android

# Vendor Native Development Kit (VNDK)

## Design Principles and Practical Migration

## Agenda

VNDK Overview

Dynamic Linker Support

Build System Support

VNDK Definition Tool

JNI Libraries in Bundled APKs

## VNDK Overview

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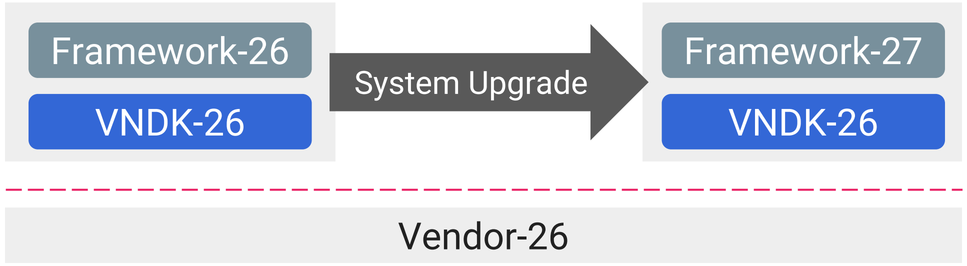
## What is the VNDK?

- The Vendor Native Development Kit (VNDK) is a **set of shared libraries** for vendors to implement vendor modules.
- The VNDK is part of vendor interface object (VINTF object).
- The VNDK is **versioned** and **stable**.

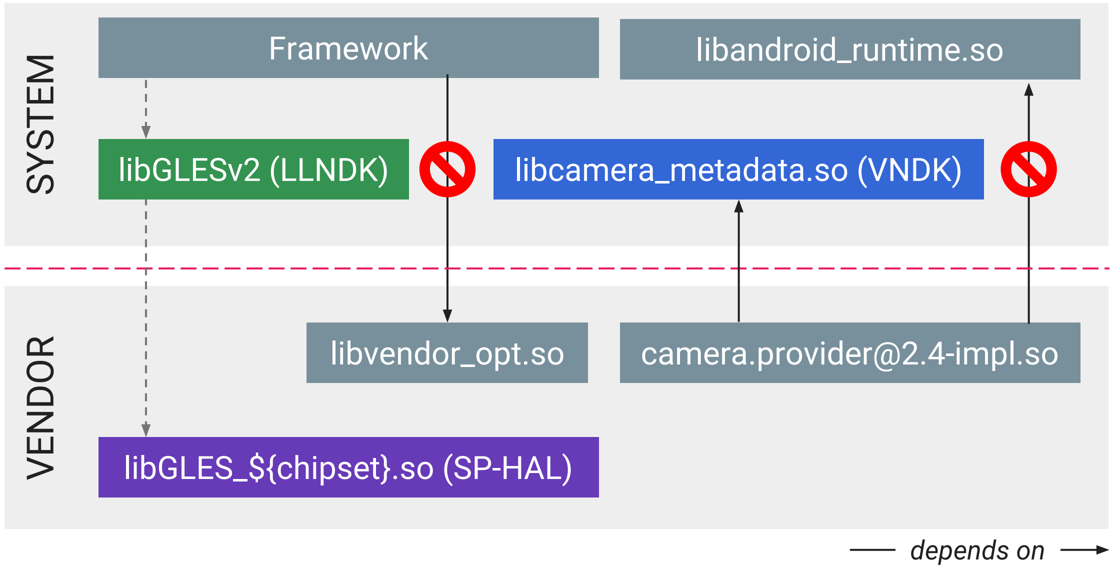


## VNDK enforcement status

- VNDK is partially implemented in **Android 8 (O)**
  - VNDK-SP (for SP-HAL) is enforced.
- VNDK is fully implemented in **Android 8.1 (O MR1)**
  - VNDK-SP (for SP-HAL) is enforced.
  - Enabling VNDK is recommended.
- Future Android releases will fully enforce the VNDK. When this occurs, **ineligible libraries will not be accessible by vendor modules at build time and runtime**.

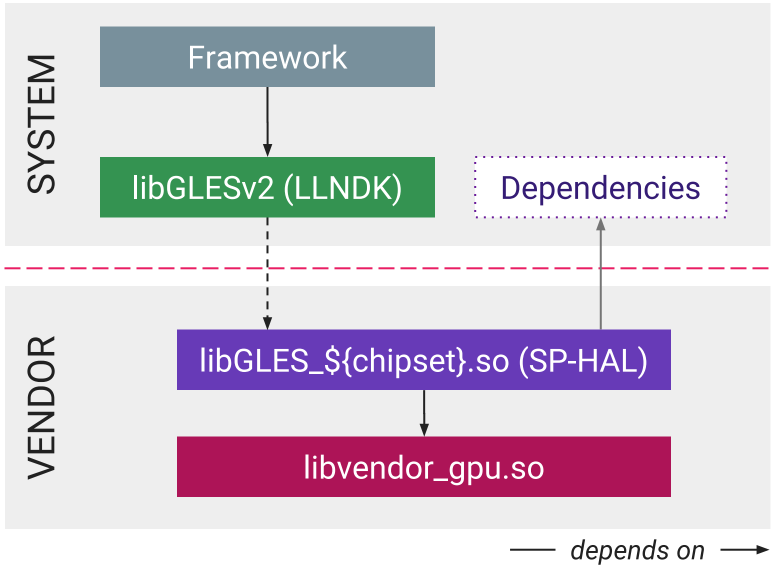
# Modular Android lib dependencies

- Vendor modules should not depend on system modules **except VNDK**.
- Framework does not depend on vendor modules **except Same-Process HAL (SP-HAL)**.


SYSTEM
Framework
libandroid_runtime.so
libGLESv2 (LLNDK)
libcamera_metadata.so (VNDK)
VENDOR
libvendor_opt.so
camera.provider@2.4-impl.so
libGLES_${chipset}.so (SP-HAL)
depends on

# Same-Process HAL (SP-HAL)

- Several time-critical HALs are **not binderized**:
  - `android.hardware.renderscript@1.0-impl`
  - `android.hardware.graphics.mapper@1.0-impl`
  - `android.hidl.memory@1.0-impl`
  - `libEGL_${chipset}`
  - `libGLES_${chipset}`
  - `vulkan.${chipset}`
- What about dependencies? Both SP-HAL and their dependencies applies.



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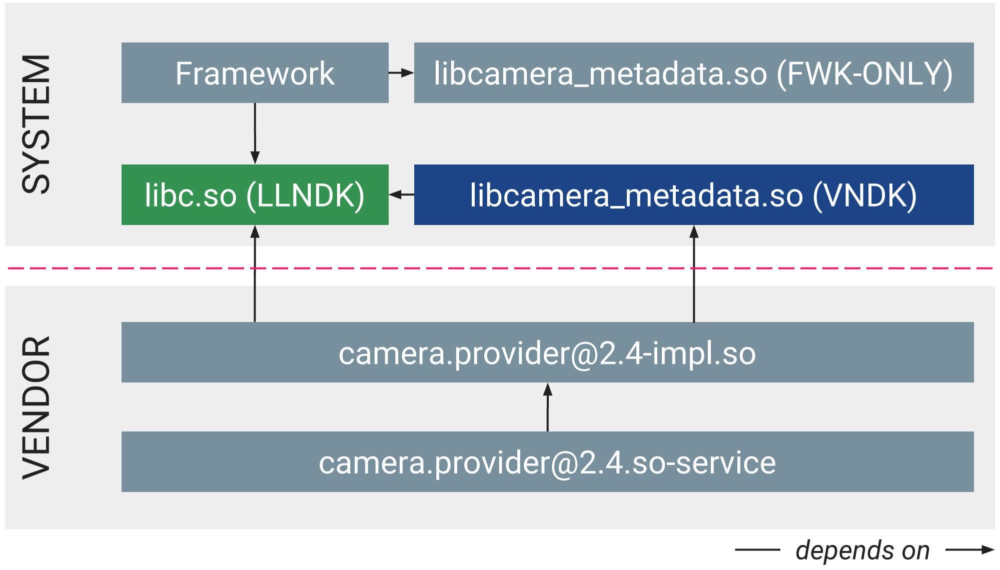
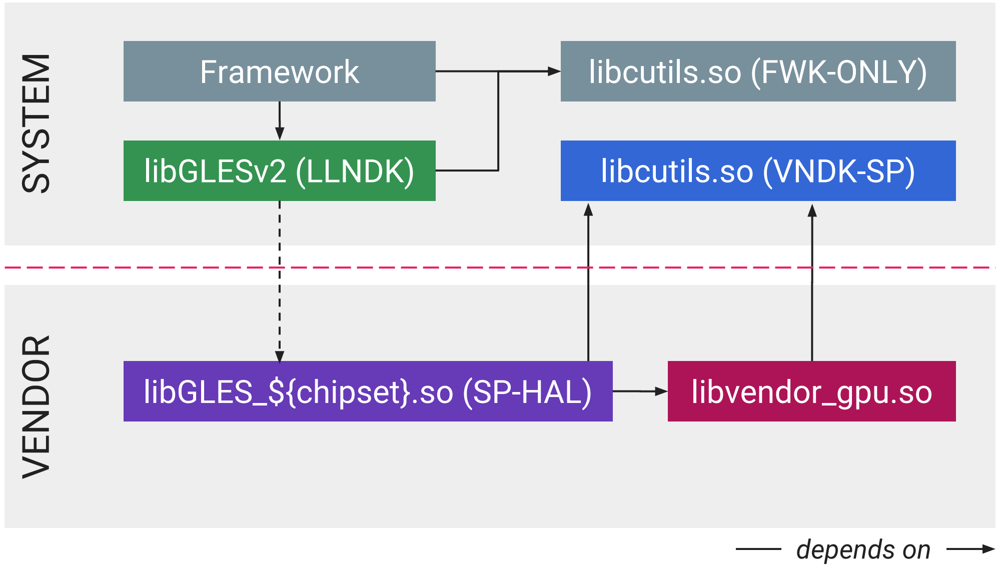
# VNDK categories

- **LLNDK** (LL-NDK + SP-NDK)
  - Shared libraries with stable APIs and loosely coupled with the framework
  - System and vendor share the same file
- **VNDK**
  - Specialized variant for vendor modules.
  - May be a FWK-ONLY counterpart with the same name
- **VNDK-SP**
  - Same as VNDK
  - Can be used by SP-HALs
  - May be loaded into framework process


SYSTEM
Framework
libcamera_metadata.so (FWK-ONLY)
libc.so (LLNDK)
libcamera_metadata.so (VNDK)
VENDOR
camera.provider@2.4-impl.so
camera.provider@2.4.so-service
depends on

# VNDK-SP: Dependency of Same-Process HAL

- SP-HAL must only depend on LLNDK or VNDK-SP (both SP-HAL and their dependencies apply).
- VNDK-SP and its FWK-ONLY counterpart (shared lib with same name) may be loaded into the same process.



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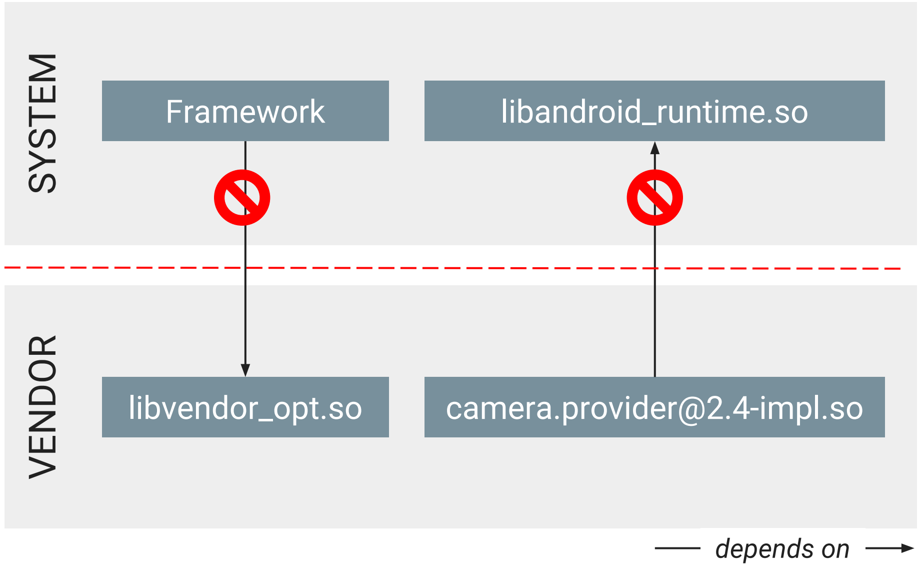
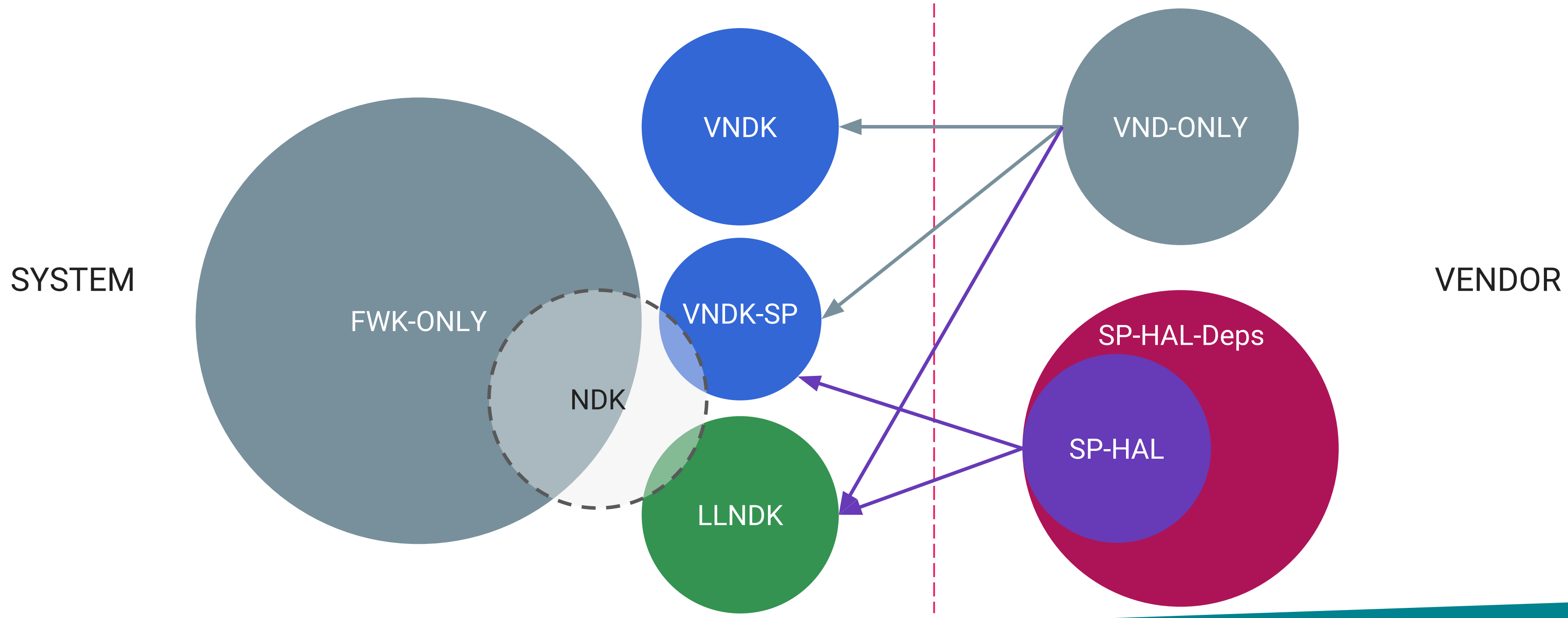
## Other categories

- **FWK-ONLY**
  - Other shared libraries on the system partition
  - Vendor modules must not depend on these libraries
- **VND-ONLY**
  - Other (i.e., non-SP-HAL) shared libraries on the vendor partition
  - Framework modules must not depend on these libraries

Cross-partition dependencies must be in LLNDK, VNDK, VNDK-SP, and SP-HAL (recommended in Android 8.1 and enforced in Android 9).



## Category relationships



## Category libraries

### LLNDK

**libEGL**
**libGLESv1_CM**
**libGLESv2**
**libGLESv3**
libRS
libandroid_net#
**libc**
**libdl**
**liblog**
**libm**
libnativewindow
libsync
libvndksupport#

*# LLNDK but not NDK*

### VNDK-SP

android.hardware.graphics.allocator@2.0
android.hardware.graphics.common@1.0
android.hardware.graphics.mapper@2.0
android.hardware.renderscript@1.0
android.hidl.memory@1.0
android.hidl.memory@1.0-impl
libRSCpuRef
libRSDriver
libRS_internal
libbacktrace
**libbase**
libbcinfo
libblas
**libc++**
libcompiler_rt
**libcutils**
libhardware
libhidlbase
libhidlmemory
libhidltransport
libhwbinder
libion
liblzma
libunwind
libunwindstack
**libutils**
libz*

** In some configurations, libz belongs to LLNDK but there should be no differences.*

Definitive list at /system/etc/ld.config.txt.

## Eligible list

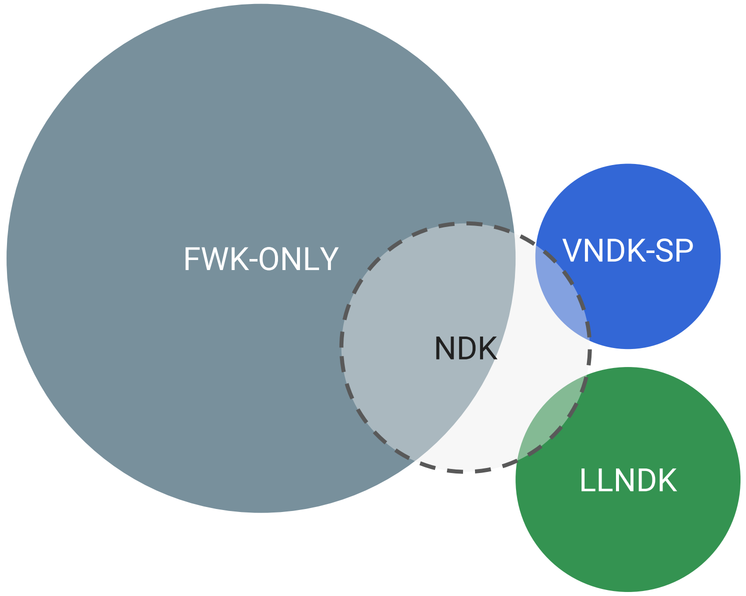
- List of shared libraries that have been reviewed.
- Found in: `${AOSP}/development/vndk/tools/definition-tool/datasets/eligible-list*.csv`

## Some NDK libs not visible to vendor modules

**libandroid.so**
libaaudio.so
libcamera2ndk.so
libicui18n.so
libicuuc.so
libjnigraphics.so
**libmediandk.so**
libneuralnetworks.so
libOpenMAXAL.so
libOpenSLES.so
**libstdc++.so***
libvulkan.so
libwebviewchromium_plat_support.so

These libraries are **highly coupled** with the framework, thus they do not belong to LLNDK.

Vendor modules must **not** depend on these shared libraries.



** Use libc++ instead of libstdc++.*

# VNDK extensions

- Vendor modules may need **extra APIs** or **extra functionalities** from the VNDK libraries.
- VNDK can be extended, but they must remain **ABI compatible** to the AOSP VNDK.
    - Symbols must not be removed.
    - Exposed structures must not be altered (including struct/class layout and vtable)
- **Goal is to ensure all extensions are drop-in replacements of the AOSP VNDK shared libraries.**

```c
struct Example {
  int a_;
  int bias_;
};

Example *example_create(int a) {
  Example *e =
    (Example *)malloc(sizeof(Example));
  e->a_ = a;
  e->bias_ = rand();
  return e;
}

int example_get_a(Example *e) {
  return e->a_ + e->bias_;
}
/* Extensions */
void example_set_bias(Example *e, int b) {
  e->bias_ = b;
}
```

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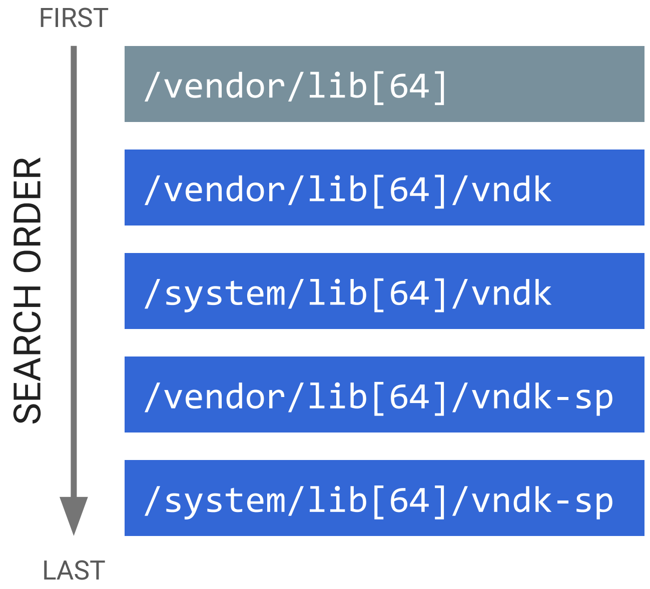
# Extended VNDK libraries

- Must be installed to `/vendor/lib[64]/{,vndk,vndk-sp}`
- Otherwise, vendor modules will fail **VTS** tests on **GSI**, which is required to pass compliance.
- Use as a **last resort** because extended VNDK shared libraries are not framework-only OTA updatable.
- **VNDK definition tool** can provide a preliminary set of libraries.



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## Degenerated VNDK (8.0) vs. Treble VNDK (8.1)

**Android 8.0 (O)** adopts the **degenerated VNDK directory layout**:

- VNDK-SP libraries have extra copies in `/system/lib[64]/vndk-sp`
- Both framework and vendor modules are using shared libraries in `/system/lib[64]`

**Android 8.1 (O MR1)** adopts the **Treble VNDK directory layout**:

- VNDK-SP libraries have extra copies in `/system/lib[64]/vndk-sp`
- VNDK libraries have extra copies `/system/lib[64]/vndk`
- Vendor modules are only using `/system/lib[64]/{vndk,vndk-sp}`
- Framework modules are only using `/system/lib[64]`

## Directory layout

| Category | Android 8.0 (O) | Android 8.1 (O MR1) | Independent System Updates |
|---|---|---|---|
| FWK-ONLY | /system/lib[64] | /system/lib[64] | Everything may change |
| LLNDK | /system/lib[64] | /system/lib[64] | New APIs or implementation |
| VNDK-SP | /system/lib[64]/vndk-sp | /system/lib[64]/vndk-sp | Old APIs with security fixes |
| VNDK-SP-EXT | /vendor/lib[64]/vndk-sp | /vendor/lib[64]/vndk-sp | N/A |
| VNDK | /system/lib[64] (degenerated) | /system/lib[64]/vndk | Old APIs with security fixes (only 8.1) |
| VNDK-EXT | /vendor/lib[64] | /vendor/lib[64]/vndk | N/A |
| VND-ONLY | /vendor/lib[64] | /vendor/lib[64] | N/A |

## Dynamic Linker Support

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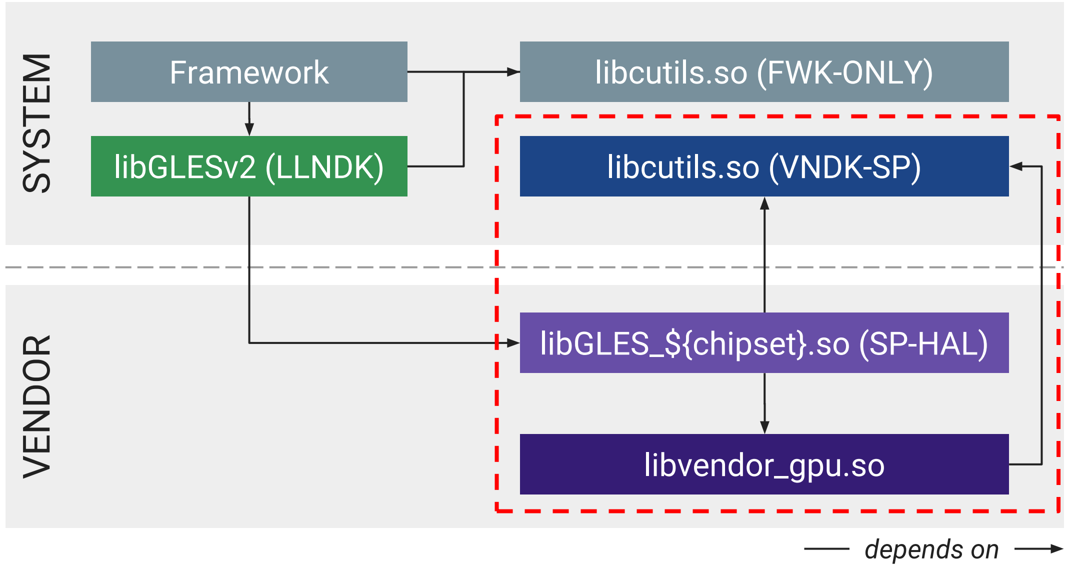
## Isolate SP-HAL and VNDK-SP

- SP-HAL from the vendor partition is loaded into framework processes; may depend on **VNDK-SP**.
- Framework modules may depend on **FWK-ONLY counterpart** (shared lib with same name with VNDK-SP).
- Loading two shared libraries with the same soname causes problems (libraries may have different symbols after updates).
- Enforced in Android 8.0 (O) (`PRODUCT_FULL_TREBLE:=true`)



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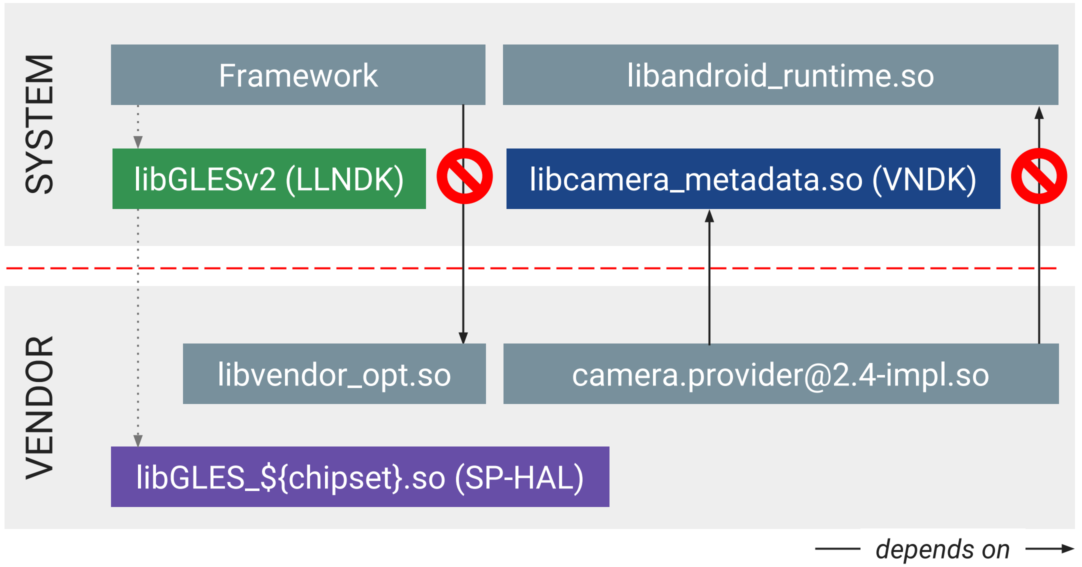
# Isolate system and vendor

- Isolate shared library dependencies. Dynamic linker should not load shared libraries from the other partition except VNDK or SP-HAL.
- Not enforced in Android 8.0
- Recommended in Android 8.1. If BOARD_VNDK_VERSION is specified, enforced by default; to disable, add `BOARD_VNDK_RUNTIME_DISABLE:=true`
- Enforced in **Android 9**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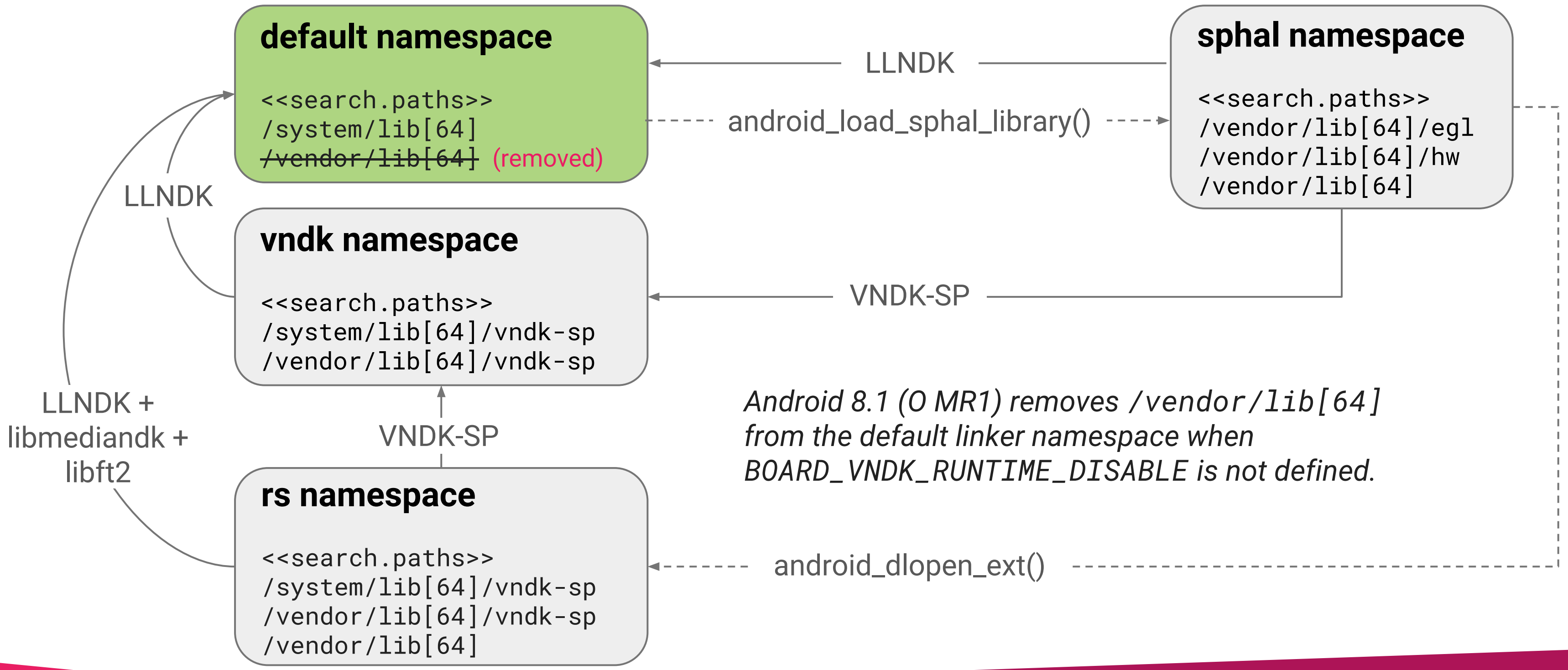
libGLESv2 (LLNDK)
libcamera_metadata.so (VNDK)
VENDOR
libvendor_opt.so
camera.provider@2.4-impl.so
libGLES_${chipset}.so (SP-HAL)
depends on

## Dynamic linker namespace

- **Dynamic linker** `/system/bin/linker[64]` is a part of Bionic that loads and links ELF shared objects at runtime. This program:
  - Is the first program being run after the kernel maps the executable into memory.
  - Is responsible to load `DT_NEEDED` entries and resolve undefined symbols.
  - Implements `dlopen()` and `android_dlopen_ext()`.
- **Dynamic linker namespace** is the underlying mechanism that **isolates SP-HALs and VNDK-SP**. This mechanism isolates shared libraries and provides fine-grained control on:
  - Dynamic **shared libraries** resolution
  - **symbol** resolution

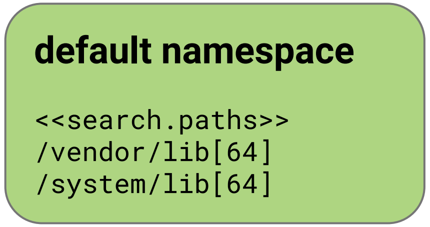
# Framework process linker namespaces (Android 8.1)



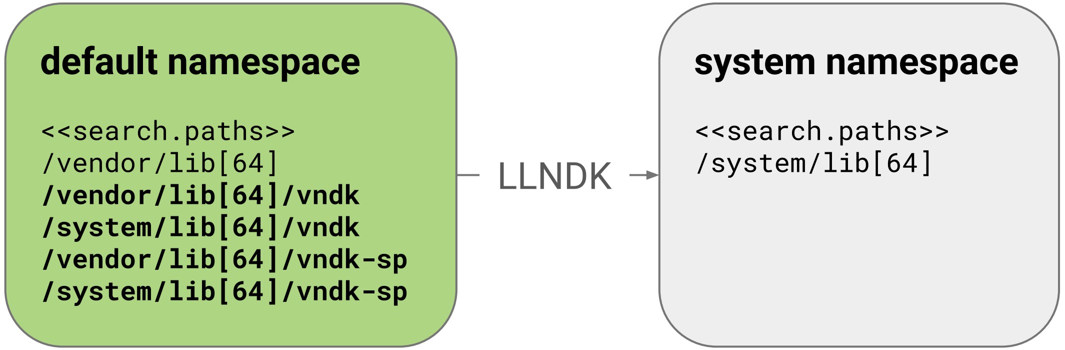
*Android 8.1 (O MR1) removes `/vendor/lib[64]` from the default linker namespace when `BOARD_VNDK_RUNTIME_DISABLE` is not defined.*

## Vendor process linker namespaces

- In Android 8.0 (O), `/system/lib[64]` is in the **default linker namespace** of vendor processes.



- In Android 8.1 (O MR1), `/system/lib[64]` is **removed** if `BOARD_VNDK_RUNTIME_DISABLE` is not defined.



## ld.config.txt

- Dynamic linker namespace is configured by `/system/etc/ld.config.txt`.
  - **INI file format**
  - Source code at `${AOSP}/system/core/rootdir/etc/ld.config*.txt`
- `ld.config.txt` must **not be modified**.
  - CTS verifies this file is intact.
  - Learning the file format can help in understanding how VNDK works.

## ld.config.txt structure

- `dir.name` assignments specify the section that will be chosen.
- For example, the `[system]` section is chosen if the main executable of the process resides in `/system/bin`.
- Each section represents a graph with:
  - **linker namespaces** as nodes
  - links for **fallback lookups**

```
dir.system = /system/bin
dir.vendor = /vendor/bin

[system]
additional.namespaces = sphal,vndk,rs

namespace.default.isolated = true
namespace.default.search.paths = …
namespace.default.permitted.paths = …

namespace.sphal.isolated = true
namespace.sphal.visible = true
namespace.sphal.search.paths = …
namespace.sphal.permitted.paths = …
namespace.sphal.link.default.shared_libs =

[vendor]
```

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# ld.config.txt namespace properties

**For each section**, `additional.namespaces` specifies the names of other linker namespaces in addition to the default namespace.

**For each linker namespace:**

- `isolated`.Whether `permitted.paths` is enforced
- `permitted.paths`. Permitted path (in addition to `search.paths`) when `isolated` is `true`.
- `search.paths`. Directories to search when dynamic linker resolves to an *soname**.
- `visible`. Whether namespace can be found by `android_get_exported_namespace()`.

```
dir.system = /system/bin
dir.vendor = /vendor/bin

[system]
additional.namespaces = sphal,vndk,rs

namespace.default.isolated = true
namespace.default.search.paths = …
namespace.default.permitted.paths = …

namespace.sphal.isolated = true
namespace.sphal.visible = true
namespace.sphal.search.paths = …
namespace.sphal.permitted.paths = …
namespace.sphal.link.default.shared_libs =

[vendor]
```

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** If someone passes a full path to dlopen(), search.paths is irrelevant.*

# ld.config.txt fallback links

- `namespace.${name}.link.${another}.shared_libs` specifies the *soname* that can go through the fallback link to the linker namespace `${another}`.
- If an *soname* cannot be resolved in linker namespace `${name}` and *soname* is one of the property values, the dynamic linker attempts to resolve the soname in the linker namespace `${another}`.
- Example: if `/vendor/lib/hw/vulkan.${chipset}.so` depends on `libc.so` but `libc.so` is neither in `/vendor/lib/hw` nor `/vendor/lib`, the dynamic linker attempts to find `libc.so` in the `default` namespace.

```
dir.system = /system/bin

[system]
additional.namespaces = sphal,vndk,rs

namespace.default.search.paths =
    /system/${LIB}

namespace.sphal.search.paths =
    /vendor/${LIB}/hw:/vendor/${LIB}

namespace.sphal.link.default.shared_libs =
    libc.so:libm.so
```

## Build System Support

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## Motivations

- **Duplicate shared libraries when necessary**
  - Build vendor variant for users in vendor partitions
  - VNDK, VNDK-SP may be duplicated when needed
- **Make the build dependencies explicit**
  - Check whether headers, static libraries, shared libraries are available
  - Define the VNDK libraries that have to be installed into Generic System Image (GSI)
  - Generate VNDK snapshots for cross version system image development

# Recap: VNDK categories

- **LLNDK** (LL-NDK + SP-NDK)
  - Shared libraries with stable APIs and loosely coupled with the framework
  - System and vendor share the same file
- **VNDK**
  - Specialized variant for vendor modules.
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- **VNDK-SP**
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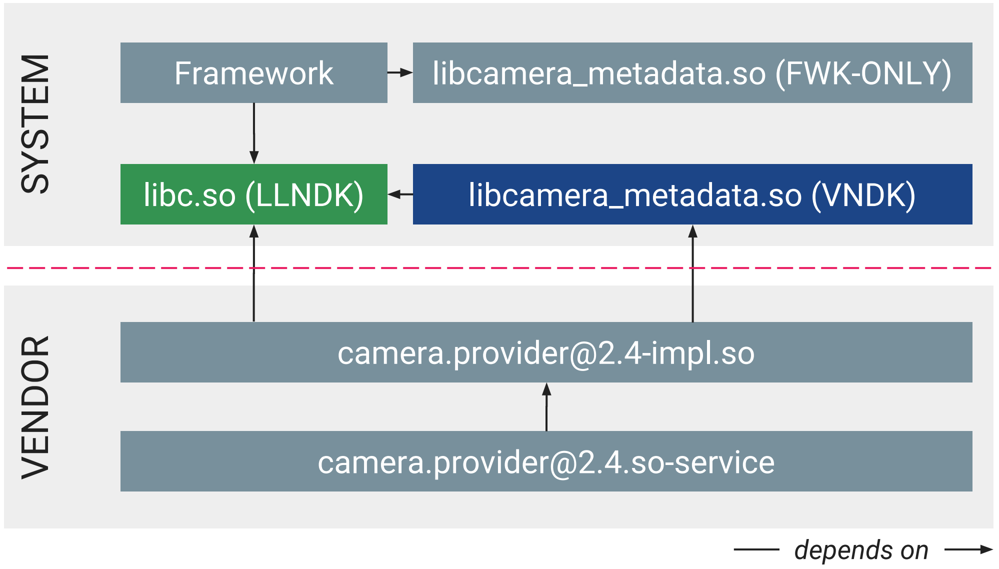
  - Can be used by SP-HALs
  - May be loaded into framework process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VENDOR
camera.provider@2.4-impl.so
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depends on

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# Build system support (Android 8.0)

- To move a module to vendor partition:
    - Add **LOCAL_VENDOR_MODULE:=true** to Android.mk (or LOCAL_PROPRIETARY_MODULE)
    - Add **vendor:true** to Android.bp (or proprietary)
- To install a module to **both system and vendor partitions**, you need tricky build rules (see right, assigns *intermediate files* to LOCAL_PREBUILT_MODULE_FILE).

```
define define-vndk-lib
include $$(CLEAR_VARS)
LOCAL_MODULE := $1.$2
LOCAL_MODULE_CLASS := SHARED_LIBRARIES
LOCAL_PREBUILT_MODULE_FILE := $$(TARGET_OUT_INTERMEDIATE_LIBRARIES)/$1.so
LOCAL_STRIP_MODULE := false
LOCAL_MULTILIB := first
LOCAL_MODULE_TAGS := optional
LOCAL_INSTALLED_MODULE_STEM := $1.so
LOCAL_MODULE_SUFFIX := .so
LOCAL_MODULE_RELATIVE_PATH := $3
LOCAL_VENDOR_MODULE := $4
include $$(BUILD_PREBUILT)

ifneq ($$(TARGET_2ND_ARCH),)
ifneq ($$(TARGET_TRANSLATE_2ND_ARCH),true)
include $$(CLEAR_VARS)
LOCAL_MODULE := $1.$2
LOCAL_MODULE_CLASS := SHARED_LIBRARIES
LOCAL_PREBUILT_MODULE_FILE :=
$$($$(TARGET_2ND_ARCH_VAR_PREFIX)TARGET_OUT_INTERMEDIATE_LIBRARIES)/$1.so
LOCAL_STRIP_MODULE := false
LOCAL_MULTILIB := 32
LOCAL_MODULE_TAGS := optional
LOCAL_INSTALLED_MODULE_STEM := $1.so
LOCAL_MODULE_SUFFIX := .so
LOCAL_MODULE_RELATIVE_PATH := $3
LOCAL_VENDOR_MODULE := $4
include $$(BUILD_PREBUILT)
endif  # TARGET_TRANSLATE_2ND_ARCH is not true
endif  # TARGET_2ND_ARCH is not empty
endef
```

# Build system support (Android 8.1)

- **BOARD_VNDK_VERSION := current** enables full VNDK support.
- If **BOARD_VNDK_VERSION := current** is specified in BoardConfig.mk, the build system:
    - Checks the header search path (and removes global default search paths).
    - Checks the link types of the shared libraries (i.e. vendor module can link only to LLNDK or vendor_available).
    - Builds vendor-specific VNDK libraries and install them to `/system/lib[64]/{vndk,vndk-sp}`.
    - Builds vendor-specific libraries and install them to `/vendor/lib[64]`.

VNDK-related properties in Android.bp:

- `vendor: true`
- `vendor_available: true`
- `vndk.enabled: true`
- `vndk.support_system_process: true`

# vendor & vendor_available (Android 8.1)

- **vendor** specifies whether an Android.bp module is an vendor module or not.
  - If false, it cannot depend on the module with vendor equal to true.
  - If true, it can depend only on LLNDK or the module with `vendor_available` equal to true.
- **vendor_available** specifies whether an Android.bp module (header lib, static lib, or shared lib) is available to vendor.
  - If true and a **framework module** uses this module, the module is installed to the system partition.
  - If true and a **vendor module** uses this module, the vendor variant is built.
    - If `vndk.enabled` is `false` (or undefined), the module is installed to `/vendor/lib[64]`.
    - If `vndk.enabled` is `true`, the module is installed to `/system/lib[64]/vndk` or `/system/lib[64]/vndk-sp`.

## VNDK section (Android 8.1)

- **vndk.enabled** specifies whether an Android.bp module is a VNDK library or not. It is a prerequisite to set `vendor_available` to true.
- **vndk.support_system_process** specifies whether an Android.bp module is a VNDK-SP library or not. Both `vendor_available` and `vndk.enabled` are prerequisites.

```
cc_library {
    name: "libvendor_available",
    vendor_available: true,
}
cc_library {
    name: "libvndk",
    vendor_available: true,
    vndk: {
        enabled: true,
    },
}
cc_library {
    name: "libvndksp",
    vendor_available: true,
    vndk: {
        enabled: true,
        support_system_process: true,
    },
}
```

## target.vendor (8.1)

- `target.vendor` specifies vendor-specific build options.
    - Use the `exclude_srcs` property to exclude framework-specific source files.
    - Use the `exclude_shared_libs` property to exclude framework-specific shared libraries.

```
cc_library {
  name: "libvnd_specific_example",
  vendor_available: true,
  target: {
    vendor: {
      exclude_srcs: ["framework_only.c"],
      exclude_shared_libs: ["libfwk_only"],
      cflags: ["-DEXTRA_VND_C_FLAGS"],
      cppflags: ["-DEXTRA_VND_CPP_FLAGS"],
    },
  },
}
```

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## Build support summary

- Define a vendor module which must be installed to vendor partition
  - `LOCAL_VENDOR_MODULE := true (Android.mk)`
  - `vendor: true` (Android.bp)
- Enable full VNDK build-time support (Android 8.1)
  - `BOARD_VNDK_VERSION := current (BoardConfig.mk)`
  - Build two variants: `vendor_available: true`
  - VNDK: `vndk.enabled: true`
  - VNDK-SP: `vndk.support_system_process: true`
- Disable runtime dynamic linker isolation between framework and vendor (Android 8.1)
  - `BOARD_VNDK_RUNTIME_DISABLE := true` (BoardConfig.mk)

## VNDK Definition Tool

## VNDK definition tool

- Scans the shared library dependencies
- Computes VNDK sets
- Checks for dependency violations
- Source at:
  `${AOSP}/development/vndk/tools/definition-tool/vndk_definition_tool.py`

## Commands

- **vndk**. List VNDK libraries and other libraries that should be copied to vendor partitions.
- **check-dep**. Check for violations in shared library dependencies.
- **deps**. Print all resolved dependencies of shared libraries.
- **deps-insight**. Create HTML to show shared library dependencies.

## vndk

- Lists VNDK-SP libraries and other libraries that should be copied to vendor partitions.
- Command line options:
  - **`--system`**: Path to your system partition directory.
  - **`--vendor`**: Path to your vendor partition directory.
  - **`--aosp-system`**: Path to GSI system partition directory (convert image with simg2img then mount).
  - **`--tag-file`**: Path to eligible list CSV file.
  - **`--load-extra-deps`**: Path to file specifying extra shared library dependencies.
  - **`--full`**: List all categories (for debugging).

```
vndk_definition_tool.py vndk \
  --system path/system \
  --vendor path/vendor \
  --aosp-system path/gsi/system \
  --tag-file eligible-list.csv \
  --load-extra-deps deps.txt
```

```
vndk_sp:
/system/lib/vndk-sp/libcutils.so

vndk_sp_ext:
/vendor/lib/vndk-sp/libion.so

extra_vendor_libs:
/vendor/lib/libvendor.so
```

## check-dep

- Checks the dependencies and list the violating shared libraries and symbols.
- VNDK command line options plus:
    - **`--module-info`**: Path to `${ANDROID_PRODUCT_OUT}/module-info.json`
- Prints the following info or each violation:
    - Violating module and source path
    - Ineligible dependencies and source paths
    - Imported symbols from ineligible dependencies

```
vndk_definition_tool.py check-dep \
  --system path/system \
  --vendor path/vendor \
  --aosp-system path/gsi/system \
  --tag-file eligible-list.csv \
  --load-extra-deps deps.txt \
  --module-info module-info.json
```

```
/vendor/lib/libviolating.so
    MODULE_PATH: libviolating/source
    /system/lib/libineligible1.so
        MODULE_PATH: ineligible1/source
        symbol_a
        symbol_b
    /system/lib/libineligible2.so
        MODULE_PATH: ineligible2/source
        symbol_c
```

# deps and deps-insight

- Debugging commands that print dependencies of shared libraries.
- **deps** prints plain text output
- **deps-insight** generates HTML for interactive investigation.
- Command line options are similar to the `check-dep` commands.

```
vndk_definition_tool.py deps \
  --system path/system \
  --vendor path/vendor \
  --load-extra-deps deps.txt \
  --module-info module-info.json
```

```
vndk_definition_tool.py deps-insight \
  --system path/system \
  --vendor path/vendor \
  --aosp-system path/gsi/system \
  --tag-file eligible-list.csv \
  --load-extra-deps deps.txt \
  --module-info module-info.json
```

## JNI Libraries in Bundled APKs

# JNI libraries in bundled apps (Android 8.1)

| Shared libraries location | Bundled system app `/system/app` | Bundled vendor app `/vendor/app` | Downloaded app `/data/app` |
|---|---|---|---|
| `/system/lib[64]` | All | `/system/etc/public.libraries.txt` (NDK) + LLNDK | `/system/etc/public.libraries.txt` (NDK) |
| `/vendor/lib[64]` | `/vendor/etc/public.libraries.txt` | All | `/vendor/etc/public.libraries.txt` |
| `/system/lib[64]/vndk-sp` | x | Public VNDK-SP | x |
| `/system/lib[64]/vndk` | x | x | x |