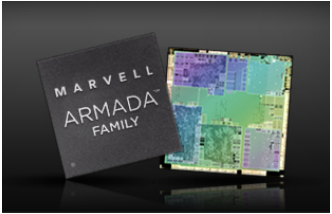
# ARM support in the Linux kernel

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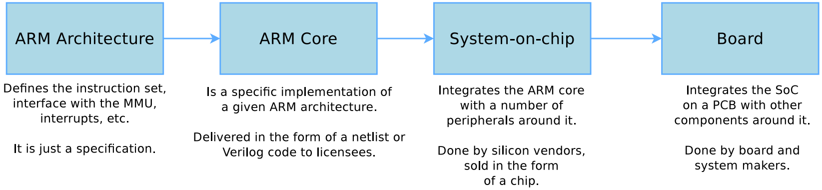
# Thomas Petazzoni

- CTO and Embedded Linux engineer at Free Electrons
  - Embedded Linux **development**: kernel and driver development, system integration, boot time and power consumption optimization, consulting, etc.
  - Embedded Linux **training**, Linux driver development training and Android system development training, with materials freely available under a Creative Commons license.
  - **We're hiring!**
  - `http://free-electrons.com`
- Contributing the **kernel support for the new Armada 370 and Armada XP** ARM SoCs from Marvell (widely used in NAS devices).
- Major contributor to **Buildroot**, an open-source, simple and fast embedded Linux build system
- Living in **Toulouse**, south west of France

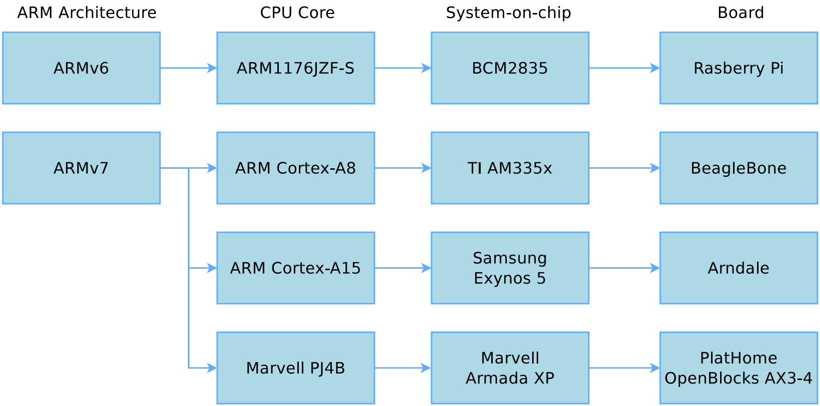
# Agenda

- Background on the ARM architecture and Linux support
- The problems
- Changes in the ARM kernel support
- Getting the support for a SoC in mainline, story of Armada 370/XP

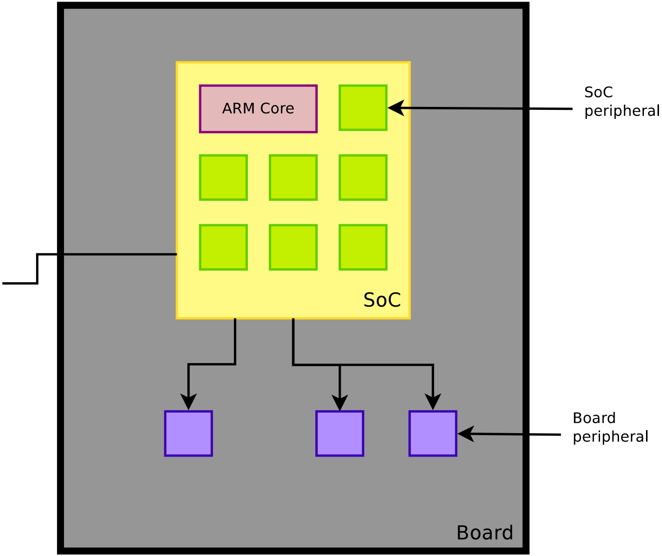
# From the ARM architecture to a board



# From the ARM architecture to a board, examples



# Schematic view of a board



# No standardization

- Beyond the ARM core itself, a lot of freedom is left to the SoC vendor.
- There is **no standard** for the devices, the management of clocks, pinmuxing, IRQ controllers, timers, etc.
  - Note: some things like IRQ controllers and timers are now standardized.
- There **is no mechanism** to enumerate the devices available inside the SoC. All devices have to be known by the kernel.

# “Old” ARM code organization in the Linux kernel

- `arch/arm/`
  - `arch/arm/{kernel,mm,lib,boot}/`
    The core ARM kernel. Contains the code related to the ARM core itself (MMU, interrupts, caches, etc.). Relatively small compared to the SoC-specific code.
  - `arch/arm/mach-<foo>/`
    The SoC-specific code, and board-specific code, for a given SoC family.
    - `arch/arm/mach-<foo>/board-<bar>.c`.
      The board-specific code.
- `drivers/`
  The device drivers themselves.

# Issue #1: too much code, lack of review

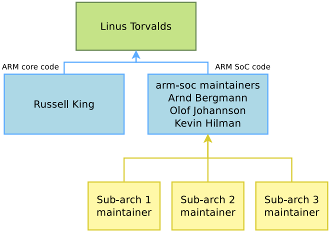
- **Exploding number of ARM SoC**, from different vendors
- The historical maintainer, Russell King, got **overflowed by the amount of code** to review.
- Code started to flow directly from sub-architecture maintainers directly to Linus Torvalds.
- Focus of each sub-architecture teams on **their own problems**, no vision of the other sub-architectures.
- Consequences: lot of code **duplication**, **missing common infrastructures**, maintenability problems, etc.
- Linus Torvalds, March 2011: *Gaah. Guys, this whole ARM thing is a f*cking pain in the ass*.

# Issue #2: the need for multiplatform kernel

- On x86 PC, one can build a **single kernel image** (with many modules) that boots and work on all PCs
- Good for distributions: they can ship a single kernel image.
- On ARM, it was **impossible to build a single kernel** that would boot on systems using different SoCs.
- Issue for distributions: they have to build and maintain a kernel image almost for each ARM hardware platform they want to support.
- Need for **ARM multiplatform support** in the kernel.

# Change #1: *arm-soc* and maintainers

- A new maintainer team for the ARM sub-architectures: **Arnd Bergmann** (Linaro) (currently replaced by Kevin Hilman) and **Olof Johansson** (Google)
- All the ARM SoC-specific code goes through them, in a tree called **arm-soc**
  - They send the changes accumulated in arm-soc to Linus Torvalds.
  - Those maintainers have a **cross-SoC view**: detection of things that should be factorized, consistency accross SoC-specific code.
  - Core ARM changes continue to go through **Russell King**.
  - Role of the **Linaro** consortium



# Change #2: Before the Device Tree... (1)

- Most devices inside an ARM SoC and on the board cannot be dynamically enumerated: they have to be **statically described**.
- The old way of doing this description was by using **C code**, registering `platform_device` structures for each hardware device. Each board was identified by a unique *machine ID* passed by the bootloader.
- This code represented a significant portion of the code in `arch/arm/mach-<foo>`.

# Change #2: Before the Device Tree... (2)

From arch/arm/mach-at91/at91sam9263_devices.c

```
static struct resource udc_resources[] = {
	[0] = {
		.start	= AT91SAM9263_BASE_UDP,
		.end	= AT91SAM9263_BASE_UDP + SZ_16K - 1,
		.flags	= IORESOURCE_MEM,
	},
	[1] = {
		.start	= NR_IRQS_LEGACY + AT91SAM9263_ID_UDP,
		.end	= NR_IRQS_LEGACY + AT91SAM9263_ID_UDP,
		.flags	= IORESOURCE_IRQ,
	},
};

static struct platform_device at91_udc_device = {
	.name		= "at91_udc",
	.id		= -1,
	.dev		= {
				.platform_data		= &udc_data,
	},
	.resource	= udc_resources,
	.num_resources	= ARRAY_SIZE(udc_resources),
};

some_init_code() {
	platform_device_register(&at91_udc_device);
}
```

# Change #2: Device Tree

- This has been replaced by a hardware description done in structure separated from the kernel, called the **Device Tree**.
  - Also used on PowerPC, Microblaze, ARM64, Xtensa, OpenRisc, etc.
  - Not invented specifically for Linux: was part of the OpenFirmware standard used on PowerPC.
- The *Device Tree Source*, in text format, gets compiled into a *Device Tree Blob*, in binary format, thanks to the *Device Tree Compiler*.
  - Sources are stored in `arch/arm/boot/dts`
- At boot time, the kernel parses the *Device Tree* to instantiate the available devices.
- Can also be used by other platform software than Linux: the U-Boot and Barebox bootloaders have started using it as well.

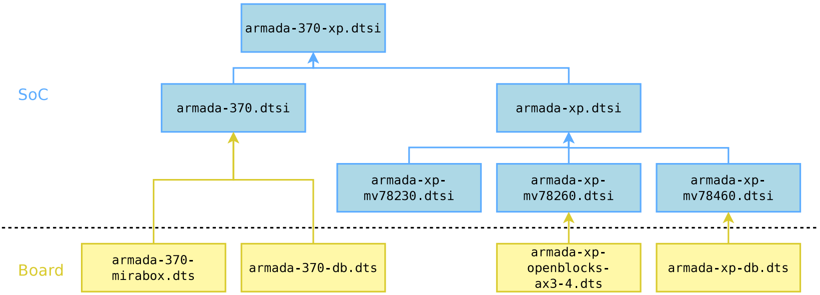
# Change #2: SoC Device Tree example

```
/include/ "skeleton.dtsi"
/ {
        compatible = "brcm,bcm2835";
        model = "BCM2835";
        interrupt-parent = <&intc>;

        chosen {
                bootargs = "earlyprintk console=ttyAMA0";
        };

        soc {
                compatible = "simple-bus";
                #address-cells = <1>;
                #size-cells = <1>;
                ranges = <0x7e000000 0x20000000 0x02000000>;

                [...]
                intc: interrupt-controller {
                        compatible = "brcm,bcm2835-armctrl-ic";
                        reg = <0x7e00b200 0x200>;
                        interrupt-controller;
                        #interrupt-cells = <2>;
                };
                uart@20201000 {
                        compatible = "brcm,bcm2835-pl011", "arm,pl011", "arm,primecell";
                        reg = <0x7e201000 0x1000>;
                        interrupts = <2 25>;
                        clock-frequency = <3000000>;
                        status = "disabled";
                };
        };
};
```

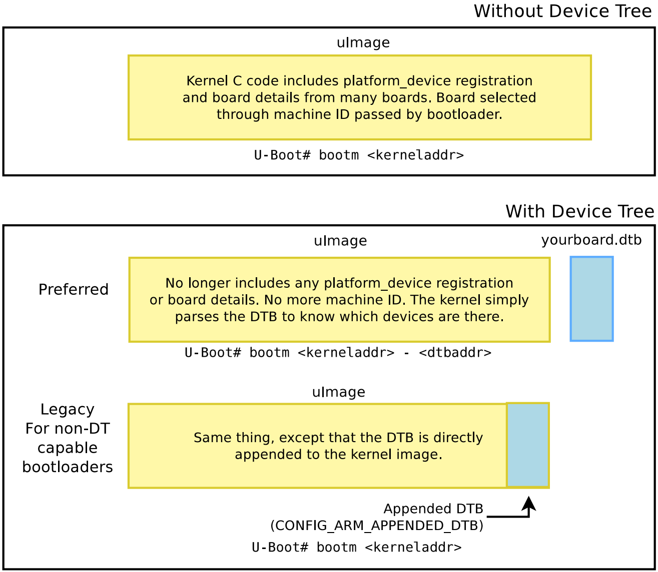
# Change #2: Board Device Tree example

```
/dts-v1/;
/memreserve/ 0x0c000000 0x04000000;
/include/ "bcm2835.dtsi"

/ {
        compatible = "raspberrypi,model-b", "brcm,bcm2835";
        model = "Raspberry Pi Model B";

        memory {
                reg = <0 0x10000000>;
        };
        soc {
                uart@20201000 {
                      status = "okay";
                };
        };
};
```

# Change #2: Device Tree inheritance



# Change #2: Booting with a Device Tree



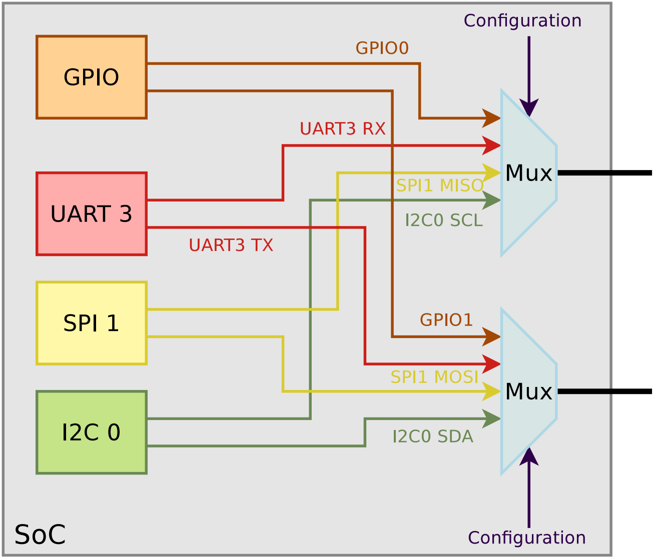
# Change #2: The notion of *DT binding*

- The idea of the *Device Tree* is that it should be a data structure that **represents the hardware**.
  - It should not be specific to Linux.
  - It should not contain *configuration*, but only *hardware description*
- The *Device Tree* becomes part of the kernel ABI. The kernel must remain capable of using old Device Trees.
- **Device Tree bindings** are the description of a particular entry of the Device Tree to represent a specific device (or set of devices).
  - Due the ABI stability requirement, they must be very carefully designed.
  - A specific mailing list, and a team of maintainers has been assigned to review those bindings.
  - `Documentation/devicetree/bindings/`
  - Increase in complexity?

# Change #3: Multiplatform kernel

- Fits the need of distributions willing to build a single kernel image that works on many ARM platforms.
- The SoC choice now contains a **Allow multiple platforms to be selected** option, and all the SoC families that are compatible with this can be compiled together in the same kernel.
  - There is still a split between ARMv4/ARMv5 on one side, and ARMv6/ARMv7 on the other side.
- A **lot of changes** have been done in the ARM kernel to make this possible: avoid two different platforms from defining the same symbol, from using the same header names, no more `#ifdef` but runtime detection instead.
- The support for all new SoCs **must use the multiplatform** mechanism.

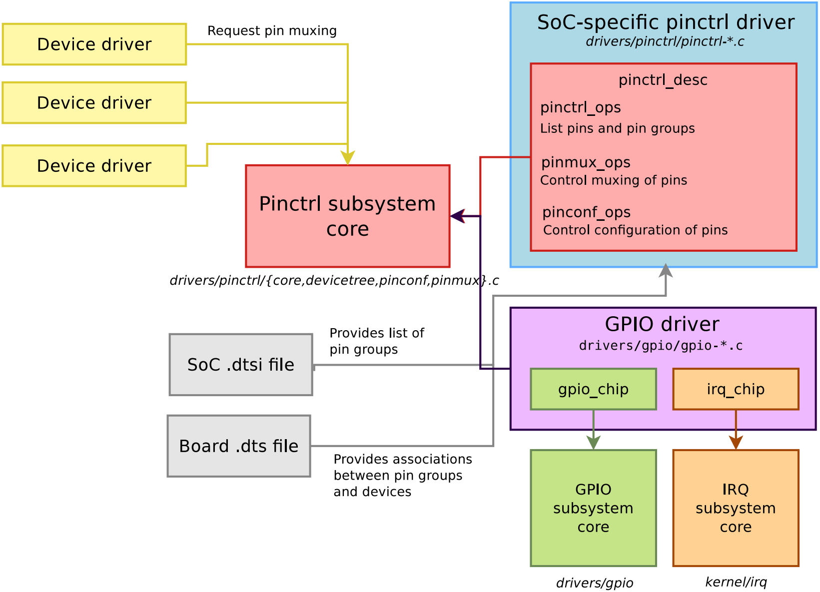
# Change #4: Pinctrl subsystem, introduction



# Change #4: Pinctrl subsystem, old code

- Each ARM sub-architecture had its own pin-muxing code
- The API was specific to each sub-architecture
- A lot of similar functionality implemented in different ways
- The pin-muxing had to be done at the SoC level, and couldn't be requested by device drivers

# Change #4: Pinctrl subsystem, new subsystem



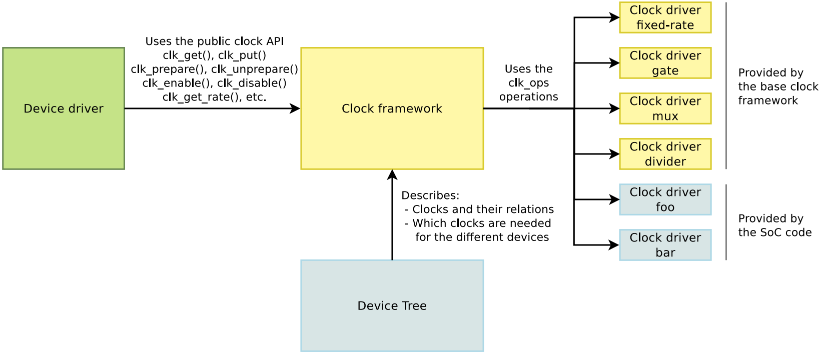
# Change #5: Clocks

- In a System-on-Chip, all peripherals are driven by one or more **clocks**.
- Those clocks are organized in a **tree**, and often are **software configurable**.
- Since quite some time, the kernel had a simple API: `clk_get`, `clk_enable`, `clk_disable`, `clk_put` that were used by device drivers.
- Each ARM sub-architecture had its **own implementation** of this API.
- Does not work for **multiplatform** kernels.
- Does not allow **code sharing**, and common mechanisms.

# Change #5: Common clock framework

- A proper **common clock framework** has been added in kernel 3.4, released in May 2012
- This framework:
  - Implements the `clk_get`, `clk_put`, `clk_prepare`, `clk_unprepare`, `clk_enable`, `clk_disable`, `clk_get_rate`, etc. **API for usage by device drivers**
  - Implements **some basic clock drivers** (fixed rate, gatable, divider, fixed factor, etc.) and allows the implementation of **custom clock drivers** using `struct clk_hw` and `struct clk_ops`
  - Allows to declare the available clocks and their association to devices in the Device Tree (preferred) or statically in the source code (old method)
  - Provides a *debugfs* representation of the clock tree
  - Is implemented in `drivers/clk`

# Change #5: Common clock framework architecture

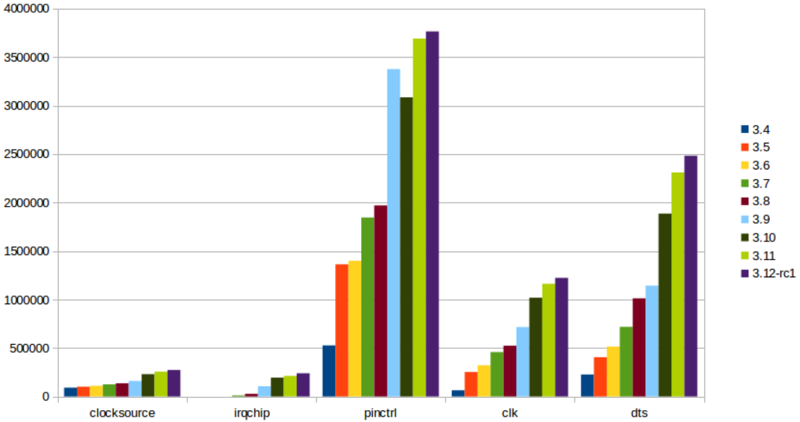


# Change #6: More things in drivers/

- Another goal of the ARM cleanup is to have less code in `arch/arm` and create proper drivers and related infrastructures.
- For example

| | |
|---|---|
| IRQ controller drivers | `drivers/irqchip/` |
| Timer drivers | `drivers/clocksource/` |
| PCI host controller drivers | `drivers/pci/host/` |
| Clock drivers | `drivers/clk/` |
| Pinmux drivers | `drivers/pinctrl/` |
| Memory drivers | `drivers/memory/` |
| Bus drivers | `drivers/bus/` |

# Adoption rate




Size in bytes of the source code, in the following directories: `drivers/clocksource`, `drivers/irqchip`, `drivers/pinctrl`, `drivers/clk`, `arch/arm/boot/dts`.

# Armada 370/XP, Linux 3.6

Device Tree (SoC and board)
`arch/arm/boot/dts/`

Basic "initialization" C file + basic header files
`arch/arm/mach-mvebu/`

Timer driver
`drivers/clocksource/`

IRQ controller driver
`drivers/irqchip/`

earlyprintk support
`arch/arm/include/debug`

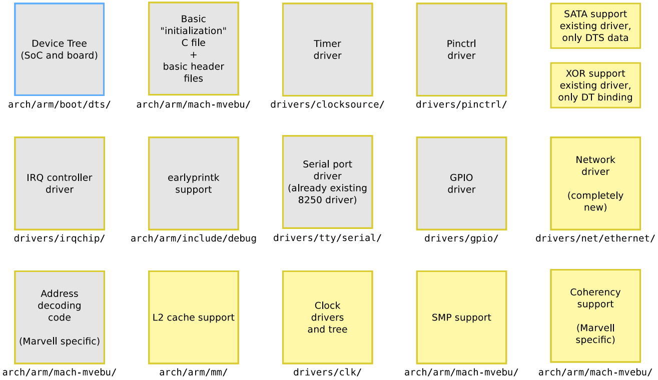
Serial port driver (already existing 8250 driver)
`drivers/tty/serial/`

**Total: 10 patches**

# Armada 370/XP, Linux 3.7

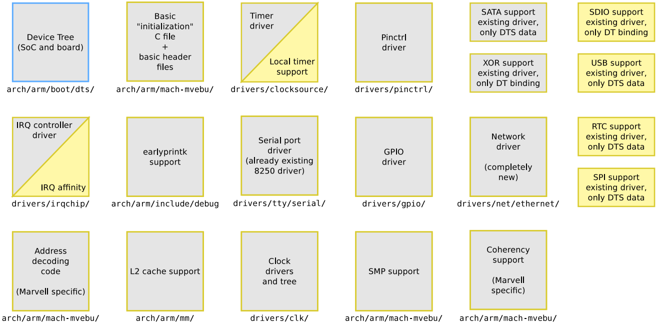
- Device Tree (SoC and board) — `arch/arm/boot/dts/`
- Basic "initialization" C file + basic header files — `arch/arm/mach-mvebu/`
- Timer driver — `drivers/clocksource/`
- Pinctrl driver — `drivers/pinctrl/`
- IRQ controller driver — `drivers/irqchip/`
- earlyprintk support — `arch/arm/include/debug`
- Serial port driver (already existing 8250 driver) — `drivers/tty/serial/`
- GPIO driver — `drivers/gpio/`
- Address decoding code (Marvell specific) — `arch/arm/mach-mvebu/`

**Total: 35 patches**




**Total: 99 patches**

# Armada 370/XP, Linux 3.9




**Total: 58 patches**

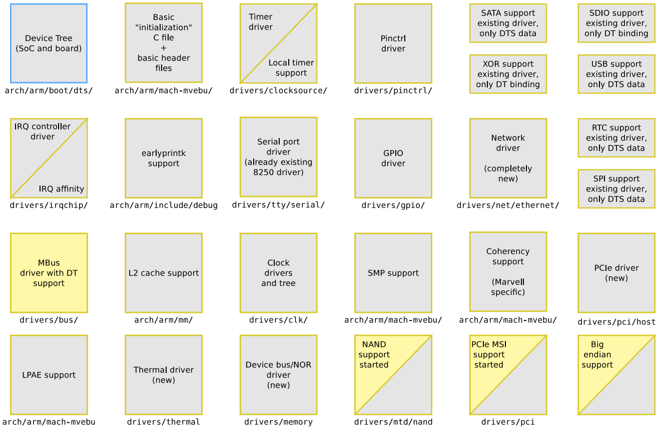
# Armada 370/XP, Linux 3.10


**Total: 57 patches**

# Armada 370/XP, Linux 3.11


**Total: 66 patches**

# Armada 370/XP, Linux 3.12-rc1




**Total: 92 patches**

# Getting an ARM SoC in mainline

- **Throw away the vendor BSP code**. Most likely it is completely crappy. You have to start from scratch.
- **Start small**, and send code piece by piece. Don't wait to have everything fully working.
- **Comply with the latest infrastructure changes**: Device Tree, clock framework, pinctrl subsystem. They are mandatory.
- **Read and post to the LAKML**, Linux ARM Kernel Mailing List
- **Listen to reviews and comments**, and repost updated versions regularly.
- **Look at recently merged sub-architectures**: highbank, mvebu, sunxi, bcm2835, socfpga, etc.

# And now...

*Over the last year, ARM has gone from a constant headache every merge window to an outstanding citizen in the Linux community*

Linus Torvalds, August 2012

# Questions?

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Thanks to Gregory Clement, Ezequiel Garcia (Free Electrons, working with me on Marvell mainlining), Lior Amsalem and Maen Suleiman (Marvell)



http://free-electrons.com/pub/conferences/2013/kernel-recipes/arm-support-kernel/