# Workshop Agenda – Feb 25th 2015

| Time | Presenter | Title |
|---|---|---|
| 09:30 | T. König | Talk – bwHPC Concept & bwHPC-C5 - Federated User Support Activities |
| 09:45 | R. Walter | Talk – bwHPC architecture (bwUniCluster, bwForCluster JUSTUS, ForHLR Phase I) |
| 10:00 | A. Fuchs | Talk – Cluster: Access, Data Transfer and Storage, GUI |
| *10:30* | | *Break* |
| 10:45 | R. Barthel | Talk – File System, Software System (modulefiles), Batch System |
| 11:10 | A. Fuchs | Tutorial – bwUniCluster: Access, Data Transfer, Compiling, Modulefiles, Batch Job Scripting |
| *11:50* | | *Lunch Break* |
| 13:00 | R. Barthel | Talk – Advanced Bash Scripting |
| 13:30 | R. Barthel | Tutorial – Advanced (Batch) Job Scripting |
| *14:15* | | *Break* |
| 14:30 | A. Fuchs | Tutorial – Compiling, Makefile, Parallelising |
| 15:15 | | User Forum – Solving User Cases |
| *16:00* | | *End* |

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# bwHPC Course: Advanced Bash Scripting

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www.bwhpc-c5.de

# How to read the following slides

| Abbreviation/Colour code | Full meaning |
|---|---|
| `$ command -option value` | `$` = prompt of the interactive shell<br>The full prompt may look like:<br>`user@machine:path$`<br>The command has been entered in the interactive shell session |
| `<integer>`<br>`<string>` | <> = Placeholder for integer, string etc |
| `foo, bar` | Metasyntactic variables |
| `${WORKSHOP}` | `/pfs/data1/software_uc1/bwhpc/kit/workshop/2015-02-25` |

# Sources of this slides?

- http://tldp.org/HOWTO/Bash-Prog-Intro-HOWTO.html (intro)
- http://tldp.org/LDP/abs/html (advanced)
- $ man bash

# Why (not) Bash?!

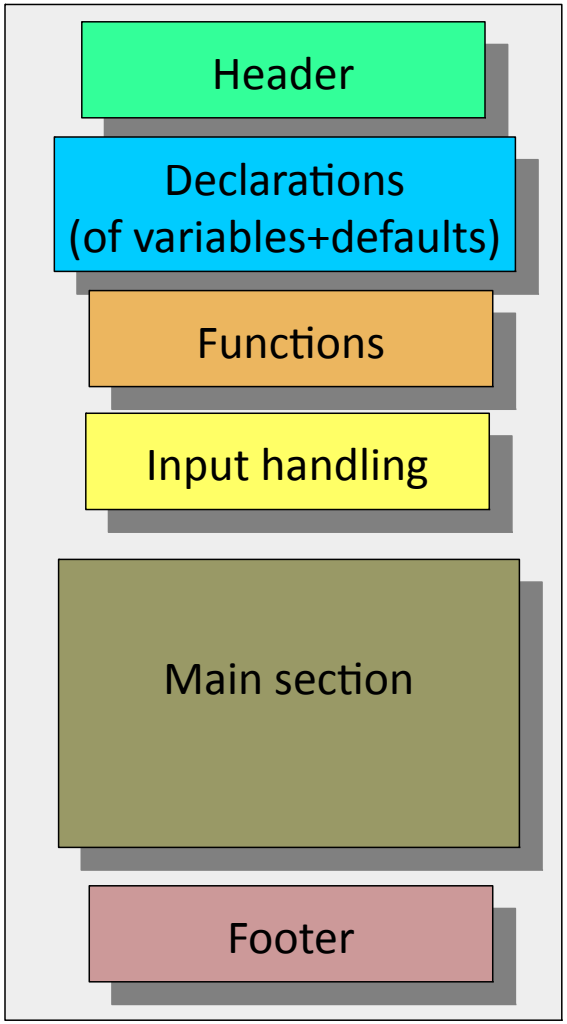
- Great at:
  - managing batch jobs
  - managing external programs
  - invoking entire UNIX command stack & many builtins
- Powerful scripting language
- Portable and version-stable
- Bash almost everywhere installed

- Less useful when:
  - Resource-intensive tasks (e.g. sorting, recursion, hashing)
  - Heavy-duty math operations
  - Extensive file operations
  - Need for native support of multi-dimensional arrays

# Goal

- Be descriptive!
  - Comment your code
    - e.g. via headers sections of script and functions.
  - Decipherable names for variables and functions
- Organise and structure!
  - Break complex scripts into simpler modules

    e.g. use functions
  - Use exit codes
  - Use standardized parameter flags for script invocation.





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# Header & Line format

- Sha-Bang = '#!'

  → at head of file = 1. line only!

```
#!/bin/bash
```

  - Options: e.g. debugging shell):

```
#!/bin/bash -x
```

  - #!/bin/sh → invokes default shell interpreter → mostly Bash
  - If path of bash shell varies:

```
#!/usr/bin/env bash
```

- Line ends with no special character!
  - But multiple statements in one line to be separated by:

    ;  Comma

```
$ echo hello; echo World; echo bye
```

# Bash Output

- **echo**

  a) trails every output with a „newline“

```
$ echo hello; echo World
hello
World
```

  b) prevent newline:

```
$ echo -n hello; echo World
helloWorld
```

  c) parsing „escape sequences“

```
$ echo -e "hello\nWorld"
hello
World
```

- **printf** = enhanced echo
  - by default no „newline“ trailing
  - formated output

```
$ printf hello; printf World
helloWorld$
```

```
$ printf "%-9.9s: %03d\n" "Integer" "5"
Integer  : 005
```

# Globbing

- = filename expansion

  → recognices and expands „wildcards“
- but this is **not** a Regular Expression interpretion

- wildcards:

  *  = any multiple characters

  ?  = any single character

  []  = to list specific character

  e.g. list all files starting with a or b

```
$ ls [a,b]*
```

  ^  = to negate the wildcard match

  e.g. list all files not starting with a

```
$ ls [^a]*
```

# Variables (1)

- Substitution:
  - No spaces before and after '='
  - Brace protect your variables!
  - Values can be generated by commands

```
var1=value
var2=${var2}
var2=$(date)
```

- Bash variables are untyped

  → essentially strings,

  → depending on content arithmetics permitted

```
$ a=41; echo $((a+1))
42
```

```
$ a=BB; echo $((a+1))
1
```

→ string has an integer value of 0

- declare/typeset (bash builtin)
  - set variable to integer, readonly, array etc.

```
$ declare -r a=1
$ let a+=1
bash: a: readonly variable
```

```
$ array=( '1 2' 3 4 5)
$ echo ${array[0]}
1 2
```

→ space is separator

# Variables (2)

- declare – *cont.*
  - Excursion: store file content in array:
    - a) 1 element per string
    - b) 1 element for whole file
    - c) 1 element per line

```
a=( $(< file) )
```

```
a=( "$(< file)" )
```

```
while read -r line; do a+=("${line}") ; done < file
```

  - Identifying variable var:

```
declare | grep var
```

- Usage only without $ prefix when declare, assign, export, unset

```
declare -i a=41
export a
echo ${a}
unset a
echo ${a}
```

→ use ${} instead of simply $ to avoid problems manipulating variables

# Comments and Quotes

**#** Comments

- at beginning
- at the end
- exception: escaping, quotes, substitution

```
# This line is not executed
```

```
echo 'something' # Comment starts here
```

**** Escape = Quoting mechanism for single characters

```
echo \#
```

**'** Full Quotes = Preserves all special characters within

```
echo '#'
```

**"** Partial Quotes = Preserves some of the special characters, but not `${var}`

```
var=42

echo "\${var} = ${var}"
echo '\${var} = ${var}'
```

# Manipulation of Variables (1)

| Syntax | Does? | Examples |
|---|---|---|
| `${#var}` | String length | `$ A='abcdef_abcd'; echo ${#A}`<br>`11` |
| `${var:pos:len}` | Substring extraction: | |
| | a) via Parameterisation | `$ POS=3; echo ${A:${POS}:2}`<br>`de` |
| | b) Indexing from right | `$ echo ${A:(-2)}`<br>`cd` |
| `${var#sstr}` | Strip shortest match of $sstr from front of $var | `$ sstr=a*b; echo ${A#${sstr}}`<br>`cdef_abcd` |
| `${var%sstr}` | Strip shortest match of $sstr from back of $var | `$ sstr=c*d; echo ${A%${sstr}}`<br>`abcdef_ab` |
| `${var/sstr/repl}` | Replace first match of $sstr with $repl | `$ sstr=ab; rp=AB; echo ${A/${sstr}/${rp}}`<br>`ABcdef_abcd` |
| `${var//sstr/repl}` | Replace all matches of $sstr with $repl | `$ echo ${A//${sstr}/$rp}`<br>`ABcdef_ABcd` |
| `${var/#sstr/repl}` | If $sstr matches frond end, replace by $repl | `$ sstr=a; rp=z_; echo ${A/#${sstr}/${rp}}`<br>`z_bcdef_abcd` |
| `${var/%sstr/repl}` | If $sstr matches back end, replace by $repl | `$ sstr=d; rp=_z; echo ${A/%${sstr}/${rp}}`<br>`abcdef_abc_z` |

# Manipulation of Arrays

| Syntax | Does? | Examples |
|---|---|---|
| `${#array[@]}` | Number of elements | `$ dt=( $(date) ); echo ${#dt[@]}`<br>`6` |
| `${array[@]:p1:p2}` | Print elements from no. **p1** to **p2**: | `$ echo ${dt[@]:1:2}`<br>`Feb 25` |
| `${array[@]#sstr}` | Strip shortest match of $sstr from front of all elements of Array | `$ sstr=W*d; echo ${dt[@]#${sstr}}`<br>`Feb 25 10:18:22 CET 2015` |

- Adding elements to an array:

  a) at the end:

```
$ dt+=( "AD" )
$ echo ${dt[@]}
Wed Feb 25 17:18:22 CET 2015 AD
```

  b) inbetween

```
$ dt=( ${dt[@]:0:2} ':-)' ${dt[@]:2}} )
$ echo ${dt[@]}
Wed Feb 25 :-) 17:18:22 CET 2015
```

# Output & Input Redirection (1)

| Syntax | Does? | Examples |
|---|---|---|
| `exe > log` | Standard output (stdout) of application exe is (over)written to file log | `$ date > log; cat log` |
| `exe >> log` | Standard output (stdout) of application exe is append to file log | `$ date >> log; cat log` |
| `exe 2> err` | Standard output (stderr) of application exe is (over)written to file err | `$ date 2> err; cat err` |
| `exe 2>> log` | Standard output (stderr) of application exe is append to file log | `$ date 2>> err; cat err` |
| `exe >> log 2>&1` | Redirects stderr to stdout | `$ date >> log 2>&1` |
| `exe1 \| exe2` | Passes stdout of exe1 to standard input (stdin) of exe2 of next command | *# Print stdout & stderr to screen and then append both to file*<br>`$ date 2>&1 \| tee -a log` |
| `exe < inp` | Accept stdin from file inp | `$ wc -l < file` |

# Output & Input Redirection (2)

- Take care of order when using redirecting
  - e.g:

```
ls -yz >> log 2>&1
```

→ Stdout redirected to file
→ Stderr redirected to file redirectd stdout

```
ls -yz 2>&1 >> log
```

→ Stderr redirected to stdout (channel)
→ Stdout redirected to file

- Suppressing stderr

```
ls -yz >> log 2>/dev/null
```

Usage? Keep variable empty when error occurs,

→ e.g. number of files with extension log

```
list_logs="$(ls *.log 2>/dev/null)"
```

# Output & Input Redirection (3)

- Redirection of „all“ output in shell script to one user file

  → generalise = define variable

```
#!/bin/bash

log="blah.log"
err="blah.err"

echo "value 1" >> ${log} 2>> ${err}
command >> ${log} 2>> ${err}
```

  → or use exec

```
#!/bin/bash

exec > "blah.log" 2> "blah.err"

echo "value 1"
command
```

→ all stdout and stderr after 'exec'
will be written to blah.log and blah.err resp.

# Manipulation of Variables (2)

- Example:

${WORKSHOP}/exercises/bash/var_manipulation.sh

```
#!/bin/bash

## Purpose: Define automatic output names for executables

exe="binary.x"

## Assume: $exe contains extension .x or .exe etc
sstr=".*"
log="${exe%${sstr}}.log"  ## replace extension with .log
err="${exe%${sstr}}.err"  ## replace extension with .err

## Define command: echo and run
echo "${exe} >> ${log} 2>> ${err}"
${exe} >> ${log} 2>> ${err}
```

# Expansion of Variables

| Syntax | Does? | Examples |
|---|---|---|
| `${var-${def}}` | If $var not set, set value of $def | `$ unset var; def=new; echo ${var-${def}}`<br>`new` |
| `${var:-${def}}` | If $var not set or *is empty*, set value of $def | `$ var=''; def=new; echo ${var:-${def}}`<br>`new` |
| | | `# Output name for interactive and MOAB`<br>`jobID=${MOAB_JOBID:-${BASHPID}}` |
| `${var:?${err}}` | If $var not set or *is empty,* print $err and abort script with exit status of 1 | `$ var=''; err='ERROR - var not set'`<br>`$ echo ${var:?${err}}`<br>`bash: var: ERROR - var not set` |

# Exit & Exit Status

- Exit terminates a script
- Every command returns an exit status
  - successfull = 0
  - non-successfull > 0 (max 255)
- $? = the exit status of last command executed (of a pipe)

```
ls -xy; echo $?
2
```

- Special meanings (avoid in user-specified definitions):
  - 1 = Catchall for general errors
  - 2 = Misuse of shell builtins
  - 126 = Command invoked cannot execute (e.g. /dev/null)
  - 127 = "command not found"
  - 128 + n = Fatal error signal "n" (e.g. kill -9 of cmd in shell returns 137)


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# (Conditional) Tests

```
if condition1 ; then
   do_if_cond1_true/0
elif condition2 ; then
   do_if_cond2_true/0
else
   do_the_default
fi
```

| condition | Does? | Examples |
|---|---|---|
| `(( ))` | Arithmetic evaluation | `$ if (( 2 > 0 )) ; then echo yes ; fi`<br>`yes` |
| `[ ]` | Part of (file) test builtin, arithmetic evaluation only with `-gt`, `-ge`, `-eq`, `-lt`, `-le`, `-ne` | `$ if [ 2 -gt 0 ] ; then echo yes ; fi`<br>`yes`<br>`$ # existance of file`<br>`$ if [ -e "file" ] ; then echo yes ; fi` |
| `[[ ]]` | Extented test builtin; allows usage of `&&`, `\|\|`, `<`, `>` | `$ a=8; b=9`<br>`$ if [[ ${a} < ${b} ]]; then echo $? ; fi`<br>`0` |


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# Typical File Tests

- (not) exists:
```
if [ ! -e "file" ] ; then echo "file does not exist" ; fi
```
- file is not zero:
```
[ -s "file" ] && (echo "file greater than zero")
```
- file is directory:
```
[ -d "file" ] && (echo "This is a directory")
```

- readable:
- writeable:
- executable:

```
[ -r "file" ]

[ -w "file" ]

[ -x "file" ]
```

- newer that file2:
```
[ "file" -nt "file2" ]
```

- Pitfalls when using variables:

wrong:
```
$ unset file_var; if [ -e ${file_var} ] ; then echo "yes" ; fi
yes
```

right:
```
$ unset file_var; if [ -e "${file_var}" ] ; then echo "yes" ; fi
```


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# for Loops

```
for arg in list
   do
    command
done
```

- Iterates command(s) until all arguments of *list* are passed
- *list* may contain globbing wildcards

- Example

```
#!/bin/bash

## Purpose: Loop over generated integer sequence
counter=1
for i in {1..10} ; do
   echo "loop no. ${counter}: ${i}"
   let counter+=1
done
```

# while Loops

```
while condition
   do
    command
done
```

- Iterates command(s) as long as *condition* is true (or exit status 0)
- Allows indefinite loops

- Example

```
#!/bin/bash

## Purpose: Loop until max is reached
max=10
i=1
while (( ${max} >= ${i} )) ; do
   echo "${i}"
   let i+=1
done
```

# Positional parameters

= Arguments passed to the script from the command line

| Special variable | Meaning, notes |
|---|---|
| `$0` | Name of script itself |
| `$1, $2, $3` | First, second, and third argument |
| `${10}` | 10th argument, but: `$10 = $1 + 0` |
| `$#` | Number of arguments |
| `$*` | List of all arguments as one single string |
| `$@` | List of all arguments, each argument separately quoted |

- Example:

  Show differences between `${*}` and `${@}`

`${WORKSHOP}/exercises/bash/special_var_01.sh`

```
echo "Number PPs: ${#}"

i=1
for PP in "${@}" ; do
   printf "%3.3s.PP: %s\n" "${i}" "${PP}"
   let i+=1
done

i=1
for PP in "${*}" ; do
   printf "%3.3s.PP: %s\n" "${i}" "${PP}"
   let i+=1
done
```

# Conditional evaluation - case

```
case variable in
   condition1)
      do_if_cond1_true/0
      ;;
   *)
      do_the_default
      ;;
esac
```

- analog to switch in C/C++
- to simplify multiple if/then/else
- each condition block ends with double semicolon
- If a condition tests true:
  - a) commands in that block are executed
  - b) case block terminates


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# Processing Input without getopts

- Combining: Positional parameter + case + while

${WORKSHOP}/exercises/bash/proc_input.sh

```
#!/bin/bash

## Purpose: Processing positional parameters

while (( ${#} > 0 )) ; do
   case "${1}" in

      ## script option: -h
      -h) echo "${1}: This option is for HELP"  ;;

      ## script option: -i + argument
      -i) echo "${1}: This option contains the argument ${2}"
          shift ;;


      ## default
       *) echo "${1}: This is non-defined PP"   ;;
   esac
   ## Shifting positional parameter one to the left: $1 <-- $2 <-- $3
   shift
done
```

# Lifetime of Variables (1)

- Script execution:
  - assigned variables only known during runtime
  - assigned variables not known in „slave“ scripts until „exported“
  - Example:

${WORKSHOP}/exercises/bash/master_parse_var.sh
${WORKSHOP}/exercises/bash/slave_get_var.sh

```
#!/bin/bash

## Purpose: Demonstrate parsing of assigned variables

var1="Non-exported value of var1"
export var2="Exported value of var2"
slave_sh="./slave_get_var.sh"

## check if $slave_sh is executable for user
echo "${0}: \$var1 = $var1"
echo "${0}: \$var2 = $var2"
if [ -x "${slave_sh}" ] ; then
   "${slave_sh}"
fi
```

- But: export of variables in script to interactive shell session only via:

  `$ source script.sh` (compare `~/.bashrc`)

# Lifetime of Variables (2)

- Environmental variables

  a) can be read in e.g. `my_workDIR=${PWD}`

  b) during script changed, example:

```
...
## Purpose: Demonstrating effects on environmental variables

## Changing it during runtime
export HOME="new_home_dir"
echo "${0}: \${HOME} = ${HOME}"
...
```

${WORKSHOP}/exercises/bash/env_var.sh

```
$ echo ${HOME}; ./env_var.sh; echo ${HOME}
/home/kit/scc/ab1234
./env_var.sh: ${HOME} = new_home_dir
/home/kit/scc/ab1234
```

# awk & sed: Command substitution

- **awk**

  → full-featured text processing language with a syntax reminiscent of C

  → use for complicated arithmetics or text or RE processing

  - Examples:

    a) logarithm of variable:

    ```
    a=10; echo ${a} | awk '{print log($1)}'
    ```

    b) first column reformated:

    ```
    awk '{printf "%20.20s\n",$1}' file
    ```

  - One-liners: http://awk.info/?OneLiners

- **sed**

  → non-interactive stream editor

  → use for deleting blank or commented lines etc

  - Example: delete all blank lines of a file:

    ```
    sed '/^$/d' file
    ```

  - One-liners: http://sed.sourceforge.net/sed1line.txt

# Functions (1)

```
function my_name ()
{
    commands
}
```

- Stores a series of commands for ***later*** or ***repeative*** execution
- Functions are called by writing the name
- **Like scripts:** functions handle positional parameters
- Example:

${WORKSHOP}/exercises/bash/fct_01.sh

```
#!/bin/bash

## Purpose: Demonstrating features of functions

## Add to printf command a common string
function my_printf ()
{
   printf "${0}: $(date): ${@}"
}

my_printf "Hello World\n"
```

# Functions (2)

- **`local`** variables: values do not exist outside function, example:

```
#!/bin/bash
## Purpose: Demonstrating features of functions

var1="global value"

## Function: assign to global var1 temporarily a local value
function locally_mod_var ()
{
   local var1=${1}
   if [ -z "${var1}" ] ; then
      return 1
   fi
   echo "fct: local \${var1} = ${var1}"
   var1="new value in fct"
   echo "fct: local \${var1} = ${var1}"
}

echo "main: global \${var1} = ${var1}"
locally_mod_var "${var1}"
echo "main: global \${var1} = ${var1}"
```

${WORKSHOP}/exercises/bash/fct_02.sh

- **`return`**: Terminates a function, optionally takes integer = „exit status of the function“

Thank you for your attention!