Embedded Linux

ECE 373

- I'll take "Gizmos" for $200, please, Alex

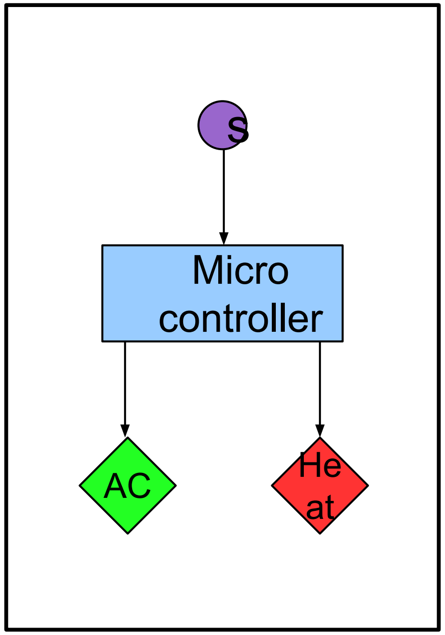
- They're called Embedded Computers

Embedded Computers

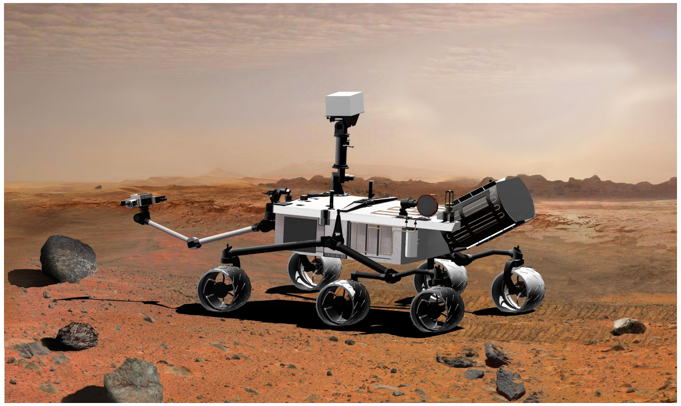
- computer system designed to do one or a few dedicated and/or specific functions
- often with real-time computing constraints
- part of a complete device often including hardware and mechanical parts

Simple drone for repetitive jobs

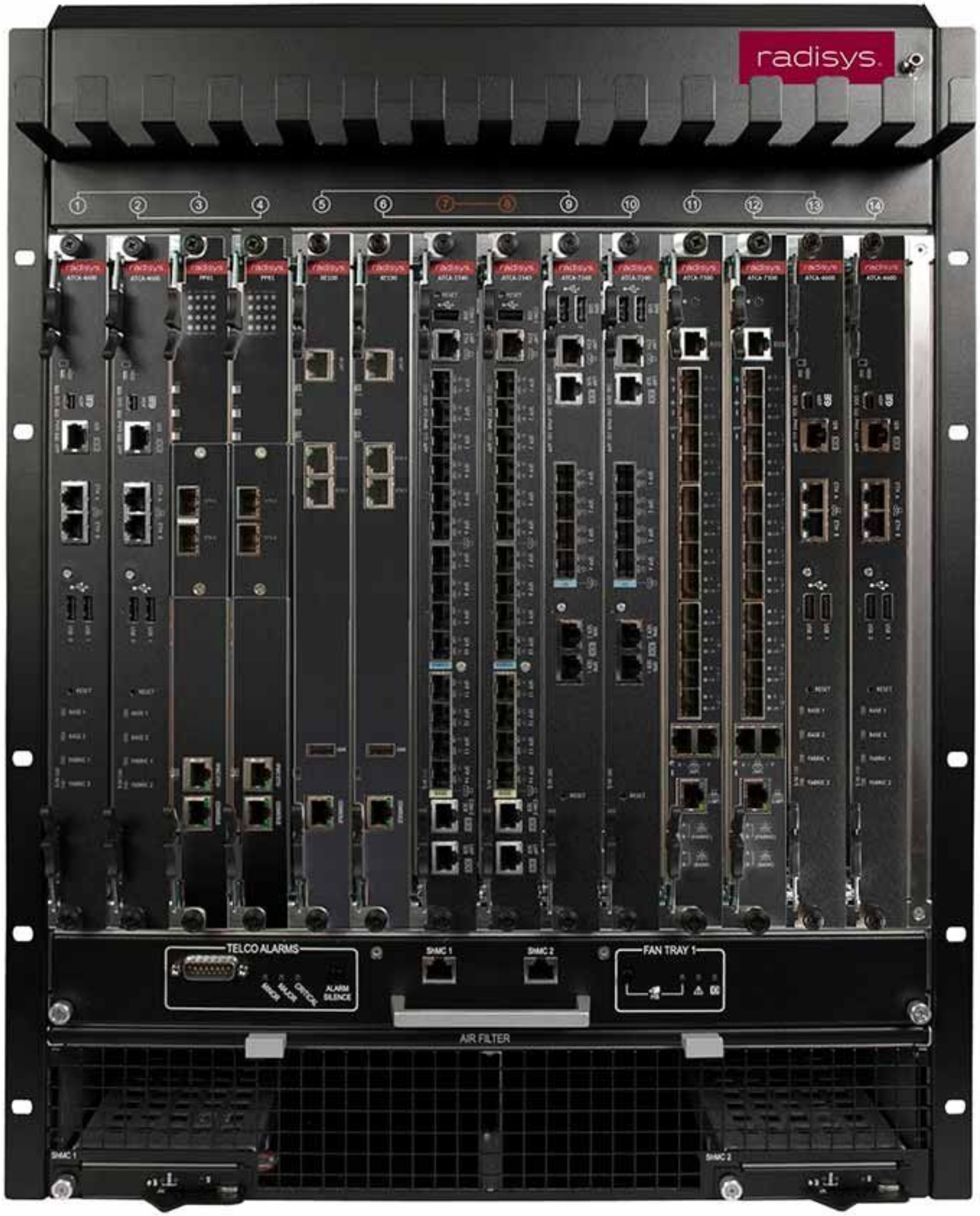
- While (have power)
  - Sleep 10
  - Read temperature sensor
  - If too hot
    - Turn on air conditioner
  - Else If too cold
    - Turn on heat
  - Else
    - Turn off heat
    - Turn off air conditioner



Some not so simple

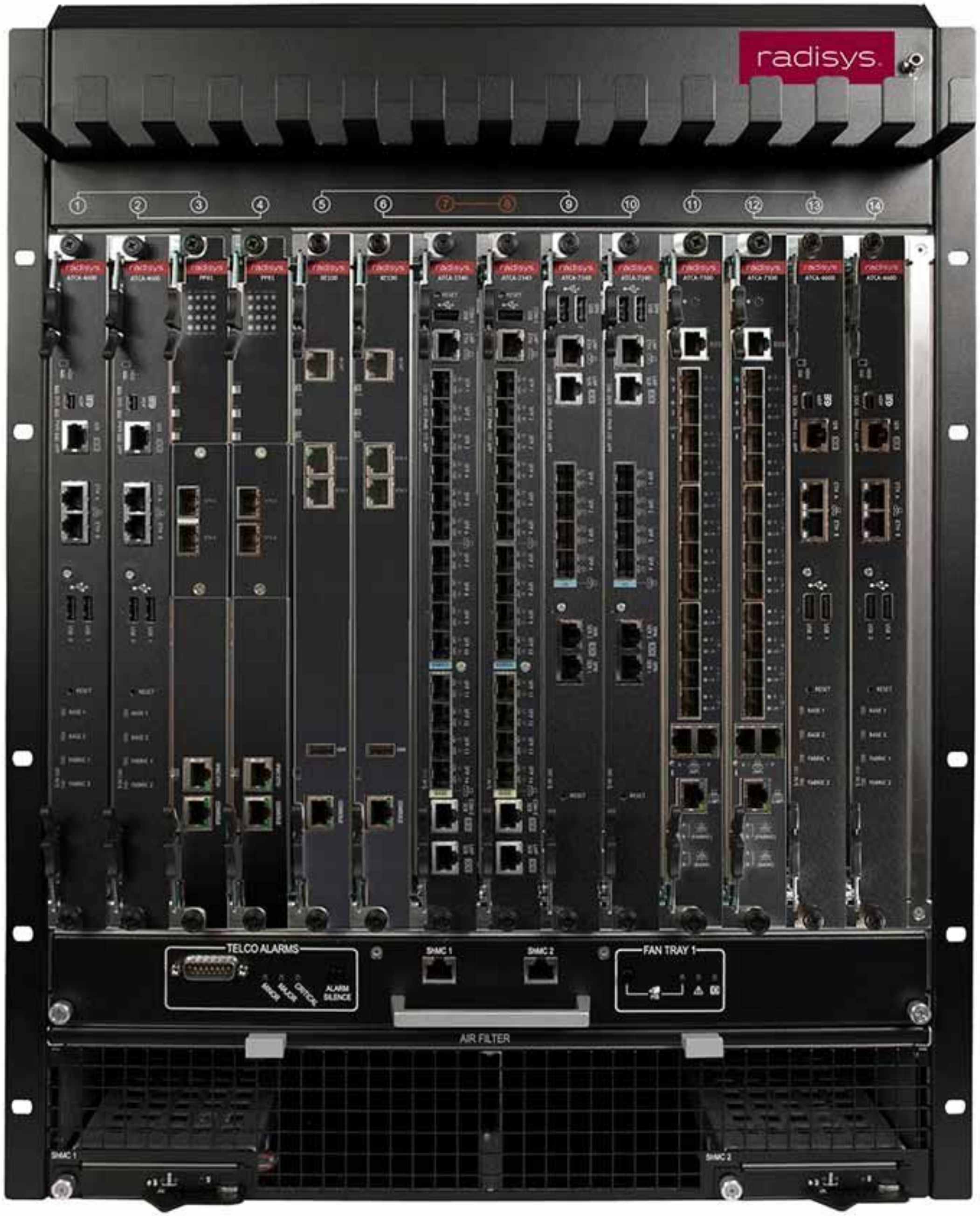


Count the embedded controllers



- Radisys T40 ATCA

Count the embedded controllers



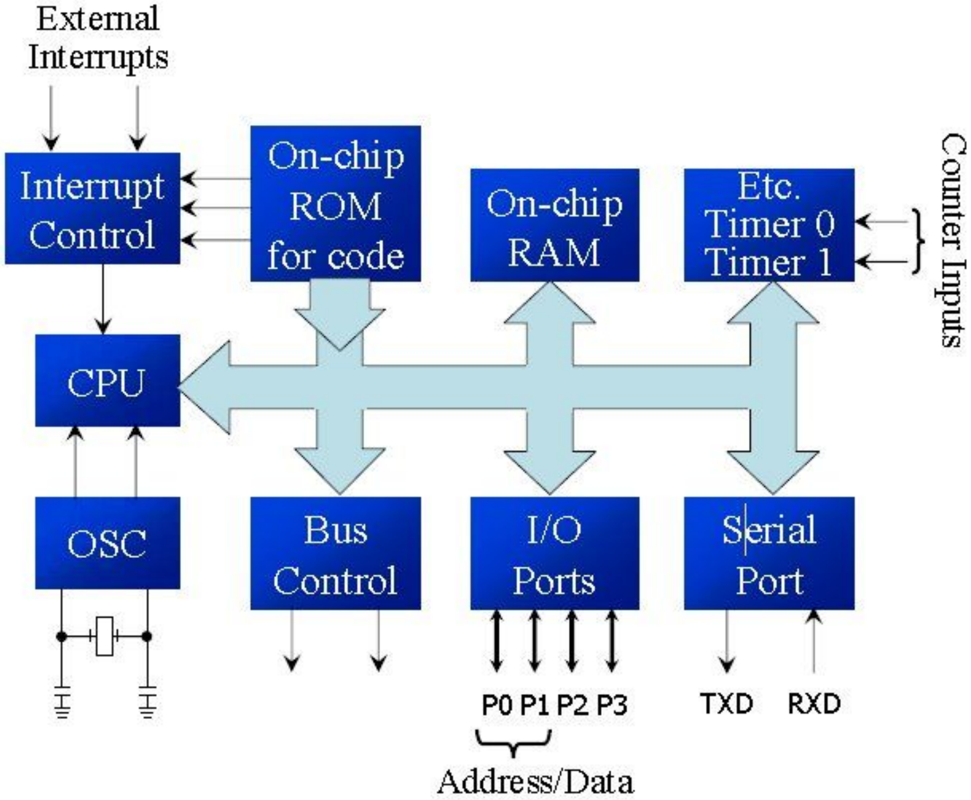
- Radisys T40 ATCA

- 2 – Failover SCMs
  - System Control Modules
- 14 – BMC per SBC
  - Board Management Controller
  - Single Board Computer
- 14 – 40GbE per SBC
  - Network between SBCs
- 14 – RTM per SBC?
  - Rear Transition Module
- Other devices?

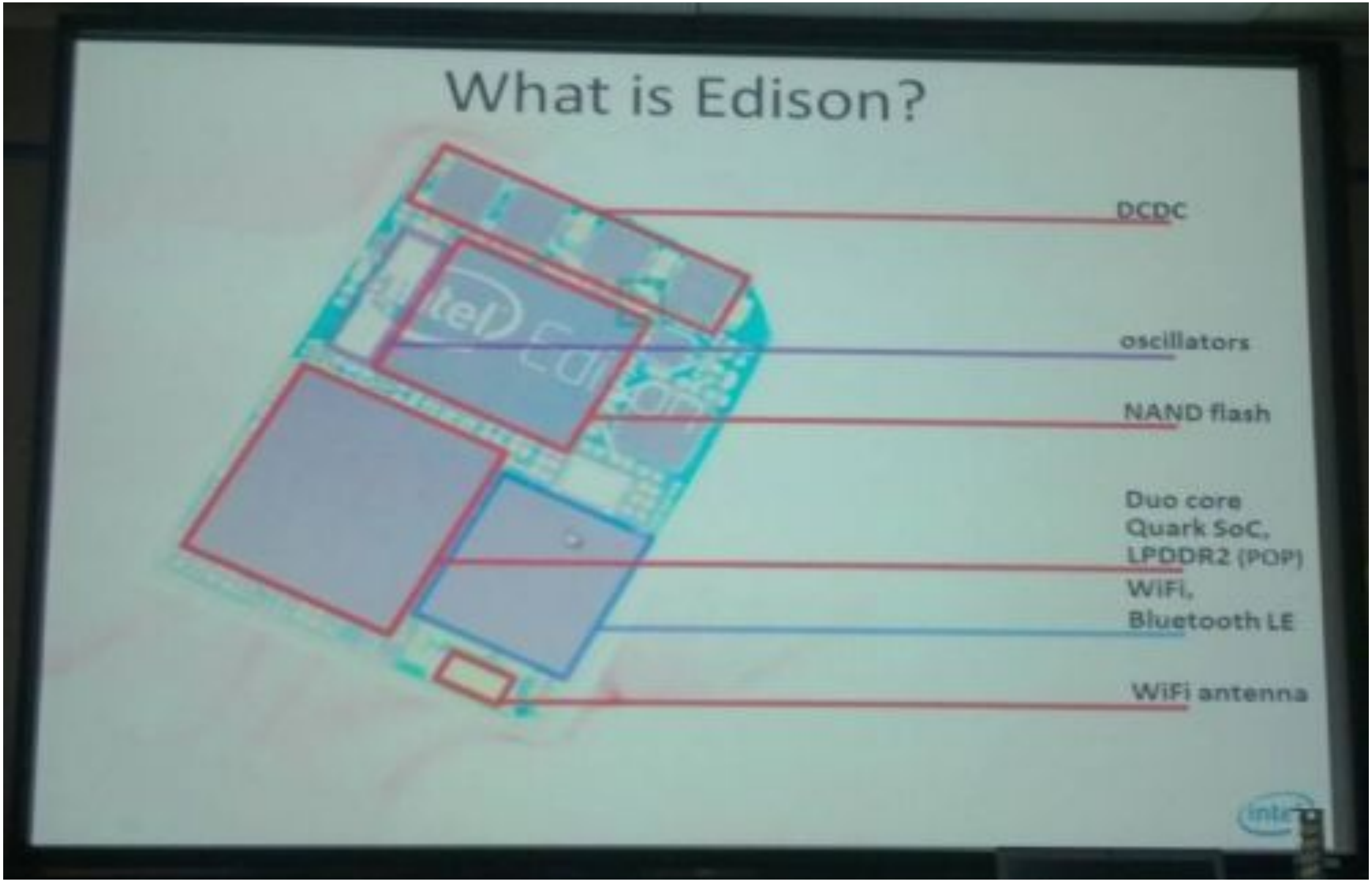
- ...at least 44 per platform

8051

- Small, cheap, simple
- Created 1980, still used now
- ½ of all little devices by some estimates
- Everything you need for a basic microcontroller



"Edison"



What is Edison?

DCDC

oscillators

NAND flash

Duo core
Quark SoC,
LPDDR2 (POP)

WiFi,
Bluetooth LE

WiFi antenna

Typical Requirements

- Inexpensive
- Reliable
- Non-stop
- Low power
- Fast start
- Secure

Inexpensive Hardware

- SoC or small motherboard
- Small low power CPU
- EEPROM and/or SDRAM
- No hard drive, but maybe SIMM or SD chip
- JTAG for debug, maybe a serial output
- No big video or sound (Raspberry Pi?)
- Maybe some LEDs, relays on GPIOs, etc.

Small SW Footprint

- Less memory = less cost
- Less memory forces less SW
- Remove unnecessary modules
  - SCSI? Fancy Communications?
  - Multiprocessor?
  - 20 different network chip drivers?
  - Printer support?
  - Fancy memory allocation schemes?
- See Linux kernel config file

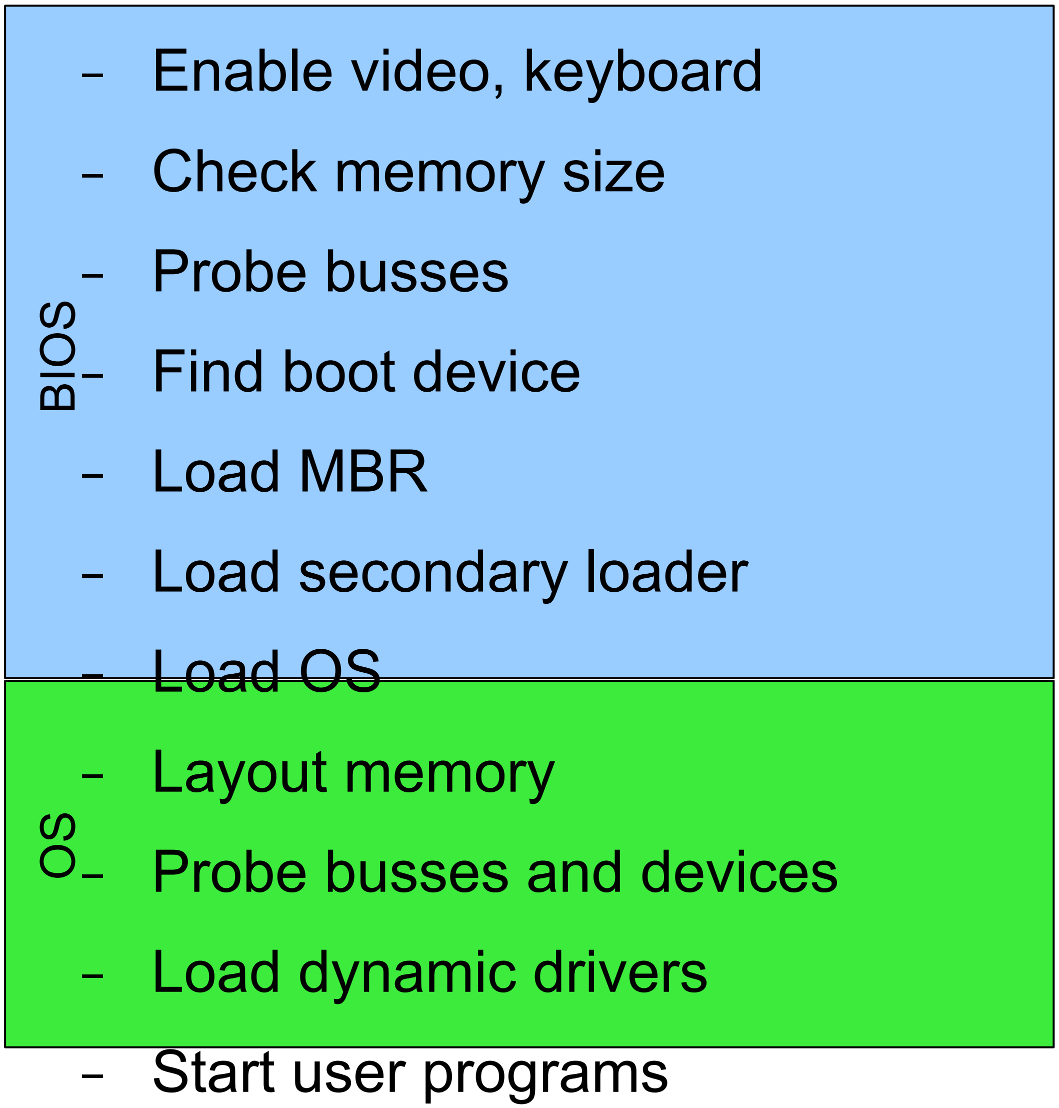
Compact boot loaders

- Common loaders
  - LILO – early and simply Linux kernel boot
  - grub – current standard kernel boot
  - RedBoot – tuned by Redhat
  - YAMON – MIPS
  - U-Boot – ARM and PowerPC
  - Extlinux – Flexible, simple

- Typical actions
  - Chip reset vector to rom (bios or bootloader)
  - Copy OS loader from flash, jump to it

PC - Fast Start?

- PC BIOS



  - Enable video, keyboard
  - Check memory size
  - Probe busses
  - Find boot device
  - Load MBR
  - Load secondary loader
  - Load OS
  - Layout memory
  - Probe busses and devices
  - Load dynamic drivers
  - Start user programs

Embedded fast start

- PC BIOS

  BIOS

  - Enable video, keyboard
  - Check memory size
  - Probe buses
  - Find boot device
  - Load MBR
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  OS

  - Layout memory
  - Probe buses and devices
  - Load dynamic drivers
  - Start user programs

- Redboot or ...
  - Self check
  - Start OS
  - Start LEDs, buttons etc
  - Start main program

Minimal Configuration

- PC BIOS

BIOS

  - Enable video, keyboard
  - Check memory size
  - Probe buses
  - Find boot device
  - Load MBR
  - Load secondary loader
  - Load OS

OS

  - Layout memory
  - Probe buses and devices
  - Load dynamic drivers
  - Start user programs

- Redboot or ...
  - Self check
  - Start OS
  - Start LEDs, buttons etc
  - Start main program

- Known config
  - No HW probing needed
  - No unnecessary drivers
  - Pre-loaded OS image

Low power

- Low power devices
  - Smaller devices
  - Slower CPU clock
    - No heat sink needed
  - No hard drive
- Low power demand from SW
  - Fewer interrupts to allow CPU to sleep more
    - Trade latency for power
  - Tricks to not compute things – e.g. Data tables
    - Trade memory space for power

Non-stop

- Battery backup (low power)
- No memory leaks
- No counter overflow
- Fast error recovery
- Environmental error handling
  - Too hot or too cold
  - Battery runs low
  - Other sensor issues?

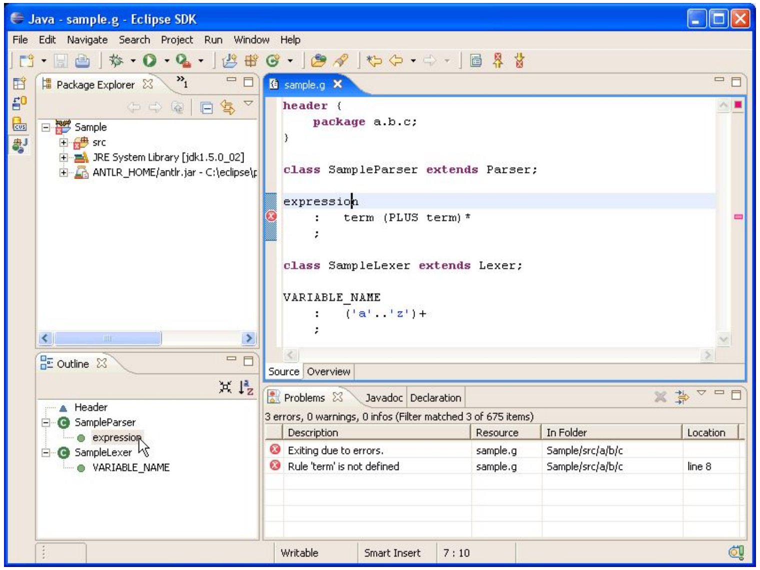
How secure do you need it?

- Relaxed
  - Mini PC with removeable SIMM as HD
  - Network connection?
- Common
  - Small board
  - Serial connection for updates and/or debug
- Tight

  - Crypto protections on firmware
  - Soldered EEPROM
  - Dipped in epoxy
  - Hard to debug and update

SW Development

- Edit source in comfort
  - Standard editor
  - Embedded SW toolset
    - Often includes HW debug goodies



```
header {
    package a.b.c;
}

class SampleParser extends Parser;

expression
    :   term (PLUS term)*
    ;

class SampleLexer extends Lexer;

VARIABLE_NAME
    :   ('a'..'z')+
    ;
```

3 errors, 0 warnings, 0 infos (Filter matched 3 of 675 items)

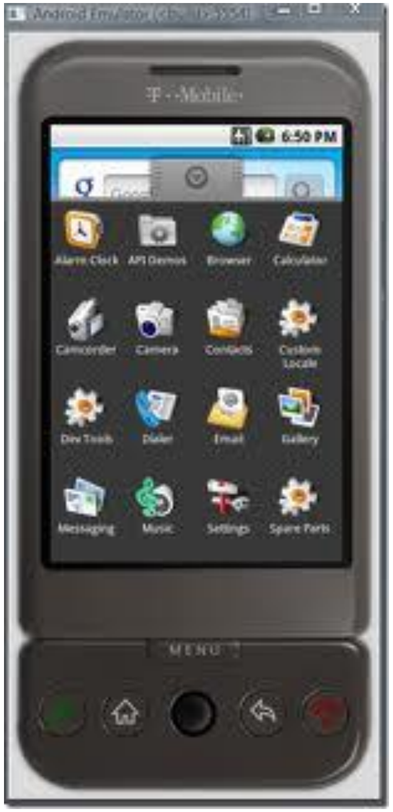
Description	Resource	In Folder	Location
Exiting due to errors.	sample.g	Sample/src/a/b/c	
Rule 'term' is not defined	sample.g	Sample/src/a/b/c	line 8

- Cross compile on fast PC
  - ARM or other target compilers on x86 desktop
  - Copy image to target device
    - Burn new eeprom? Load thru serial connection?

Test and Debug

- Serial output trace
- Blinky lights
- JTAG control for host control and src debug
- Live command line on target

Fakin' It

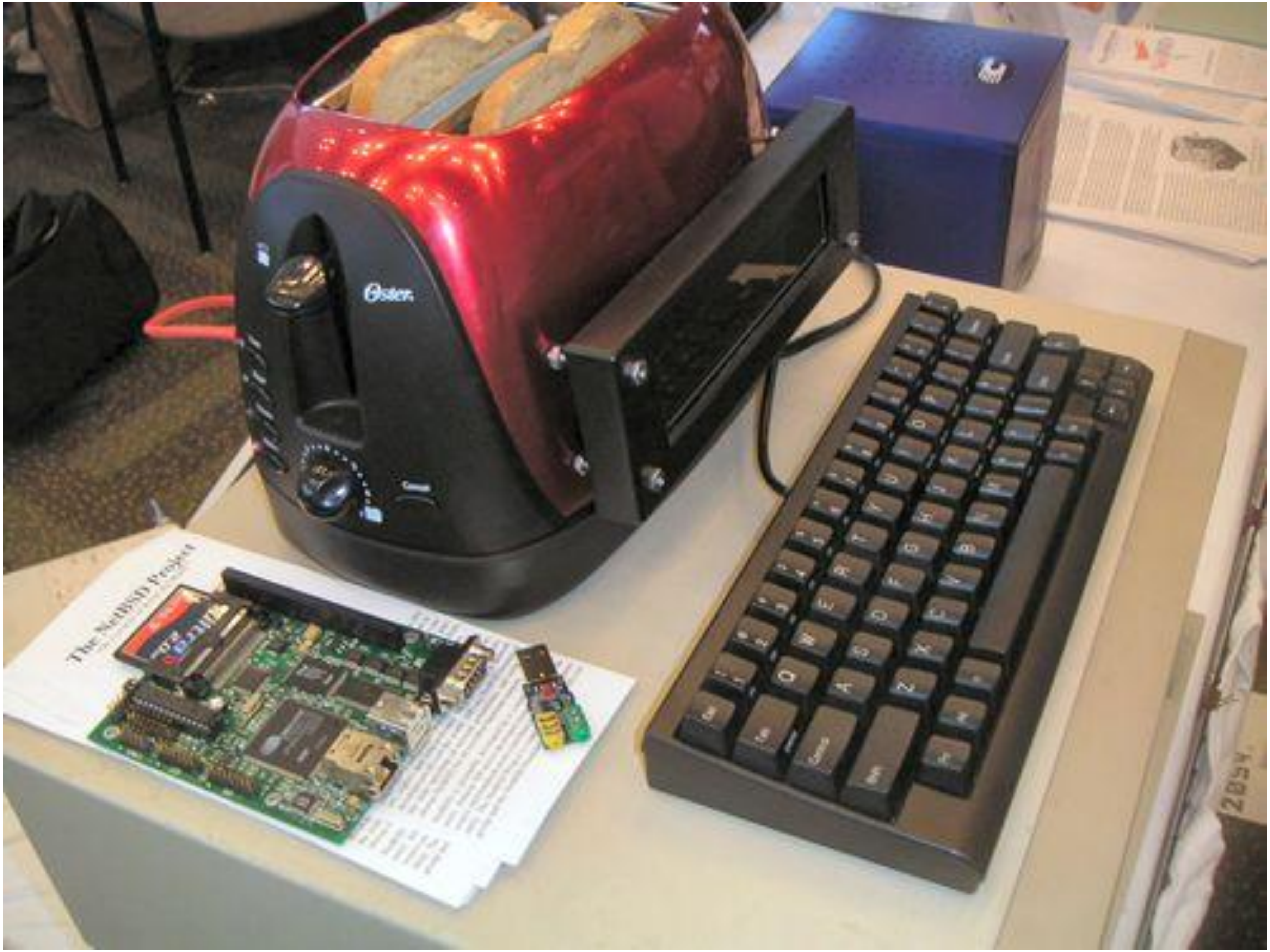


- Virtual Machines
  - Run "HW" in desktop environment
  - Vmware, KVM, VirtualBox, others...
- Emulators
  - QEMU – x86, ARM, PowerPC, MIPS, Sparc
  - android SDK
  - MAME – arcade game hw
  - PalmOS emulator (POSE)

Linux specifically embedded

- Wind River
- MontaVista
- BusyBox
- uClinux
- OpenWRT
- Moblin/MeeGo
- Android
- VMware ESX
- Many more...

NetBSD Toaster



Readings

- ELDD: Chapter 18; Chapter 21 pg 605-609
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- Other (optional):
  - O'Reilly Books: Building Embedded Linux Systems
  - Embedded Linux Primer: A Practical Real-World Approach (2nd Edition)
  - Tutorials from vendor websites