The BaBar Online Detector Control System Upgrade
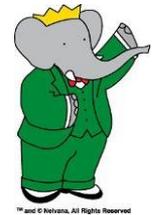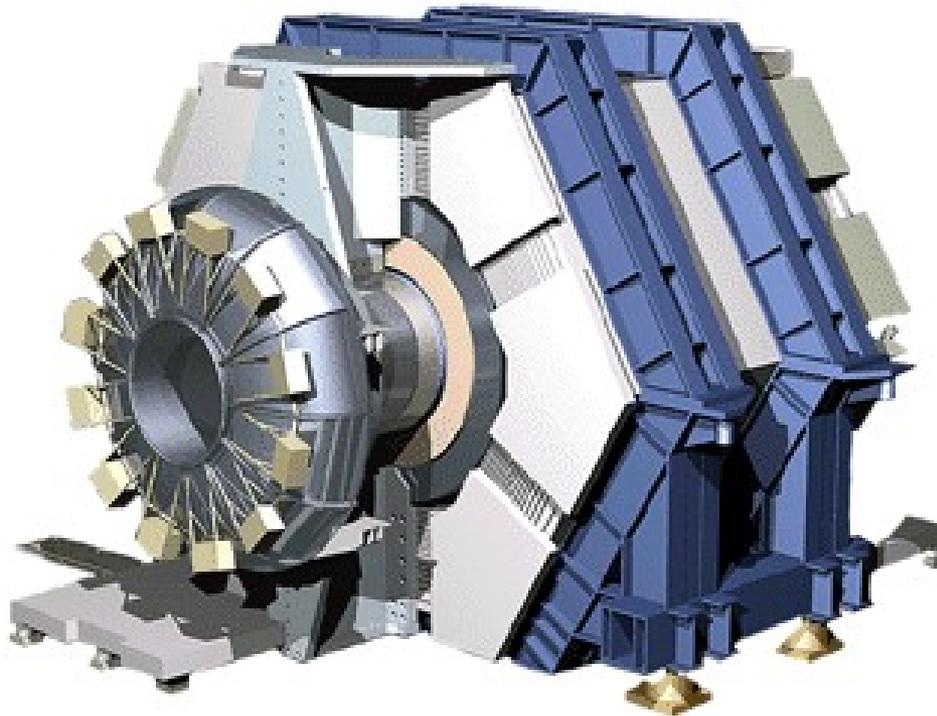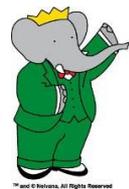
Matthias Wittgen, SLAC

Outline

- ➤ **BaBar Online Detector System**

- ➤ **EPICS**

- ➤ **Motivation for Upgrade**

- ➤ **First Attempt with RTEMS**

- ➤ **Second Attempt Linux**

- ➤ **Conclusions**

BaBar Detector Control System

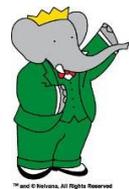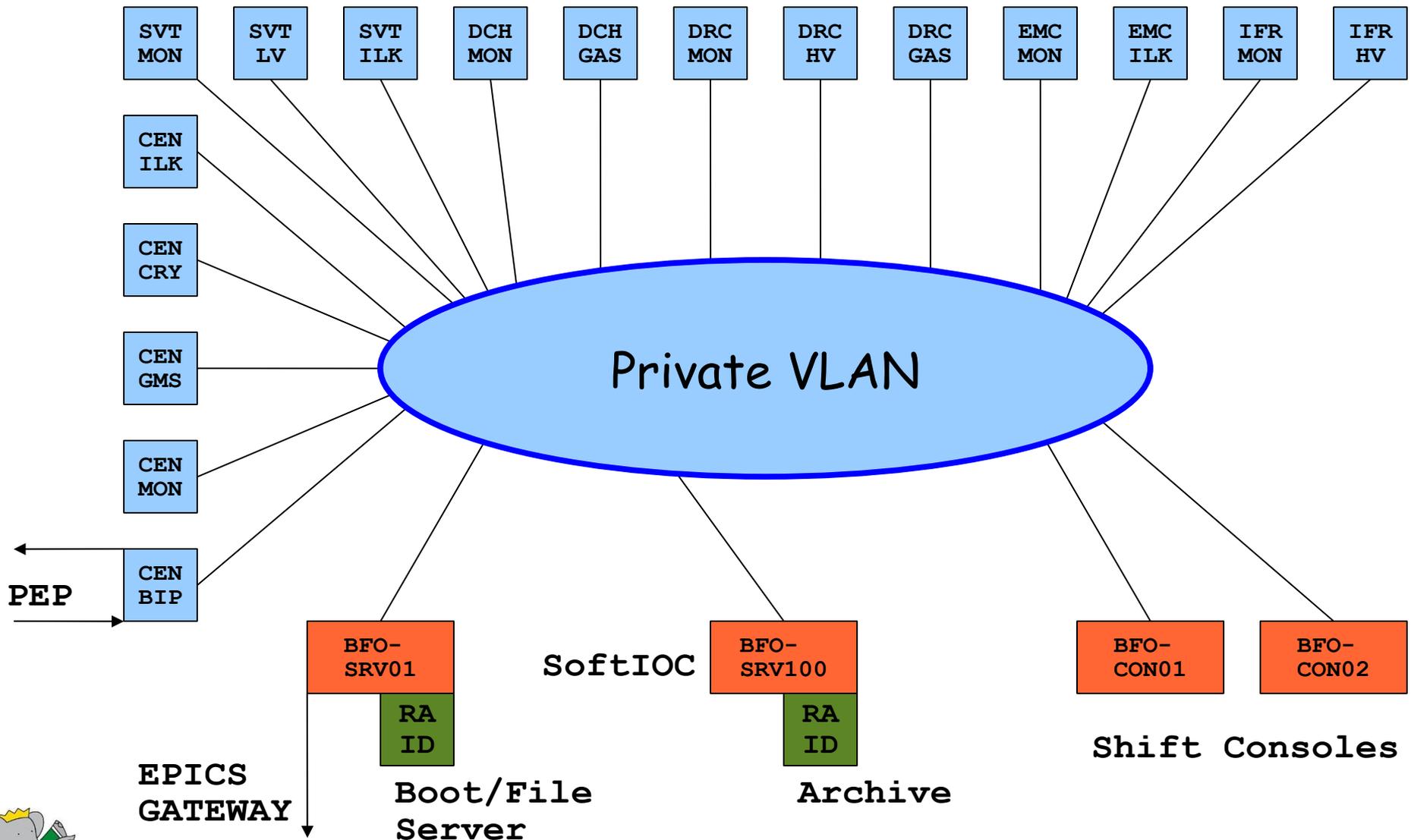- **17 IOCs in VME crates**
  - Mvme177 with 33Mhz 68040 and 32MB RAM
  - Commissioned in the late 1990

- **One infrastructure server**
  - Boot and disk server for IOCs
  - EPICS gateway

- **One application server**
  - Archiving, softIOCs

- **Two terminals for shifters**

- **Interconnected on private VLAN**
  - Security issue (access through gateway machines)
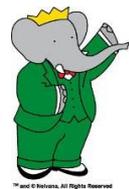
Detector Control System Setup

BaBar IOC overview
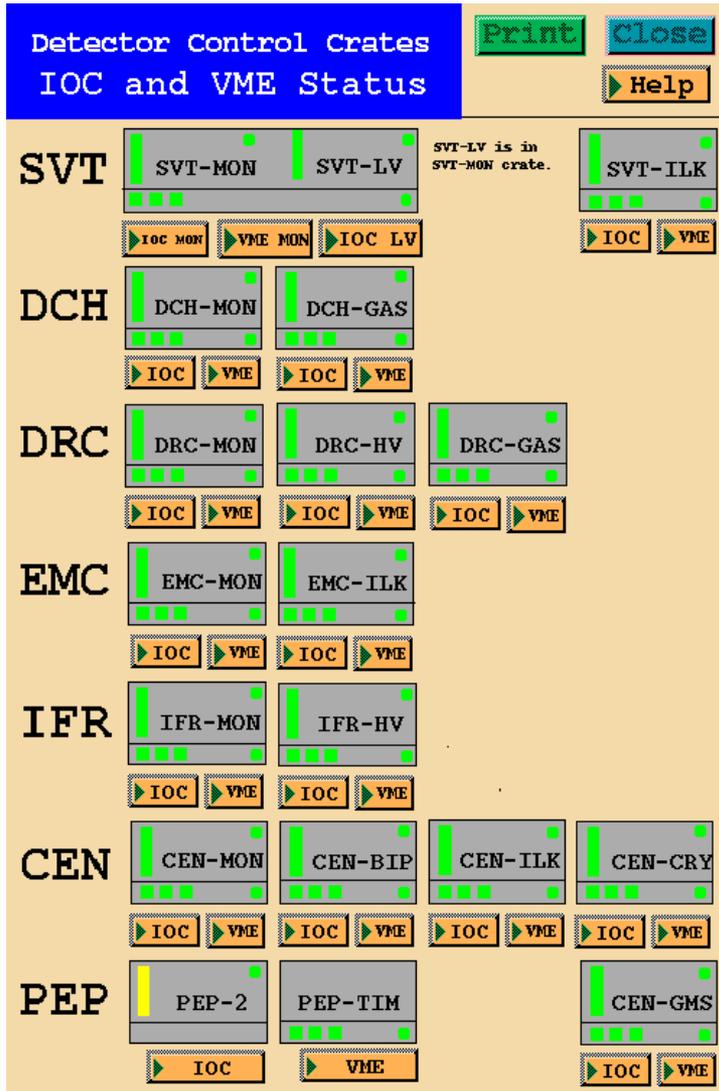
SVT: ~ 3400 channels

DCH: ~ 5000 channels

DRC: ~ 40000 channels

EMC: ~ 7000 channels

IFR: ~ 50000 channels

CEN:~ 10000 channels

Experimental Physics and Industrial Control System

- ➤ **EPICS core application running on a I/O Controller**

- ➤ **Key concept is a database of records**
  - ○ Values, Alarm Limits, Alarm Status

- ➤ **Records can refer to each other**
  - ○ PV Replication, Calculations

- ➤ **Records can get their input from device drivers**
    - Interface to Hardware (mainly VME)

- ➤ **PV can be distributed via LAN**
  - ○ Channel access (monitoring, archiving, GUIs)
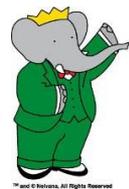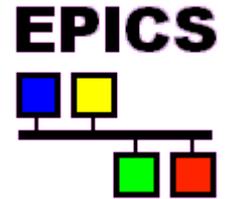
EPICS software upgrade

- ➢ **BaBar was using EPICS release 3.13 since startup**

- ➢ **Beginning of 2005 update of all IOCs to 3.14**

- ➢ **Major improvement in 3.14 is portability**

- ➢ **OSI (operating system independent) layer**

- ➢ **So called softIOC**
  - ○ IOC running on Linux/Solaris hosts
  - ○ No hardware access implemented in OSI layer

- ➢ **Improved stability**

- ➢ **But more hardware resources needed**

- ➢ **Supports more embedded OS than vxWorks**
  - ○ RTEMS
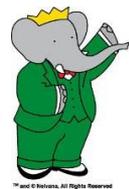
Why upgrade?

- **Mvme177 not really available any more**
  - $7000 for latest version with 50MHz CPU and 128 MB RAM

- **LST upgrade adds 20000 additional channels**

- **Several bottlenecks**
  - Memory
  - CPU too slow to serve EPICS channels
  - 10 MBit network
  - VxWorks network resources (number of file descriptors)
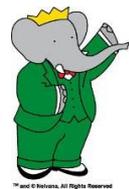
Hardware upgrade

- ## Mvme5500
  - 1 GHz PowerPC 7455 (equivalent to G4)
  - 512 MB RAM upgradeable to 1 GByte
  - Two network interfaces 100/1000 GBit

- ## Already used in EPICS community

- ## BSP for vxWorks and RTEMS available

- ## Cost about $3000

- ## Using vxWorks would have required no license

- ## Latest version was not supported by EPICS
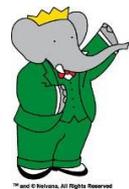
First Attempt: RTEMS

➢ **Real-Time Embedded System**

➢ **Pros:**

o Board support package for mvme5500

o Already supported by EPICS

➢ **Cons:**

o No shell or loadable module support

o Limited debugging support: remote gdb

➢ **CEXP**

o VxWorks like shell with loadable module support and C like regular expression language
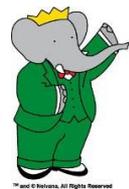
First (failed) Attempt: RTEMS

➢ **In 2005 the LST was partially installed with 7 out 21 HV power supplies integrated into the control system**

➢ **CANBUS interface for communication between HV power supplies and IOC**

➢ **System worked reliably through BaBar Run 4**

➢ **Didn't work with all 21 HVPS**

- No memory management in RTEMS
- No overcommitment of memory
- Running out of memory during startup
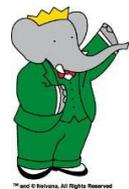
Let's go Linux
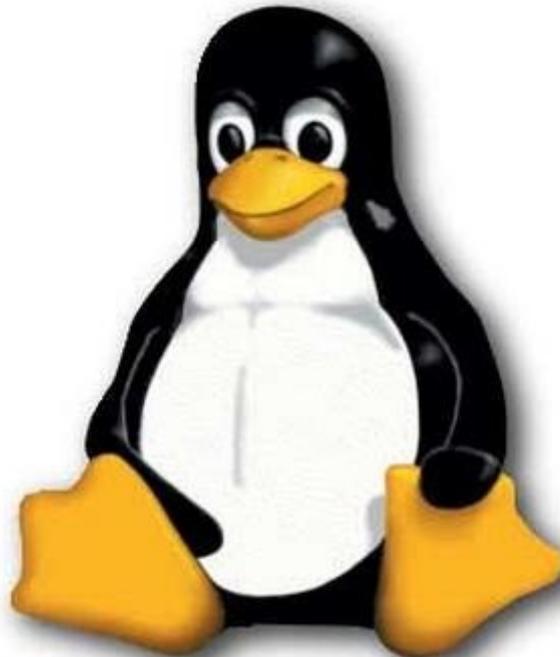
Second Attempt: Linux

- **Kernel patches for MVME5500 for 2.6 from Motorola**

  - Not quit up-to-date. Two subversions behind

- **Embedded Linux Development Kit ELDK available for PowerPC**

  - Gcc cross-compiler for i386 Linux
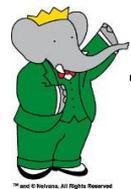
  - Small base distribution with native gcc and gdb

- **Not really real-time, but EPICS isn't really either**

- **Write(small) OSI layer for EPICS to access VME**

- **Fine with polling device drivers**

- **Native Linux drivers for interrupt driven devices**

  - How to propagate interrupts into user-space
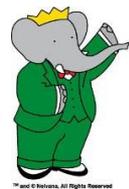
Problems Linux did solve

- ## Found many bugs in our EPICS device drivers

  - EPICS application can be run in gdb

  - Dereferencing of NULL pointer don't cause SEGV on vxWorks and RTEMS

  - Core dumps allowed us to find some race conditions leading to crashes

- ## EPICS can run in user-space

- ## No reboots required any more

  - Restart of EPICS application sufficient

  - 30 second downtime to make changes to EPICS instead of 2-10 mins for a reboot
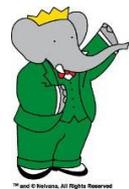
Top on Linux IOC

```
top - 17:13:46 up 10 days, 22:00,  1 user,  load average: 0.35, 2.10, 1.78
Tasks: 431 total,   3 running, 428 sleeping,   0 stopped,   0 zombie
Cpu(s):  4.6% us,  2.3% sy,  0.0% ni, 92.5% id,  0.3% wa,  0.0% hi,  0.3% si
Mem:    514868k total,   199040k used,   315828k free,        0k buffers
Swap:        0k total,        0k used,        0k free,    96120k cached

  PID USER      PR  NI  VIRT  RES  SHR S %CPU %MEM    TIME+  COMMAND
 3969 babar     16   0  140m  80m 2792 S  1.6 16.0 734:59.91 ifr-mon.iocsh
 3984 babar     16   0  140m  80m 2792 S  1.6 16.0  1956:58 ifr-mon.iocsh
 4817 babar     16   0  2916 1424  944 R  1.0  0.3   0:00.66 top
 4025 babar     15   0  140m  80m 2792 S  0.7 16.0  1355:50 ifr-mon.iocsh
 3957 babar     15   0  140m  80m 2792 S  0.3 16.0 255:13.53 ifr-mon.iocsh
 3972 babar     15   0  140m  80m 2792 S  0.3 16.0  14:21.00 ifr-mon.iocsh
 3985 babar     15   0  140m  80m 2792 S  0.3 16.0 800:50.88 ifr-mon.iocsh
 4206 babar     16   0  140m  80m 2792 S  0.3 16.0  61:35.03 ifr-mon.iocsh
 4252 babar     16   0  140m  80m 2792 S  0.3 16.0   4:53.38 ifr-mon.iocsh
    1 root      16   0  1632  592  520 S  0.0  0.1   1:14.00 init
    2 root      34  19     0    0    0 S  0.0  0.0   0:00.00 ksoftirqd/0
    3 root      RT   0     0    0    0 S  0.0  0.0   0:00.04 watchdog/0
    4 root      10  -5     0    0    0 S  0.0  0.0   0:00.08 events/0
    5 root      11  -5     0    0    0 S  0.0  0.0   0:00.01 khelper
    6 root      10  -5     0    0    0 S  0.0  0.0   0:00.00 kthread
   15 root      16  -5     0    0    0 S  0.0  0.0   0:00.00 kblockd/0
   59 root      20   0     0    0    0 S  0.0  0.0   0:00.00 pdflush
```
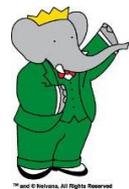
Conclusions

- ➤ **5 out of 17 IOC replaced so far by mvme5500**

- ➤ **Switching to Linux provided a very stable environment for running EPICS**

- ➤ **Better debugging tools**

- ➤ **Made IOCs running vxWorks more stable**

- ➤ **Went from about 2 IOC crashes a week to virtually zero**

- ➤ **Pentium based SBC probably better choice**
  - o Runs Scientific Linux out of the box

References

- **EPICS**
  - o http://www.aps.anl.gov/epics

- **RTEMS**
  - o http://www.rtems.com

- **CEXP/GeSYS**
  - o http://www.slac.stanford.edu/comp/unix/package/rtems/doc

- **Kernel Patches for MVME5500**
  - o https://mcg.motorola.com/cfm/templates/linux.cfm?PageID=705

- **ELDK**
  - o http://www.denx.de/wiki/DULG/ELDK