Yocto on the Edge

Unusual challenges when building not so embedded systems

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Yocto Project Dev Day

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vGRID by SaferCities

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Embedded Systems Developer

- since 2015 with inovex
- has a Master's degree in Embedded Systems
- studies Electrical Engineering as a hobby

Main Topics

- Embedded Systems
- Yocto Linux
- Linux Kernel
- AOSP/AAOS
- IoT

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work based on kirkstone

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bugs caused by my distraction ninja

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vGRID by SaferCities

About the project and requirements

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SaferCities is a New Zealand based company that provides independent subject matter expertise consulting around CCTV and related systems, as well as the **vGRID SaferCity Platform**.
vGRID enables CCTV & ANPR asset owners to share with one another and law enforcement, regardless of CCTV system (or VMS), network configuration or brand.
vGRID is used across the whole of New Zealand by New Zealand Police, and is used by other Police forces in Australia, and is undergoing trials in the USA.

For more information, please see https://vgrid.io or https://safercities.com

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switching to ...

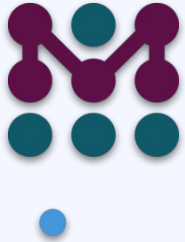
... to get
full platform control

- containers and system
- updates

fulfill high security requirements

- user management
- system integrity
- encrypted data

yocto PROJECT



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Working with x86

Workflows, Debugging, Provisioning

- interfaces like UART, JTAG, … directly accessible
- often SD cards for development and eMMC for production
- e.g. jumpers and/or manufacturer tools needed to flash eMMC

-> diverse, but known tooling

- mostly no accessible debug interfaces -> use screen and keyboard, screen capture tools, …
- boots from USB for development, SSD/NVMe for production
- create a “self-installing image” from a USB drive

-> less diverse but unknown and “limited”

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Provisioning - Self-installing Yocto from a USB drive

Updated on February 16, 2023 / Bennie Affleck

Self-installing Yocto Image from a USB drive

Tech Blog | Yocto

We are all familiar with the process of installing a desktop operating system onto a PC; simply insert the installation media, typically a USB stick, and boot the device. A minimal version of the OS then runs to perform the process of partitioning discs and installing the full OS.

Yocto also has the ability to generate a self-installing image, just like a desktop operating system. For an embedded system that can boot from a USB drive this gives some significant advantages:

https://www.thegoodpenguin.co.uk/blog/self-installing-yocto-image-from-a-usb-drive/

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Usual workflow

process and put rootfs together

ready to be deployed

parts needed in boot partition

IMGDEPLOYDIR

${WORKDIR}/deploy-${PN}-image-complete

DEPLOY_DIR_IMAGE

${DEPLOY_DIR}/images/${MACHINE}/

IMAGE_BOOT_FILES

-> files installed into boot partition when using WIC with bootimg-partition

Source files need to be located in DEPLOY_DIR_IMAGE.

rootfs

-> used by WIC rootfs plugin

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Installer

IMGDEPLOYDIR

${WORKDIR}/deploy-${PN}-image-complete

kernel and rootfs from intermediate location

IMAGE_BOOT_FILES

-> files installed into boot partition when using WIC with bootimg-partition

Source files need to be located in DEPLOY_DIR_IMAGE.

DEPLOY_DIR_IMAGE

${DEPLOY_DIR}/images/${MACHINE}/

initramfs with init-install-efi.sh

rootfs

-> used by WIC rootfs plugin

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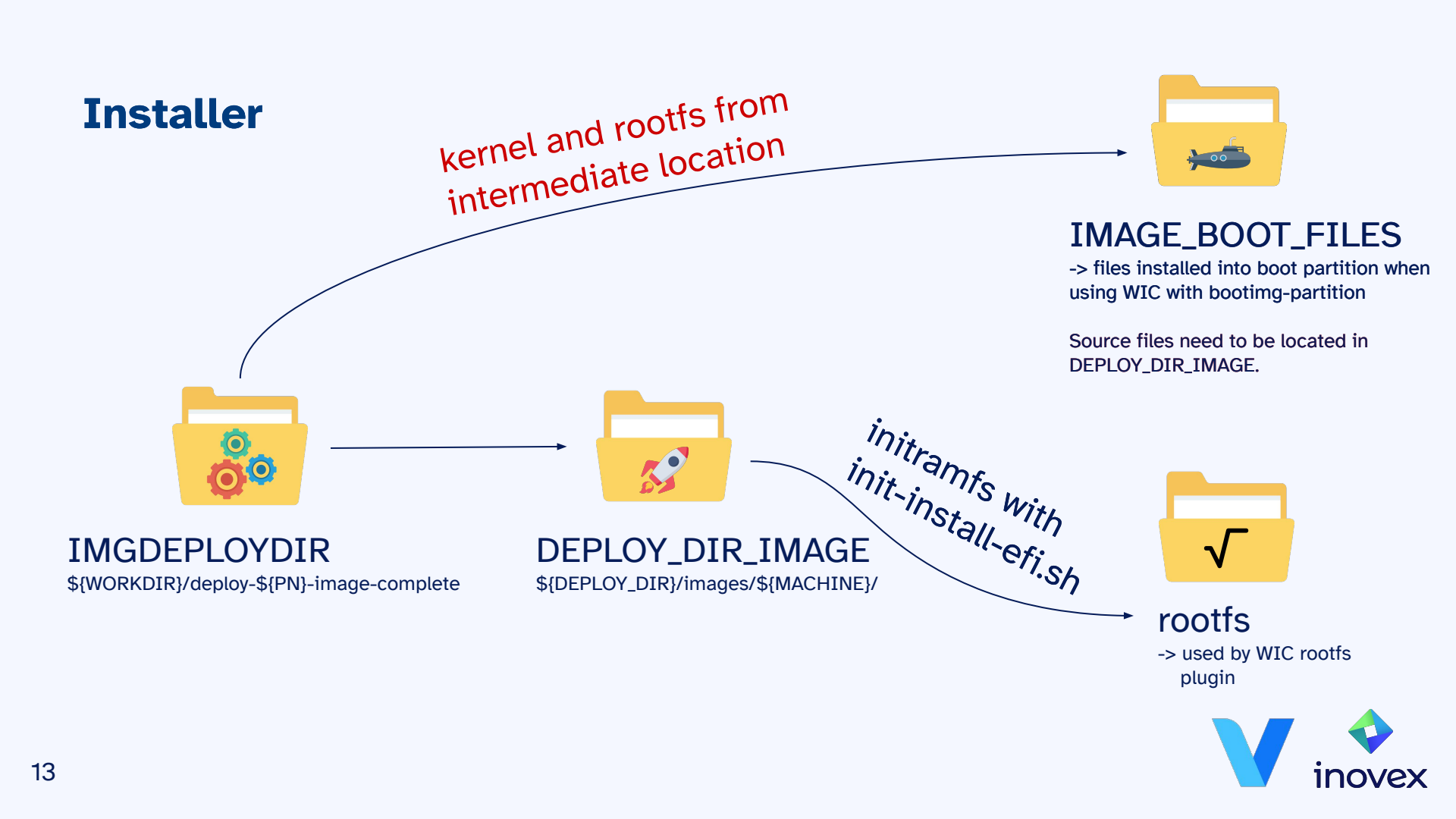
Installer



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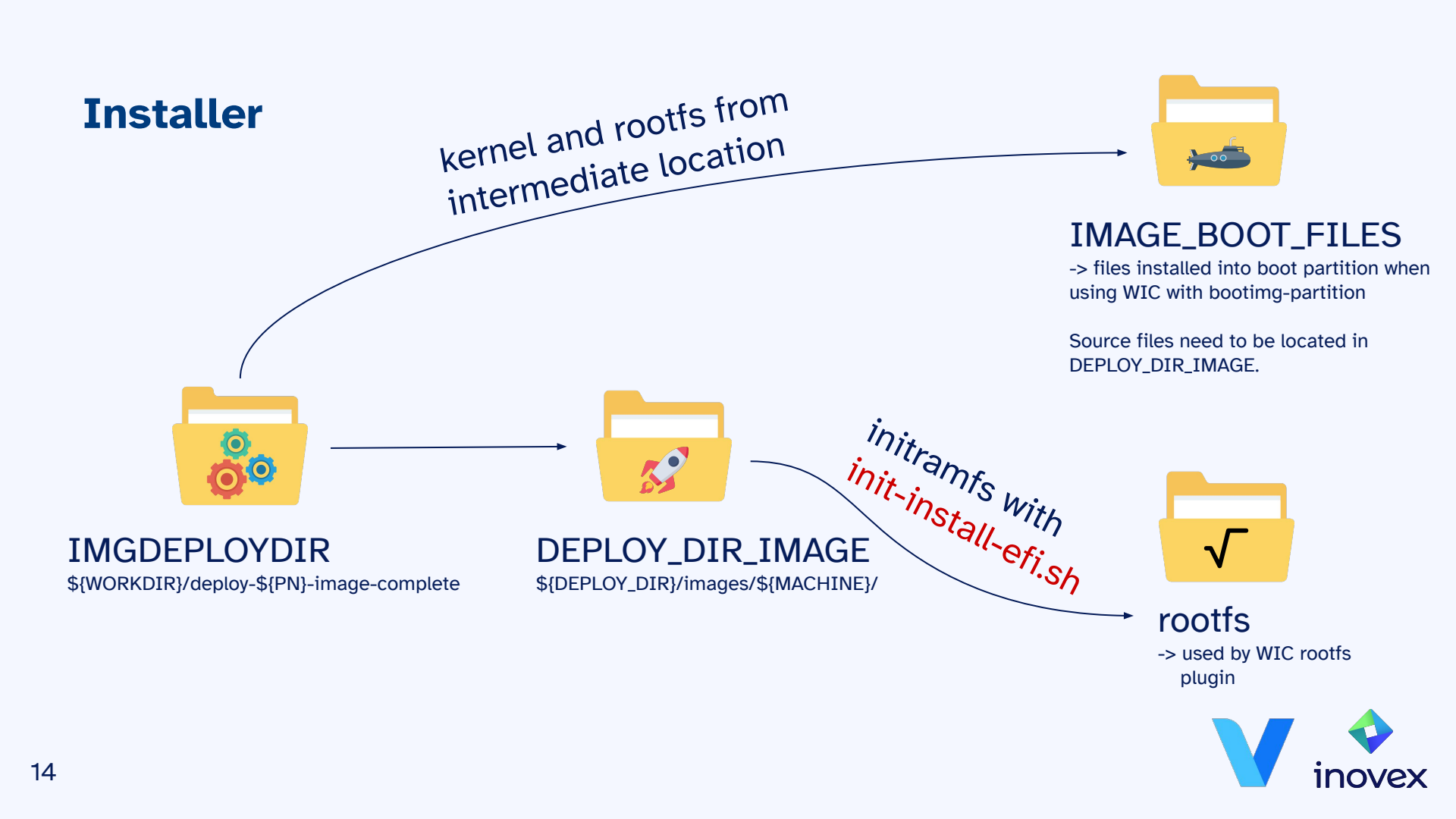
Installer



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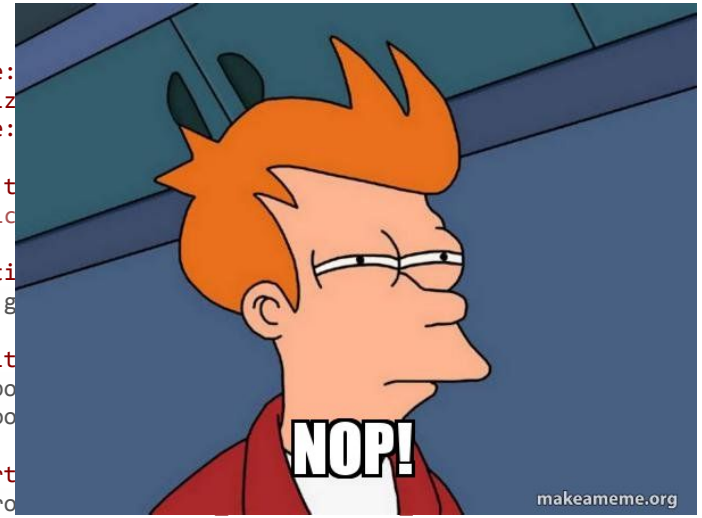
init-install-efi.sh

```
bootfs=${device}${part_prefix}1
rootfs=${device}${part_prefix}2
swap=${device}${part_prefix}3

echo "*****************"
echo "Boot partition size:
echo "Rootfs partition siz
echo "Swap partition size:
echo "*****************"
echo "Deleting partition t
dd if=/dev/zero of=${devic

echo "Creating new partiti
parted ${device} mklabel g

echo "Creating boot partit
parted ${device} mkpart bo
parted ${device} set 1 boo

echo "Creating rootfs part
parted ${device} mkpart ro

echo "Creating swap partition on $swap"
parted ${device} mkpart swap linux-swap $swap_start 100%

parted ${device} print
```



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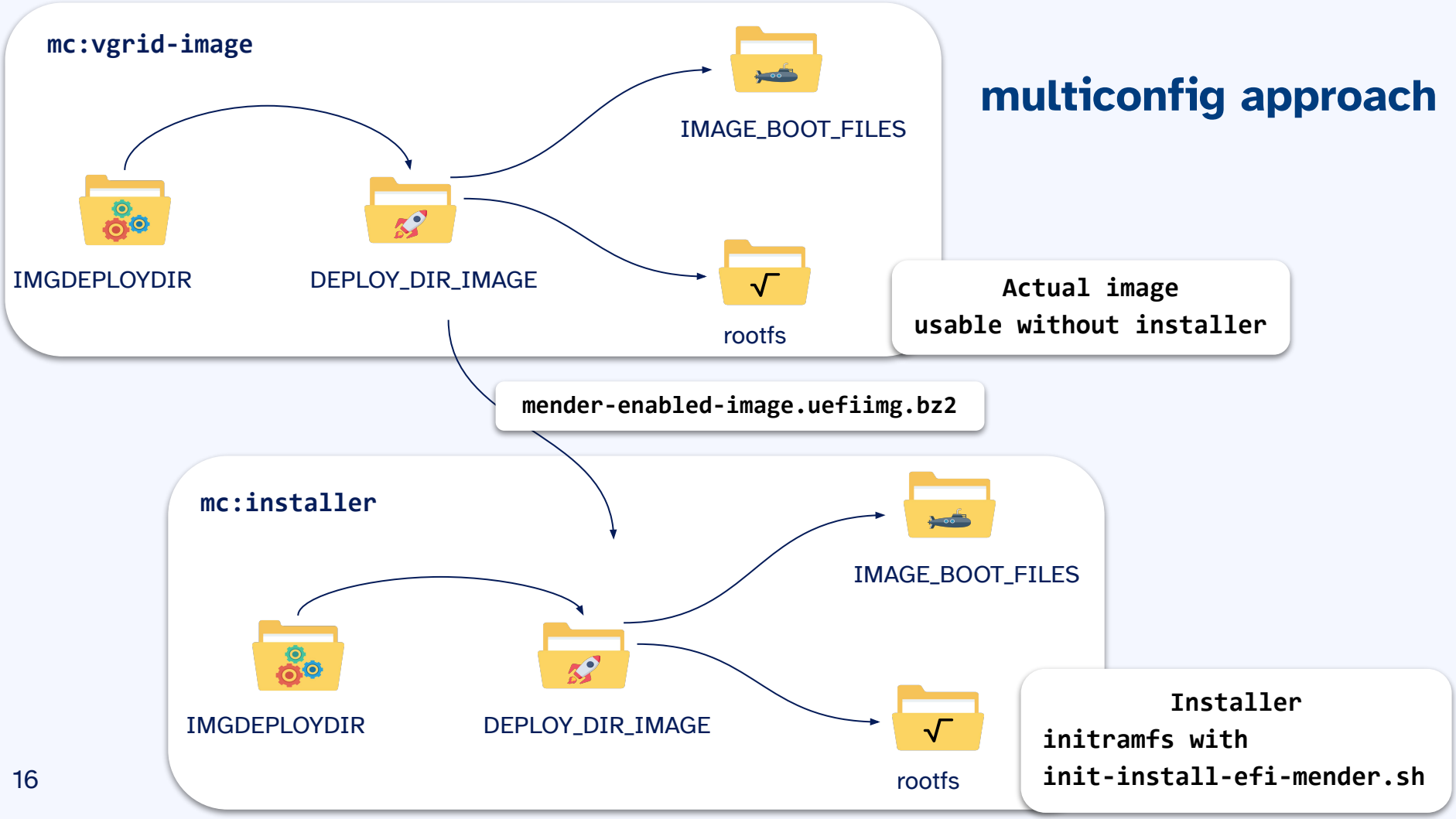
multiconfig approach



vgrid-images-buildtask.bb

```
SUMMARY = "Build the actual images as an inner payload"

PACKAGE_ARCH = "${MACHINE_ARCH}"
PACKAGES = "${PN}"

INHIBIT_DEFAULT_DEPS = "1"

# Variables to control where images are found: the multiconfig name, and the deploy dir.
CONTAINER_PACKAGE_MC ?= "vgrid-images"

CONTAINER_PACKAGE_DEPLOY_DIR = "${TOPDIR}/tmp-vgrid-images-glibc/deploy/images/intel-corei7-64"

do_install[mcdepends] += "mc:vgrid-installer:vgrid-images:vg-image-provisioning:do_image_complete"
do_install[mcdepends] += "mc:vgrid-installer:vgrid-images:vg-image-update:do_image_complete"

do_install() {
       install ${CONTAINER_PACKAGE_DEPLOY_DIR}/${IMAGE}.uefiimg.bz2 ${D}/${BASE}.uefiimg.bz2
}

FILES:${PN} = "/${BASE}.uefiimg.bz2"

# we don't need those!
do_configure[noexec] = "1"
do_compile[noexec] = "1"
deltask do_populate_sysroot
```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vgrid-image-installer.bb

```
SUMMARY = "Minimal installer image"

require recipes-core/images/core-image-base.bb

PACKAGE_INSTALL:append = " vgrid-images-buildtask"
```

vgrid-distro-installer.bb

```
IMAGE_BOOT_FILES:append = " \
   ${IMAGE_ROOTFS}/${PAYLOAD_IMG_NAME}.uefiimg.bz2 \
"
```

kas-installer.yml

```
header:
    version: 16
    includes:
    - kas/common-intel.yml

distro: vgrid-distro-installer
target: mc:vgrid-installer:vg-image-installer

local_conf_header:
    usb-provisioning: |
      BBMULTICONFIG = "vgrid-images vgrid-installer"
```


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Login Users

with read-only rootfs and A/B updates

- but sound and secure

Requirements & Challenges

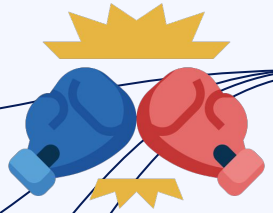
user who is allowed to log in

A/B partitioning schema for OTA updates

read-only rootfs

dm-verity

general security



secure password per device
or
enforce password change

/etc/passwd needs to be writable

create **volatile-bind** for /etc and use encrypted partition as a target

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volatile-binds.bb

```
# We need to overlay /etc for writeable system configurations,
# e.g. changing the user's password.
VOLATILE_BINDS:append = " \
  /data/config /etc\n \
"

# We need to make sure the target directories exist otherwise
# the bind-mount will fail
FILES:${PN} +=  " \
  /data/config \
"

do_install:append() {
  install -d ${D}/data/config
}
```

Other possible implementations:

- overlayfs.bbclass
- overlayfs-etc.bbclass

OverlayFS and its use in Yocto Project

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vgrid-image.bb

```
ROOTFS_POSTPROCESS_COMMAND +=
'${@bb.utils.contains_any('VG_FEATURES', 'vg-expire-password', 'set_password_expiry; ', '',d)}'

set_password_expiry() {
    export PSEUDO="${FAKEROOTENV} ${STAGING_DIR_NATIVE}${bindir}/pseudo"
    flock -x ${IMAGE_ROOTFS}${sysconfdir} -c "$PSEUDO chage -R ${IMAGE_ROOTFS} -d0 ${AUTHORIZED_USER_NAME}"
}
```


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Encrypted data partition

Utilizing LUKS2, TPM2 and systemd

Encrypt on runtime

systemd

systemd service
- triggers encryption
- runs before **data.mount**

LUKS
Linux Unified Key Setup

encryption script
- write LUKS header on existing partition
  cryptsetup reencrypt --encrypt
- actual online encryption
  cryptsetup reencrypt

systemd

LUKS
Linux Unified Key Setup

encryption script
- link TPM to LUKS device
  systemd-cryptenroll

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Prepare in image

fstab

```
- UUID=<data-uuid> /data ext4 rw 0 2
+ /dev/mapper/data /data ext4 rw 0 2
```

crypttab

```
data UUID=<data-uuid> none tpm2-device-auto,tpm2-pcrs=7
```

fstab is modified by Mender in a ROOTFS_POSTPROCESS_COMMAND !

At early boot and when the system manager configuration is reloaded, /etc/crypttab is translated into systemd-cryptsetup@.service units by systemd-cryptsetup-generator(8).

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Dealing with Limits

Using KAS to patch .bbclass, .inc or similar “unpatchable” files in Yocto

kas/common.yml

```
    meta-mender:
        layers:
            meta-mender-core:
        branch: kirkstone
        url: https://github.com/mendersoftware/meta-mender.git
        path: sources/meta-mender
        patches:
          encrypted-data:
            repo: meta-vgrid
            path: patches/meta-mender/mender-use-mapper-device-for-data.patch
```

meta-vgrid/patches/meta-mender/mender-use-mapper-device-for-data.patch

```
diff --git a/meta-mender-core/classes/mender-setup-image.inc b/meta-mender-core/classes/mender-...
index 85383d27..3fc4097a 100644
--- a/meta-mender-core/classes/mender-setup-image.inc
+++ b/meta-mender-core/classes/mender-setup-image.inc
@@ -58,7 +58,7 @@ mender_update_fstab_file() {
     fi

     mkdir -p ${IMAGE_ROOTFS}/data
-    printf "%-20s %-20s %-10s %-21s %-2s %s\n" ${tmpDataPart} /data ${MENDER_DATA_PART_FSTYPE} ...
+    printf "%-20s %-20s %-10s %-21s %-2s %s\n" ${MENDER_DATA_PART_CRYPT} /data ${MENDER_DATA_PA...
```


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Why and when am I using this mechanism?

- patching files where .bbappend is not possible, e.g. .bbclass, .inc, ROOTFS_POSTPROCESS_COMMAND functions, ...

- when copying the file to our own layer does not make sense, e.g.
  - just a one-line change
  - want to get updates and see if the original file changes

- when copying the file to our own layer does not work, e.g.
  - an e.g. .inc file that's already used in the original layer
  - priority issues

-> not Yocto-by-book, but a really clean and maintainable way to work around limits
-> no replacement for .bbappend!

vgrid-distro.conf

```
PACKAGECONFIG:append:pn-cryptsetup = " cryptsetup veritysetup udev luks2"
PACKAGECONFIG:append:pn-systemd = " cryptsetup tpm2"
```

systemd_%.bbappend

```
do_install:append() {
    install -d ${D}${libdir}/cryptsetup
    install -m 0755 ${
                    $
}

FILES:${PN}:append = "
  ${base_libdir}/cryptsetup/libcryptsetup-token-systemd-tpm2.so \
  ${libdir}/cryptsetup/libcryptsetup-token-systemd-tpm2.so \
"
```

Fixed in scarthgap!

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encrypt-data.sh

```
echo "Generating a new key..."
/usr/bin/openssl rand -base64 44 > ${tmp_key_file}


echo "Writing encryption headers..."
/bin/cat "${tmp_key_file}" | /usr/sbin/cryptsetup reencrypt --encrypt --type luks2 --key-slot=1 \
--batch-mode --init-only --reduce-device-size 32M --offset="${OFFSET}" "${data_dev}" data


# Enrolling the TPM2 integration only works after the online encryption step is finished.
echo "Encrypting the data partition..."
/bin/cat ${tmp_key_file} | /usr/sbin/cryptsetup reencrypt --offset="${OFFSET}" "${data_dev}"


echo "Deploying TPM2 keys..."
export PASSWORD="$(cat ${tmp_key_file})"
/usr/bin/systemd-cryptenroll --tpm2-device=auto --tpm2-pcrs=7 "${data_dev}"
unset PASSWORD
```


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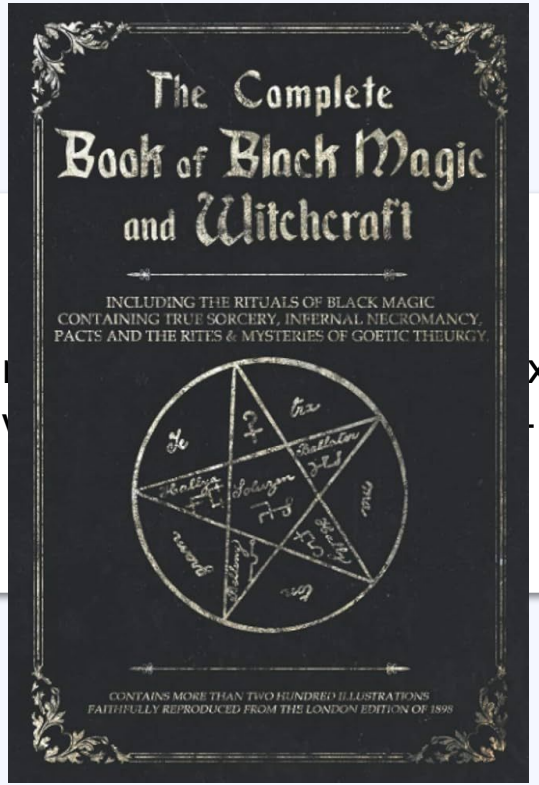
secure-boot

and Mender



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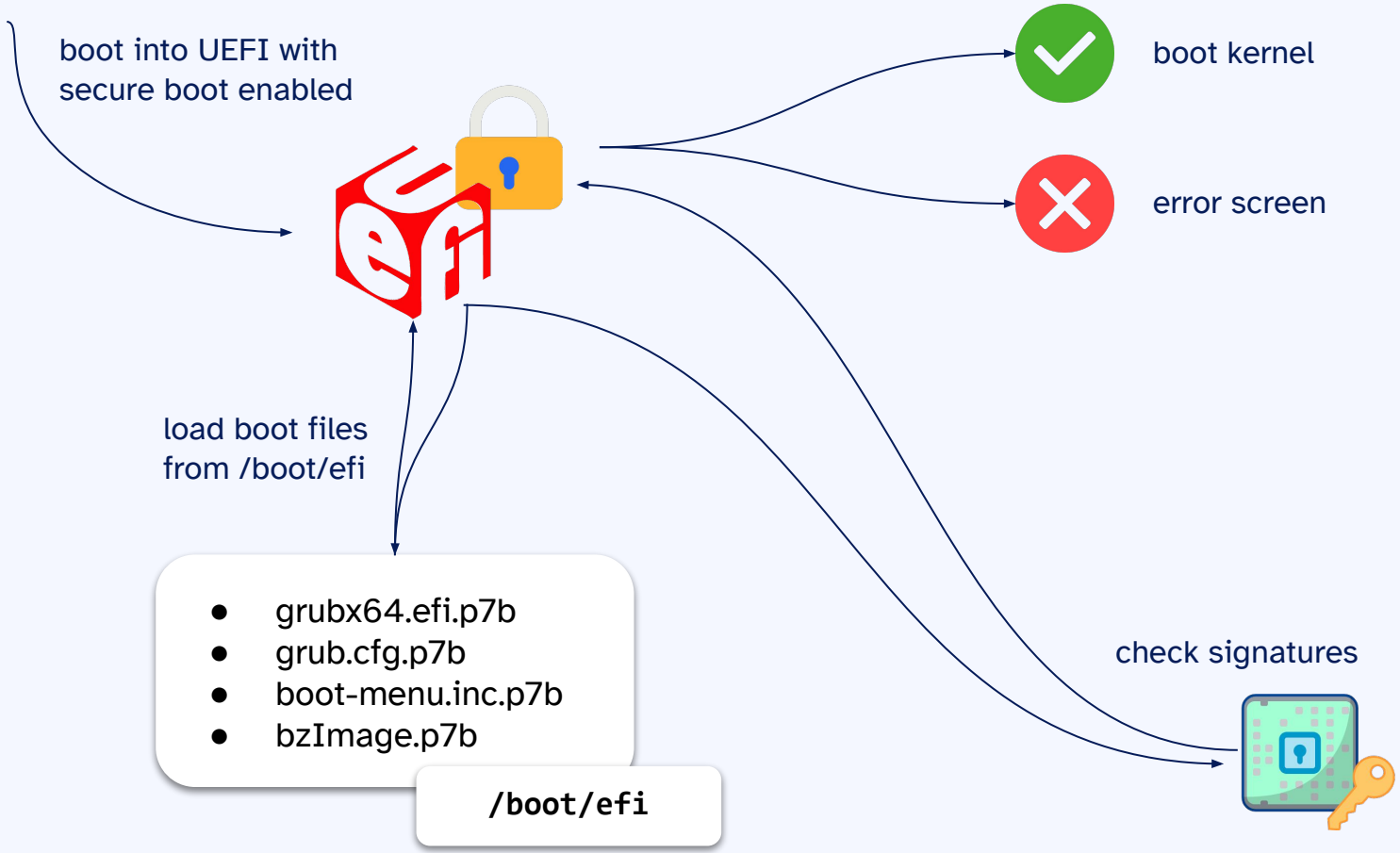
boot into UEFI with
secure boot enabled
boot kernel
error screen
load boot files
from /boot/efi
grubx64.efi.p7b
grub.cfg.p7b
boot-menu.inc.p7b
bzImage.p7b
/boot/efi
check signatures

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meta-secure-core/meta-efi-secure-boot

- grub-efi, efitools, mokutil, shim, ...
- patches for GRUB
- signing tasks for kernel, bootloader, ...
- TPM integration for keys and certificates
- automated certificate provisioning boot step

... but all examples and documentation utilize an initramfs!

Best read for kirkstone: Discussion on Mender and secure boot

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vgrid-distro.conf

```
MACHINE_FEATURES:append = " efi tpm2"
DISTRO_FEATURES:append = " \
    security \
    tpm2 \
    efi-secure-boot \
"

MOK_SB = ""
SIGNING_MODEL = "user"
```

vgrid-image.bb

```
IMAGE_INSTALL:append = " \
    tpm2-tools \
    libtss2-tcti-device \
    efitools \
    seloader \
    update-signed-kernel-state-script \
"

# Deploy kernel and signature to boot partition.
# They cannot be verified on rootfs partition.
#
# Mender processes IMAGE_BOOT_FILES and has some issues with multiline parsing
IMAGE_BOOT_FILES:append = " ${KERNEL_IMAGETYPE} ${KERNEL_IMAGETYPE}${SB_FILE_EXT}"
```


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overwritten
90_mender_boot_grub.cfg

```
...

mender_kernel_path=""
if [ "${drop_to_grub_prompt}" = "no" ];
then
    search --no-floppy --label --set=root boot
    if linux "${mender_kernel_path}/${kernel_imagetype}" root="${mender_kernel_root}" ${bootargs};
    then
        if test -n "${initrd_imagetype}" -a test -e "${mender_kernel_path}/${initrd_imagetype}";
        then
            initrd "${mender_kernel_path}/${initrd_imagetype}"
        fi
        maybe_pause "Pausing before booting."
        boot
    fi
    maybe_pause "Pausing after failed boot."
fi
```


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It works now, but ...

the kernel image within the boot partition is NOT managed by Mender!

- use Mender state scripts to copy the kernel to `/boot/efi`
  - executed as **Enter** or **Leave** action to the Mender states
  - **`ArtifactInstall_Leave_05_kernel_update`**
  - **`ArtifactRollback_Leave_05_kernel_rollback`**

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And in the end?

We have built a ~~hopefully~~ rock-solid and secure system,

with clean, understandable and maintainable code.

And a lot time spent into bringing pieces together!

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Thank you!

Time for questions.

vGRID by SaferCities

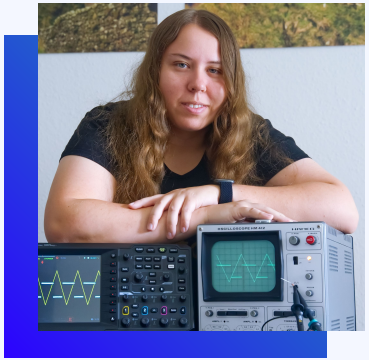
https://vgrid.io

https://safercities.com

inovex is an IT project center driven by innovation and quality, focusing its services on ‘Digital Transformation’.

- founded in 1999
- 500+ employees
- 8 offices across Germany

www.inovex.de



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