

UPSTREAM

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Android* Software Updates

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Agenda

- Introduction
- Filesystem Configuration
- Releasetools
- Recovery Console
- Updater
- SW Update Lifecycle
- Wrap-up

INTRODUCTION

Capabilities

- Full Image SW Updates
 - Updates from any compatible prior SW version
 - At creation time, can set flag to enforce rollback protection; older SW versions cannot be installed on top of newer ones
- Incremental SW Updates
 - `bsdiff` patching on a per-file basis for contents of /system and boot images
 - Typically much smaller than a full image update
- Updates all partitions and boot images
 - Extensible to update special firmware or baseband software via plug-ins
- ASLR
 - Address Space Layout Randomization
 - Binaries written to the device during update are 'retouched'
- Update zip files have embedded digital signature
 - verified by `android.os.RecoverySystem.verifyPackage()` API and also the RC
- Safely restartable in the event of a power loss
 - Patched files are swapped with originals with `rename()`
 - Device keeps booting into RC until process is complete
 - RC itself updated after SW update is done and booted into new Android image via oneshot `flash-recovery init` service
- At creation time, updates can be configured to force Factory Data Reset in case update has incompatible userdata
 - In a perfect world, only used during development, end users will hate you
- *Updater* program which actually applies the update lives inside the signed SW update package and not on the device

AOSP Software Update Components

- Releasetools
 - Create digitally signed software updates from a target-files-package (TFP)
 - TFP generated by Android* build system
 - Substitute testing for production keys inside a TFP
- android.os.RecoverySystem APIs
 - Framework APIs to verify & install SW updates
 - Handles verification of OTA update digital signature
 - Writes RC command files into /cache/recovery and reboots into Recovery Console
 - Also used to engage Factory Data Reset
- Recovery Console (RC)
 - Alternate boot environment
 - Verify & Apply SW updates
 - Perform Factory Data Reset
 - Typically controlled by command files left by RecoverySystem APIs
 - Hidden menu for manual interaction
- Updater
 - SW update logic, binary inside SW update package
 - AOSP implementation runs script in Edify language
 - Platform-specific tasks implemented in plug-ins
- SW Update UI intent from Settings application

Missing Pieces

- Not all components for an end-to-end solution are open source
 - Remote server backend to host updates (the Server)
 - Client-side mechanism to check and download updates (the Fetcher)
 - Client-side notification UI that SW Updates are available (the Notifier)
- Clearly defined layers of abstraction should make these more or less drop-in
 - Only the server and fetcher care about OTA protocol unless part of a larger device management framework like OMA-DM
 - Fetcher/Notifier in most cases the same APK
 - Works with rest of the SW Update system via `android.os.RecoverySystem` APIs
 - Settings app integration:
 - Notifier APK should have activity with intent filter for `android.settings.SYSTEM_UPDATE_SETTINGS` to check for updates
 - Launched when user clicks About tablet -> System Updates
 - BootReceiver to check for RC messages in `/cache/recovery`
 - No other framework modifications should be necessary
 - Any vendor that proposes invasively hacking up the framework to support OTA should be regarded with extreme suspicion unless they are doing OMA-DM

Limitations

- No support for disk re-partitioning
 - Leave lots of slack space in `/system` for future Android releases
 - Leave slack space in `boot` and `recovery` partitions for future boot images
 - `/cache` should be large enough to hold a compressed SW update, two-thirds of `/system` size to be safe
- One update applied at a time
- Device can't be used while updates are applied

FILESYSTEM CONFIGURATION

Partition Layout

- boot
 - AOSP boot image
 - Linux kernel and ramdisk mounted as root filesystem
 - Contains *init* and essential tools to mount `/system` and boot the rest of Android
- system
 - All Android system applications and libraries
 - Always mounted read-only except in context of an OTA update
 - Incremental updates depend on `/system` being in a specific state
- data
 - Downloaded applications
 - Application data
 - Dalvik cache
 - Typically not touched by OTA updates
 - Erased by Factory Data Reset

Partition Layout (continued)

- `recovery`
 - Alternate AOSP boot image
 - Ramdisk contains 'recovery' program which is the RC implementation
- `misc`
 - Very small size, does not contain a filesystem
 - Has Bootloader Control Block (BCB) written directly to the block device node
 - Used to communicate between RC and the bootloader
- `cache`
 - Temporary storage, contents can be erased at any time
 - Used by some applications as a temporary storage/download area
 - Requires special APK permissions
 - Downloaded OTA updates stored here
 - Used as temporary storage by *applypatch*
 - Erased during Factory Data Reset

Android Boot Images

- Container file format, with metadata, kernel image, ramdisk, and optional 2nd-stage bootloader image
- Created by `system/core/mkbootimg`
- Used in two places
 - Called by the build system to create boot images in `$OUT` as part of a normal build
 - Also created by *Releasetools* when assembling an OTA update from a target-files-package
- Projects that have special boot image types should override/extend *mkbootimg*

recovery.fstab

- Specification file for all the **filesystems** on the device
 - Not a partitioning specification, no offset/ordering/partition size information
- Used by RC and *Releasetools*
- Maps mount points to device nodes and filesystem types
- **length=** argument to specify filesystem size (not partition)
 - Defaults to fill partition when formatted by RC
 - Negative argument fills partition minus specified amount, typically used to leave 16K at the end of /data to support encryption
 - Otherwise, format the partition to specified size

Software Update Creation

RELEASETOOLS

Target-Files-Package (TFP)

- Created by `'make target-files-package'`
 - Build logic in `build/core/Makefile`
- Zip file containing snapshot of a particular SW release, everything needed to create an OTA update
 - A single TFP used to create a full image update
 - Two TFPs used to create an incremental update
- Add additional device-specific blobs by defining “radio files”
 - Seems to be a legacy name, doesn't necessarily have anything to with device's radio
 - In `AndroidBoard.mk`:
 - `$(call add-radio-file,myblob.dat)`
 - Ends up in `target-files-package` in `RADIO/` directory
 - Platform-specific extensions to *Releasetools* will handle these files

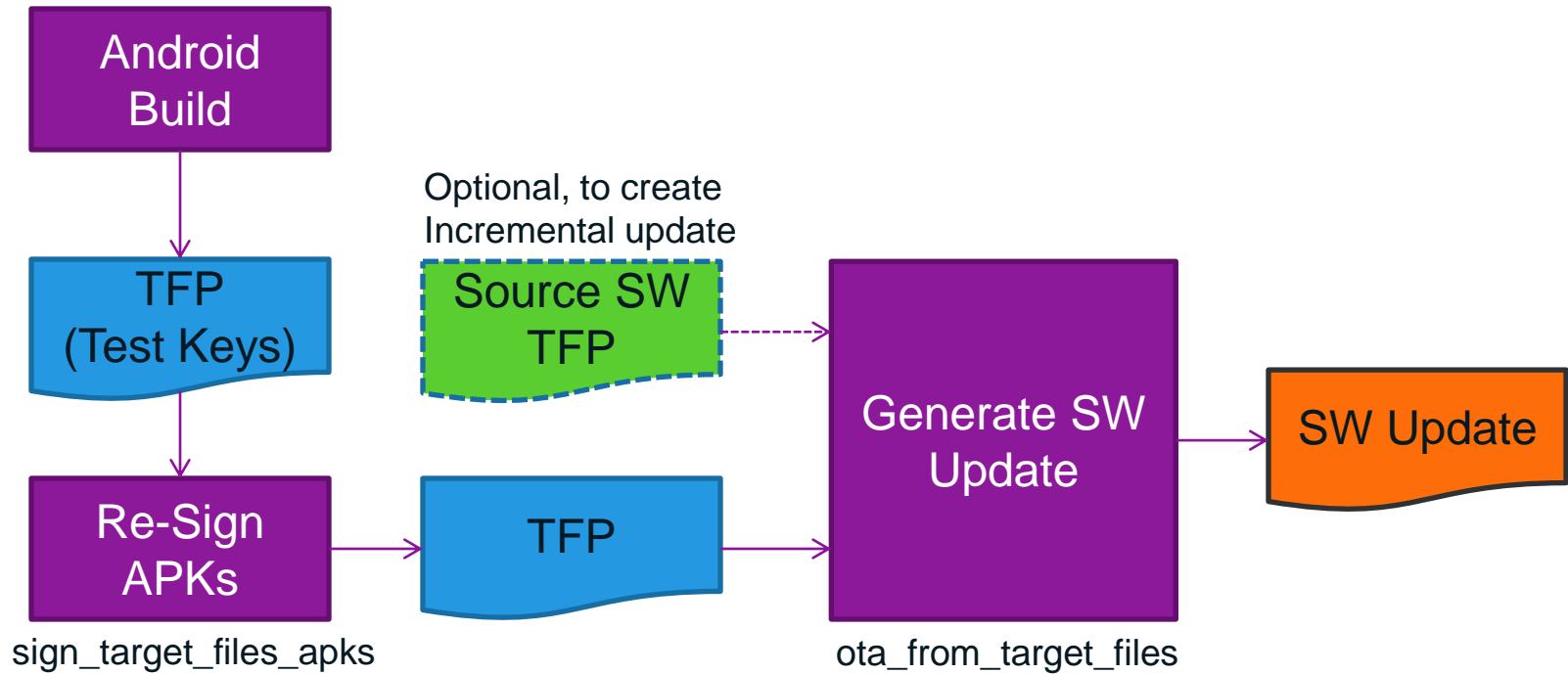
Android Security

- All APKs are digitally signed
 - Updates to the same application must be signed by the same key otherwise app data will be inaccessible
 - Apps that want to share the same user ID must be signed with the same key
 - LOCAL_CERTIFICATE specifies the key; defaults to **testkey**
- OTA updates will be discarded if not signed with one of the expected keys
- AOSP has four keys in build/target/product/security
 - Testkey: Default key to sign APKs
 - Platform: Core platform packages are signed with this
 - Shared: Data sharing between Home and Contacts processes
 - Media: Packages in the media/download system
- 2048-bit RSA keys with public exponent 3. Created with *openssl*
- Cannot ship a product with the AOSP keys that are in the build
 - Test keys should only be used during development, enforced by CTS case
 - `sign_target_files_apks` tool in *Releasetools* used to swap out the AOSP test keys in the TFP with the real production keys
 - Re-signs all APK files with new keys
 - Swaps out OTA verification key in RC ramdisk

ota_from_target_files

- Lives with the rest of the *Releasetools* in `build/tools/releasetools`
- Script to create OTA updates from one or more TFPs. Some useful options:
 - `--incremental-from <TFP>`
 - creates an incremental update from a source TFP
 - `--wipe-user-data`
 - OTA package will erase /data when installed
 - `--no_prereq`
 - Disable rollback protection checks
 - `--package_key`
 - Key to use to sign the package; defaults to testkey
- For most platform-specific update tasks, Python extensions can be implemented to perform additional tasks in the update
- Creates a SW update package containing all images, *updater* binary, and Edify script that *updater* interprets to apply the SW update
- TFP not normally contain built boot images
 - Boot image components included (bzImage, ramdisk contents, 2nd-stage bootloader) so that `ota_from_target_files` can generate them
 - Intermediate step: `sign_target_files_apks` modifies TFP to substitute test keys with production keys
 - `GetBootableImage()` does look for prebuilt boot images under `BOOTABLE_IMAGES/` in the TFP, but no way to substitute the OTA keys in a prebuilt RC boot image with `sign_target_files_apks`!
 - No support in build system, would have to manually place in TFP
 - Would have to build them with production keys already inside RC ramdisk

SW Update Creation



Releasetools Extensions

- “Radio files” specified in `AndroidBoard.mk` will be populated in the TFP
- To extend *Releasetools* to work with these files, create a Python module with the following functions
 - `FullOTA_Assertions()`
 - Called after emitting the block of assertions at the top of a full OTA package
 - `FullOTA_InstallEnd()`
 - Called at the end of full OTA installation
 - `IncrementalOTA_Assertions()`
 - Called after emitting the block of assertions at the top of an incremental OTA package
 - `IncrementalOTA_VerifyEnd()`
 - Called at the end of the verification phase of incremental OTA installation; put checks here to abort the script before any changes are made
 - `IncrementalOTA_InstallEnd()`
 - Called at the end of incremental OTA installation
 - All functions passed an ‘info’ option which has pointers to
 - `zipfile.ZipFile` objects for source and target TFPs, output zip file. Used to move files or create patches from TFPs and place inside the SW update
 - Script object to append additional Edify script commands
 - Use `ota_from_target_files` code as a guide
- Put path to this module in `TARGET_RELEASETOOLS_EXTENSIONS` in `BoardConfig.mk`
- Relevant `ota_from_target_files` options
 - `--device_specific` path to *Releasetools* extension module
 - `--extra` to pass additional key/value pairs accessible by *Releasetools* extension
 - `--extra_script` to directly add commands to the generated *updater* Edify script

Other Releasetools

- `img_from_target_files`
 - TFP as input
 - Produces an image zipfile suitable for use with 'fastboot update'
 - Might be better to have *Fastboot* accept a real SW update and reboot into RC to apply it
- `check_target_files_signatures`
 - Looks for problems with package signatures inside a TFP
 - Can be used to check for compatibility problems between two TFPs (key changes, etc.)

SW Update Alternate Boot Environment

RECOVERY CONSOLE (RC)

Recovery Console

- Alternate boot image, a few ways to enter
 - `reboot recovery` from a shell
 - `RecoverySystem` APIs in Android Framework
 - OEMs often implement a bootloader ‘magic key’
- Pictorial interface, no localization
- Hidden non-localized menu for manual tasks
 - Factory Data Reset
 - Find and select SW update on SD Card
 - Other platform-specific tasks as implemented in Recovery Console UI plug-in
- Log files saved in `/cache/recovery`
 - All stdout/stderr from RC and *Updater*
 - Edify `ui_print()` commands

/misc and the BCB

- Tiny partition used for communication between *RC* and bootloader, and for RC to save state information
- Contains **Bootloader Control Block (BCB)**
 - `command[32]`: Commands for the bootloader
 - “boot-recovery” boot into RC instead of Android
 - Other platform-specific commands may be implemented for update tasks that must be done by the bootloader
 - If empty, garbage, or no known commands matched, normal Android boot
 - `status[32]`: Return status field written by bootloader after performing platform-specific commands
 - No specification, platform-dependent
 - `recovery[1024]`: Command line for Recovery Console
 - Arguments tokenized by ‘\n’
 - Invalid if first argument not ‘recovery’

Recovery Console Control

- Comments at the beginning of `bootable/recovery/recovery.c` are out of date
- Upon startup, looks for command line arguments in decreasing precedence:
 - Actual command line to 'recovery', debug-only scenario
 - `BCB.recovery`
 - Command file in `/cache/recovery/command` (written by RecoverySystem APIs)
 - RecoverySystem doesn't write to BCB due to permissions on doing raw block device I/O
- Always copies arguments into `BCB.recovery` and sets `BCB.command` to "boot-recovery"
 - Makes sure we keep booting into RC with the same arguments in event of unexpected power loss
 - Don't rely solely on `/cache/recovery/command` for this
- `finish_recovery()`
 - Called when requested operations (SW update, factory data reset, etc) are complete, whether successful or failed
 - BCB is cleared so that subsequent reboot goes back into Android
 - Copies all logs to `/cache/recovery/`
 - If no arguments were given to RC, displays error image and waits for menu input
- A divergent update process is **very very bad**, should always at some point complete so that `finish_recovery()` can be called
 - Else the device will get stuck, user resets it, gets stuck again, can never boot back into Android

Bootloader Integration

- Linux kernel should write “`boot-recovery`” into `BCB.command` and zero out `BCB.recovery` if “`recovery`” is supplied as a `reboot()` argument
 - Implement in a driver via `register_reboot_notifier()`
- Bootloader selects boot image (or other task) based on `BCB.command`
 - `BCB.command` is persistent; keep booting into RC until RC clears it
 - Garbage or zeroed out contents should simply boot into Android

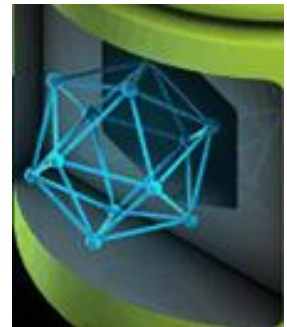
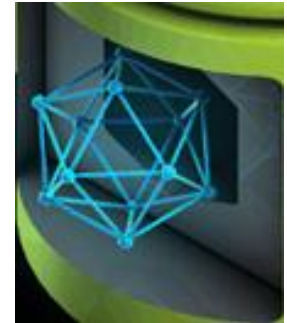
Recovery Console UI Plug-in

- Device-specific policy and extensions for RC
 - Copy `bootable/recovery/default_recovery_ui.c` into your `$(TARGET_DEVICE_DIR)` space and create as a static library
 - Set `TARGET_RECOVERY_UI_LIB` in `BoardConfig.mk` to the `$(LOCAL_MODULE)` for this library
- Capabilities
 - Define additional menu items
 - Customize `MENU_ITEMS[]` and add logic to `device_perform_action()`
 - Extra device wiping code implemented in `device_wipe_data()`
 - Customization of branding graphics done in `device_ui_init()`
 - Additional initialization tasks in `device_recovery_start()`
 - Customize effect of keystrokes with `device_handle_key()`
 - Key chords can be implemented by additionally checking `ui_key_pressed(code)`
 - Implementation of device-specific commands in `device_perform_action()`
 - Policy on whether to show the hidden RC menu in `device_toggle_display()`
 - Policy on whether to reboot on key press in `device_reboot_now()`

Recovery Branding

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- Image-only GUI; in case of a problem user must call customer care
- Built-in images can be replaced by putting images in `$(TARGET_DEVICE_DIR)/recovery/res`
 - Must be 8-bit PNGs in RGB or RGBA format
 - Keep same filenames
- Number of animation frames for items, offsets, etc., can be set in `UIParameters` struct passed to `device_ui_init()` in UI plug-in
- `bootable/recovery/make-overlay.py` script helps create the base image plus overlay frames and computed offsets for animations



UPDATER

Updater binary

- Lives inside the SW update zip
 - No need for security checks since signature of SW update has been verified
 - Nice to have this in the zip so that all SW update implementation code doesn't need to exist a priori
- Not strictly required to use the *updater* implementation in AOSP
 - RC fork/execs *updater* and communicates via pipe
 - RC passes in 3 arguments
 - RC API version (currently 3)
 - file descriptor for communication pipe
 - path to the SW update zip file
 - *Updater* writes string commands over the pipe to set progress bar parameters or print strings to the hidden Recovery UI; see `bootable/recovery/install.c`
- AOSP implementation interprets a script inside the SW update written in Edify language
- Platform-specific *updater* capabilities implemented in plug-ins
- **Be sure *updater* terminates!** Corner cases where it doesn't terminate effectively bricks the device

Recovery From Boot

- RC itself is not updated during the course of a SW update
 - Makes sure that the same RC (from the source SW version) is used throughout the update even if power lost
 - Useful for key revocation scenarios
- Oneshot init.rc service `flash_recovery`
 - Runs `/system/etc/install-recovery`
 - Checks SHA1 of Recovery image to detect whether it needs to be patched
 - No-op if matches patched SHA1
 - Applies a patch to the boot image to create the RC image, which is written to the recovery partition

Applypatch

- Used by incremental updates to patch /system files and boot images
- When calculating binary diffs, is able to detect compressed file headers and break files into chunks
 - For gzip, does not work well unless file was compressed with same version of deflate() algorithm that it has access to
 - 'gzip' has a much older deflate() than zlib (gzip does not link against zlib, it is self-contained)
 - Hence all ramdisks should be compressed with zlib-linked 'minigzip' and so should bzImages
 - May have to hack your kernel build to use minigzip instead of gzip
- Uses bsdiff algorithm
 - Bsdiffs can take a while to compute
 - In particular, diffs of files that both contain large regions of all 0s elicits worst-case $O(n^2)$ performance – don't diff padding!

Edify Language

- Scripting language to specify SW update tasks
- Everything is an *expression*
 - Expressions evaluate to strings
 - ; operator is a sequence point, value returned is right side
 - Boolean operators supported, concatenation, equality
 - `if ... then ... else ... endif` and `if ... then ... endif` blocks
 - Empty string is Boolean “false”, all other strings are “true”
 - Functions return expressions and take expressions as arguments
 - No language support for loops
 - Short-circuiting `&&` and `||` operators
- All functions implemented in C, cannot declare functions in an Edify script
- Implementations for built-in Edify functions in `bootable/recovery/updater/install.c`
 - Use this code as a guide when implementing your own functions
- Additional functions implemented in plug-ins\
- See `bootable/recovery/edify/README` for language specification

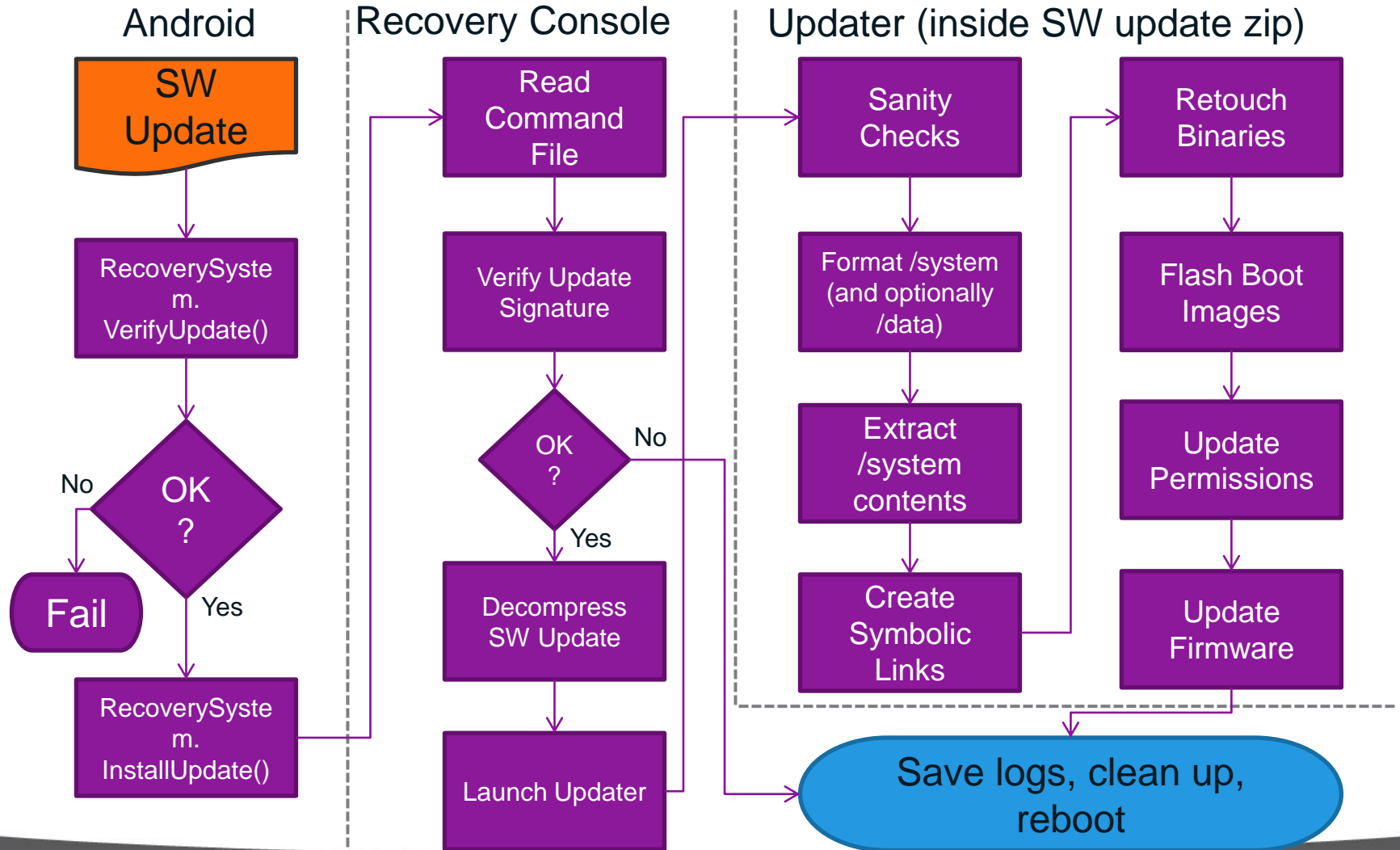
Updater Plug-ins

- Multiple updater libraries can be defined
 - Create a static library in Android build in device-specific area
 - Put module names in BoardConfig.mk `TARGET_RECOVERY_UPDATER_LIBS`
 - Each library needs a registration function, which gets called by *Updater* when it starts up
 - `void Register_$LOCAL_MODULE()`
 - Calls `RegisterFunction()` for each new Edify command
 - Use `bootable/recovery/updater/install.c` as a guide
 - Additional supporting static libraries can be added to updater by putting their module names in `TARGET_RECOVERY_UPDATER_EXTRA_LIBS`
- Edify API defined in `bootable/recovery/edify/expr.h`

Putting It All Together

SW UPDATE LIFECYCLE

SW Update Application (Full Image)



WRAP-UP

Productization Tasks

- Define recovery.fstab
- Add platform-specific blobs via “radio files” Makefile directives
- Implement RC UI plug-in
 - Add branding images if necessary
 - Add platform-specific tasks
 - Map the buttons how you want them
 - Additional tasks for Factory Data Reset
- Implement *Updater* plug-in
 - Implement Edify commands in C for platform-specific update tasks
- Implement *Releasetools* extensions
 - Add logic to patch or add RADIO/ images to the OTA update
 - Add Edify commands to handle them in updater script
 - Add additional assertions/verification steps as needed
- Add BoardConfig.mk variables to declare all plugins/extensions and supporting libraries
- Hook up download agent to Settings application via intent filter
- Kernel/Bootloader integration to use BCB
- Generate production keys
- Shouldn't need to modify the Android framework, build/core, or bootable/recovery
- Have a GOOD ongoing test plan and dogfood as much as possible

Tips

- Firmware updating
 - If FW image can be read back at runtime:
 - Read FW image and save to a file
 - Apply binary patch with applypatch
 - Flash it back
 - Otherwise:
 - Put the firmware image somewhere on /system
 - Will get patched with everything else on /system during the update
 - Query current FW version, compare to version living on /system
 - If different flash it
 - For FW that affects device boot, make sure FW flashing is safely restartable!
- You should not have to modify the RC, do all your extensions in plug-ins
 - Rule of thumb for all Android platform development: don't change the framework unless you have a really good reason to do so
 - If you do modify Android, do so with upstreaming in mind
- Incremental updates assume /cache is mounted
 - No explicit guarantees that RC will mount it for you
 - Seems to be a bug in ota_from_target_files, add script.Mount("/cache") right before script.CacheFreeSpaceCheck()
- Testing, testing, testing!!!!
 - Create SW update packages in your internal releases and make people (field testers, QA, developers) use them
 - Automated testing is also your friend
 - Buildbot, Jenkins, etc
 - Software update is the one mechanism on the device that *has* to work
 - Fortunately *Updater* is in the SW update package and not on the device

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