTC RAM protocol with a builtin version.

Note: Builtin version of Apple RTC RAM protocol may filter out I/O attempts to certain RTC memory addresses. The list of addresses can be specified in `4D1FDA02-38C7-4A6A-9CC6-4BCCA8B30102:rtc-blacklist` variable as a data array.

10. AppleSecureBoot

Type: plist boolean

Failsafe: false

Description: Replaces the Apple Secure Boot protocol with a builtin version.

11. AppleSmcIo

Type: plist boolean

Failsafe: false

Description: Replaces the Apple SMC I/O protocol with a builtin version.

This protocol replaces [the](#) legacy VirtualSmc UEFI driver, and is compatible with any SMC kernel extension. However, in case [the FakeSMC](#) kernel extension is used, manual NVRAM key variable addition may be needed.

12. AppleUserInterfaceTheme

Type: plist boolean

Failsafe: false

Description: Replaces the Apple User Interface Theme protocol with a builtin version.

13. DataHub

Type: plist boolean

Failsafe: false

Description: Replaces the Data Hub protocol with a builtin version.

Note: This will discard all previous entries if the protocol was already installed, so all properties required for [the](#) safe operation of the system must be specified in ~~your configuration~~ [the configuration file](#).

14. DeviceProperties

Type: plist boolean

Failsafe: false

Description: Replaces the Device Property protocol with a builtin version. This may be used to ensure full compatibility on VMs and legacy Macs.

Note: This will discard all previous entries if the protocol was already installed, so all properties required for safe operation of the system must be specified in ~~your configuration~~ the configuration file.

15. FirmwareVolume

Type: plist boolean

Failsafe: false

Description: Wraps Firmware Volume protocols, or installs a new version, to support custom cursor images for FileVault 2. Set to **true** to ensure FileVault 2 compatibility on anything other than on VMs and legacy Macs.

Note: Several virtual machines ~~including VMware~~, including VMware, may have corrupted cursor images in HiDPI mode and thus, may also require enabling this setting.

16. HashServices

Type: plist boolean

Failsafe: false

Description: Replaces Hash Services protocols with builtin versions. Set to **true** to ensure FileVault 2 compatibility on platforms with defective SHA-1 hash implementations. This can be determined by an invalid cursor size when UIScale is set to 02. Platforms earlier than APTIO V (Haswell and older) are typically affected.

17. OSInfo

Type: plist boolean

Failsafe: false

Description: Replaces the OS Info protocol with a builtin version. This protocol is typically used by the firmware and other applications to receive notifications from the macOS bootloader.

18. UnicodeCollation

Type: plist boolean

Failsafe: false

Description: Replaces unicode collation services with builtin versions. Set to **true** to ensure UEFI Shell compatibility on platforms with defective unicode collation implementations. Legacy Insyde and APTIO platforms on Ivy Bridge, and earlier, are typically affected.

11.13 Quirks Properties

1. ActivateHpetSupport

Type: plist boolean

Failsafe: false

Description: Activates HPET support.

Older boards like ICH6 may not always have HPET setting in the firmware preferences, this option tries to force enable it.

2. DisableSecurityPolicy

Type: plist boolean

Failsafe: false

Description: Disable platform security policy.

Note: This setting disables various security features of the firmware, defeating the purpose of any kind of Secure Boot. Do NOT enable if using UEFI Secure Boot.

3. ExitBootServicesDelay

Type: plist integer

Failsafe: 0

Description: Adds delay in microseconds after EXIT_BOOT_SERVICES event.

This is a very rough workaround to circumvent the **Still waiting for root device** message on some APTIO IV firmware (ASUS Z87-Pro) particularly when using FileVault 2. It appears that for some reason, they execute code in parallel to EXIT_BOOT_SERVICES, which results in the SATA controller being inaccessible from macOS. A better approach is required and Acidanthera is open to suggestions. Expect 3 to 5 seconds to be adequate when this quirk is needed.

4. IgnoreInvalidFlexRatio

Type: plist boolean

Failsafe: false

Description: Some types of firmware (such as APTIO IV) may contain invalid values in the MSR_FLEX_RATIO (0x194) MSR register. These values may cause macOS boot failures on Intel platforms.

Note: While the option is not expected to harm unaffected firmware, its use is recommended only when specifically required.

5. ReleaseUsbOwnership

Type: plist boolean

Failsafe: false

Description: Attempt to detach USB controller ownership from the firmware driver. While most types of firmware manage to do this properly, or at least have an option for this, some do not. As a result, the operating system may freeze upon boot. Not recommended unless specifically required.

6. RequestBootVarRouting

Type: plist boolean

Failsafe: false

Description: Request redirect of all Boot prefixed variables from EFI_GLOBAL_VARIABLE_GUID to OC_VENDOR_VARIABLE_GUID.

This quirk requires OC_FIRMWARE_RUNTIME protocol implemented in `OpenRuntime.efi`. The quirk lets default boot entry preservation at times when the firmware deletes incompatible boot entries. In summary, this quirk is required to reliably use the Startup Disk preference pane in firmware that is not compatible with macOS boot entries by design.

By redirecting Boot prefixed variables to a separate GUID namespace with the help of `RequestBootVarRouting` quirk we achieve multiple goals:

- Operating systems are jailed and only controlled by OpenCore boot environment to enhance security.
- Operating systems do not mess with OpenCore boot priority, and guarantee fluent updates and hibernation wakes for cases that require reboots with OpenCore in the middle.
- Potentially incompatible boot entries, such as macOS entries, are not deleted or corrupted in any way.

7. TscSyncTimeout

Type: plist integer

Failsafe: 0

Description: Attempts to perform TSC synchronisation with a specified timeout.

The primary purpose of this quirk is to enable early bootstrap TSC synchronisation on some server and laptop models when running a debug XNU kernel. For the debug kernel the TSC needs to be kept in sync across the cores before any kext could kick in rendering all other solutions problematic. The timeout is specified in microseconds and depends on the amount of cores present on the platform, the recommended starting value is 500000.

This is an experimental quirk, which should only be used for the aforementioned problem. In all other cases, the quirk may render the operating system unstable and is not recommended. The recommended solution in the other cases is to install a kernel [driver-extension](#) such as VoodooTSCSync, TSCAdjustReset, or CpuTscSync (a more specialised variant of VoodooTSCSync for newer laptops).

Note: This quirk cannot replace the kernel [driver-extension](#) because it cannot operate in ACPI S3 (sleep wake) mode and because the UEFI firmware only provides very limited multicore support which prevents precise updates of the MSR registers.

8. UnblockFsConnect

Type: plist boolean

Failsafe: false

Description: Some types of firmware block partition handles by opening them in By Driver mode, resulting in an inability to install File System protocols.

Note: This quirk is useful in cases where unsuccessful drive detection results in an absence of boot entries.

11.14 ReservedMemory Properties

1. Address

Type: plist integer

Failsafe: 0

Description: Start address of the reserved memory region, which should be allocated as reserved effectively marking the memory of this type inaccessible to the operating system.

The addresses written here must be part of the memory map, have a `EfiConventionalMemory` type, and be page-aligned (4 KBs).

Note: Some types of firmware may not allocate memory areas used by S3 (sleep) and S4 (hibernation) code unless CSM is enabled causing wake failures. After comparing the memory maps with CSM disabled and enabled, these areas can be found in the lower memory and can be fixed up by doing the reservation. [See `Sample.plist` for more file for details.](#)

2. Comment

Type: plist string

Failsafe: Empty

Description: Arbitrary ASCII string used to provide human readable reference for the entry. Whether this value is used is implementation defined.

3. Size

Type: plist integer

Failsafe: 0

Description: Size of the reserved memory region, must be page-aligned (4 KBs).

4. Type

Type: plist string

Failsafe: Reserved

Description: Memory region type matching the UEFI specification memory descriptor types. Mapping:

- Reserved — `EfiReservedMemoryType`
- LoaderCode — `EfiLoaderCode`
- LoaderData — `EfiLoaderData`
- BootServiceCode — `EfiBootServicesCode`
- BootServiceData — `EfiBootServicesData`
- RuntimeCode — `EfiRuntimeServicesCode`
- RuntimeData — `EfiRuntimeServicesData`
- Available — `EfiConventionalMemory`
- Persistent — `EfiPersistentMemory`
- UnusableMemory — `EfiUnusableMemory`
- ACPIReclaimMemory — `EfiACPIReclaimMemory`
- ACPIMemoryNVS — `EfiACPIMemoryNVS`
- MemoryMappedIO — `EfiMemoryMappedIO`
- MemoryMappedIOPortSpace — `EfiMemoryMappedIOPortSpace`
- PalCode — `EfiPalCode`

5. Enabled

Type: plist boolean

Failsafe: false

Description: This region will not be reserved unless set to `true`.

12 Troubleshooting

12.1 Legacy Apple OS

Older operating systems may be more complicated to install, but ~~sometimes can be necessary to use for all kinds of~~ are sometimes necessary for various reasons. While a compatible board identifier and CPUID are the obvious requirements for proper functioning of an older operating system, there are many other less obvious things to consider. This section ~~tries to cover~~ covers a common set of issues relevant to installing older macOS operating systems.

While newer operating systems can be downloaded over the internet, older operating systems did not have installation media for every minor release. For compatible distributions of such, download a device-specific image and modify it if necessary. Visit this archived Apple Support article for a list of the bundled device-specific builds for legacy operating systems. However, as this may not always be accurate, the latest versions are listed below.

12.1.1 macOS 10.8 and 10.9

- Disk images on these systems use the Apple Partitioning Scheme and require the OpenPartitionDxe driver to run DMG recovery and installation (included in OpenDuet). It is possible to set `DmgLoading to Disabled` to run the recovery without DMG loading avoiding the need for OpenPartitionDxe.
- Cached kernel images often do not contain family drivers for networking (IONetworkingFamily) or audio (IOAudioFamily) requiring the use of Force loading in order to inject networking or audio drivers.

12.1.2 macOS 10.7

- All previous issues apply.
- SSSE3 support (not to be confused with SSE3 support) is a hard requirement for macOS 10.7 kernel.
- Many kexts, including Lilu when 32-bit kernel is used and a lot of Lilu plugins, are unsupported on macOS 10.7 and older as they require newer kernel APIs, which are not part of the macOS 10.7 SDK.
- Prior to macOS 10.8 KASLR sliding is not supported, which will result in memory allocation failures on firmware that utilise lower memory for their own purposes. Refer to acidanthera/bugtracker#1125 for tracking.

12.1.3 macOS 10.6

- All previous issues apply.
- SSSE3 support is a requirement for macOS 10.6 kernel with 64-bit userspace enabled. This limitation can mostly be lifted by enabling the LegacyCommpage quirk.
- Last released installer images for macOS 10.6 are macOS 10.6.7 builds 10J3250 (for MacBookPro8,x) and 10J4139 (for iMac12,x), without Xcode). These images are limited to their target model identifiers and have no `-no_compat_check` boot argument support. Modified images (with ACDT suffix) without model restrictions can be found here (MEGA Mirror), assuming macOS 10.6 is legally owned. ~~Read~~ Refer to the DIGEST.txt ~~for more~~ file for details. Note that these are the earliest tested versions of macOS 10.6 with OpenCore.

Model checking may also be erased by editing OSInstall.mpkg with e.g. Flat Package Editor by making Distribution script to always return `true` in `hwbeModelCheck` function. Since updating the only file in the image and not corrupting other files can be difficult and may cause slow booting due to kernel cache date changes, it is recommended to script image rebuilding as shown below:

```
#!/bin/bash
# Original.dmg is original image, OSInstall.mpkg is patched package
mkdir R0
hdiutil mount Original.dmg -noverify -noautoopen -noautoopenrw -noautofsck -mountpoint R0
cp R0/.DS_Store DS_STORE
hdiutil detach R0 -force
rm -rf R0
hdiutil convert Original.dmg -format UDRW -o ReadWrite.dmg
mkdir RW
xattr -c OSInstall.mpkg
```

```
hdiutil mount ReadWrite.dmg -noverify -noautoopen -noautoopenrw -noautofsck -mountpoint RW
cp OSInstall.mpkg RW/System/Installation/Packages/OSInstall.mpkg
killall Finder fsevents
rm -rf RW/.fsevents
cp DS_STORE RW/.DS_Store
hdiutil detach RW -force
rm -rf DS_STORE RW
hdiutil convert ReadWrite.dmg -format UDZO -o ReadOnly.dmg
```

12.1.4 macOS 10.5

- All previous issues apply.
- This macOS version does not support x86_64 kernel and requires i386 kernel extensions and patches.
- This macOS version uses the first (V1) version of `prelinkedkernel`, which has kext symbol tables corrupted by the kext tools. This nuance renders `prelinkedkernel` kext injection impossible in OpenCore. `Mkext` kext injection will still work without noticeable performance drain and will be chosen automatically when `KernelCache` is set to `Auto`.
- Last released installer image for macOS 10.5 is macOS 10.5.7 build 9J3050 (for MacBookPro5,3). Unlike the others, this image is not limited to the target model identifiers and can be used as is. The original 9J3050 image can be found here (MEGA Mirror), assuming macOS 10.5 is legally owned. ~~Read~~ [Refer to the DIGEST.txt for more file for](#) details. Note that this is the earliest tested version of macOS 10.5 with OpenCore.

12.1.5 macOS 10.4

- All previous issues apply.
- This macOS version has a hard requirement to access all the optional packages on the second DVD disk installation media, requiring either two disks or USB media installation.
- Last released installer images for macOS 10.4 are macOS 10.4.10 builds 8R4061a (for MacBookPro3,1) and 8R4088 (for iMac7,1). These images are limited to their target model identifiers as on newer macOS versions. Modified 8R4088 images (with ACDT suffix) without model restrictions can be found here (MEGA Mirror), assuming macOS 10.4 is legally owned. ~~Read~~ [Refer to the DIGEST.txt for more file for](#) details. Note that these are the earliest tested versions of macOS 10.4 with OpenCore.

12.2 UEFI Secure Boot

OpenCore is designed to provide a secure boot chain between firmware and operating system. On most x86 platforms trusted loading is implemented via UEFI Secure Boot model. Not only OpenCore fully supports this model, but it also extends its capabilities to ensure sealed configuration via vaulting and provide trusted loading to the operating systems using custom verification, such as Apple Secure Boot. Proper secure boot chain requires several steps and careful configuration of certain settings as explained below:

1. Enable Apple Secure Boot by setting `SecureBootModel` to run macOS. Note, that not every macOS is compatible with Apple Secure Boot and there are several other restrictions as explained in Apple Secure Boot section.
2. Disable DMG loading by setting `DmgLoading` to `Disabled` if users have concerns of loading old vulnerable DMG recoveries. This is **not** required, but recommended. For the actual tradeoffs see the details in DMG loading section.
3. Make sure that APFS JumpStart functionality restricts the loading of old vulnerable drivers by setting `MinDate` and `MinVersion` to 0. More details are provided in APFS JumpStart section. An alternative is to install `apfs.efi` driver manually.
4. Make sure that `Force` driver loading is not needed and all the operating systems are still bootable.
5. Make sure that `ScanPolicy` restricts loading from undesired devices. It is a good idea to prohibit all removable drivers or unknown filesystems.

6. Sign all the installed drivers and tools with the private key. Do not sign tools that provide administrative access to the computer, such as UEFI Shell.
7. Vault the configuration as explained Vaulting section.
8. Sign all OpenCore binaries (`BOOTX64.efi`, `BOOTIa32.efi`, `OpenCore.efi`, custom launchers) used on this system with the same private key.
9. Sign all third-party operating system (not made by Microsoft or Apple) bootloaders if needed. For Linux there is an option to install Microsoft-signed Shim bootloader as explained on e.g. Debian Wiki.
10. Enable UEFI Secure Boot in firmware preferences and install the certificate with a private key. Details on how to generate a certificate can be found in various articles, such as this one, and are out of the scope of this document. If Windows is needed one will also need to add the Microsoft Windows Production CA 2011. To launch option ROMs or to use signed Linux drivers, Microsoft UEFI Driver Signing CA will also be needed.
11. Password-protect changing firmware settings to ensure that UEFI Secure Boot cannot be disabled without the user's knowledge.

12.3 Windows support

Can I install Windows?

While no official Windows support is provided, 64-bit UEFI Windows installations (Windows 8 and above) prepared with Boot Camp are supposed to work. Third-party UEFI installations as well as systems partially supporting UEFI boot, such as Windows 7, might work with some extra precautions. Things to consider:

- MBR (Master Boot Record) installations are legacy and will not be supported.
- All the modifications applied (to ACPI, NVRAM, SMBIOS, etc.) are supposed to be operating system agnostic, i.e. apply equally regardless of the OS booted. This enables Boot Camp software experience on Windows.
- macOS requires the first partition to be EFI System Partition, and does not support the default Windows layout. While OpenCore does have a workaround for this, it is highly recommend not to rely on it and install properly.
- Windows may need to be reactivated. To avoid it consider setting SystemUUID to the original firmware UUID. Be aware that it may be invalid on old firmware, i.e., not random. If there still are issues, consider using HWID or KMS38 license or making the use `Custom UpdateSMBIOSMode`. Other nuances of Windows activation are out of the scope of this document and can be found online.

What additional software do I need?

To enable operating system switching and install relevant drivers in the majority of cases Windows support software from Boot Camp is required. For simplicity of the download process or when configuring an already installed Windows version a third-party utility, Brigadier, can be used successfully. Note, that 7-Zip may be downloaded and installed prior to using Brigadier.

Remember to always use the latest version of Windows support software from Boot Camp, as versions prior to 6.1 do not support APFS, and thus will not function correctly. To download newest software pass most recent Mac model to Brigadier, for example `./brigadier.exe -m iMac19,1`. To install Boot Camp on an unsupported Mac model afterwards run PowerShell as Administrator and enter `msiexec /i BootCamp.msi`. If there is a previous version of Boot Camp installed it should be removed first by running `msiexec /x BootCamp.msi` command. `BootCamp.msi` file is located in `BootCamp/Drivers/Apple` directory and can be reached through Windows Explorer.

While Windows support software from Boot Camp solves most of compatibility problems, the rest may still have to be addressed manually:

- To invert mouse wheel scroll direction `FlipFlopWheel` must be set to 1 as explained on SuperUser.
- `RealTimeIsUniversal` must be set to 1 to avoid time desync between Windows and macOS as explained on SuperUser (this is typically not required).
- To access Apple filesystems such as HFS+ and APFS, separate software may need to be installed. Some of the known utilities are: Apple HFS+ driver (workaround for Windows 10), HFSExplorer, MacDrive, Paragon APFS, Paragon HFS+, TransMac, etc. Remember to never ever attempt to modify Apple file systems from Windows as this often leads to irrecoverable data loss.

Why do I see Basic data partition in [the](#) Boot Camp Startup Disk control panel?

[The](#) Boot Camp control panel uses [the](#) GPT partition table to obtain each boot option name. After installing Windows separately ~~the partition will have~~, [the partition has](#) to be relabelled manually. This can be done with many utilities including [the](#) open-source gdisk utility. Reference example:

```
PS C:\gdisk> .\gdisk64.exe \\.\\physicaldrive0
GPT fdisk (gdisk) version 1.0.4
```

```
Command (? for help): p
Disk \\.\\physicaldrive0: 419430400 sectors, 200.0 GiB
Sector size (logical): 512 bytes
Disk identifier (GUID): DEC57EB1-B3B5-49B2-95F5-3B8C4D3E4E12
Partition table holds up to 128 entries
Main partition table begins at sector 2 and ends at sector 33
First usable sector is 34, last usable sector is 419430366
Partitions will be aligned on 2048-sector boundaries
Total free space is 4029 sectors (2.0 MiB)
```

Number	Start (sector)	End (sector)	Size	Code	Name
1	2048	1023999	499.0 MiB	2700	Basic data partition
2	1024000	1226751	99.0 MiB	EF00	EFI system partition
3	1226752	1259519	16.0 MiB	0C01	Microsoft reserved ...
4	1259520	419428351	199.4 GiB	0700	Basic data partition

```
Command (? for help): c
Partition number (1-4): 4
Enter name: BOOTCAMP
```

```
Command (? for help): w
```

```
Final checks complete. About to write GPT data. THIS WILL OVERWRITE EXISTING PARTITIONS!!
```

```
Do you want to proceed? (Y/N): Y
OK; writing new GUID partition table (GPT) to \\.\\physicaldrive0.
Disk synchronization succeeded! The computer should now use the new partition table.
The operation has completed successfully.
```

Listing 4: Relabeling Windows volume

How ~~to do~~ [I](#) choose Windows BOOTCAMP with custom NTFS drivers?

Third-party drivers providing NTFS support, such as NTFS-3G, Paragon NTFS, Tuxera NTFS or Seagate Paragon Driver disrupt certain macOS functionality, including [the](#) Startup Disk preference pane normally used for operating system selection. While the recommended option remains not to use such drivers as they commonly corrupt the filesystem, and prefer the driver bundled with macOS with optional write support (command or GUI), there still exist vendor-specific workarounds for their products: Tuxera, Paragon, etc.

12.4 Debugging

Similar to other projects working with hardware OpenCore supports auditing and debugging. The use of NOOPT or DEBUG build modes instead of RELEASE can produce a lot more debug output. With NOOPT source level debugging with GDB or IDA Pro is also available. For GDB check OpenCore Debug page. For IDA Pro, version 7.3 or newer is needed, and Debugging the XNU Kernel with IDA Pro may also help.

To obtain the log during boot serial port debugging can be used. Serial port debugging is enabled in **Target**, e.g. 0xB for onscreen with serial. To initialise serial within OpenCore use **SerialInit** configuration option. For macOS the best choice is CP2102-based UART devices. Connect motherboard TX to USB UART RX, and motherboard GND to USB UART GND. Use **screen** utility to get the output, or download GUI software, such as CoolTerm.

Note: On several motherboards (and possibly USB UART dongles) PIN naming may be incorrect. It is very common to have GND swapped with RX, thus, motherboard “TX” must be connected to USB UART GND, and motherboard “GND” to USB UART RX.

Remember to enable COM port in firmware settings, and never use USB cables longer than 1 meter to avoid output corruption. To additionally enable XNU kernel serial output `debug=0x8` boot argument is needed.

12.5 Tips and Tricks

1. How ~~to do I~~ debug boot ~~failure~~failures?

~~Normally it is enough to obtain~~Obtaining the actual error message ~~is usually adequate~~. For this, ensure that:

- A DEBUG or NOOPT version of OpenCore is used.
- Logging is enabled (1) and shown onscreen (2): Misc → Debug → Target = 3.
- Logged messages from at least DEBUG_ERROR (0x80000000), DEBUG_WARN (0x00000002), and DEBUG_INFO (0x00000040) levels are visible onscreen: Misc → Debug → DisplayLevel = 0x80000042.
- Critical error messages, such as DEBUG_ERROR, stop booting: Misc → Security → HaltLevel = 0x80000000.
- Watch Dog is disabled to prevent automatic reboot: Misc → Debug → DisableWatchDog = true.
- Boot Picker (entry selector) is enabled: Misc → Boot → ShowPicker = true.

If there is no obvious error, check the available workarounds in the Quirks sections one by one. For early boot troubleshooting, for instance, when OpenCore menu does not appear, using UEFI Shell (bundled with OpenCore) may help to see early debug messages.

2. How ~~to do I~~ debug macOS boot ~~failure~~failures?

- Refer to boot-args values such as `debug=0x100`, `keepsyms=1`, `-v`, and similar.
- Do not forget about AppleDebug and ApplePanic properties.
- Take care of Booter, Kernel, and UEFI quirks.
- Consider using serial port to inspect early kernel boot failures. For this `debug=0x108`, `serial=5`, and `msgbuf=1048576` boot arguments are needed. Refer to the patches in Sample.plist when dying before serial init.
- Always read the logs carefully.

3. How ~~to do I~~ customise boot entries?

OpenCore follows standard Apple Bless model and extracts the entry name from `.contentDetails` and `.disk_label.contentDetails` files in the booter directory if present. These files contain an ASCII string with an entry title, which may then be customised by the user.

4. How ~~to do I~~ choose the default boot entry?

OpenCore uses the primary UEFI boot option to select the default entry. This choice can be altered from UEFI Setup, with the macOS Startup Disk preference, or the Windows Boot Camp Control Panel. Since choosing OpenCore’s `BOOTx64.EFI` as a primary boot option limits this functionality in addition to several types of firmware deleting incompatible boot options, potentially including those created by macOS, users are strongly encouraged to use the `RequestBootVarRouting` quirk, which will preserve the selection made in the operating system within the OpenCore variable space. Note, that `RequestBootVarRouting` requires a separate driver for functioning.

5. What is the simplest way to install macOS?

Copy online recovery image (`*.dmg` and `*.chunklist` files) to `com.apple.recovery.boot` directory on a FAT32 partition with OpenCore. Load the OpenCore picker and choose the entry, it will have a `(dmg)` suffix. Custom name may be created by providing `.contentDetails` file.

To download recovery online `macrecovery.py` can be used.

For offline installation refer to How to create a bootable installer for macOS article. Apart from App Store and `softwareupdate` utility there also are third-party utilities to download an offline image.

6. Why do online recovery images (`*.dmg`) fail to load?

This may be caused by missing HFS+ driver, as all presently known recovery volumes have HFS+ filesystem.

7. Can I use this on Apple hardware or virtual machines?

Sure, most relatively modern Mac models including MacPro5,1 and virtual machines are fully supported. Even though there are little to none specific details relevant to Mac hardware, some ongoing instructions can be found on MacRumors.com.

8. Why must Find&Replace patches be equal in size?

For machine code (x86 code) it is not possible to do differently sized replacements due to relative addressing. For ACPI code this is risky, and is technically equivalent to ACPI table replacement, thus not implemented. More detailed explanation can be found on AppleLife.ru or in the ACPI section of this document.

9. How can I decide which Booter quirks to use?

These quirks originate from AptioMemoryFix driver but provide a wider set of changes specific to modern systems. Note, that OpenRuntime driver is required for most configurations. To get a configuration similar to AptioMemoryFix the following set of quirks should be enabled:

- ProvideConsoleGop (UEFI quirk)
- AvoidRuntimeDefrag
- DiscardHibernateMap
- EnableSafeModeSlide
- EnableWriteUnprotector
- ForceExitBootServices
- ProtectMemoryRegions
- ProvideCustomSlide
- RebuildAppleMemoryMap
- SetupVirtualMap

However, as of today, such set is strongly discouraged as some of these quirks are not necessary to be enabled or need additional quirks. For example, DevirtualiseMmio and ProtectUefiServices are often required, while DiscardHibernateMap and ForceExitBootServices are rarely necessary.

Unfortunately for some quirks such as RebuildAppleMemoryMap, EnableWriteUnprotector, ProtectMemoryRegions, SetupVirtualMap, and SyncRuntimePermissions there is no definite approach even on similar systems, so trying all their combinations may be required for optimal setup. Refer to individual quirk descriptions in this document for ~~more~~ details.