Getting Started with EPICS Lecture Series

Input/Output Controller (IOC) Overview

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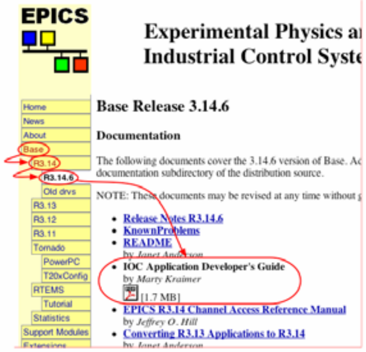
IOC Overview

- What is an EPICS Input/Output Controller
- How to create a new IOC application
- How to build an IOC application
- How to run an IOC application on various platforms
- Console interaction with an IOC application (iocsh)

Reference

EPICS: Input/Output Controller Application Developers Guide

Go to EPICS home page:
http://www.aps.anl.gov/epics/
then follow links, as shown



Experimental Physics a
Industrial Control Syste

Base Release 3.14.6

Documentation

The following documents cover the 3.14.6 version of Base. Ac
documentation subdirectory of the distribution source.

NOTE: These documents may be revised at any time without g

- Release Notes R3.14.6
- KnownProblems
- README
  by Janet Anderson
- IOC Application Developer's Guide
  by Marty Kraimer
  [1.7 MB]
- EPICS R3.14 Channel Access Reference Manual
  by Jeffrey O. Hill
- Converting R3.13 Applications to R3.14
  by Janet Anderson

What is an Input/Output Controller?

The answer used to be easy – "A single-board computer running the vxWorks real-time operating system and installed in a VME chassis".

What is an Input/Output Controller?

An IOC can also be an embedded microcontroller, a rack-mount server, a laptop PC or Mac, a desktop PC or Mac, or a standalone single-board computer.

It may be running on Linux, Windows, Solaris, Darwin, RTEMS, HP-UX or vxWorks

What is an Input/Output Controller?

Some definitions from the first lecture:

- A computer running *iocCore,* a set of EPICS routines used to define process variables and implement real-time control algorithms
- *iocCore* uses database records to define process variables and their behavior

What does an Input/Output Controller do?

- **As its name implies, an IOC often performs input/output operations to attached hardware devices.**
- **An IOC associates the values of EPICS process variables with the results of these input/output operations.**
- **An IOC can perform sequencing operations, closed-loop control and other computations.**

‘Host-based’ and ‘Target’ IOCs

- **‘Host-based’ IOC**
  - Runs in the same environment as which it was compiled
  - ‘Native’ software development tools (compilers, linkers)
  - Sometimes called a ‘Soft’ IOC
  - IOC is an program like any other on the machine
  - Possible to have many IOCs on a single machine
- **‘Target’ IOC**
  - Runs in a different environment than where compiled
  - ‘Cross’ software development tools
  - vxWorks, RTEMS
  - IOC boots from some medium (usually network)
  - IOC is the only program running on the machine

IOC Software Development Area

- **IOC software is usually divided into different <top> areas**
  - Each <top> provides a place to collect files and configuration data associated with one or more similar IOCs
  - Each <top> is managed separately
  - A <top> may use products from other <top> areas (EPICS base, for example can be thought of as just another <top>)

IOC Software Development Tools

- **EPICS uses the GNU version of make**
  - Almost every directory from the <top> on down contains a ‘Makefile’
  - Make recursively descends through the directory tree
    - *Determines what needs to be [re]built*
    - *Invokes compilers and other tools as instructed in Makefile*
  - GNU C/C++ compilers or vendor compilers can be used
- **No fancy ‘integrated development environment’**

IOC Application Development Examples

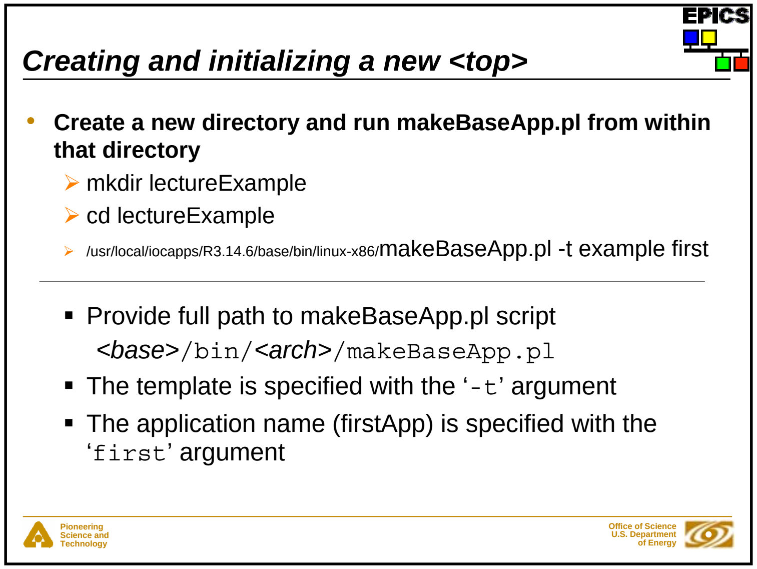
The following slides provide step-by-step examples of how to:

- **Create, build, run the example IOC application on a 'host' machine (Linux, Solaris, Darwin, etc.)**
- **Create, build, run the example IOC application on a vxWorks 'target’ machine**

Each example begins with the use of ‘makeBaseApp.pl’

The ‘makeBaseApp.pl’ program

- **Part of EPICS base distribution**
- **Populates a new, or adds files to an existing, <top> area**
- **Requires that your environment contain a valid EPICS_HOST_ARCH (EPICS base contains scripts which can set this as part of your login sequence)**
  - linux-x86, darwin-ppc, solaris-sparc, win32-x86
- **Creates different directory structures based on a selection of different templates**
- **Commonly-used templates include**
  - ioc - Generic IOC application skeleton
  - example - Example IOC application

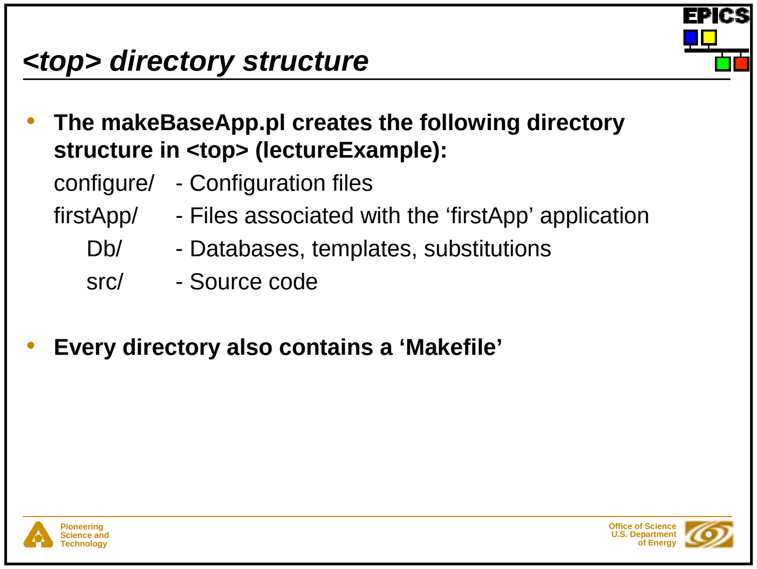


Creating and initializing a new <top>

- **Create a new directory and run makeBaseApp.pl from within that directory**
  - mkdir lectureExample
  - cd lectureExample
  - /usr/local/iocapps/R3.14.6/base/bin/linux-x86/makeBaseApp.pl -t example first

---

- Provide full path to makeBaseApp.pl script
  <base>`/bin/`*<arch>*`/makeBaseApp.pl`
- The template is specified with the '`-t`' argument
- The application name (firstApp) is specified with the '`first`' argument

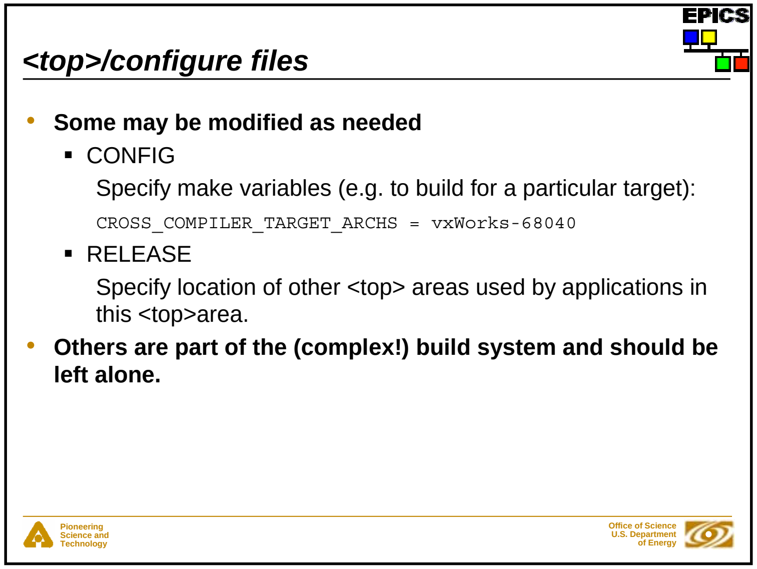


<top> directory structure

- **The makeBaseApp.pl creates the following directory structure in <top> (lectureExample):**

configure/	- Configuration files
firstApp/	- Files associated with the 'firstApp' application
Db/	- Databases, templates, substitutions
src/	- Source code

- **Every directory also contains a 'Makefile'**



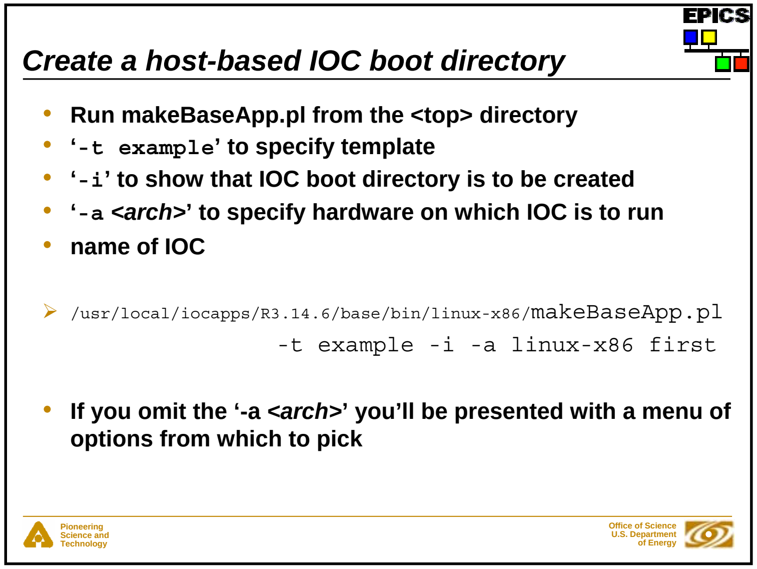
<top>/configure files

- **Some may be modified as needed**
  - CONFIG

    Specify make variables (e.g. to build for a particular target):

    ```
    CROSS_COMPILER_TARGET_ARCHS = vxWorks-68040
    ```
  - RELEASE

    Specify location of other <top> areas used by applications in this <top>area.
- **Others are part of the (complex!) build system and should be left alone.**



Create a host-based IOC boot directory

- **Run makeBaseApp.pl from the <top> directory**
- **'`-t example`' to specify template**
- **'`-i`' to show that IOC boot directory is to be created**
- **'`-a` *<arch>*' to specify hardware on which IOC is to run**
- **name of IOC**

```
/usr/local/iocapps/R3.14.6/base/bin/linux-x86/makeBaseApp.pl
                    -t example -i -a linux-x86 first
```

- **If you omit the '-a *<arch>*' you'll be presented with a menu of options from which to pick**

<top> directory structure

- **The command from the previous slide creates an additional directory in <top>:**

iocBoot/	- Directory containing per-IOC boot directories
iocfirst/	- Boot directory for ‘iocfirst’ IOC

Build the application

- **Run the GNU make program**
  - ‘make’ on Darwin, Linux, Windows
  - ‘gnumake’ on Solaris
- `make`

  or
- `make -w`
- **Runs lots of commands**

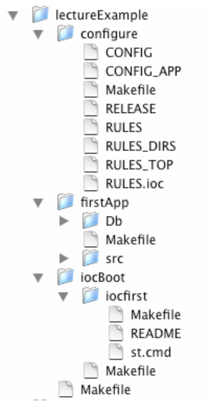
<top> directory structure after running `make`

- **These additional directories are now present in <top>**

bin/	- Directory containing per-architecture directories
linux-x86/	- Object files and executables for this architecture
lib/	- Directory containing per-architecture directories
linux-x86/	- Object libraries for this architecture
dbd/	- Database definition files
db/	- Database files (record instances, templates)

- **There may be other directories under bin/ and lib/, too**.

<top> directory structure after running `make`



```
▼ lectureExample
    ▼ configure
          CONFIG
          CONFIG_APP
          Makefile
          RELEASE
          RULES
          RULES_DIRS
          RULES_TOP
          RULES.ioc
    ▼ firstApp
        ▶ Db
          Makefile
        ▶ src
    ▼ iocBoot
        ▼ iocfirst
              Makefile
              README
              st.cmd
          Makefile
      Makefile
```

IOC startup

- **IOCs read commands from a startup script**
  - Typically ‘st.cmd’ in the <top>/iocBoot/<iocname>/ directory
- **vxWorks IOCs read these scripts with the vxWorks shell**
- **Other IOCs read these scripts with the iocsh shell**
- **Command syntax can be similar but iocsh allows more familiar form too**
- **Script was created by ‘`makeBaseApp.pl -i`’ command**
- **For a ‘real’ IOC you’d likely add commands to configure hardware modules, start sequence programs, update log files, etc.**

Example application startup script

```
 1  #!../../bin/linux-x86/first
 2
 3  ## You may have to change first to something else
 4  ## everywhere it appears in this file
 5
 6  < envPaths
 7
 8  cd ${TOP}
 9
10  ## Register all support components
11  dbLoadDatabase("dbd/first.dbd")
12  first_registerRecordDeviceDriver(pdbbase)
13
14  ## Load record instances
15  dbLoadRecords("db/dbExample1.db","user=norumeHost")
16  dbLoadRecords("db/dbExample2.db","user=norumeHost,no=1,scan=1 second")
17  dbLoadRecords("db/dbExample2.db","user=norumeHost,no=2,scan=2 second")
18  dbLoadRecords("db/dbExample2.db","user=norumeHost,no=3,scan=5 second")
19  dbLoadRecords("db/dbSubExample.db","user=norumeHost")
20
21  ## Set this to see messages from mySub
22  #var mySubDebug 1
23
24  cd ${TOP}/iocBoot/${IOC}
25  iocInit()
26
27  ## Start any sequence programs
28  #seq sncExample,"user=norumeHost”
```

Example application startup script

```
1  #!../../bin/linux-x86/first
```

- This allows a host-based IOC application to be started by simply executing the st.cmd script
- If you’re running this on a different architecture the ‘linux-x86’ will be different
- If you gave a different IOC name to the ‘`makeBaseApp.pl -i`’ command the ‘first’ will be different
- Remaining lines beginning with a ‘#’ character are comments

Example application startup script

```
6  < envPaths
```

- The application reads commands from the ‘envPaths’ file created by ‘`makeBaseApp -i`’ and ‘make’
- The envPaths file contains commands to set up environment variables for the application:
  - Architecture
  - IOC name
  - <top> directory
  - <top> directory of each component named in configure/RELEASE
- These values can then be used by subsequent commands

```
epicsEnvSet(ARCH,"linux-x86")
epicsEnvSet(IOC,"iocfirst")
epicsEnvSet(TOP,"/home/phoebus/NORUME/lectureExample")
epicsEnvSet(EPICS_BASE,"/usr/local/iocapps/R3.14.6/base")
```

Example application startup script

```
cd ${TOP}
```

- The working directory is set to the value of the ${TOP} environment variable (as set by the commands in ‘envPaths’)
- Allows use of relative path names in subsequent commands

Example application startup script

```
dbLoadDatabase("dbd/first.dbd")
```

- Loads the database definition file for this application
- Describes record layout, menus, drivers

Example application startup script

```
first_registerRecordDeviceDriver(pdbbase)
```

- Registers the information read from the database definition files

Example application startup script

```
dbLoadRecords("db/dbExample1.db","user=norumeHost")
dbLoadRecords("db/dbExample2.db","user=norumeHost,no=1,scan=1 second")
dbLoadRecords("db/dbExample2.db","user=norumeHost,no=2,scan=2 second")
dbLoadRecords("db/dbExample2.db","user=norumeHost,no=3,scan=5 second")
dbLoadRecords("db/dbSubExample.db","user=norumeHost")
```

- Read the application database files
  - These define the records which this IOC will maintain
  - A given file can be read more than once (with different macro definitions)

Example application startup script

24 cd ${TOP}/iocBoot/${IOC}

- The working directory is set to the per-IOC startup directory

Example application startup script

25 iocInit()

- Activates everything
- After reading the last line of the ‘st.cmd’ script the IOC continues reading commands from the console
  - Diagnostic commands
  - Configuration changes

Running a host-based IOC

- Change to IOC startup directory (the one containing the st.cmd script)
  - **`cd iocBoot/iocfirst`**
- Run the IOC executable with the startup script as the only argument
  - **`../../bin/linux-x86/first st.cmd`**
- The startup script commands will be displayed as they are read and executed
- When all the startup script commands are finished the iocsh will display an ‘`epics>` ’ prompt and wait for commands to be typed.

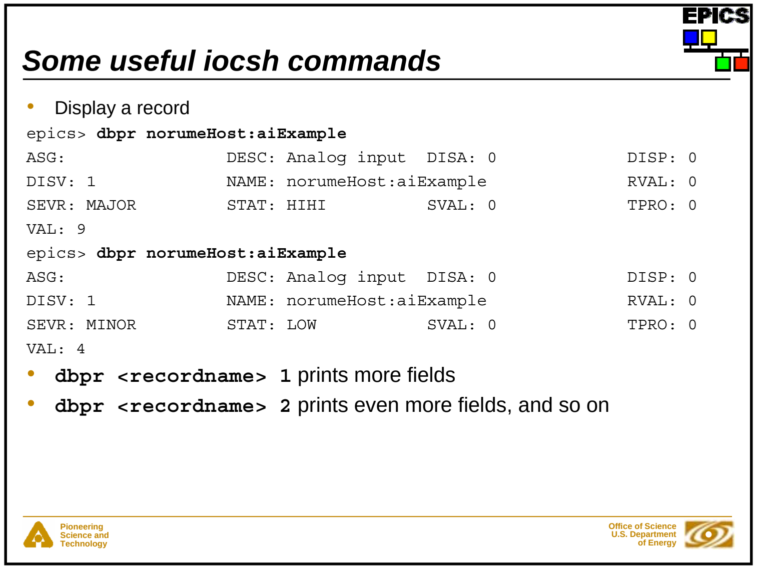
```
iocInit()
#####################################################################
###  EPICS IOC CORE built on Jun 23 2004
###  EPICS R3.14.6 $R3-14-6$ $2004/05/28 19:27:47$
#####################################################################
Starting iocInit
## Start any sequence programs
#seq sncExample,"user=norumeHost"
iocInit: All initialization complete
epics>
```

Some useful iocsh commands

- Display list of records maintained by this IOC

```
epics> dbl
norumeHost:aiExample
norumeHost:aiExample1
norumeHost:aiExample2
norumeHost:aiExample3
norumeHost:calcExample
norumeHost:calcExample1
norumeHost:calcExample2
norumeHost:calcExample3
norumeHost:compressExample
norumeHost:subExample
norumeHost:xxxExample
```

- **Caution – some IOCs have a lot of records**

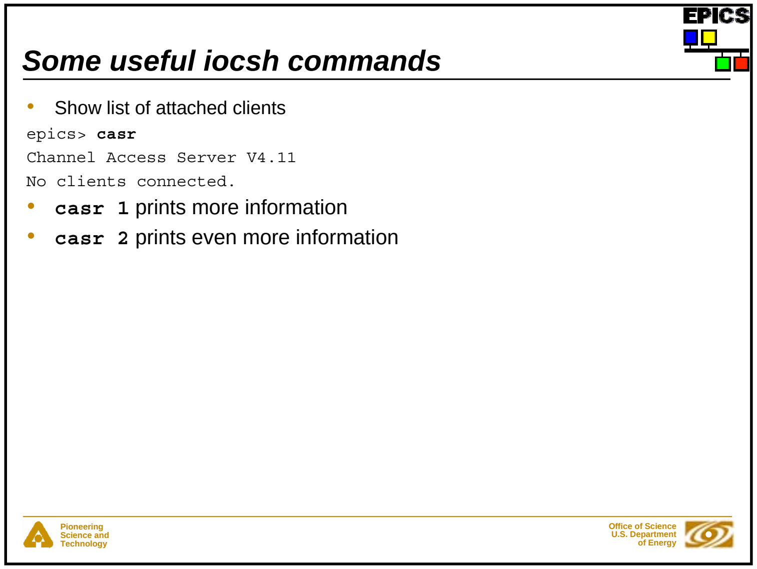


Some useful iocsh commands

- Display a record

```
epics> dbpr norumeHost:aiExample
ASG:                DESC: Analog input  DISA: 0             DISP: 0
DISV: 1             NAME: norumeHost:aiExample              RVAL: 0
SEVR: MAJOR         STAT: HIHI          SVAL: 0             TPRO: 0
VAL: 9
epics> dbpr norumeHost:aiExample
ASG:                DESC: Analog input  DISA: 0             DISP: 0
DISV: 1             NAME: norumeHost:aiExample              RVAL: 0
SEVR: MINOR         STAT: LOW           SVAL: 0             TPRO: 0
VAL: 4
```

- **`dbpr <recordname> 1`** prints more fields
- **`dbpr <recordname> 2`** prints even more fields, and so on

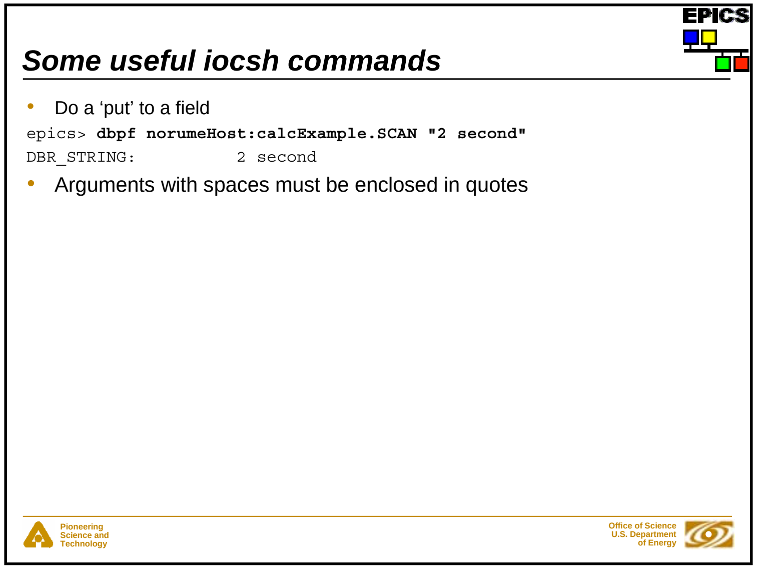


Some useful iocsh commands

- Show list of attached clients

```
epics> casr
Channel Access Server V4.11
No clients connected.
```

- **`casr 1`** prints more information
- **`casr 2`** prints even more information

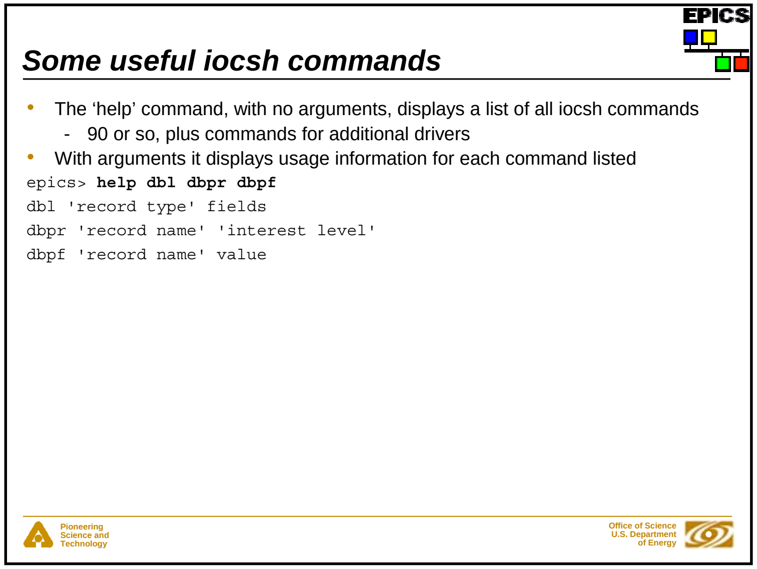


Some useful iocsh commands

- Do a ‘put’ to a field

```
epics> dbpf norumeHost:calcExample.SCAN "2 second"
DBR_STRING:          2 second
```

- Arguments with spaces must be enclosed in quotes



Some useful iocsh commands

- The ‘help’ command, with no arguments, displays a list of all iocsh commands
  - 90 or so, plus commands for additional drivers
- With arguments it displays usage information for each command listed

```
epics> help dbl dbpr dbpf
dbl 'record type' fields
dbpr 'record name' 'interest level'
dbpf 'record name' value
```

Terminating a host-based IOC

- Type ‘`exit`’ to the iocsh prompt
- Type your ‘interrupt’ character (usually control-C)
- Kill the process from another terminal/window

Create a vxWorks IOC boot directory

- **Almost the same as for a host-based IOC**
  - just the ***<arch>*** changes
- **Run makeBaseApp.pl from the <top> directory**
- **‘`-t example`’ to specify template**
- **‘`-i`’ to show that IOC boot directory is to be created**
- **‘`-a` *<arch>*’ to specify hardware on which IOC is to run**
- **name of IOC**

```
➢ /usr/local/iocapps/R3.14.6/bin/solaris-sparc/makeBaseApp.pl
                -t example -i -a vxWorks-68040 first
```

vxWorks IOC startup script changes

- **The startup script created by ‘`makeBaseApp.pl -i`’ for a vxWorks IOC is slightly different than one created for a host-based IOC**
- **A vxWorks IOC uses the vxWorks shell to read the script**
  - a host-based IOC uses the iocsh shell
- **A vxWorks IOC incrementally loads the application binary into the vxWorks system**
  - A host-based IOC runs as a single executable image

vxWorks IOC startup script changes

- **The first few lines of the example st.cmd script for a vxWorks target are:**

```
## Example vxWorks startup file

## The following is needed if your board support package doesn't at boot time
## automatically cd to the directory containing its startup script
#cd "/home/phoebus/NORUME/lectureExample/iocBoot/iocfirst”

< cdCommands
#< ../nfsCommands

cd topbin
## You may have to change first to something else
## everywhere it appears in this file

ld < first.munch
```

vxWorks IOC startup script changes

- **There is no ‘#!’ line at the beginning of the script**
- **vxWorks IOCs can’t be started by simply executing the startup script**

vxWorks IOC startup script changes

- **The startup script reads more commands from cdCommands rather than from envPaths**
  - Assigns values to vxWorks shell variables rather than to iocsh environment variables
- **Subsequent ‘cd’ commands look like**

```
cd top
```

rather than

```
cd ${TOP}
```

vxWorks IOC startup script changes

- **The startup script contains command to load the binary files making up the IOC application**

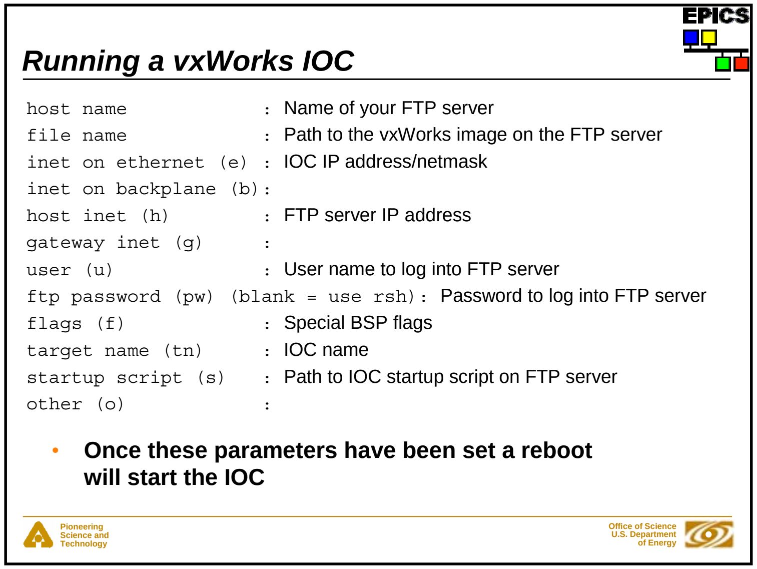
```
ld < first.munch
```

  - Binary fragments have names ending in ‘.munch’

Running a vxWorks IOC

- Set up the vxWorks boot parameters

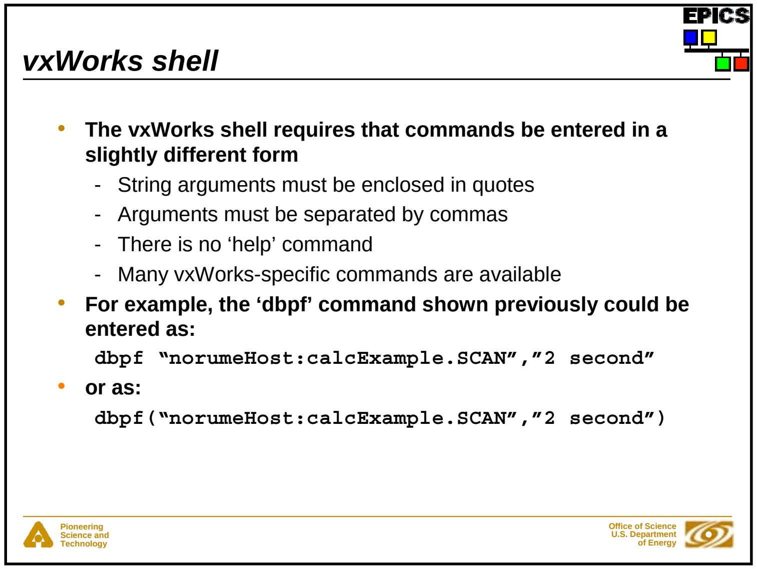
```
Press any key to stop auto-boot...
 6
[VxWorks Boot]: c
'.' = clear field;  '-' = go to previous field;  ^D = quit
boot device          : ei
processor number     : 0
host name            : phoebus
file name            : /usr/local/vxWorks/T202/mv167-asd7_nodns
inet on ethernet (e) : 192.168.8.91:fffffc00
inet on backplane (b):
host inet (h)        : 192.168.8.167
gateway inet (g)     :
user (u)             : someuser
ftp password (pw) (blank = use rsh): somepassword
flags (f)            : 0x0
target name (tn)     : iocnorum
startup script (s)   : /usr/local/epics/iocBoot/iocfirst/st.cmd
other (o)            :
```



Running a vxWorks IOC

`host name`	:	Name of your FTP server
`file name`	:	Path to the vxWorks image on the FTP server
`inet on ethernet (e)`	:	IOC IP address/netmask
`inet on backplane (b)`	:	
`host inet (h)`	:	FTP server IP address
`gateway inet (g)`	:	
`user (u)`	:	User name to log into FTP server
`ftp password (pw) (blank = use rsh)`	:	Password to log into FTP server
`flags (f)`	:	Special BSP flags
`target name (tn)`	:	IOC name
`startup script (s)`	:	Path to IOC startup script on FTP server
`other (o)`	:	

- **Once these parameters have been set a reboot will start the IOC**



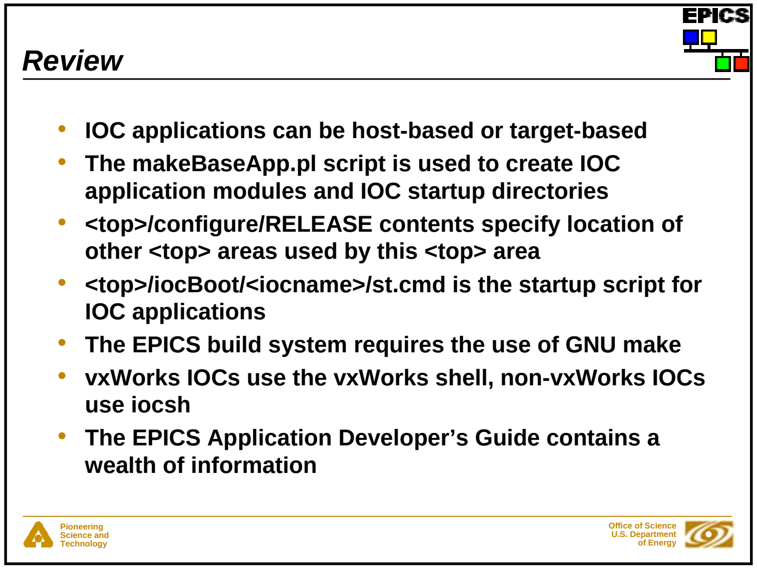
vxWorks shell

- **The vxWorks shell requires that commands be entered in a slightly different form**
  - String arguments must be enclosed in quotes
  - Arguments must be separated by commas
  - There is no ‘help’ command
  - Many vxWorks-specific commands are available
- **For example, the ‘dbpf’ command shown previously could be entered as:**

```
dbpf “norumeHost:calcExample.SCAN”,”2 second”
```

- **or as:**

```
dbpf(“norumeHost:calcExample.SCAN”,”2 second”)
```



Review

- **IOC applications can be host-based or target-based**
- **The makeBaseApp.pl script is used to create IOC application modules and IOC startup directories**
- **<top>/configure/RELEASE contents specify location of other <top> areas used by this <top> area**
- **<top>/iocBoot/<iocname>/st.cmd is the startup script for IOC applications**
- **The EPICS build system requires the use of GNU make**
- **vxWorks IOCs use the vxWorks shell, non-vxWorks IOCs use iocsh**
- **The EPICS Application Developer’s Guide contains a wealth of information**