Android OTA Updates

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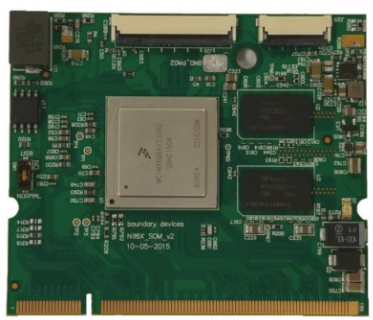
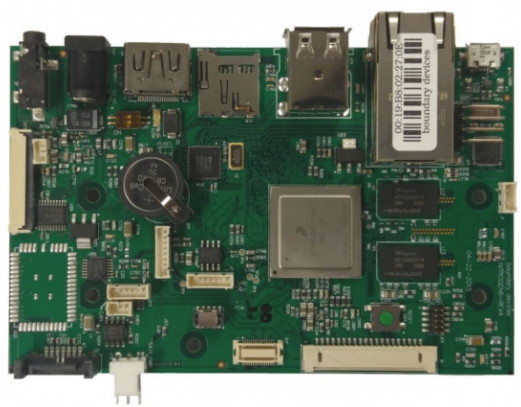
ABOUT BOUNDARY DEVICES

- Founded in **2003**
- Designs and manufactures **ARM-based** Single Board Computers (**SBC**) and System on Modules (**SoM**)
- Targets the general embedded market
- Focus on **customer service** and **fast turn-around time**
- Reference platforms & **custom designs**
- 16,000 Square Foot Facility in **Chandler, AZ**





Introduction

WHY ARE WE HERE?

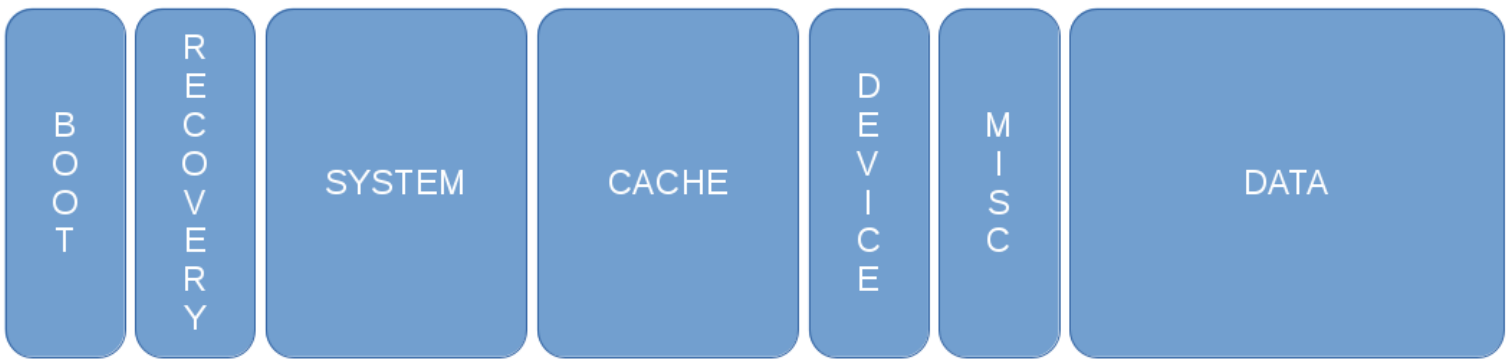
- Importance of OTA updates in the field
- Cover all aspects
  - From update creation to download to flashing
- Past experiences
  - Customers/Users feedback
- Practical approach
  - i.MX awareness
  - Demonstration on actual HW

DEMO ON HW

- Using HW to demonstrate the different steps
- Nitrogen6_MAX board
- Android Lollipop 5.1.1
  - Boundary Devices 5.1.1 release

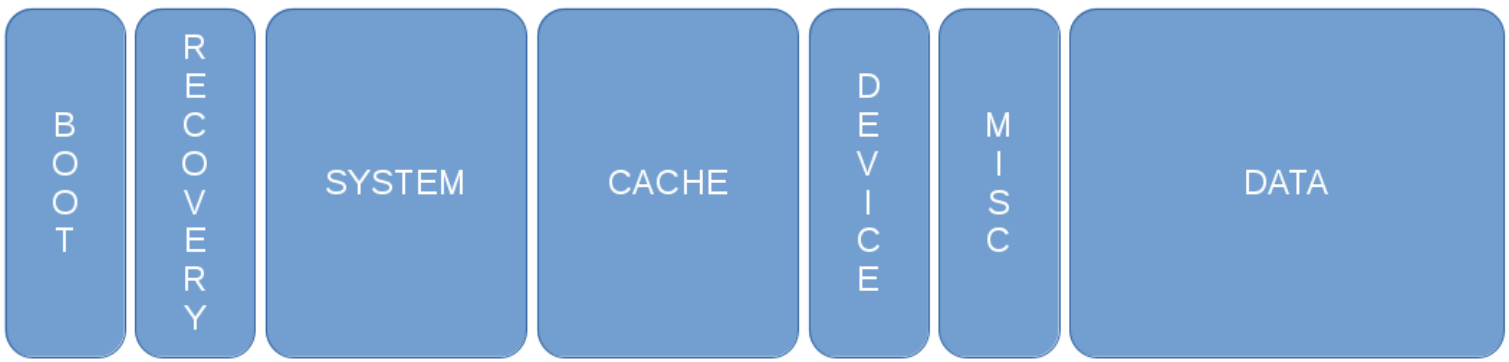
PARTITION LAYOUT

- `boot`
  - Kernel + device tree + bootargs + ramdisk
  - Raw partition created with `mkbootimg`
  - Actual `ext4` partition for Boundary Devices
- `recovery`
  - Same as `boot` with **recovery** ramdisk
- `system`
  - Contains the entire OS (framework, UI, stock apps)



PARTITION LAYOUT

- `cache`
  - Frequently accessed data and **OTA updates**
- `misc`
  - Used to communicate between RC and the bootloader
- `device`
  - Contains assets and customizations
- `data`
  - User's data: apps, settings, contacts



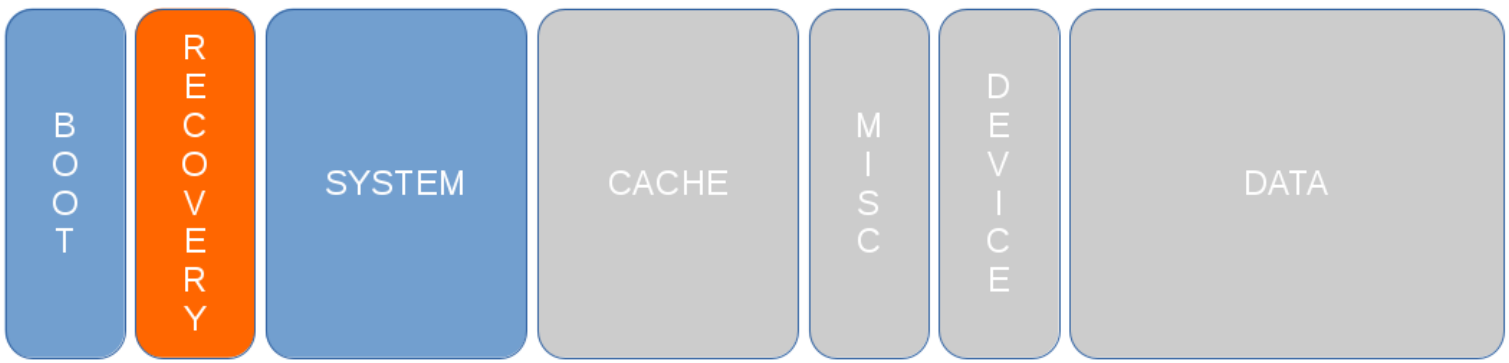
Update Mechanism

STANDARD PROCEDURE

1. Download update package
2. Check package consistency/signature
3. Reboot into Recovery Console (RC)
4. Veritying signature (again)
5. Apply update
6. Reboot into Android
7. Run recovery update script (optional)

STANDARD PROCEDURE

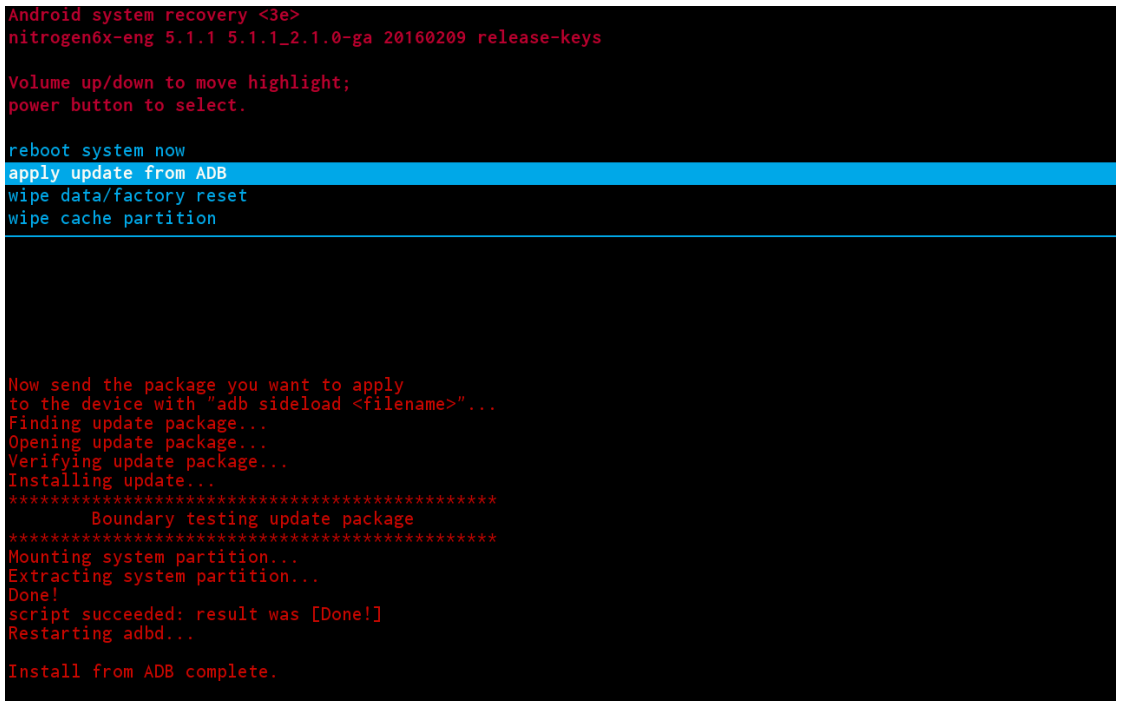
- Not all partitions updated by default
  - `/boot` and `/system`
  - `/recovery` updated at reboot if script provided
- Some partitions can be wiped
  - `/cache` and `/data`
  - Option available in `Settings` app
- Can be customized
  - To flash the bootloader for instance



OTHER OPTIONS

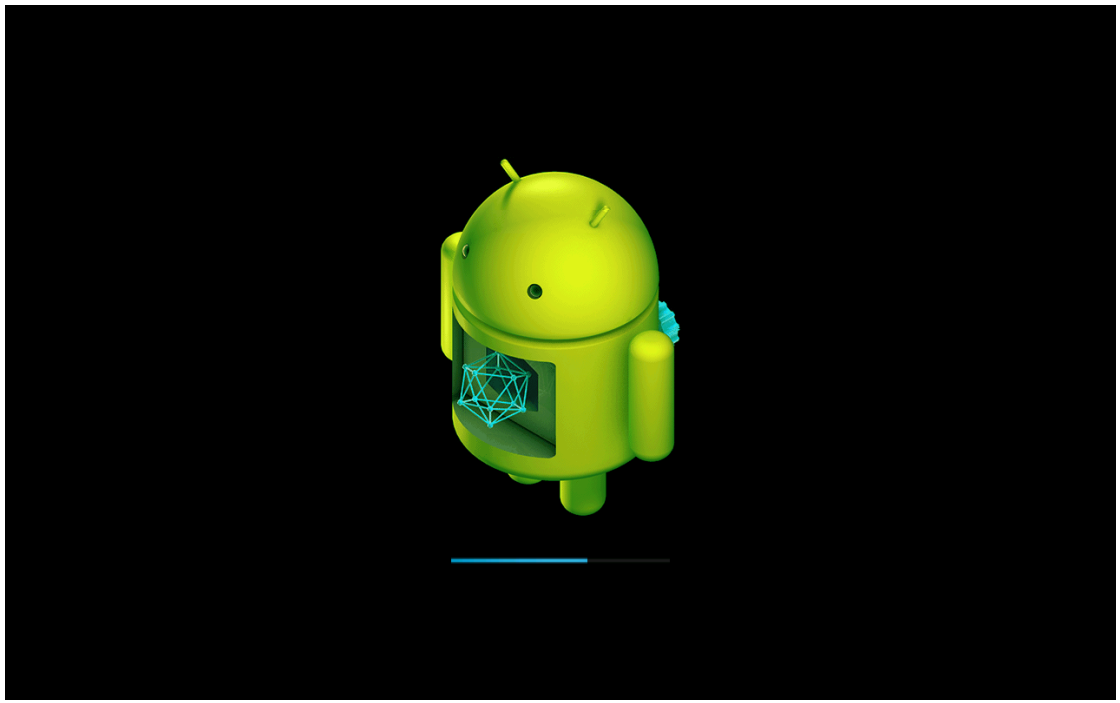
- Using `adb sideload`

```
1 $ adb reboot recovery
2 [Press VOL_UP and SEARCH]
3 [Select 'apply update from ADB']
4 $ adb sideload update.zip
```



- Uploading the update manually

```
1 $ adb push update.zip /cache/
2 $ adb shell 'mkdir /cache/recovery/'
3 $ adb shell 'echo "--update_package=/cache/update.zip" > /cache/
      recovery/command'
4 $ adb reboot recovery
```



- Releasetools
  - Create digitally signed software updates
  - Integrated in Android build system
- Recovery Console (RC)
  - Alternate boot environment
  - Verify & Apply **SW updates**
  - Minimalistic ramdisk
  - Can perform **Factory Data Reset**
  - Hidden menu for manual interaction

- `android.os.RecoverySystem` APIs
  - Framework APIs to verify & install SW updates
  - Writes RC command files into `/cache/recovery` and reboots into Recovery Console
  - Also used to engage Factory Data Reset
- 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
  - Providing a flexible approach

AOSP MISSING PIECES

- Communication between Android and bootloader
  - Vendor-specific
- Client-side OTA application
  - Mechanism to check and download updates
  - Notification UI that SW Updates are available
  - Assumed specific to each use case
- Remote server backend to host updates
  - Assumed specific to each infrastructure

NXP is providing everything you need to get started!

- Communication between Android and bootloader
  - Using the Secure Non-Volatile Storage (SNVS)
  - See `kernel_imx/arch/arm/mach-imx/system.c`
- Client-side OTA application
  - `FSLOta` application
  - Just fetching updates when explicitly started
  - Good starting point
  - See `packages/apps/fsl_imx_demo/FSLOta/`
- Remote server backend to host updates
  - `FSLOta` just requires a standard HTTP server

LIMITATIONS

- No support for disk re-partitioning
  - Not impossible but not recommended
- One update applied at a time
- Device can’t be used while updates are applied
- Errors during update typically require RMA
  - Although shouldn’t happen since power-safe

Update package

FULL UPDATE

A *full* update is a **zip archive** containing the entire final state of the device (`system`, `boot`, and `recovery` partitions).

- Automatic creation:

```
$ . build/envsetup.sh && lunch nitrogen6x-eng
$ make dist
$ ls $OUT/nitrogen6x-ota-20160415.zip
```

- Manual creation from target files:

```
$ ./build/tools/releasetools/ota_from_target_files \
  out/dist/nitrogen6x-target_files.zip ota_update.zip
```

INCREMENTAL UPDATE

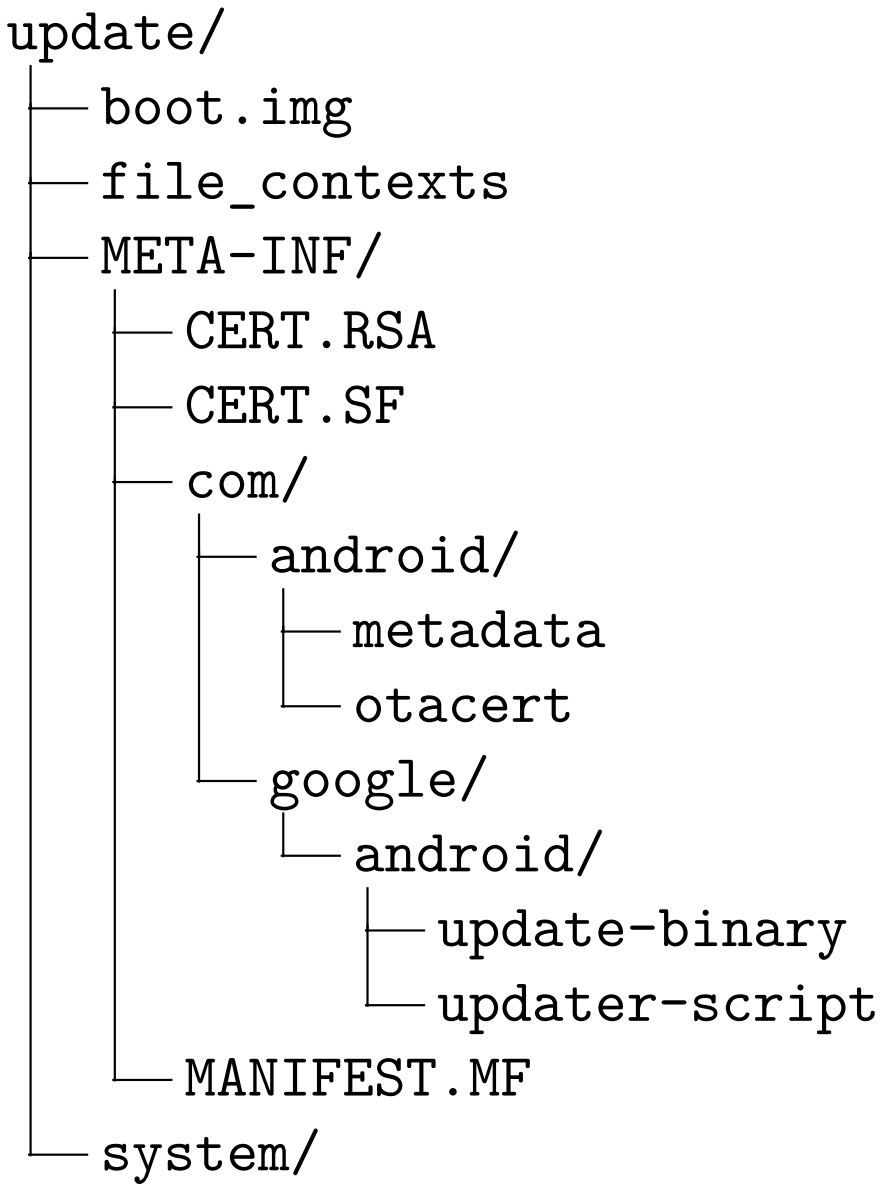
An *incremental* update is a **zip archive** containing a set of binary patches to be applied to the data already on the device.

This can result in considerably smaller update packages.

- Requires to keep the previous update target files:

```
1 $ ./build/tools/releasetools/ota_from_target_files \
2   -i PREVIOUS-nitrogen6x-target_files.zip \
3   tardis-target_files.zip incremental_ota_update.zip
```

UPDATE CONTENT



UPDATE CONTENT

- `file_contexts`
  - Contains the *SELinux* labels to apply after update
- `META-INF`
  - Hosts the package manifest file and code signatures
  - Like `META-INF` of an APK file + few files
  - `com/android/otacert` is the update signing certificate
  - `com/google/android/` contains important binaries
    - `updater-script`
    - `update-binary`

UPDATER-SCRIPT

- Created by `edify_generator.py`
- Written in `edify` scripting language
- Customization with `releasetools` extensions
  - `TARGET_RELEASETOOLS_EXTENSIONS` in `BoardConfig.mk`
  - `FullOTA_InstallBegin()`
    - Called at the beginning of full OTA installation
  - `FullOTA_InstallEnd()`
    - Called at the end of full OTA installation
  - See all options in `common.py`

EDIFY LANGUAGE

- Scripting language to specify SW update tasks
- All functions implemented in `C`
  - See `bootable/recovery/updater/install.c`: `mount`/`unmount`/`show_progress`/`delete`/`symlink`/`getprop`/`wipe_cache`/`ui_print`...
- Cannot declare functions in an `Edify` script
  - Additional functions implemented in **plug-ins**
- See `bootable/recovery/edify/README`

UPDATE-BINARY

- AOSP `updater` implementation:
  - See `bootable/recovery/updater/updater.c`
- Forked from the `recovery` process
- Loads the `updater-script` and parses the commands
- Platform-specific `updater` capabilities implemented in **plug-ins**
- Not strictly required to use the `updater` implementation

- Multiple `updater` **plug-ins** can be defined
  - Add `TARGET_RECOVERY_UPDATER_LIBS` in `BoardConfig.mk`
  - Each library needs a registration function
    - `void Register_$LOCAL_MODULE()`
    - Calls `RegisterFunction()` for each command
- Use `bootable/recovery/updater/install.c` as a guide
- Example: add a function to flash the bootloader

- `Android.mk` example:

```
1 include $(CLEAR_VARS)
2 LOCAL_SRC_FILES := recovery_updater.c
3 LOCAL_C_INCLUDES += bootable/recovery
4 LOCAL_MODULE := librecovery_updater_imx
5 include $(BUILD_STATIC_LIBRARY)
```

- `BoardConfig.mk` addition:

```
1 TARGET_RECOVERY_UPDATER_LIBS += librecovery_updater_imx
```

- **plug-in** snippet:

```
1  #include "edify/expr.h"
2
3  Value* CustomImxFn(const char* name, State* state,
4                     int argc, Expr* argv[]) {
5      if (argc != 2) {
6          return ErrorAbort(state, "%s expects 2 args", name);
7      }
8      // Do custom work
9  }
10
11 void Register_librecovery_updater_imx() {
12     RegisterFunction("imx.custom", CustomImxFn);
13 }
```

CREATE A PACKAGE MANUALLY

1. Create an empty update package

```
$ mkdir -p update/META-INF/com/google/android/
```

2. Copy `updater` binary

```
$ cp $OUT/system/bin/updater \
  update/META-INF/com/google/android/update-binary
```

3. Create `updater-script`

```
$ vi update/META-INF/com/google/android/updater-script
  ui_print("Boundary OTA FTF update package");
```

4. Add files to be updated
5. Zip and sign the archive

```
$ cd update/ && zip -rq ../update_unsigned.zip * && cd -
$ java -jar out/host/linux-x86/framework/signapk.jar -w \
  device/fsl/common/security/testkey.x509.pem \
  device/fsl/common/security/testkey.pk8 \
  update_unsigned.zip update_signed.zip
```

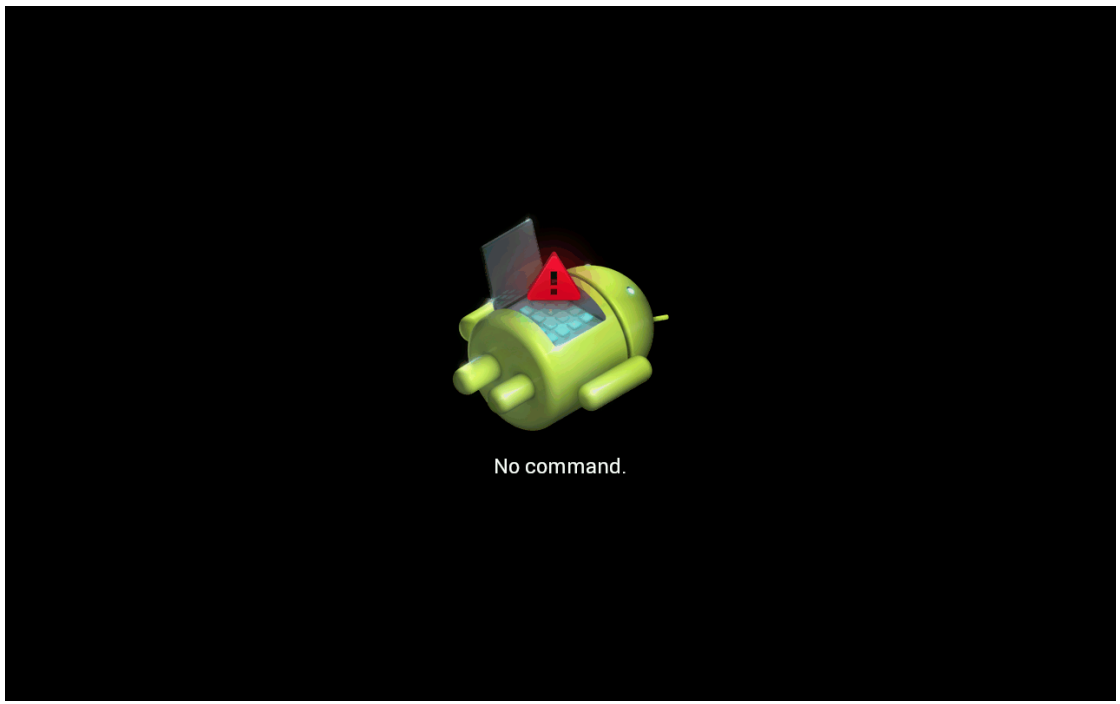
Recovery Console

RECOVERY CONSOLE

- Alternate boot image (`recovery.img`)
  - Similar to `boot.img`
  - Contains `zImage` + `dtb` + `bootargs` + `ramdisk`
- How to access it?
  - (`adb`) `reboot recovery` or button input
  - i.MX implementation:
    - When `VOL_DOWN` is pressed at bootup
    - When `SNVS_LPGPR` equals `0x80`
    - See U-Boot `arch/arm/cpu/armv7/mx6/soc.c`

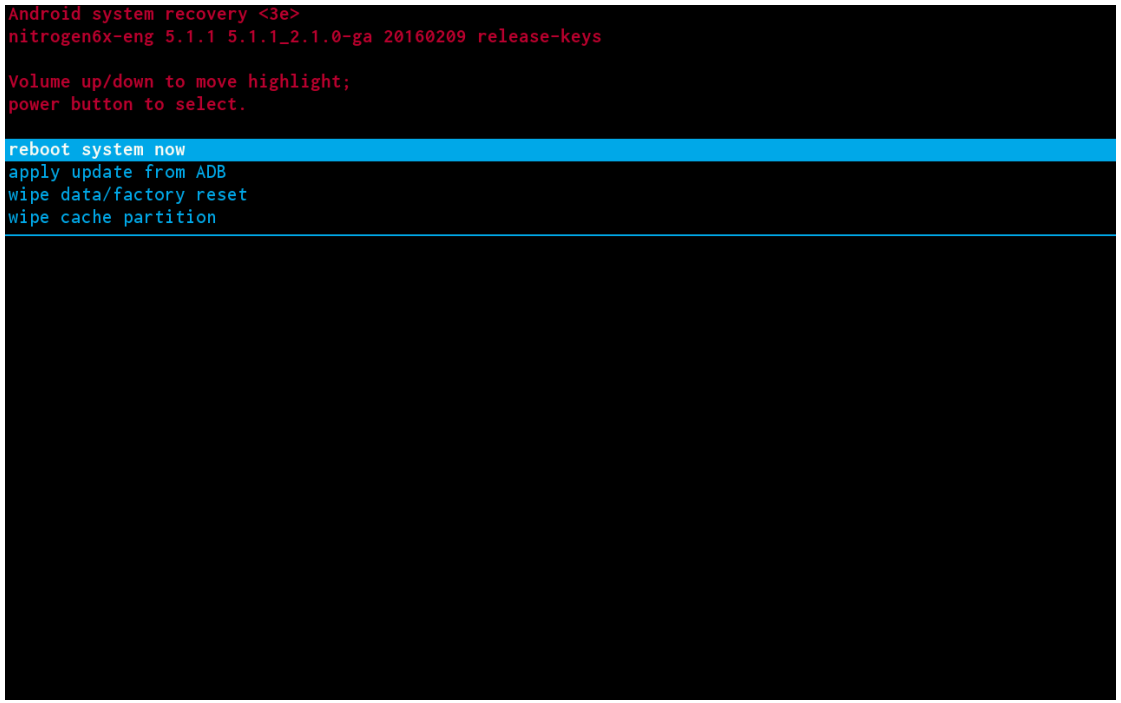
DEFAULT BEHAVIOR

- Expects information from system (update/wipe)
  - In `/cache/recovery/command`
- Otherwise waiting for a key combination
  - Reboots after a timeout (2min)



HIDDEN MENU

- Accessed when pressing `VOL_UP` and `POWER`
- Allows to perform actions manually
  - `adb sideload`
  - wipe `/cache` or `/data`



- `ramdisk-recovery.img` based on `ramdisk.img`
- Different `init*.rc` files
  - Stripped down to bare minimum
  - See `bootable/recovery/etc/init.rc`
  - Also copies all the `init.recovery.*.rc` files
- Uses `fstab` defined by `TARGET_RECOVERY_FSTAB`
- Possibility to add custom resources
  - Overwrites common resources
  - Must be in `$(TARGET_DEVICE_DIR)/recovery/res/`
- See full creation in `build/core/Makefile`

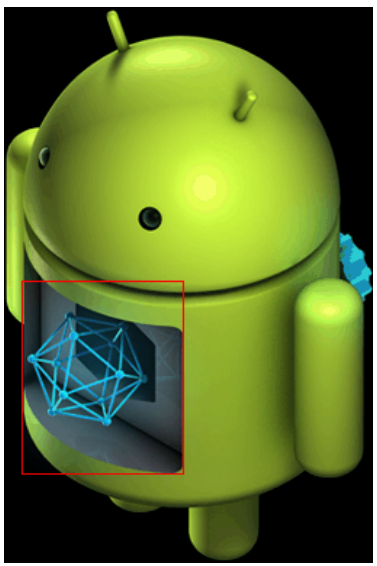
RECOVERY PLUG-IN

- One `recovery` **plug-in** can be defined
  - Add `TARGET_RECOVERY_UI_LIB` in `BoardConfig.mk`
  - Define (additional) recovery menu items
  - Additional initialization tasks in `StartRecovery()`
  - Customization of branding graphics done in `GetUI()`
  - See `bootable/recovery/default_device.cpp`
- NXP `librecovery_ui_imx`
  - See `device/fsl/common/recovery/`
  - Limits the number of menu items

- Signature check
  - OTA signing certificates in `res/keys`
- *SELinux* enabled
  - RC using custom policies
- `/misc` and **Bootloader Control Block**
  - Used for communication between RC and bootloader
  - **BCB** contains update information (progress)
  - Makes the mechanism power-safe

UI CUSTOMIZATION

- Recovery user interface consists of images
- Each element is separated to ease the customization
  - progress bar, no command icon, update icon...
  - `bootable/recovery/interlace-frames.py`
- Android 5.x displays a localized string of text
  - `development/tools/recovery_l10n/`



DIRTY TRICK

Need to add a tool to RC for debug?

- Add statically built binary to `$(TARGET_DEVICE_DIR)/recovery/res/`
- Modify `init.recovery.freescale.rc`
- Example adding `busybox`

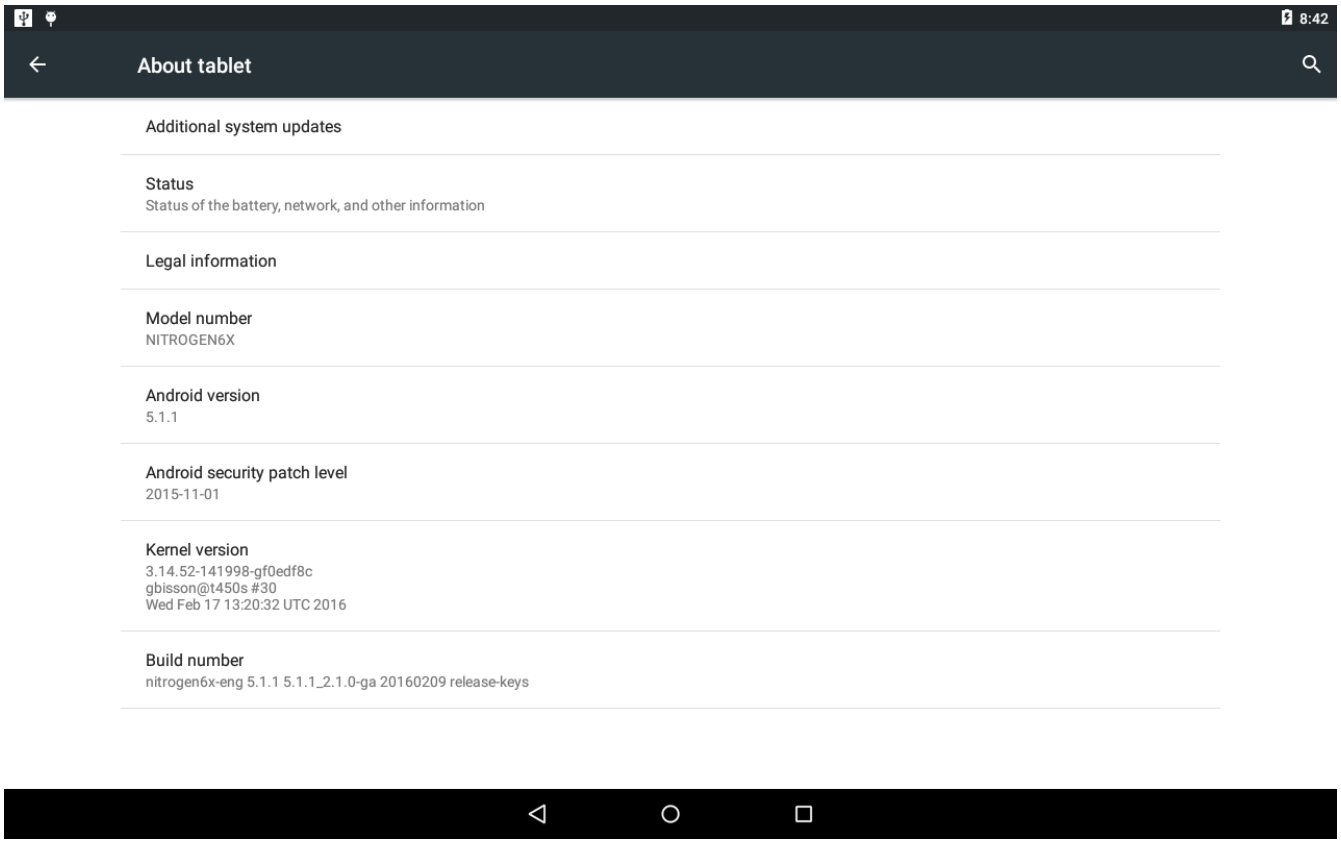
```
1  on init
2      chmod 755 /res/bin/busybox
3
4  service console /res/bin/busybox sh
5      class core
6      console
7
8  on property:ro.debuggable=1
9      start console
10
11 service busybox /res/bin/busybox --install /sbin
12     oneshot
```

OTA Application

GOAL

- Allow checking for updates manually (menu)
- Regularly checking for updates (optional)
- Making sure of the authenticity of the package
- Writing to the RC `command` file
- Reboot into recovery

Two possibilities to integrate an update app into `Setting` menu



1. `android.settings.SYSTEM_UPDATE_SETTINGS Intent`
   - Usually reserved for Google update app
   - If no app listens to this `Intent`, menu hidden
2. `additional_system_update` overlay definition
   - Recommended approach for 3rd party updates
   - NXP providing an example with `FSLOta`

```
1 <resources
      xmlns:xliff="urn:oasis:names:tc:xliff:document:1.2">
2   <string name="additional_system_update"
        translatable="false">com.fsl.android.ota</string>
3   <string name="additional_system_update_menu"
        translatable="false">com.fsl.android.ota.OtaAppActivity</stri
4 </resources>
```

ANDROID UPDATE API

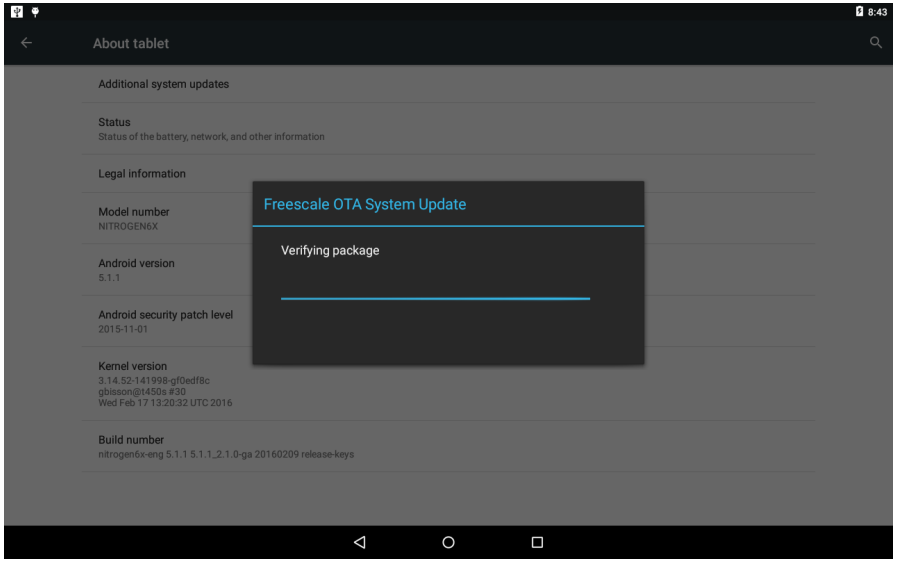
- `android.os.RecoverySystem`
  - `verifyPackage(File update, RecoverySystem.ProgressListener lstr, File certs)`
    - Verify the cryptographic signature of a package
    - Certs: `/system/etc/security/otacerts.zip`
  - `installPackage(Context context, File update)`
  - `rebootWipeCache(Context context)`
  - `rebootWipeUserData(Context context)`
    - Above 3 methods require `REBOOT` permission
    - Write to `/cache/recovery/command`
    - Reboot to Recovery Console

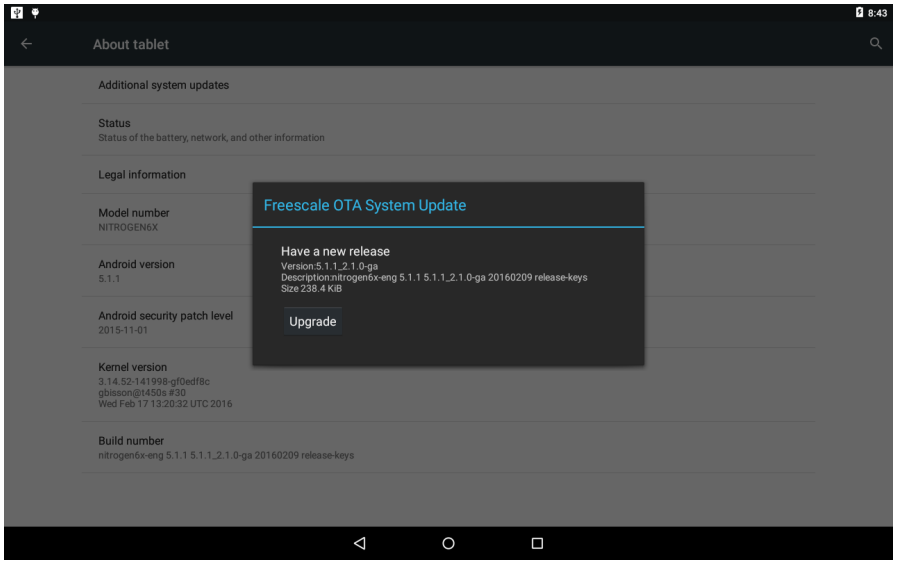
NXP sample client-side OTA application

- See `packages/apps/fsl_imx_demo/FSLOta/`
- Expects a `build.prop` at root folder
  - Directly extracted from build files
- Bases the version on `ro.build.date.utc`
- Parses `/system/etc/ota.conf` for server configuration

```
1 server=boundarydevices.com.commondatastorage.googleapis.com
2 port=80
3 ota_folder_suffix=lollipop
```

FSLOTA UI


8:43
About tablet
Additional system updates
Status
Status of the battery, network, and other information
Legal information
Model number
NITROGEN6X
Android version
5.1.1
Android security patch level
2015-11-01
Kernel version
3.14.52-141998-gf0edf8c
gbisson@t450s #30
Wed Feb 17 13:20:32 UTC 2016
Build number
nitrogen6x-eng 5.1.1 5.1.1_2.1.0-ga 20160209 release-keys
Freescale OTA System Update
Verifying package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NITROGEN6X
Android version
5.1.1
Android security patch level
2015-11-01
Kernel version
3.14.52-141998-gf0edf8c
gbisson@t450s #30
Wed Feb 17 13:20:32 UTC 2016
Build number
nitrogen6x-eng 5.1.1 5.1.1_2.1.0-ga 20160209 release-keys
Freescale OTA System Update
Have a new release
Version:5.1.1_2.1.0-ga
Description:nitrogen6x-eng 5.1.1 5.1.1_2.1.0-ga 20160209 release-keys
Size:238.4 KiB
Upgrade

ROOM FOR IMPROVEMENT

- Allowing other procotol than `http`
  - Should be configurable too
- Reading an XML file from the server
  - Would be way more flexible
  - Would remove the need of folders with endless names
  - Would avoid exposing the entire `build.prop`

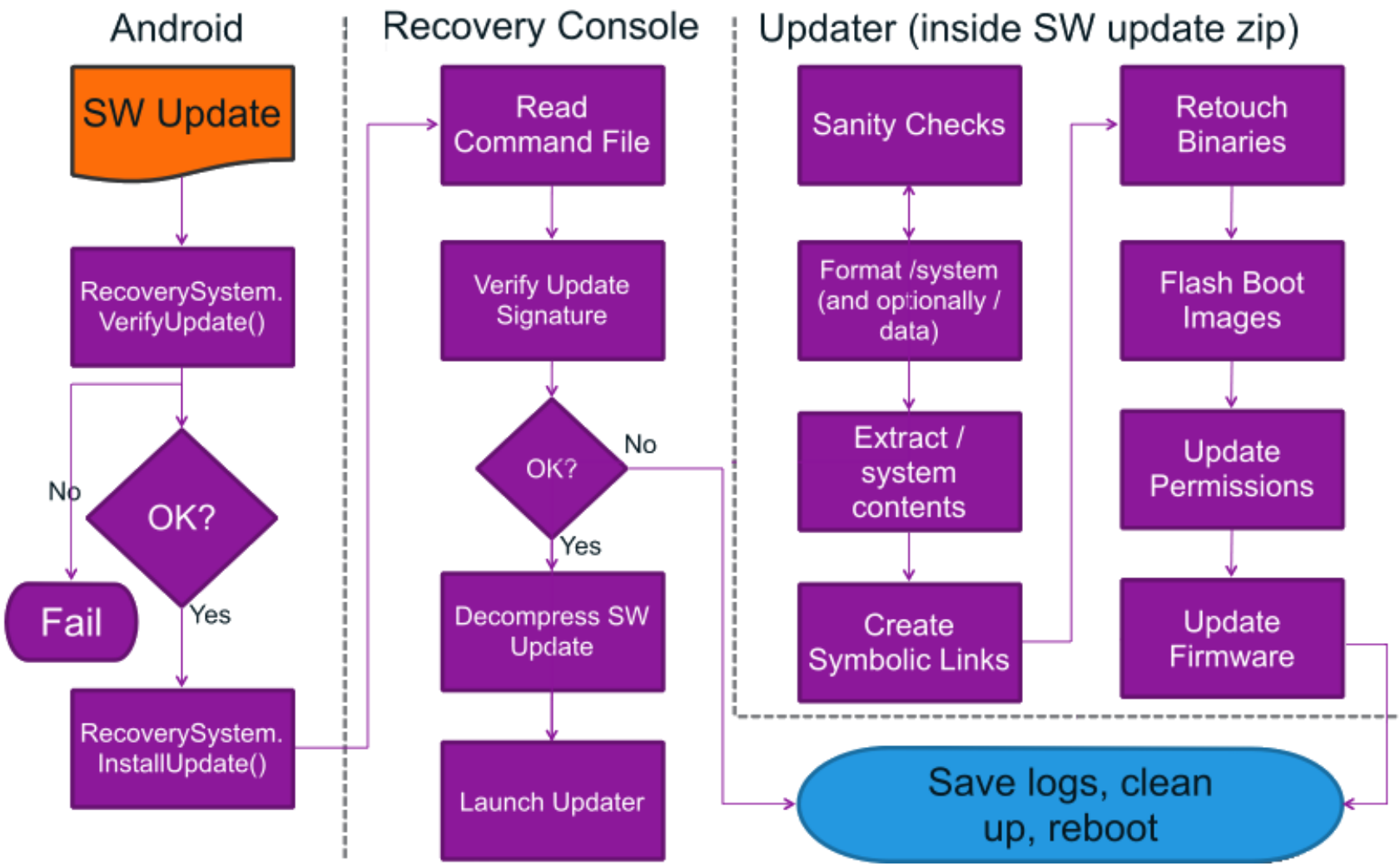
```
<ota>
  <update target="nitrogen6x">
    <file path="nitrogen6x-ota-20160209.zip"/>
    <rev version="5.1.1-2.1.0" utc="1455216172"
        incremental="20160209"/>
  </update>
  ...
</ota>
```

ROOM FOR IMPROVEMENT

- Checking for update at bootup
  - Listening to the `BOOT_COMPLETED Intent`
  - Also check the status of last update
- Checking for update periodically
  - Adding a repeated `Timer`
- Using other UI elements
  - Leveraging the `NotificationManager`
  - Having an `Activity` to setup server details and get rid of the `ota.conf`

Conclusion

UPDATE PROCESS



Credit: Andrew Boie - Android SW Updates

CONCLUSION

- Reliable update system
- AOSP providing many tools
  - Lots of possible customizations
  - Some easier than others
- NXP releasing an example for the missing parts
  - `FSLOta` can easily be customized

QUESTIONS?

REFERENCES

- Android website: **OTA Updates**
  https://source.android.com/devices/tech/ota
- Boundary Devices website: **OTA Updates**
  android-security-part-2-ota-updates
- Andrew Boie: **Android SW Updates**
  ABS-Android_SW_Updates-Boie-2015.pdf
- Nikolay Elenkov: **Android Security Internals**
  An In-Depth Guide to Android's Security Architecture

GOING FURTHER: BLOCK-BASED OTA

- Since Android 5.x, blocked-based OTA can be performed
- Only works on block devices (not MTD)
- Ensures that each device uses the exact same partition
- Enables the use of dm-verity to cryptographically sign the `system` partition
- To generate a block-based OTA, pass the `--block` option to `ota_from_target_files`
- http://source.android.com/devices/tech/ota/block.html

GOING FURTHER: HACKING UPDATER BINARY

Need a tool during the update that isn't present on the RC?

- Possibility to hack an `updater` **plug-in** to embed tools
- The **plug-in** is then in charge of extracting it
- Need to copy the static binary to a specific *ELF* section
  - Requires a custom linker script
  - Need to tweak `LOCAL_BUILT_MODULE`

```
1 $(LOCAL_BUILT_MODULE) : $(all_objects)
2   @echo "Adding tool to $<"
3   toolsecname=.extra.$$(basename $$tool);
4   $(TARGET_OBJCOPY) --add-section $$toolsecname=$$tool --set
        -section-flags $$toolsecname=load,alloc,data,readonly
        $<;
5   $(hide) $(TARGET_LD) -r -T custom.lds $< -o $(TMP);
6   $(hide) cp $(TMP) $<;
7   $(transform-o-to-static-lib)
```