

# MODEL 2070 CONTROLLER & ATC PRESENT AND FUTURE

Herasmo Iniguez, PE  
Sr. Transportation Electrical Engineer  
Caltrans

# Scope of Presentation

- Model 2070L, Early deployments
- Model 2070E, Lessons Learned Implemented
- Model 2070LX, An ATC implementation
- DHS, Security on Model 2070E and 2070LX
- ATC & TEES 2009 Model 2070-1C CPU
- TEES 2009, Background

# What is Model 2070 Controller

- The 2070 is an open-architecture Industrial Traffic Controller. This means that all the hardware components in a 2070 are standardized and interchangeable. The 2070 is also open-architecture in that it can be adapted routinely for all standards cabinets.
- The 2070 specification includes the operating system. Microware OS-9 is supplied by the controller manufacturer, not by the software supplier. Many controller makers use support from Microware to provide low-level device drivers and software. In addition to the operating system, the manufacturers are required to provide hardware device drivers. Also, they are required to provide resident in the controller, Caltrans' DAT. The DAT is used for verifying and troubleshooting features and drivers of the controller. It runs separately from other traffic control Software.
- The hardware specification does not provide software for traffic control. Traffic control software is purchased separately (just as with the Model 170), though it may be supplied by the manufacturer if so specified.

# Brief Background on Model 2070 Controller

- Draft Model 2070 Spec Dated December 1993.  
Key players in Model 2070 Development include LA DOT, Caltrans, Model 170 Vendors and Consultants.
- August 16<sup>th</sup> 2002 TEES out and Caltrans initiates process to purchase 2000 Controllers.
- July 21<sup>st</sup> 2005 Econolite becomes the first vendor in TEES 2002 QPL followed by 4 more vendors by 2008.
- September 9<sup>th</sup> 2008, Caltrans completes acceptance of 2000 Controllers from Econolite.
- January 2009 Caltrans starts new 2000 Controller contract with McCain.
- March 2010 Caltrans initiates process to replace 10,000 Model 170 Controllers with Model 2070 Controllers.
- In 2010 there were at least 17 State DOTs and at least 19 cities in California using the Model 2070 Controller.

# Typical 2070 Applications

- Traffic Signals
- Traffic Surveillance
- Transit
- Communications
- Field Master
- Ramp Metering
- Variable /Dynamic Message Sign
- Lane Use Signals

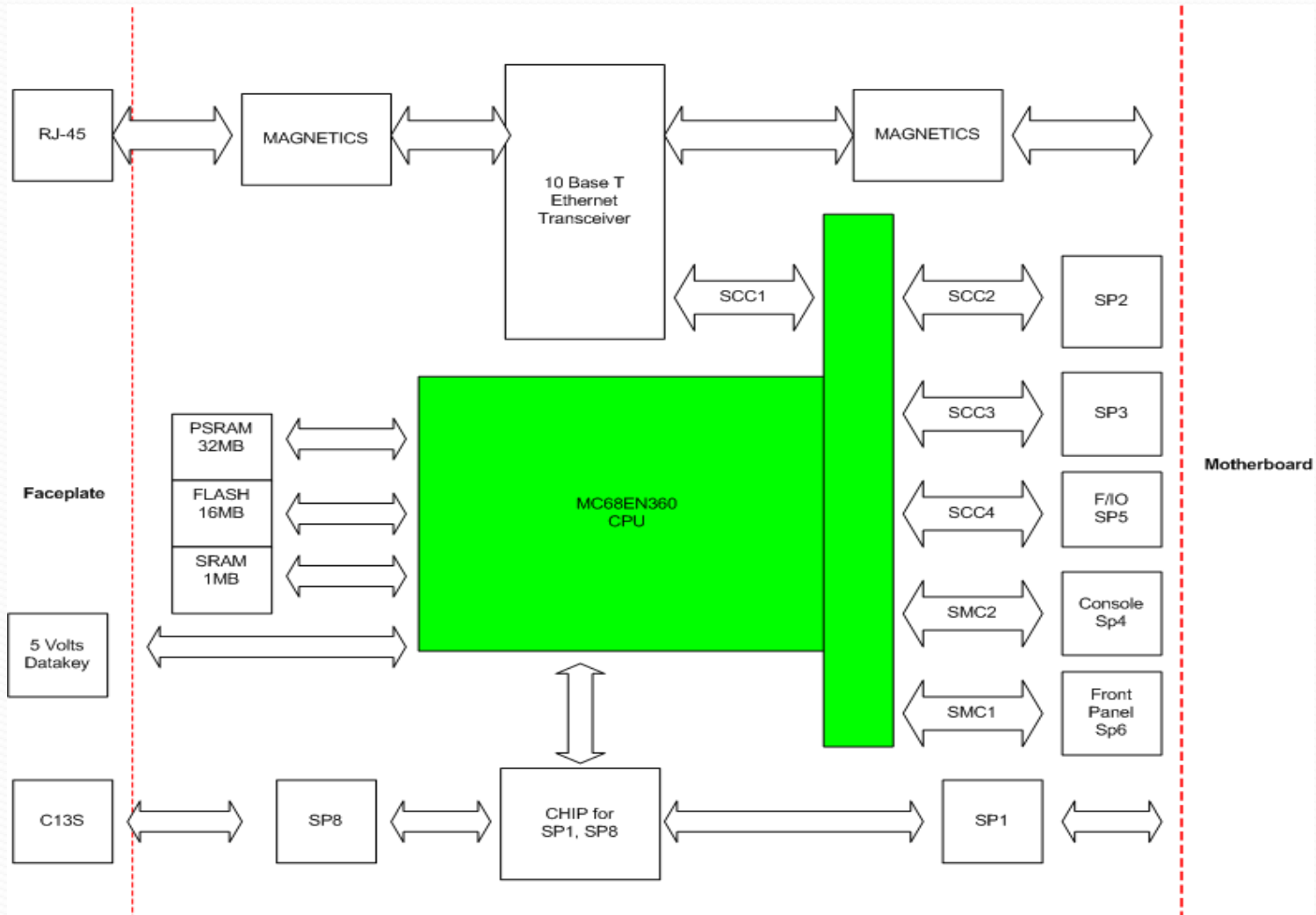
# TEES 2002 Model 2070L

- TEES 2002 and earlier Specified the 2070L Controller
- Model 2070L uses Model 2070-1B CPU Module
- Uses standard Model 2070 Box (Chassis, Field IO, Front Panel and Power Supply)

# Design of the Model 2070-1B CPU

- Based on 68360 Motorola Processor
- 4 MB of Volatile of DRAM ( or more)
- 512 KB of SRAM
- 4 MB of non-Volatile Flash RAM
- 5 V Datakey, Support 8 Mbits.
- 7 CPU ports, Including Async and Sync Serial Ports
- 1 Network Port
- Os-9 Operating System
- 1 MB DRAM (r2)

# Model 2070 – 1B CPU

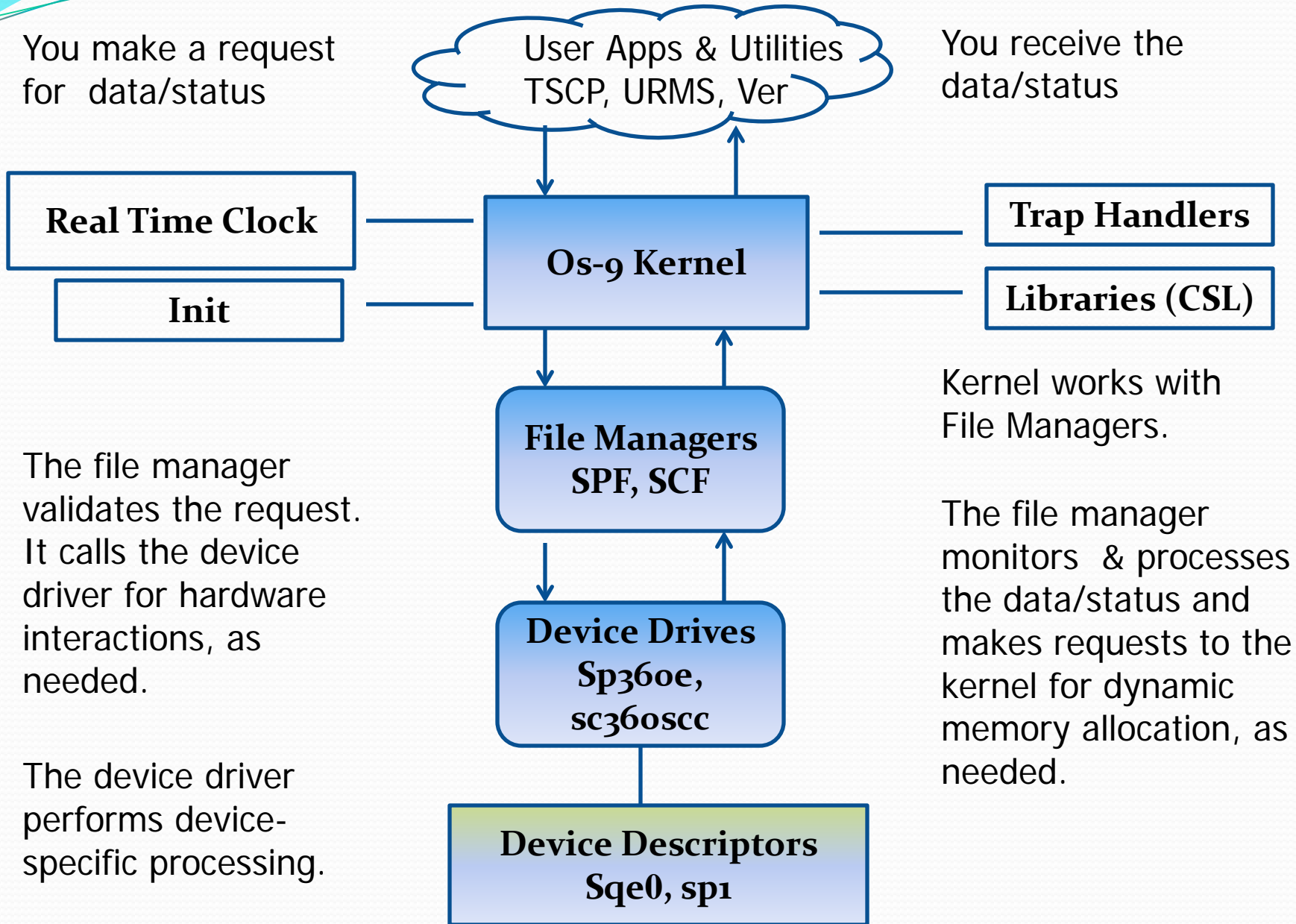




# Os-9 Real Time Operating System

You make a request for data/status

You receive the data/status



The file manager validates the request. It calls the device driver for hardware interactions, as needed.

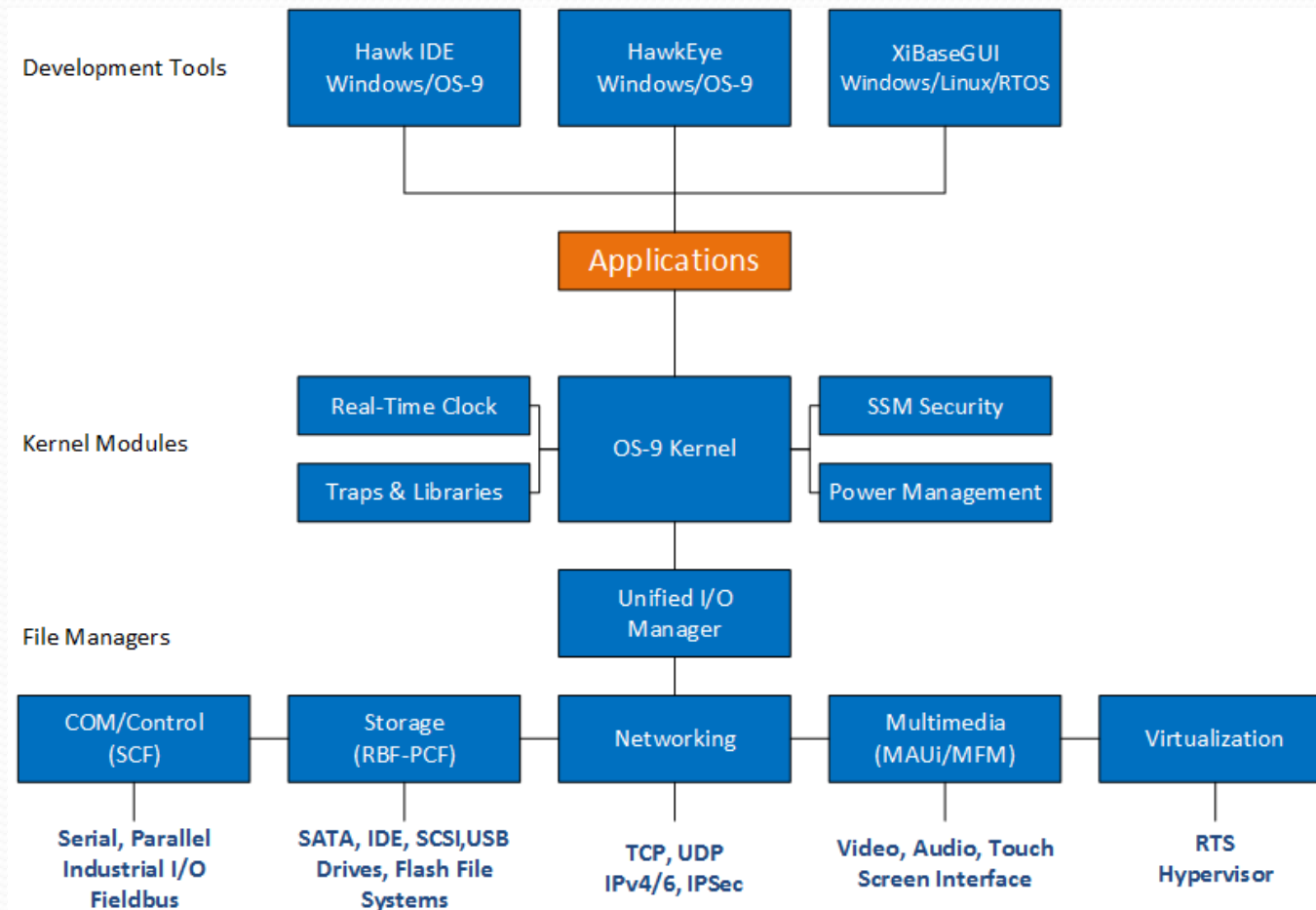
The device driver performs device-specific processing.

Kernel works with File Managers.

The file manager monitors & processes the data/status and makes requests to the kernel for dynamic memory allocation, as needed.

# os-9 Real Time Operating System

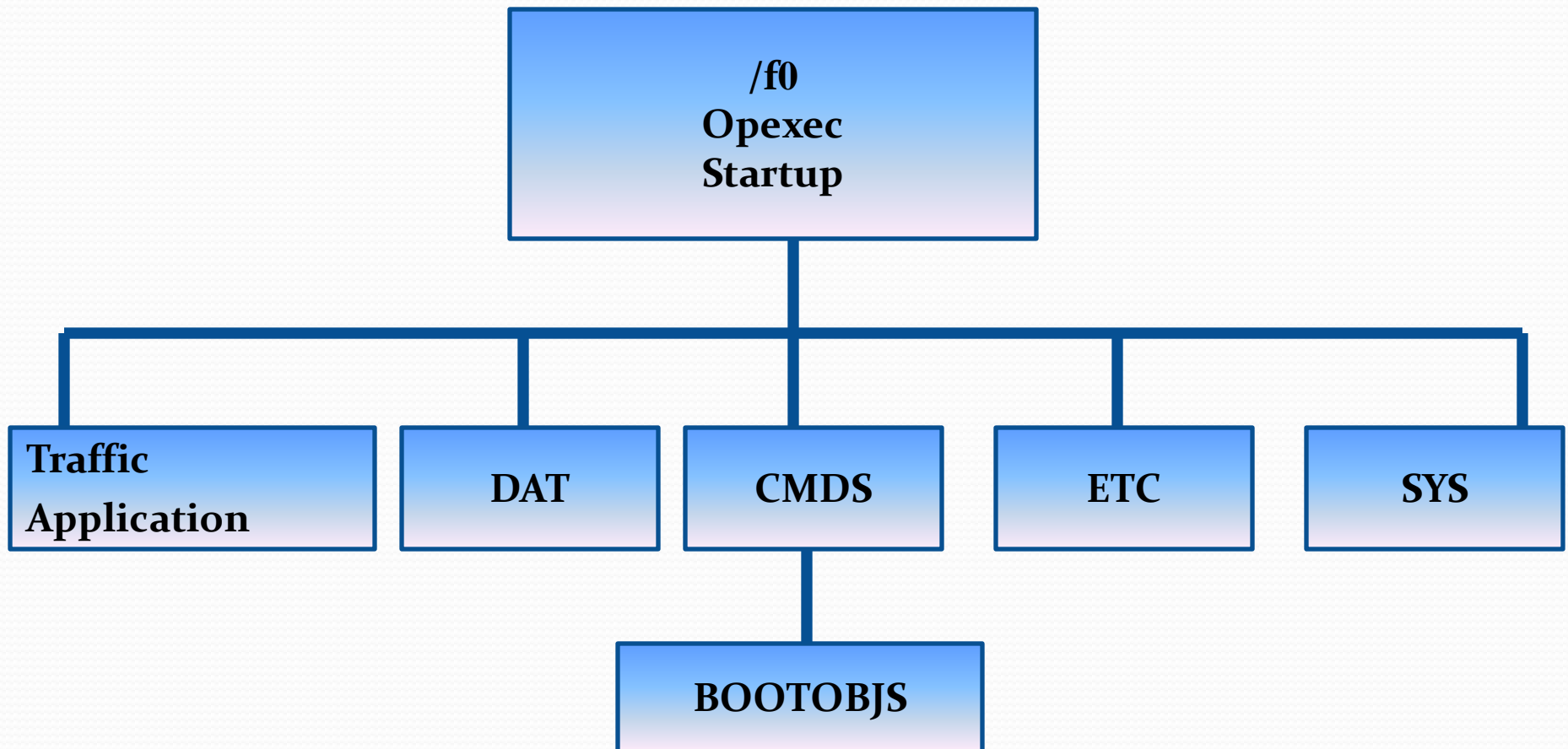
<http://www.microware.com/index.php/features>



# Model 2070-1B Memory Types

|   |  |   |
|---|--|---|
| <p>Flash /f0<br/>Application Data</p> <p>Boot Image</p> | <p>SRAM /r0<br/>Database</p> <p>Flash Write Backup</p> | <p>DRAM<br/>Free Memory</p> <p>Ramdrive /r2</p> |
| 8 MB  | 512 KB   | 1 MB  |

# File Structure of /f0 Drive (Flash Memory)



# TEES 2009

Model 2070 Controller

Model 2070E

Model 2070-1E CPU

# What's in TEES 2009?

- TEES 2002
- TEES 2002 Errata 1 and 2
- TEES 2007 Draft Comments
- TEES 2008 Draft Comments
- Total over 500 user and vendor comments

<http://www.dot.ca.gov/hq/traffops/electsys/TEES.htm>

# What aspect of the 2070 does TEES 2009 Address?

- Software Portability
- Hardware Stability
- Model 2070's Future
- Communications Modules

# What do I mean by Software Portability

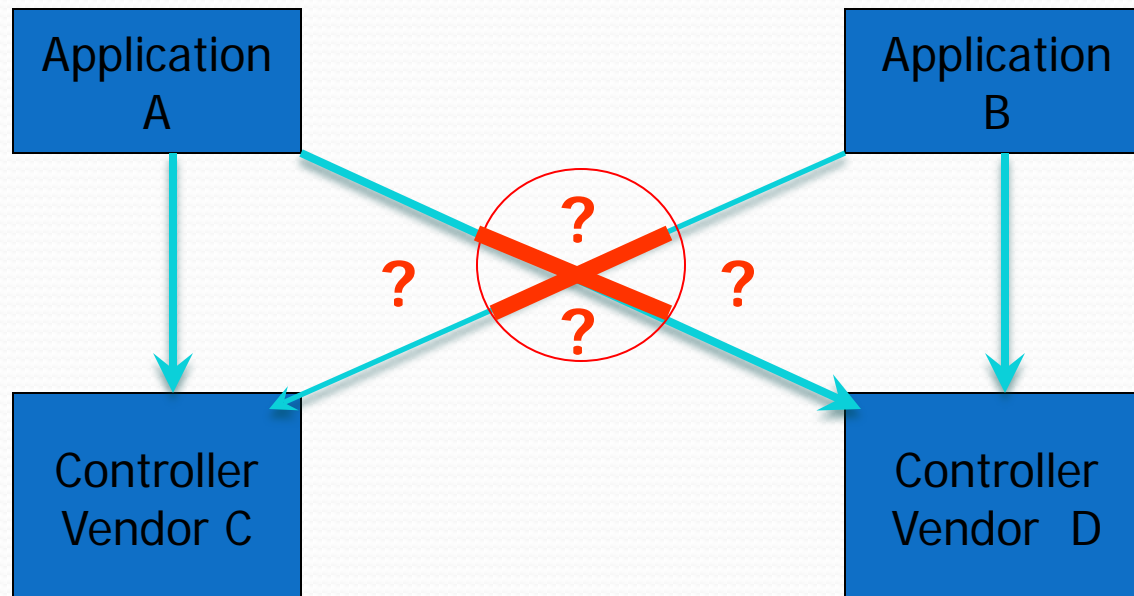
The ability to take my application, in its executable form (binary), from Vendor A's controller and run it in Vendor B's controller.

“See Photo Slide”



# Software Portability

- Controllers before these specification changes



# Hardware Stability Issues

- Hardware Resets
- Multi-Serial Port functionally Issues
- Flash memory Corruptions
- Network Stability Issues
- CPU Power Starvation Issues

# Specifications, Implementation and Testing

## “XYZ Dilemma”

- Specifications had **X** requirements
- DAT would test **Y** requirements
- Vendors implemented **Z** requirements

## TEES 2009 achieves software portability by requiring the following:

- Standardized booting procedure (TEES 2002 Errata 1 and 2)
- Standardized file system (TEES 2002 Errata 1 )
- Standardized Field IO Watchdog functionality (TEES 2007, 2008)
- Standardized Timer Drivers (TEES 2002 Errata 1, 2 and TEES 2007 Draft)
- Standardized Datakey Drivers (TEES 2002 Errata 1 and 2, TEES 2008 Draft)
- Standardized Serial Port Drivers (TEES 2009)

## TEES 2009 achieves hardware stability by requiring the following:

- Implementation of the Write Protect Bit function to allow writing to flash only when needed
- Multiple (4 simultaneous ports) serial ports to operate with a Maximum CPU Load of 30%
- Integrated store-and-forward 5 port switch
- Removing the Model 2070-4B Power Supply

# TEES 2009 achieves Network Stability (Smarts of the Network Switch)

- Prevent Full Duplex Network Communications to Controller ( Half Duplex Interface to Controller)
- Reduce CPU Load due to High Network Traffic (Switch's MAC Filtering)
- 100BaseT to Switch  $\leftrightarrow$  10BaseT to controller (Controller works @ 10 in 100 Mbps Networks)

# Synchronized Specifications, Implementation and Testing

- TEES 2009
- Latest DAT
- Intensive Testing (QPL)

# TEES 2009 Model 2070E

- TEEs 2009 Specifies 2070E Controller
- Model 2070E uses Model 2070-1E CPU Module
- Uses standard Model 2070 Box (Chassis, Field IO, Front Panel and Power Supply)
- ATC 5202 Model 2070 Controller Standard v03 (v03.04) , AASHTO, ITE and NEMA National Standard, December 2012.

[http://www.ite.org/standards/ATCcontroller/ATC5202Std\\_0304\\_122812.pdf](http://www.ite.org/standards/ATCcontroller/ATC5202Std_0304_122812.pdf)

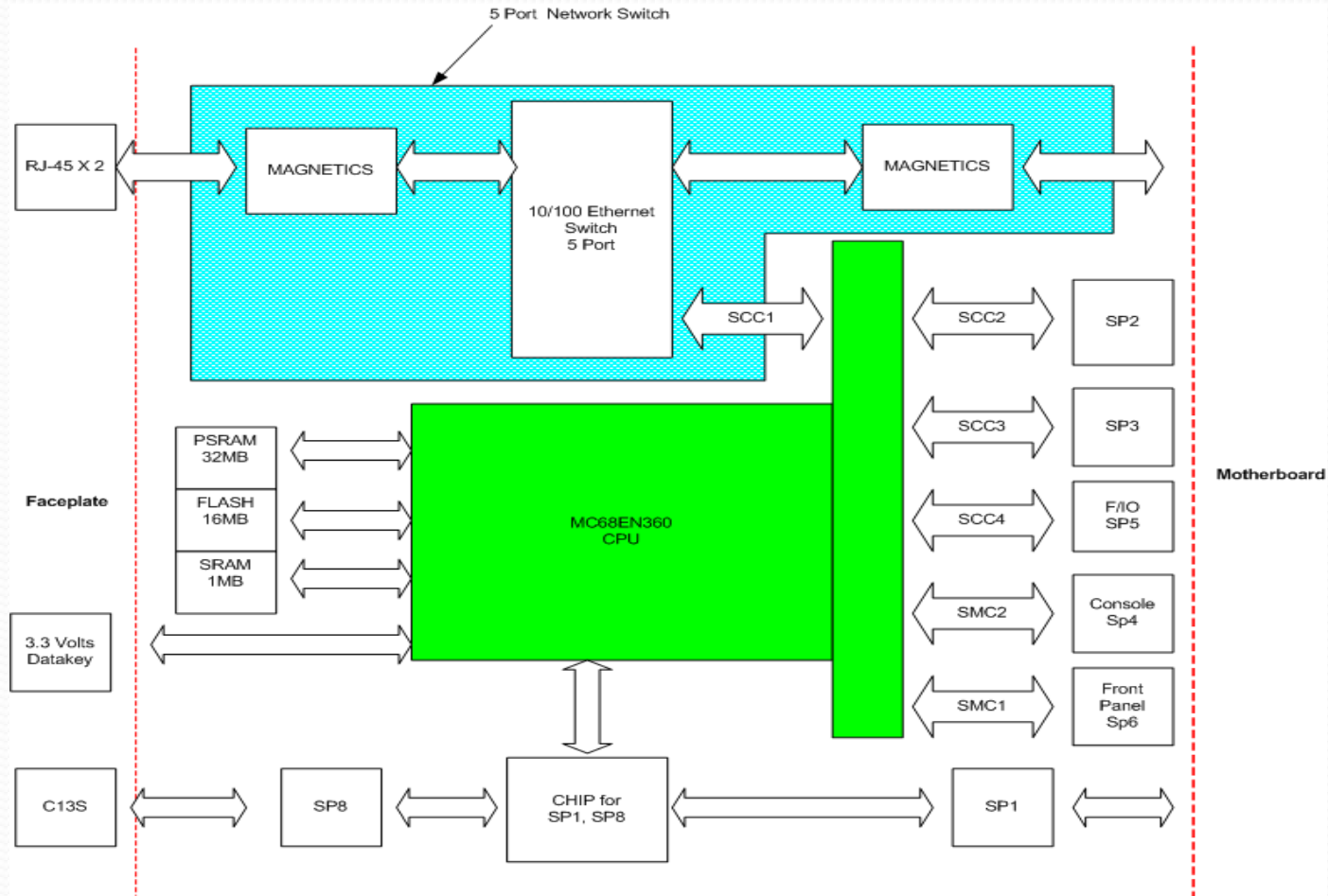


# TEES 2009 Model 2070-1E

- Based on 68360 Motorola Processor
- Provides Two RJ-45 Connectors
- Integrated 10/100 Mbps (Switch)
- 8 MBytes of FLASH
- 3.3 V Datakey, Support 32 Mbits
- 2 MBytes of DRAM (r2)
- 32 MBytes of PSRAM
- Uses OS-9 Operating System



# Model 2070-1E, CPU Block Diagram



# Safetran's Model 2070-1E



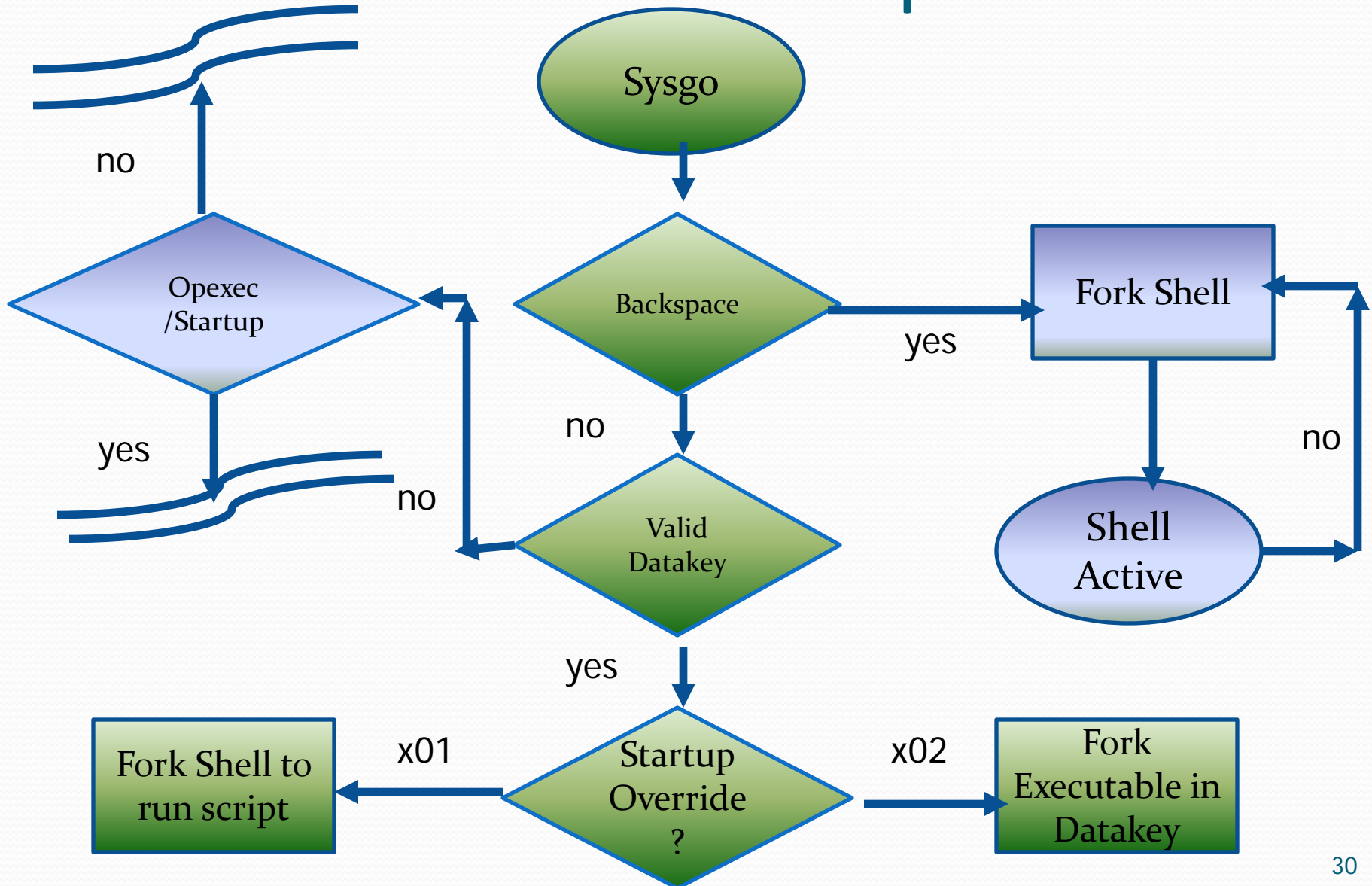
# McCain's Model 2070-1E



# Model 2070-1E Memory Types

|  |   |   |
|--|---|---|
| <p>Flash /f0</p> <p>Application Data</p> <p>Boot Image</p> | <p>SRAM /r0</p> <p>Database</p> <p>Flash Write Backup</p> | <p>PSRAM</p> <p>Free Memory</p> <p>Ramdrive /r2</p> |
| <p>8 MB</p>  | <p>512 KB</p>   | <p>r2 = 2 MB</p> <p>r4 = 4 MB</p> <p>r8 = 8 MB</p>  |

# 2070 Startup



# Datakey & Startup, Solution to all user Problems



Blue, 8 Mbits Datakey, required for every Model 2070E Controller.



# Do everything via the Front Panel





# ITE, AASHTO and NEMA National ATC Standards

- ATC Standard V5.2b 6/26/2006
- ATC 5201 Standard 6.10 Under Development
- ATC API Standard v02.06b 9/21/2007
- ATC API Standard v02.17 9/21/2011
- ATC API Validation Suite Under Development

# ATC

| ITE, NEMA, AASHTO Standard |                              | Status      | Date Published |             |  |
|----------------------------|------------------------------|-------------|----------------|-------------|--|
| ATC Standard 5.2b          |                              | Published   | 6/26/2006      |             |  |
| Processor (CPU)            | OS                           | Memory      | Security       | SD Slot     |  |
| Various                    | Minimum Linux Kernel V 2.6.9 |             | None           | None        |  |
| <b>Flash</b>               |                              | <b>DRAM</b> |                | <b>SRAM</b> |  |
| 8MB                        |                              | 16 MB       |                | 1 MB        |  |

# ATC

| Caltrans Specifications                |                                     | Status    | Date Published  |         |  |
|--|-------------------------------------|-----------|-----------------|---------|--|
| TEES 2009, Model 1C                    |                                     | Published | 3/12/2009       |         |  |
| Processor (CPU)                        | OS                                  | Memory    | Security        | SD Slot |  |
| Power PC<br>Freescale MPC<br>82XX/83XX | Minimum<br>Linux Kernel<br>V 2.6.18 |           | Yes, Integrated | Yes     |  |
| Flash                                  |                                     | DRAM      | SRAM            |         |  |
| 32MB                                   |                                     | 64MB      | 1 MB            |         |  |

# ATC

| ITE, NEMA, AASHTO Standard |                               | Status            | Date Published |             |  |
|----------------------------|-------------------------------|-------------------|----------------|-------------|--|
| ATC Standard 6.10?         |                               | Under Development |                |             |  |
| Processor (CPU)            | OS                            | Memory            | Security       | SD Slot     |  |
| Various                    | Minimum Linux Kernel V 2.6.18 |                   | None           | ???, Maybe  |  |
| <b>Flash</b>               |                               | <b>DRAM</b>       |                | <b>SRAM</b> |  |
| 16MB                       |                               | 64 MB             |                | 1 MB        |  |

# ATC

Advanced Transportation Controller

TEES 2009

Model 2070LX

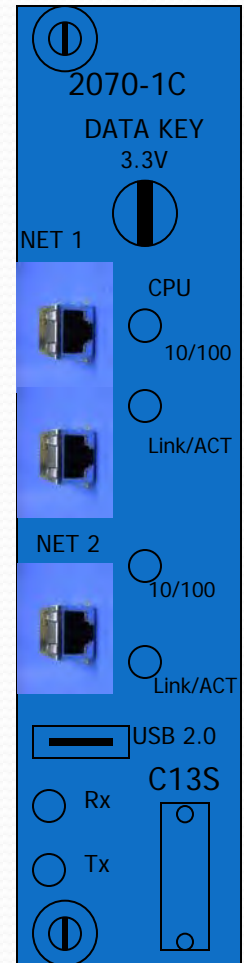
Model 2070-1C CPU

# ATC, Model 2070's Future

- TEES 2009 Specifies Model 2070LX Controller
- Model 2070LX uses Model 2070-1C CPU Module
- Model 2070LX uses standard Model 2070 Box (Chassis, Field IO, Front Panel and Power Supply)

# TEES 2009 Model 2070-1C

- Includes two integrated switches
- Allows Freescale's 82xx & 83xx CPUs
- Uses Linux Kernel 2.6.18 or Newer
- USB 2.0
- 3.3 V Datakey, Support 32Mbits
- SD Card Support
- 64 MBytes of DRAM
- 32 MBytes of FLASH
- Meets ATC Standard Ver. 6.10 +



# Model 2070-1C,CPU Block Diagram

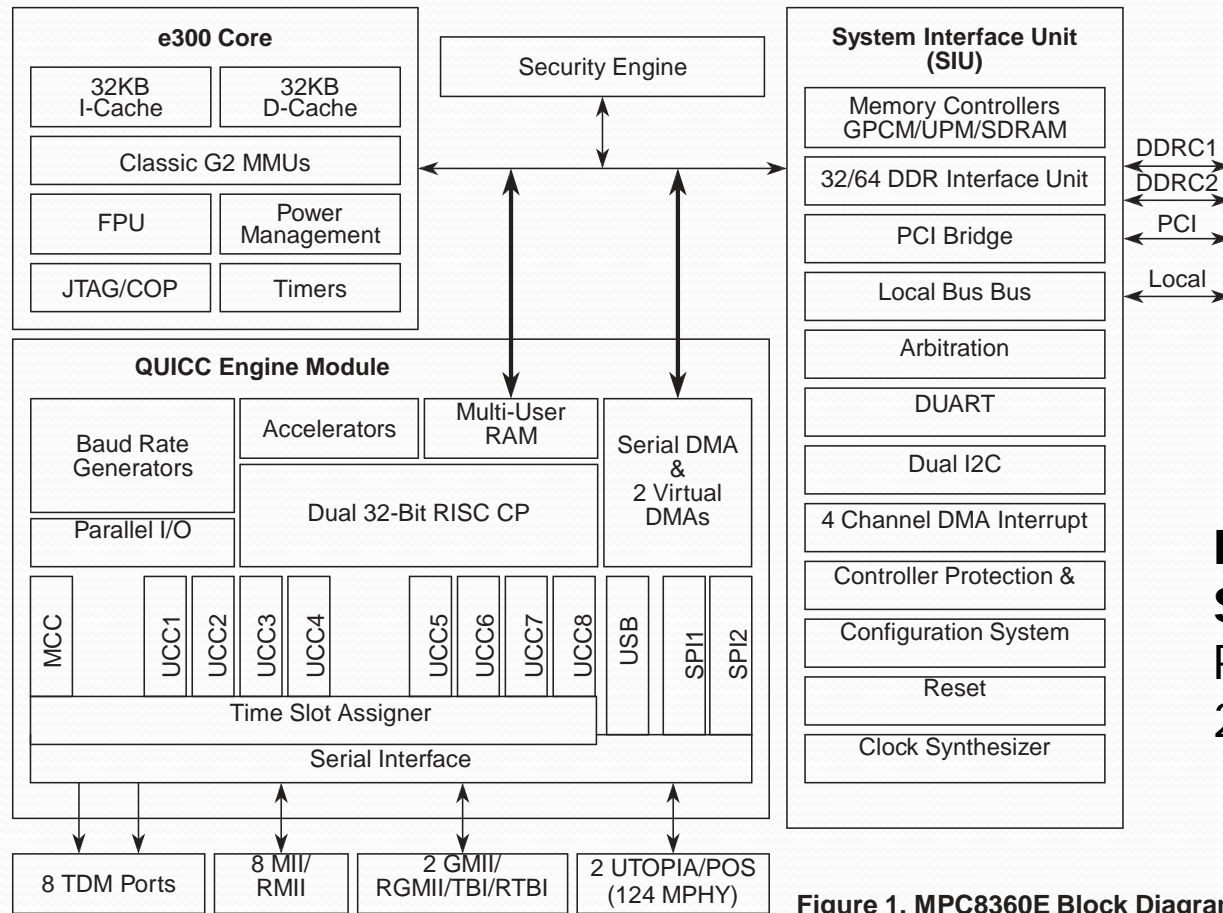


Figure 1. MPC8360E Block Diagram

**Freescale  
Semiconductor**  
Product Brief  
27/Apr/2005



# McCain's Model 2070-1C



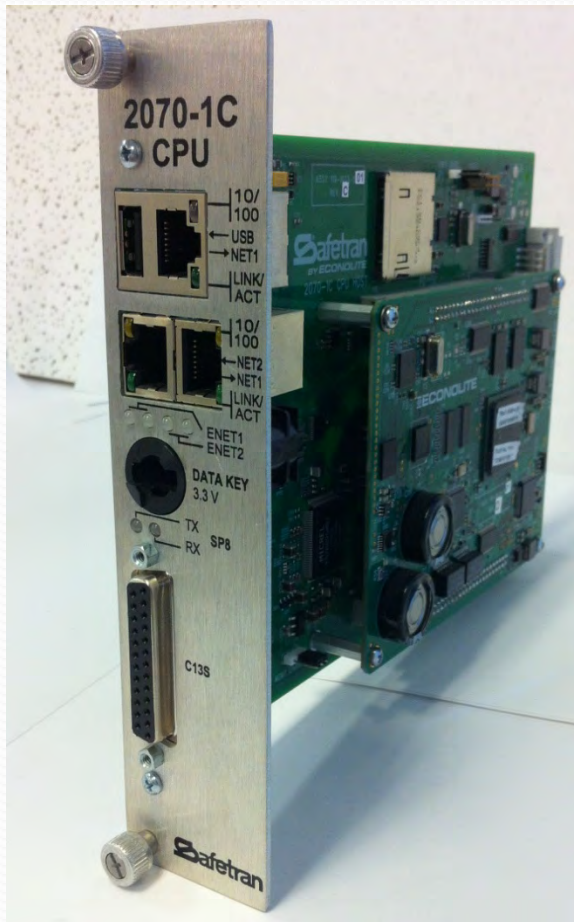
U-Boot 1.3.0

Kernel 2.6.22

glibc 2.3.6

Busybox 1.1.3

# Safetran's Model 2070-1C



U-Boot v2011.03

Kernel 2.6.35

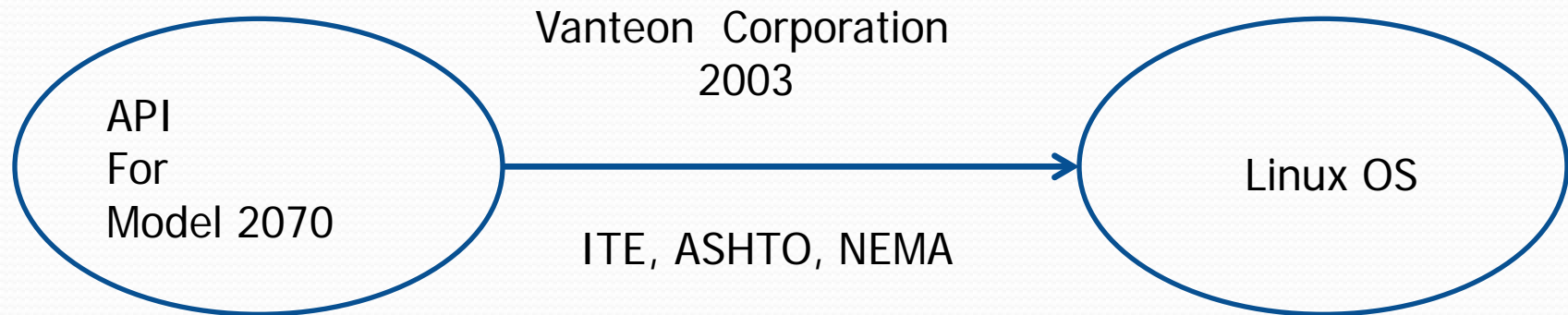
glibc 2.11.1

Busybox 1.18.5

# Controller Comparison

| Controller    | Operating System | MIPS  |
|---------------|------------------|-------|
| Model 170     | None             | 1.5   |
| Model 2070-1E | Os-9             | 4.5   |
| Model 2070-1C | Linux            | 400 + |

# How did we end up using Linux for the ATC Controller ?



Application Programming Interface (API) Standard for the Advanced Transportation Controller (ATC), Published by: AASHTO, ITE, and NEMA, Working Group Draft Version 99.09.14, September 14, 1999.

Caltrans TEES, Published November 19, 1999.

Caltrans TEES, Published August 16, 2002.

# Vanteon's Tasks

- Evaluate the proposed API Specification for portability to various operating systems and hardware platforms.
- Evaluate the proposed API Specification for completeness and consistency to determine whether the API functions are sufficient to meet the intent of creating portable traffic apps.
- Develop and evaluation plan and suite for measuring the performance of the API an a variety of operating systems and hardware platforms.
- Suggest modifications to the API spec. to accomplish our goals.

# ATC API Evaluation Development Environments

| Os-9                       | VxWorks                    | QNX                         | Monta Vista<br>Linux                      |
|----------------------------|----------------------------|-----------------------------|---|
| Model 2070                 | SandPoint<br>8240          | Pentium III                 | Pentium III                               |
| Microware<br>C/Hawk IDE    | Tornado                    | QNX                         | GNU<br>C/Kdevelop                         |
| Monolithic<br>Real Time OS | Monolithic<br>Real Time OS | Microkernel<br>Real Time OS | Monolithic<br>Linux with<br>RTOS features |

# Services of Real Time Operating Systems (RTOS)

- Shared Memory
- Semaphores
- Events
- Pipes
- Alarms
- Signals

## Vanteon's Conclusion:

All the RTOS selected implement these services differently.

# Alternative approaches recommended by Vanteon for the API

- Use the **P**ortable **O**perating **S**ystem Interface (POSIX) Standards as the API

POSIX defines the application programming interterface (API), along with command line shells and utility interfaces, for software compatibility with variants of Unix and other operating systems.

- Use “Best OS” Approach , **Linux ?**



# “POSIX” Approach

- Survey the level of support by the popular OSs
- Identify a subset to use, such as the Kernel IPC calls.
- Consider the availability of the POSIX real-time extensions

# “Best OS” Approach

- Survey of current hardware platforms
- Consider the availability of migration guides to/from other OSs.
- Consider OS availability and support options
- Consider if the OS is available from multiple vendors.
- Select the most suitable OS.

# Linux is it!!



## OK, What Distribution?

Fedora

SUSE

Ubuntu

Mandriva Linux

Debian

Slackware

Gentoo

Arch Linux

# Linux Operating System

Fedora

SUSE

Ubuntu

Mandriva Linux

Debian

Slackware

Gentoo

Arch Linux

# OK, what do we do?

- Get the Boot loader

[www.linux-sunxi.org/U-boot](http://www.linux-sunxi.org/U-boot)

- Get the Kernel from Linus Torvalds

[www.kernel.org](http://www.kernel.org)

- Get GNU C Standard Library (glibc), uClibc

[www.gnu.org/software/libc](http://www.gnu.org/software/libc)

- Get Busybox

[www.busybox.net](http://www.busybox.net)

- Get a BSP for the CPU, Example Freescale for Power PC
- Write custom drivers as required.

# Which kernel Version?

Latest Stable Kernel:

Version > 3.14.4

ATC Standard Ver. 5.2.b

Version > 2.6.9

TEES 2009

Version > 2.6.18

ATC Standard Ver. 6.10+ Vendors, McCain, Safetran

Version > 2.6.18

Version = 2.6.22, 2.6.35

# Close look at the Operating Systems

Latency:

The time delay from an interrupt to the start of processing that interrupt

| Operating System | Application    | Latency                              |
|------------------|----------------|--------------------------------------|
| Standard OS      | Non Real Time  | 100 microseconds to 100 milliseconds |
| Standard Linux   | Soft Real Time | 1 millisecond                        |
| RTOS (OS-9)      | Hard Real Time | ~ 7 microseconds                     |

# OS-9 vs Linux

- **OS-9**

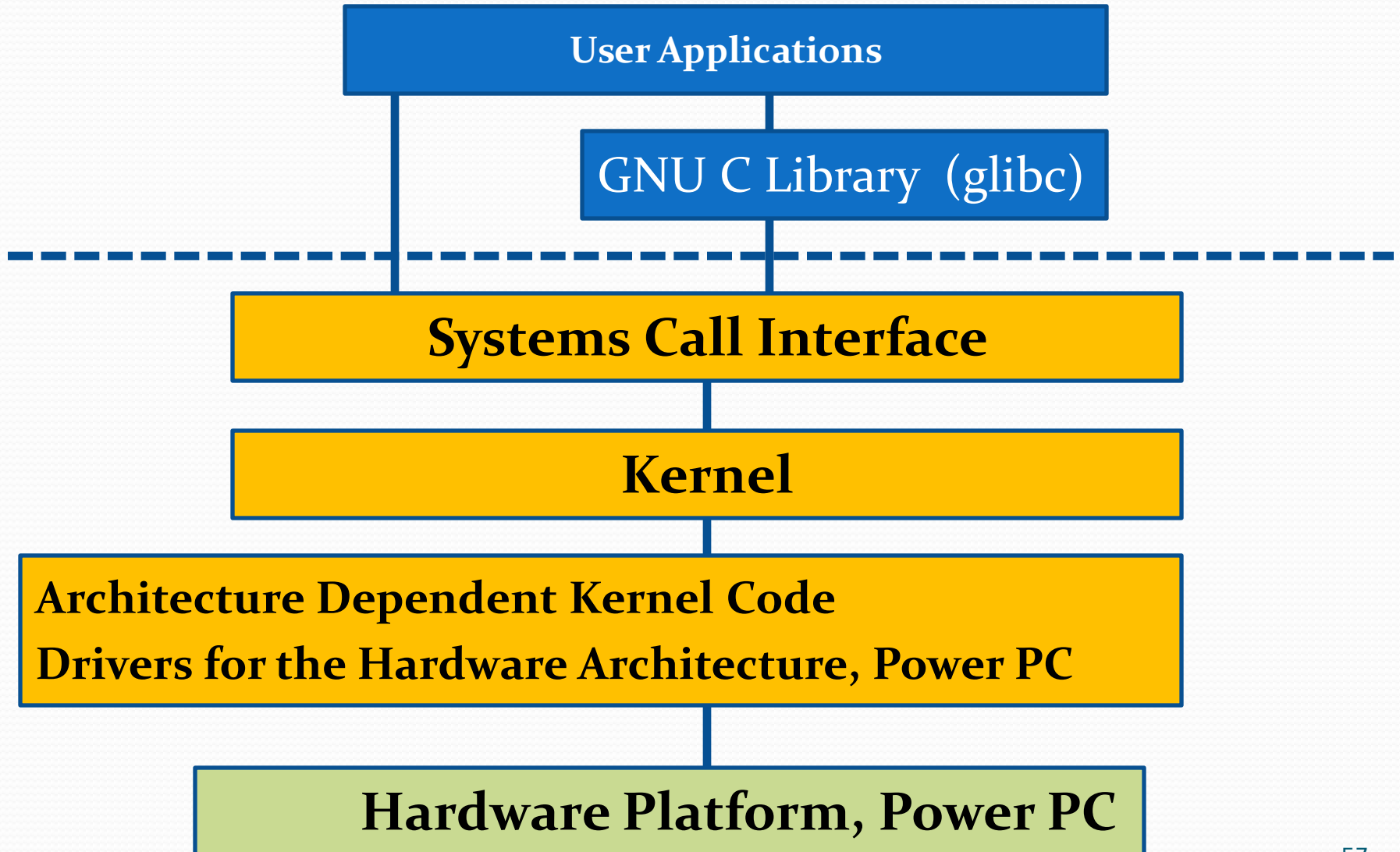
**OS-9** is **real-time**, process-based, multitasking, multi-user, Unix-like operating system.

- **Linux**

**Linux** is a **General Purpose Standard OS**, process-based, multitasking, multi-user, Unix-like operating system.



# Linux Kernel Architecture



# Real Time Operating System ?

| Real Time Operating System | Linux                                   |
|----------------------------|---|
| kernel preemption          | Preemption; Version > 2.6.18            |
| high-resolution timers,    | High-resolution timers; Version >2.6.21 |
| Shared Memory              | Version > 2.6.x and glibc Version > 2.2 |
| Real Time Signals          | Version >2.6.x                          |
| Real Time Scheduler        | Version > 2.6.x                         |

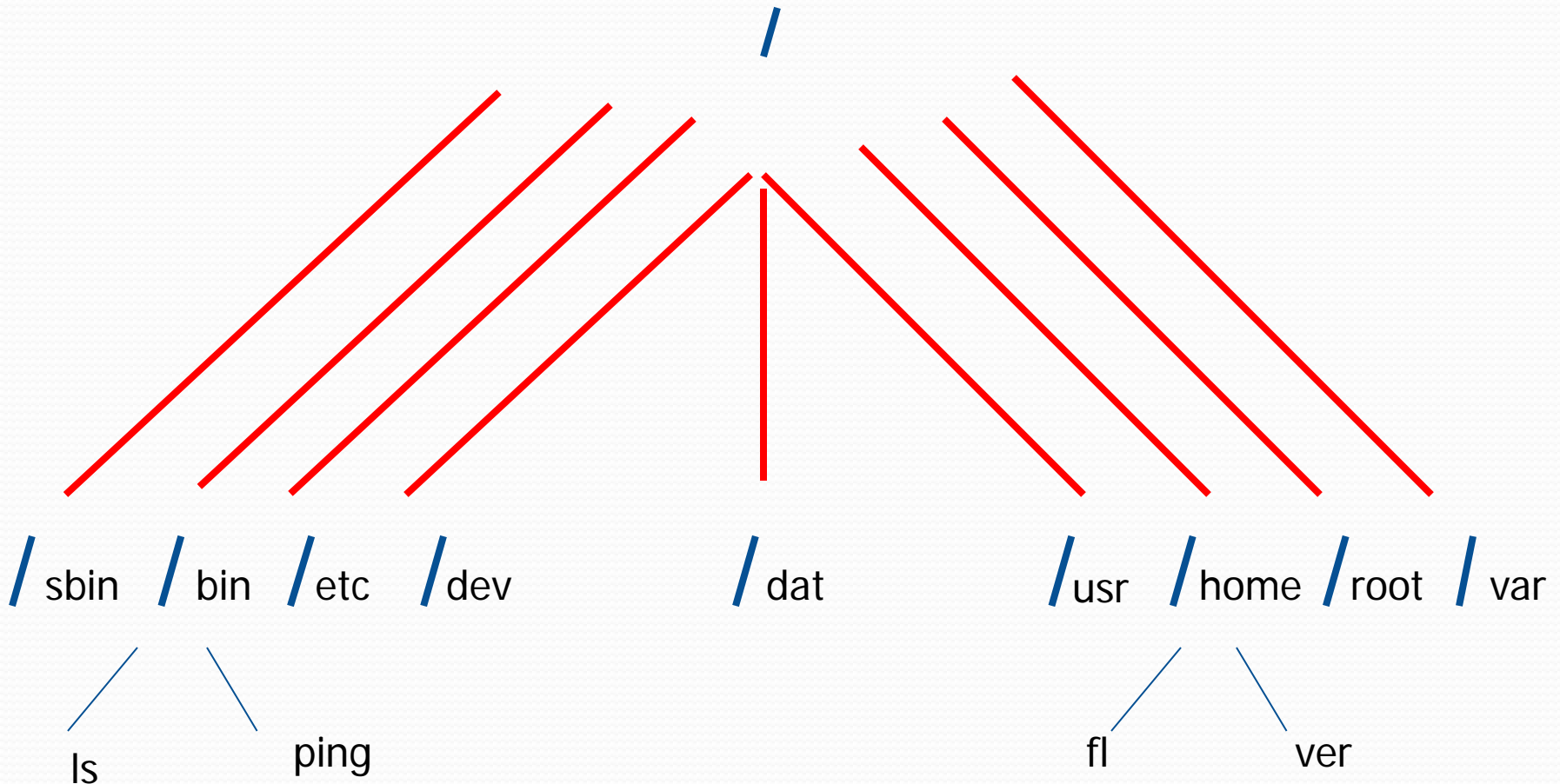
These features are defined by IEEE Standards, POSIX 1003.1b, 1003.1d and 1003.1j.

POSIX Real-time Extensions

# File System Hierarchy Standard

## FSH-2.3 , January 28, 2003.

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# DHS

## Department of Homeland Security (DHS's) National Cyber Security Division

- Tests on Model 2070 Controllers performed at the John A. Volpe National Transportation Systems Center Cyber Lab, 9/15/2011
- Recommendation adapted in TEES 2009 Errata No. 2
- Roadmap to Secure Control Systems in Transportation Sector Completed, 8/31/2012. Caltrans Working Group Member.

[http://bussafety.fta.dot.gov/uploads/resource/4320\\_filename](http://bussafety.fta.dot.gov/uploads/resource/4320_filename)

# Model 2070-1E Pre-Errata No.2

## TEES 2009 Default User Account

|          |       |
|----------|-------|
| Username | super |
| Password | user  |

- This is a super user account. A **super user** can access and manipulate any file or directory on the system regardless of the file's ownership.
- **super user** can also view and edit the password file and start and stop network services and daemons.

# Model 2070-1E Pre-Errata No.2

TEES 2009 Model 2070 Network Services

|        |      |    |
|--------|------|----|
| telnet | Port | 23 |
| ftp    | Port | 21 |

**Both telnet and ftp use TCP over IP**

- Telnet provides access (super user) to the command line interface of os-9 on a remote host.
- File Transfer Protocol (FTP) is a network protocol used to transfer files from your PC to the Model 2070 Controller.

# DHS Security Concerns

- Both Telnet and FTP, by default, does not **encrypt** any data sent over the connection (including passwords), and so it is often practical to eavesdrop on the communications and use the password later for malicious purposes.
- Super User Account **user** and **password** are readily available as part of TEES in the internet.

# Model 2070-1E Errata No.2

## Default User Account

|          |      |
|----------|------|
| Username | reg  |
| Password | user |

- This is a regular user account. A **reg user** cannot access and manipulate any file or directory on the system that are not owned by **reg user**.
- **reg user** cannot view or edit the password file and cannot start or stop network services and daemons.



# Model 2070-1E Errata No.2

## Model 2070 Network Services

|        |      |    |                  |
|--------|------|----|------------------|
| telnet | Port | 23 | Service Turn OFF |
| ftp    | Port | 21 | Service Turn OFF |

Network Services are turn OFF by default. End user will have to create Super User account and Turn ON Telnet and FTP Services when needed.

# Controller Security

| Controller    | Security Features                    | Status                                 |
|---------------|--------------------------------------|--|
| Model 170     | N/A                                  | N/A                                    |
| Model 2070-1E | Reg User Account<br>Net Ports Closed | TEES 2009 Errata<br>No. 2 Requirements |
|               | ssh, sftp                            | Under test                             |
| Model 2070-1C | Integrated Security                  | TEES 2009<br>Requirements              |

# Model 2070 Communications Modules

- Pre-2009 TEES Communication Modules:
  - Model 2070-6A and B Modems Module
  - Model 2070-7A and B Serial Module
- New Communication Modules include:
  - Model 2070-6D Fiber Modems
  - Model 2070-Fx Fiber Network Module
  - Model 2070-6W Wireless Module
  - Model 2070-9x Dial-Up Modem Module
  - Model 2070-6E Serial to Network Module
  - Model 2070-7G Universal Time Based Module



# Thanks You

*Any questions?*

# Acronyms

- ATC ... Advance Transportation Controller
- TEES ...Transportation Electrical Equipment Specifications.
- AASHTO ... American Association of State Highway and Transportation Officials.
- NEMA ... National Electrical Manufacturers Association.
- ITE ... Institute of Transportation Engineers.
- DHS ... Department of Homeland Security

# Acronyms Cont.

- SSM.... System Security Module
- DAT.... Diagnostics Acceptance Test
- DOT... Department of Transportation
- MAC... Media Access Control (MAC) as in Media Access Control Device.
- CPU.... Central Processing Unit
- MIPS... Millions of Instructions per Second.
- RAM ... Random-access memory
- SRAM ... Static Random-access memory.

# Acronyms Cont.

- DRAM ... Dynamic Random-Access Memory.
- PSRAM ... Pseudo Dynamic Random Access Memory.
- API ... Application Program Interface.
- SD ... Originally SanDisk, a memory device built to the SD Card Standard. Standard by SD Card Association. Up to 2 GBytes Capacity.
- MPC ... Motorola Power Architecture Core
- PowerPC ...(an acronym for Performance Optimization With Enhanced RISC – Performance Computing, sometimes abbreviated as PPC)
- OSI ... Open System Interconnection Model.

# Acronyms Cont.

- RISC ...Reduced Instruction Set Computing
- USB ... Universal Serial Bus
- UCC ... Fast Universal Communication Controller
- MCC ... Multichannel Controller
- SPI... Serial Peripheral Interface
- MII... Media Independent Interface
- IDE... Integrated Development Environment
- RTOS ... Real Time Operating System
- PHY ... An abbreviation for the physical layer of the OSI Model.



# Acronyms Cont.

- BSP ... Board Support Package.
- JTAG ... Joint Test Access Group
- FLASH ... Non Volatile Reprogrammable Memory
- SPx ... Serial port X on the Model 2070 and ATC.
- SCC ... Serial Communication Controller
- SMC ... Serial Management Channel
- IEEE ... Institute of Electrical and Electronics Engineers.
- GNU ... *GNU* is a recursive acronym for "*GNU's Not Unix!*",

# Acronyms Cont.

- SSH ... Secure Shell
- SFTP ... Secure FTP
- glibc ... The GNU C Libray
- ulibc ... Smaller than glibc, license under the GNU Lesser GPL.
- GPL ... The GNU General Public License. (Free Software License)
- U-Boot ... Universal Boot loader

# Acronyms Cont.

- SPF ... Stacked Protocol File Manager
- SCF ... Sequential Character File Manager; for Serial ports
- CSL ... C Shared library (OS-9)
- RBF ... Random Block File Manager; for random -access devices such as disks.
- TSCP ... Traffic Signal Control Program (Caltrans)
- URMS ... Universal Ramp Metering Software (Caltrans)
- OS ... Operating System
- PC ... Personal Computer

# Some helpful Links

- <https://www.sdcard.org/home/>
- <https://www.sdcard.org/consumers/cards>
- [http://en.wikipedia.org/wiki/Serial\\_Peripheral\\_Interface\\_Bus](http://en.wikipedia.org/wiki/Serial_Peripheral_Interface_Bus)
- [http://en.wikipedia.org/wiki/Media\\_Independent\\_Interface](http://en.wikipedia.org/wiki/Media_Independent_Interface)
- [http://en.wikipedia.org/wiki/PHY\\_%28chip%29#Ethernet\\_PHYceiver](http://en.wikipedia.org/wiki/PHY_%28chip%29#Ethernet_PHYceiver)
- [http://en.wikipedia.org/wiki/OSI\\_model](http://en.wikipedia.org/wiki/OSI_model)
- [http://cache.freescale.com/files/32bit/doc/app\\_note/AN3966.pdf](http://cache.freescale.com/files/32bit/doc/app_note/AN3966.pdf)
- [http://www.freescale.com/ja/webapp/sps/site/prod\\_summary.jsp?code=MPC855T&nodeId=018rH3Jk194204](http://www.freescale.com/ja/webapp/sps/site/prod_summary.jsp?code=MPC855T&nodeId=018rH3Jk194204)
- <http://en.wikipedia.org/wiki/GNU>
- [http://en.wikipedia.org/wiki/Secure\\_Shell](http://en.wikipedia.org/wiki/Secure_Shell)
- [http://en.wikipedia.org/wiki/SSH\\_File\\_Transfer\\_Protocol](http://en.wikipedia.org/wiki/SSH_File_Transfer_Protocol)
- <http://en.wikipedia.org/wiki/Glibc>
- <http://www.uclibc.org/about.html>
- <http://www.gnu.org/software/libc/index.html>
- <http://linux-sunxi.org/U-boot>
- <http://www.denx.de/wiki/U-Boot/WebHome>
- <http://www.denx.de/wiki/U-Boot/ReleaseCycle>