Control for High Availability, Mission Critical Networked Visualisation Systems

Barco
Security and Monitoring Division

Marc Leeman, Ph.D.

Overview

- Software Definition
- Hardware Overview
- Barco SMD Case Study
  - Typical Causes for Errors
  - Design Considerations
  - Reliable, Predictable
  - Embedded Software
  - System Layout
  - Software Control
  - Fall Back: serial
- Conclusions

What is Software?

- Software =/= Java/C++
  - Algorithmic form
    - e.g. C code
  - Relational form
    - e.g. VHDL
- Software fundamentally is the unique image or representation of physical or material alignment that constitutes configuration to or functional identity of a machine, usually a computer.
- Not all fault tolerance needs to be done in one component (e.g. uC) on one die.

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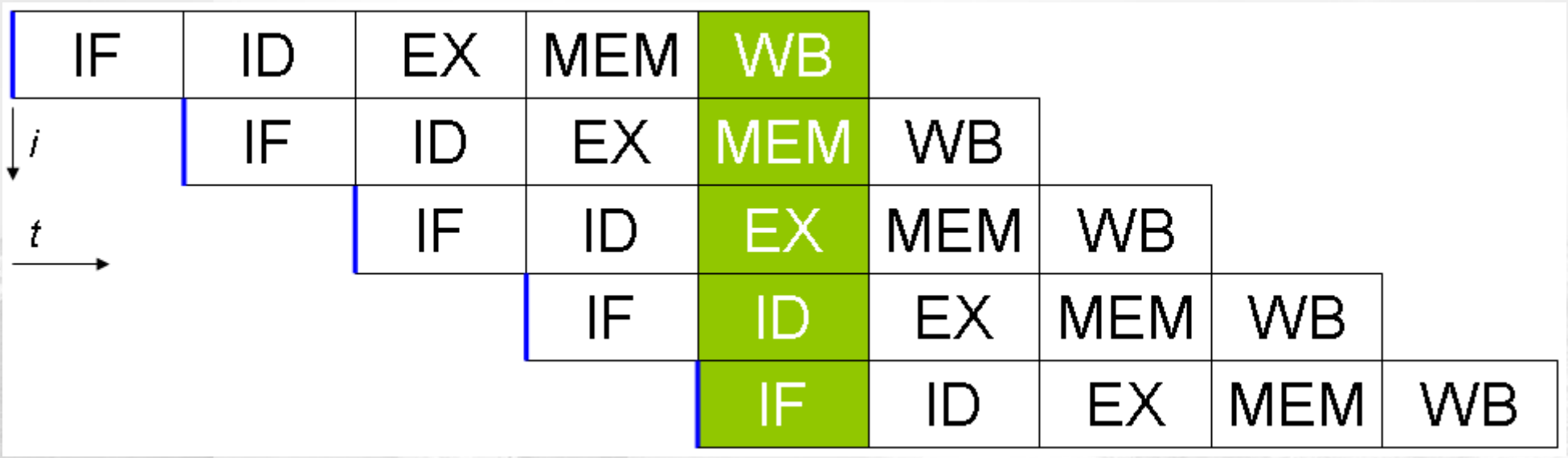
Hardware Overview

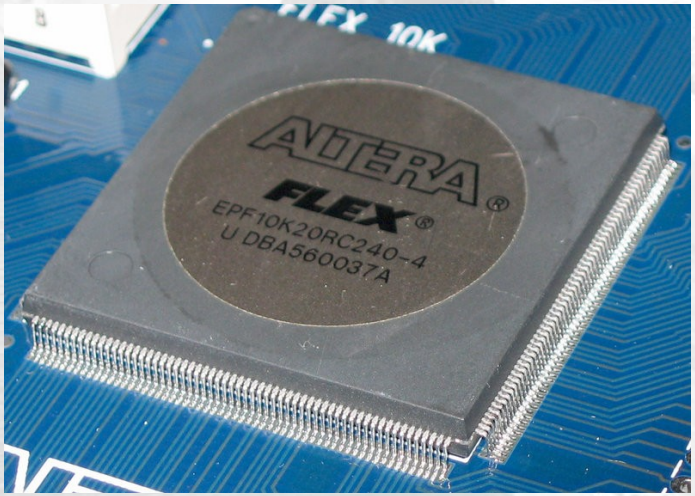
- microprocessor/microcontroller (uP/uC)
  - ia86, ia86-64
  - powerpc, arm, m68k, ...
- Digital Signal Processor
  - special class of uP
  - for digital signal processing (e.g. video and audio sampling and processing).
  - Instructions in parallel
  - Deep instruction pipeline
  - Specialised instructions (e.g. vector operations).

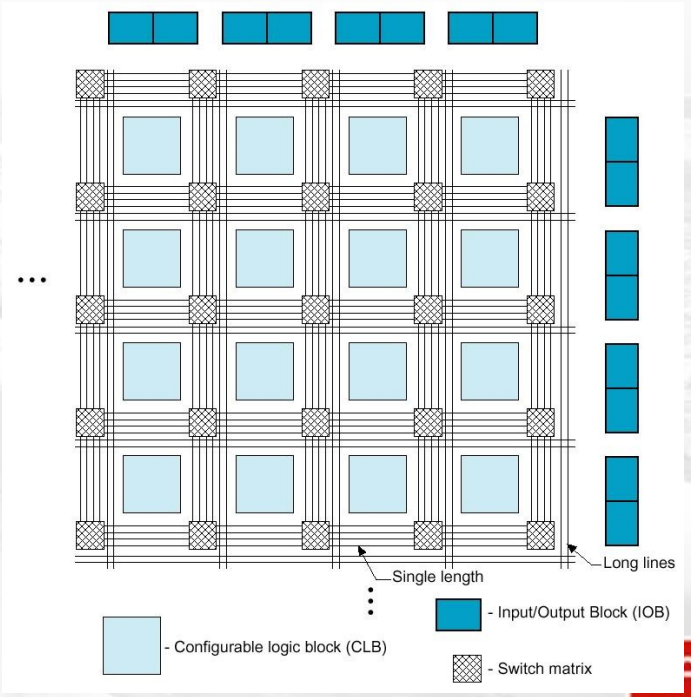
Instruction Pipeline



Hardware Overview (cont.)

- Field Programmable Gate Arrays
  - Parallel execution
  - Gates are programmed to mimic logic gates





Hardware Overview (cont.)

- Application Specific Integrated Silicon
  - expensive to develop
  - Highly dedicated, efficient and performant devices.
    - Performs one and only one function.
  - Off The Shelf usage (COTS)

Notes

- Distinction between these device classes is not so clear cut anymore
- uP has DSP properties
  - e.g. vector operations
- DSPs are equiped with uP cores
  - Da Vinci platform from TI
- FPGAs contain uP soft and hardcores

Cost/Design

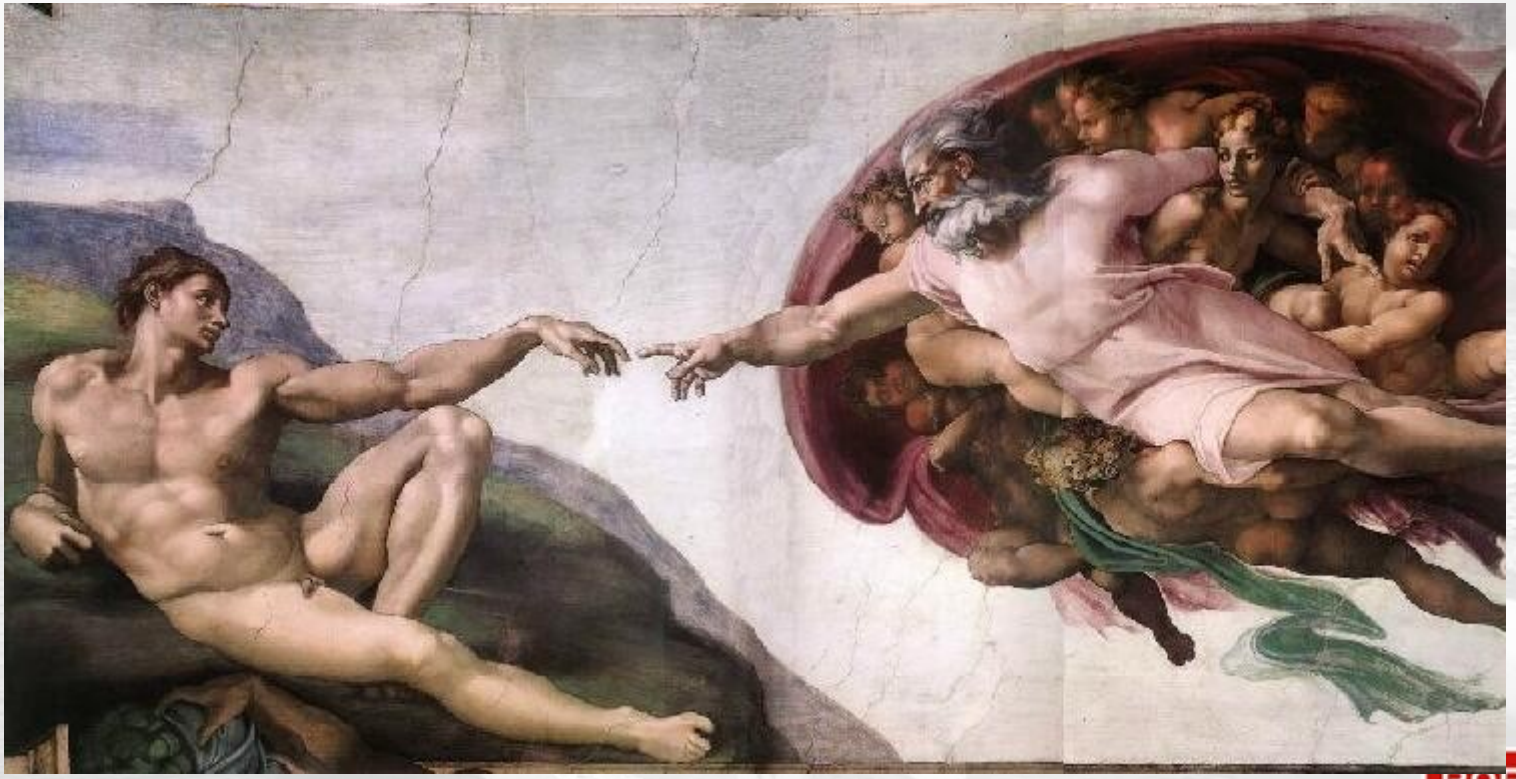
- Application Specific Integrated Circuits (ASICs) are cheap to produce but expensive to create
  - large initial investment costs
  - large volumes
- FPGAs are more expensive but lower initial development cost
  - small to middle sized volumes.

What is Software? (cont.)

- Hardware can be viewed as inanimate matter; it needs to be correct to function properly.
  - Body
- Software makes the hardware alive.
  - Flexible.
  - Can compensate for errors (cf. brain function recovery).

What is Software? (cont.)

- *Writing software is playing god (on a system level)?*



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Barco SMD case study

- Streaming Video Card
- Take in video and decode it
  - mpeg{2|4}, wavelet based, mjpeg, mxpeg, ...
  - vendor 'extensions'
  - up to 8 streams on one card
    - 1 Altera Stratix II FPGA
    - 5 DSP C64 DSPs
    - 1 PowerPC 8347 processor

Typical Causes for Errors

- Hardware failure/bugs
  - MAC hangs
- Software bugs
  - segfault, out of memory.
- Unforeseen circumstances.
- Peripheral network
  - switches, routers, network settings, ...
- STEUs (STupid End Users)
  - the most dangerous are not those that don't know the system but those that think they know the system.

Design Considerations

- Dependability
  - High Availability
  - Reliable
  - Predictable
  - Maintenance
  - Security
- Cost
- *With these in mind, select an optimal combination of devices that adequately cover the functionality*

Reliable

- Hardware
  - High uptime
  - Error correction
  - Redundancy
    - Component Level
      - e.g. networking interfaces
    - Board Level
      - Hot swap
        - in case of hardware failure/other unresolvable problems
    - System Level
      - e.g. hot stand-by

Reliable (cont.)

- Software
  - Correct **BEFORE** the faults occur
    - Inspect and correct data stream
    - Negociate settings
  - Cope with Hardware changes
    - e.g. restore settings
  - Cope/Mask Hardware failures
    - e.g. MAC lock
    - Corrupted flash sectors
  - Catch unforeseen circumstances
    - power-failure while writing to persistent media

Predictable

- A predictable situation is always to be preferred over a unknown state.
- Uncertainty = 666.
  - High cost for recovery and reconfiguration.
  - Downtime.
- Basis for recovery.
- *It is better to resort to an old predictable situation than to a another unpredicatable one.*

Embedded Software

- Systems are stand-alone/headless
  - no keyboard
  - no screen
- Some (older) systems do not provide a serial interface
- Access:
  - shell
  - BDI/JTAG probe

Small is Beautiful

	speed increase	RAM reduction	Power reduction	Cost reduction
More speed			- CPU can run slower or stay longer in power saving mode	-Slower, cheaper CPU
Less RAM	- Faster Allocations - Less swapping - Sometimes less cache flushing		-fewer/smaller RAM chips: less dynamic and standby power - CPU with less cache: less power	- Fewer/cheaper RAM chips - CPU with less cache: cheaper
Less space	- Faster application loading from storage and in RAM - Sometimes simpler, faster code	- less ram usage	- Fewer/smaller storage chips: less power	- Fewer/cheaper storage
Less power				-Cheaper batteries
Less complexity				- Less design errors

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System Layout

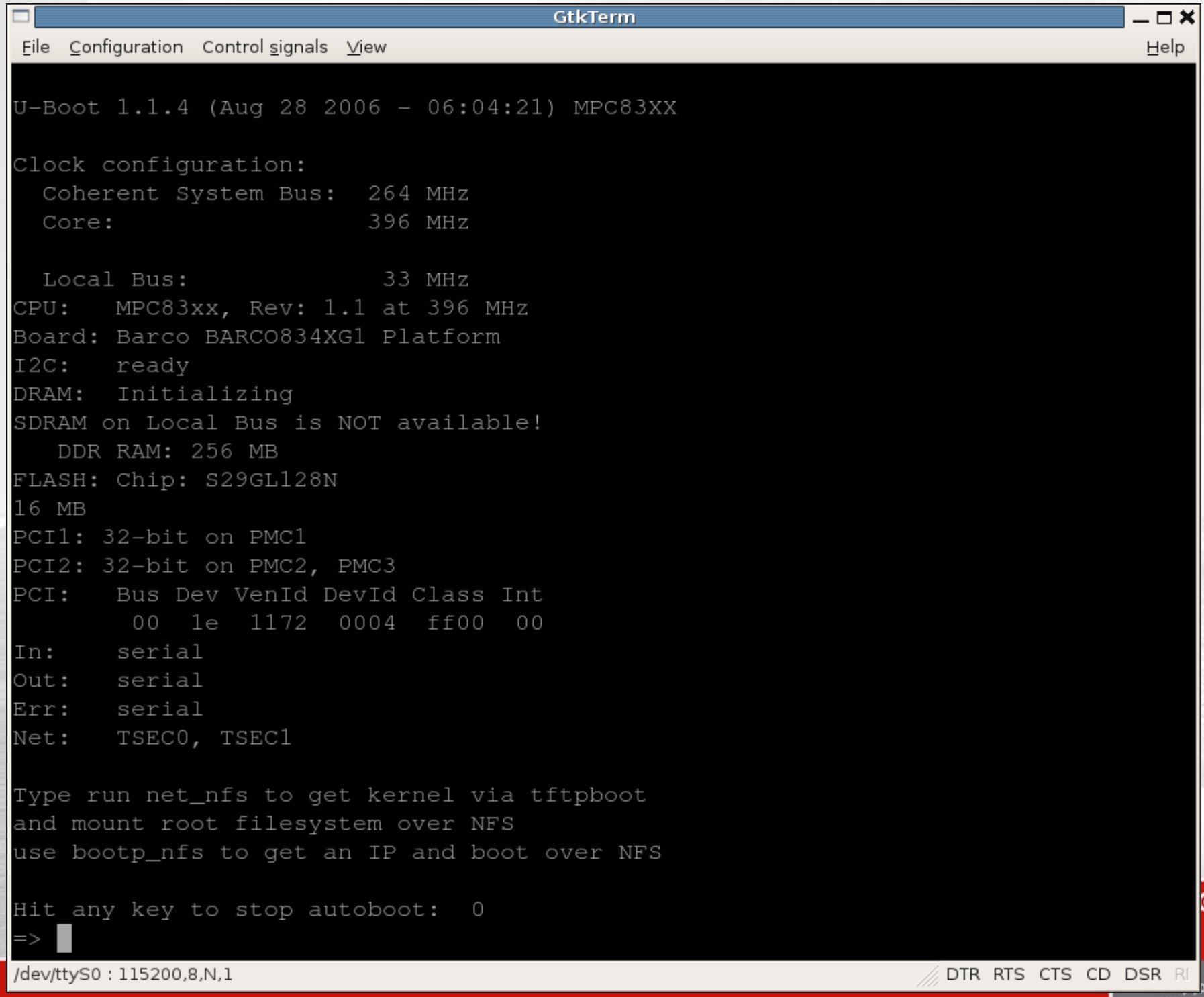
- Bootloader: Das U-Boot
  - flexible, reliable, redundancy, ...
- Kernel: Linux
  - reliable, modifiable, flexible, ...
  - open: no hidden complexity
  - closed 3rd party Oses: difficult to obtain a measure of reliability
  - Code quality of 'closed source' OSes is poor (cf. Windows CE and XP embedded).
  - No peer review

System Layout (cont.)

- System level:
  - uclibc +busybox
    - uclibc: Smaller footprint wrt to glibc applications
    - busybox: shared (startup) code
- Custom application firmware, CGI, mDNS and dropbear for shell access.

Das U-Boot

- Hardware initialisation and setup
  - set CPU (MPC8245 and MPC8347) Registers
    - some registers can only be set @startup
      - GPIO/Interrupt
      - MMU activation
- Loads Linux kernel from flash in memory and extracts it
  - adjust PC
- serial, hardware inspection, scripting, ...



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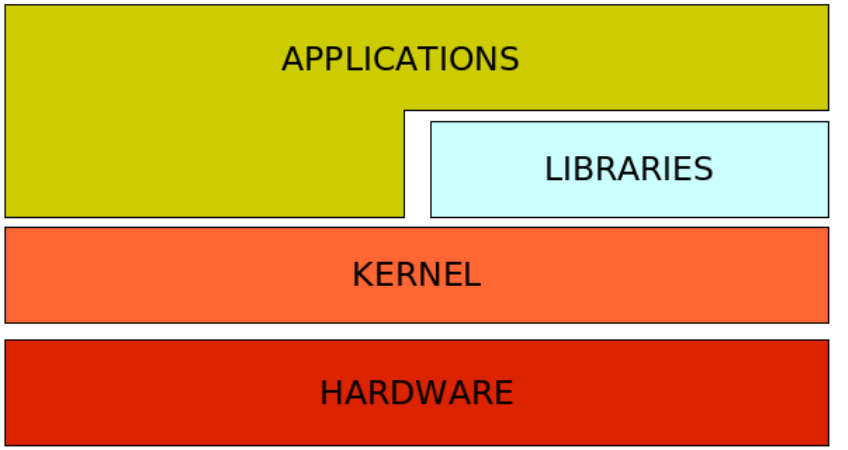
Linux Kernel

- Linux =/= OS =/= distribution!
  - GNU/Linux, GNU+Linux, ...
- Single point of access to hardware
  - All application must pass through the kernel to access components
  - User separation
- (Dependability)

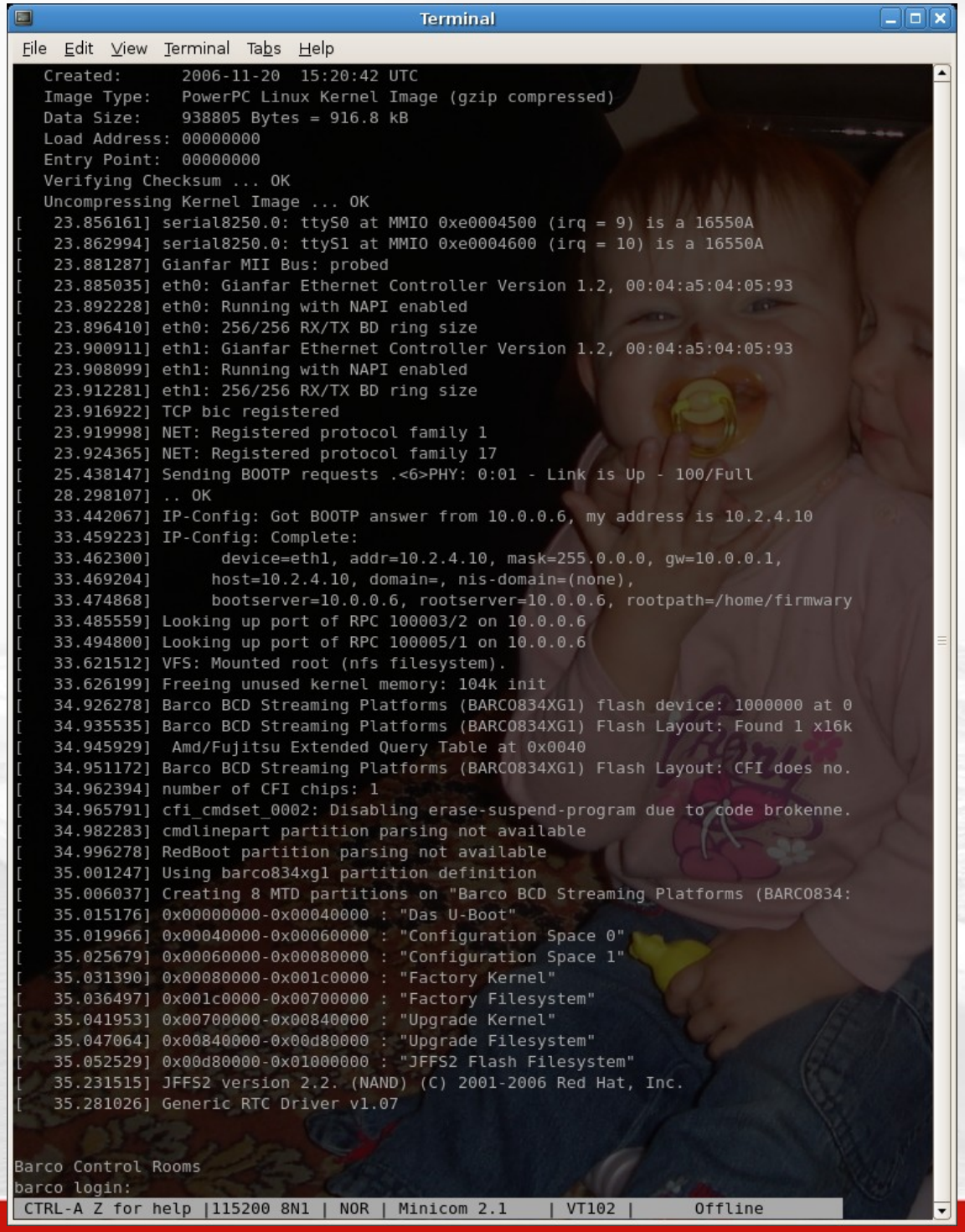


The Linux Kernel

- Basic hardware detection and initialisation
  - In the kernel image is needed:
    - minimal configuration to allow recognition of root FS
    - hardware with for root partition
      - SCSI, IDE, LIBATA, FLASH, MAC/PHY, ...
    - File system
      - ext2, ext3, jfs, xfs, nfs, reiserfs, ...
  - What is not needed:
    - Firewall (iptables), keyboard, mouse, ... (peripherals)
    - Can be postponed to the final stages of booting

The Linux Kernel (cont.)

- Good Practice
  - only include the needed functionality
  - only include the needed complexity
- Modules offer an extra level of abstraction: it is/is not in the kernel.



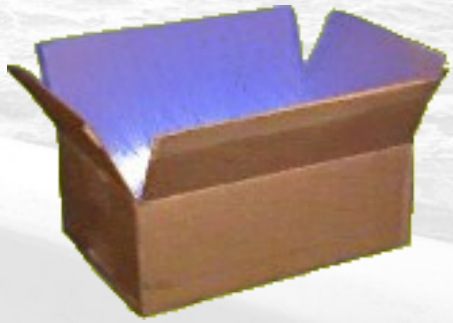
uClibc

- glibc (GNU C library):
  http://www.gnu.org/software/libc/
  Found on most computer type GNU/Linux machines
  Size on `arm`: approx 1.7 MB
- uClibc: http://www.uclibc.org/
  Found in more and more embedded Linux systems!
  Size on `arm`: approx 400 KB (you save 1.2 MB!)

C program	*Compiled with shared libraries*		*Compiled statically*	
	glibc	*uClibc*	*glibc*	*uClibc*
Plain “hello world”	4.6 K	4.4 K	475 K	25 K
Busybox	245 K	231 K	843 K	311 K

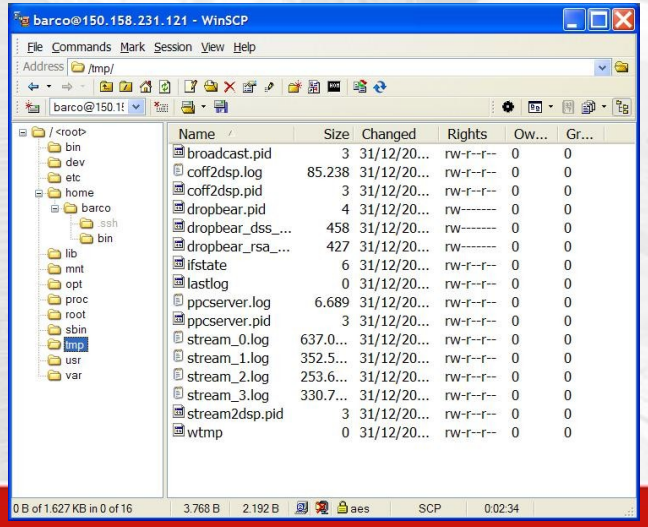
busybox

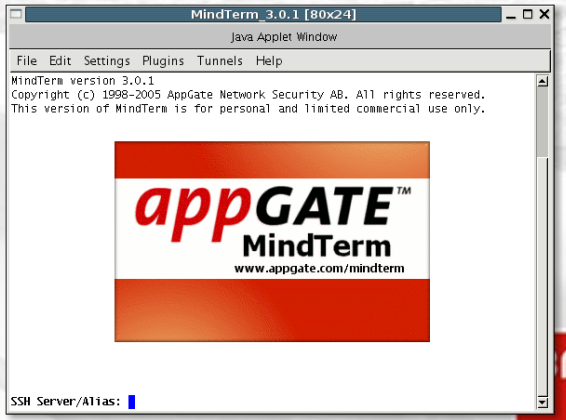
- combine unix utilities in one single small executable
- share startup code
- configurable commands
- configurable functionality of the commands
- applets easy to add



System Level

- CGI
  - Provide access levels: unauthorised access can result in parameter corruption
- Dropbear
  - Encrypted and Secure access





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What Now?

- We've minimised the possible fault footprint by carefully chosing our software modules
- Finished?
- NO
- We need to compensate for hardware/component failure
  - Software Control

Software Control

- Though hardware provisions are taken for failures, software fine-grained software control is required at all levels to tackle failures
  - Board Level
    - CPU configuration
    - Operating System
    - UserSpace applications
  - System Level

Board Level

- CPU configuration
  - RTC/Watchdog
  - Hardware provision in silicon to detect CPU lockups
    - reset CPU
- Network
  - bonding module (bonding.ko)
    - 2 physical interfaces provide one logical interface to the applications
    - one fails, the second interface takes over

Board Level (cont.)

- bonding.ko is the kernel interface
- ifenslave binds physical interfaces to the bonding interface
- a monitoring (e.g. 10 ms) interval is provided.

Board Level (cont.)

- Configuration/Save
  - CRC32 checks validity/corruption of data (e.g. jffs2.ko)
- Flash
  - writing to flash is slow
  - erase flash: set all words to 0xffffffff
  - toggle relevant bits back to 0
  - done on block size (64/128 kB).
  - Writing one bit in flash can cause the erase of 128 kB and re-writing (128*2^1024 - 1) to 0

Board Level (cont.)

- Redundant flash partition
  - CRC checked
  - bit valid toggle
  - write to flash
    - toggle current flash data as not valid
    - burn data to flash with valid bit
  - restore from flash
    - check for valid bit
    - check CRC
      - if CRC is not valid, check backup
      - if backup CRC not valid; restore with sensible defaults

Board Level (cont.)

- Current fails systems are within one device
- FPGA plays master over processor
- watchog daemon passes alive beat to FPGA
  - if watchdog is not asserted, FPGA brings processor in reset.

Board Level (cont.)

- DSP: Processor without MMU
  - no protection for different memory segments
  - rogue pointers can corrupt data/program memory
  - a reload of the program/OS is required
- Processor watches DSP (#decoded frames)
  - re-loads when #frames does no longer increment/changes

System Level

- Several boards in one case
  - 'board manager'
- Several cases in one system
  - boards backup their data to central point
  - when one board fails and is replaced (hot plug), board manger provides the needed details to restrieve settings from failed boards from central point

System Level (cont.)

- At startup of a system
  - Code is loaded from the board itself
    - modular
    - changes isolated per board
  - Code is loaded via a backplane
    - changes are system/node wide
    - 1 upgrade upgrades the system/node

Low-Level Fall-Back

- Serial interface
  - simple protocol
  - 2 lines/pins
- Spawn a shell on /dev/ttyS0
  - serial shell access
- Debugging messages are sent to serial
- Access to bootloader
  - inspect hardware
  - replace flash images

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Conclusions

- Reliability needs to be taken into account during the entire product design.
- HW/SW reliability are complementary:
  - SW masks/corrects HW faults
  - HW masks/corrects SW faults
- HW/SW Co-design

Conclusions (cont.)

- You can only write reliable software as long as you keep a clear view on the underlying hardware.
  - e.g.:
    - What are the effects of code on an instruction level?
    - What are the effects of code on memory usage?
    - How does memory usage influence runtime behaviour?