



DR&E LLGrid Portal

Interactive Supercomputing for DoD

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DR&E Portal Prototype

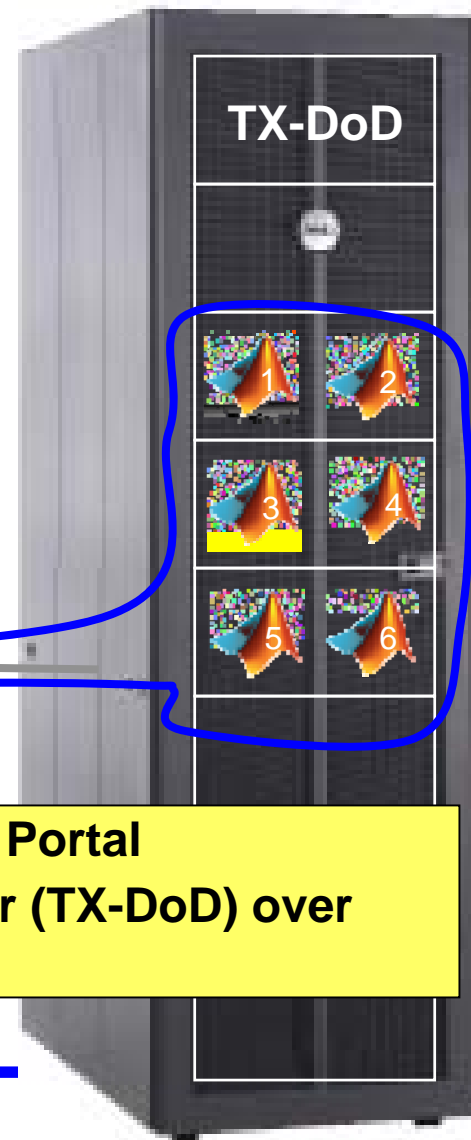
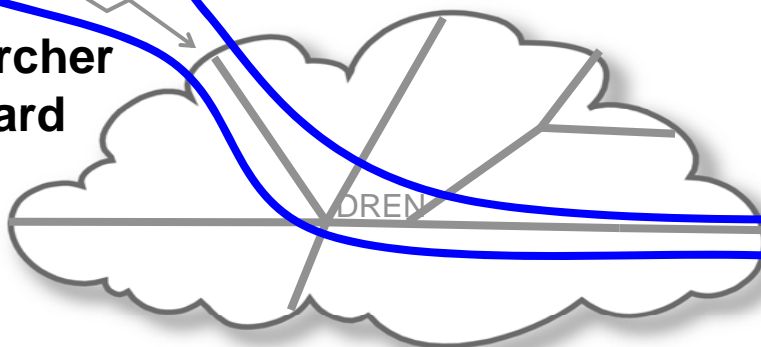
Best of desktop + Best of supercomputing



Interactive ...
“what if scenarios”

Good for experts,
great for novices

DOD researcher
w/CAC card



- HPCMP selected LLGrid for DoD wide prototype DR&E Portal
- Prototype goal: interactive pMatlab on a modest cluster (TX-DoD) over DREN alpha users with CAC authentication

Outline



- **Introduction**

- Design Overview

- Technologies

- Summary

- *LLGrid*
- *Interactive Supercomputing*
- *Parallel Matlab*

What is LLGrid?

Best of desktop + Best of supercomputing



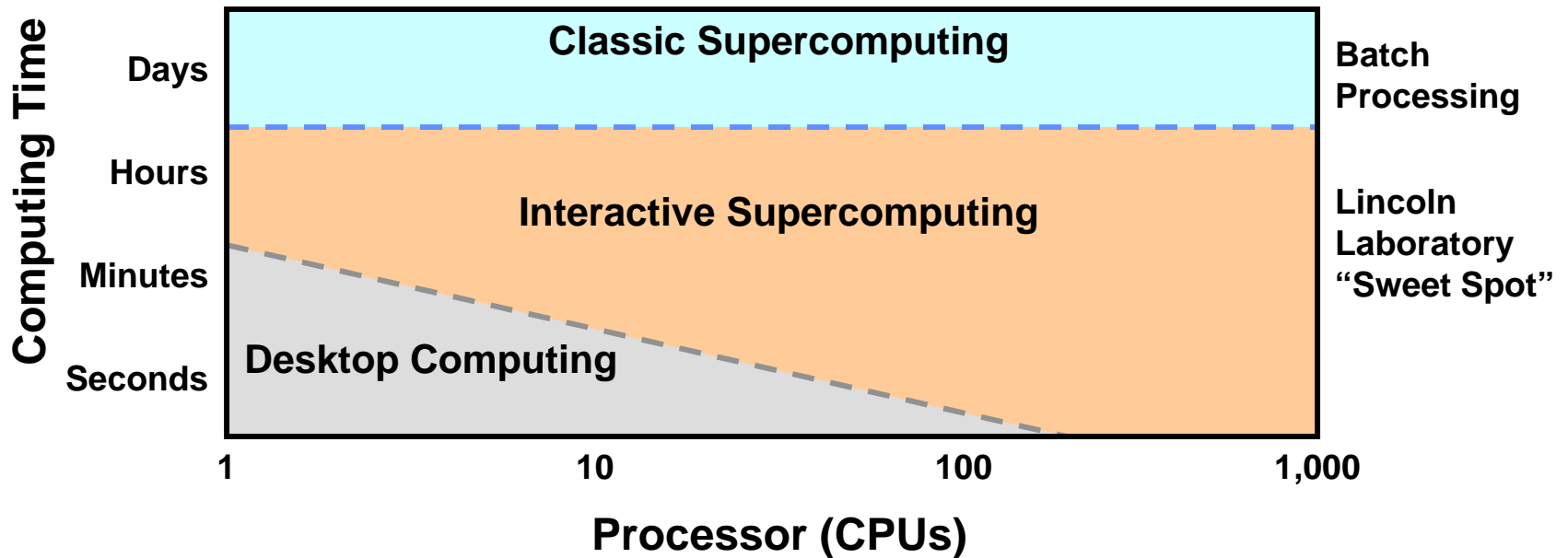
**Interactive ...
“what if scenarios”**

**Good for experts,
great for novices**



- **LLGrid is a ~400 user ~2000 processor system**
- **World’s only desktop interactive supercomputer**
 - **Dramatically easier to use than any other supercomputer**
 - **Highest fraction of staff using (20%) supercomputing of any organization on the planet**

LLGrid Interactive Supercomputing



- **Classic supercomputing:** Jobs take hours/days to run but jobs tolerate waiting in a queue
- **Interactive supercomputing:** Jobs are large requiring answers in minutes/hours but can not tolerate waiting in a queue
- **Desktop computing:** Jobs take minutes on a desktop (e.g., algorithm proof-of-principles)

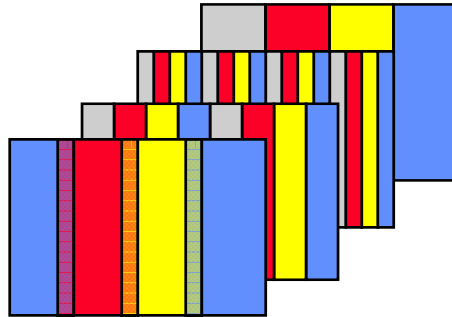
Why is LLGrid easier to use?

Universal Parallel Matlab programming

```

Amap = map([Np 1], {}, 0:Np-1);
Bmap = map([1 Np], {}, 0:Np-1);
A = rand(M,N,Amap);
B = zeros(M,N,Bmap);
B(:, :) = fft(A);
  
```

- pMatlab runs in all parallel Matlab environments
- Only a few functions are needed
 - Np
 - Pid
 - map
 - local
 - put_local
 - global_index
 - agg
 - SendMsg/RecvMsg



Jeremy Kepner

Parallel MATLAB
for Multicore and Multinode Computers

SOFTWARE • ENVIRONMENTS • TOOLS

- **Distributed arrays have been recognized as the easiest way to program a parallel computers since the 1970s**
 - Only a small number of distributed array functions are necessary to write nearly all parallel programs
- **LLGrid is the first system to deploy interactive distributed arrays**

Outline

- Introduction

- **Design Overview**

- *Requirements*
- *Phases*
- *Architecture*

- Technologies

- Summary



Requirements for DR&E Portal

- **Cannot utilize any new networking ports**
 - Hypertext Transport Protocol (http) – port 80
 - Secure Sockets Layer (ssl) – port 443
- **Cannot install new software on desktop computers**
- **Dual-layer authentication**
 - CAC Card with SSL certificates
 - PIN authentication
- **Traverse multiple organizations over DREN**
- **Isolate users accounts from each other**
- **Intuitive to go from serial to parallel coding**
- **Desktop computer is one of computational workers**

Prototype Components: Pre-alpha cluster (TX-DoD)

- **Provided an icon on scientists' and engineers' desktops that provides them tools to do their jobs faster**
 - **pMatlab is first tool in the suite (extensible over time)**
- **Dedicated cluster at LL on DREN**
 - **40 node blade system along with 8 TB of parallel storage**
- **Used for initial development**
 - **LLGrid software stack deployed and modified to work in HPCMP environment based on requirements**
- **Software stack copied to alpha cluster**
- **Maintained as a mirror system for development purposes**



Prototype Components: alpha cluster testbed

- **Experimental testbed on DREN**
- **Used for trials with alpha users**
- **Software stack was copied from pre-alpha and modified based on trials; changes folded back to alpha mirror (TX-DoD)**
- **Software stack copied to beta system**



LLGrid Software Stack

Mac Client

Win7 Client

Web Server

Login Node

Compute Node

Storage

Cluster Mngr

MATLAB /
Octave
pMatlab /
gridMatlab

MATLAB /
Octave
pMatlab /
gridMatlab

MATLAB /
Octave
pMatlab /
gridMatlab

MATLAB /
Octave
pMatlab /
gridMatlab

Sun Grid Engine (SGE) Scheduler

https
WebDAV

Lustre 1.8.1

Local FS

https
WebDAV

grsecurity Patches

Mac OS X

Windows 7

Linux OS (2.6.27.10 Kernel)

Hardware / Network

User Desktops

- Windows 7 and Mac OS X supported
- Portal connection options: WebDAV over https (port 443)

Cluster Management: LL-modified Rocks 5.2

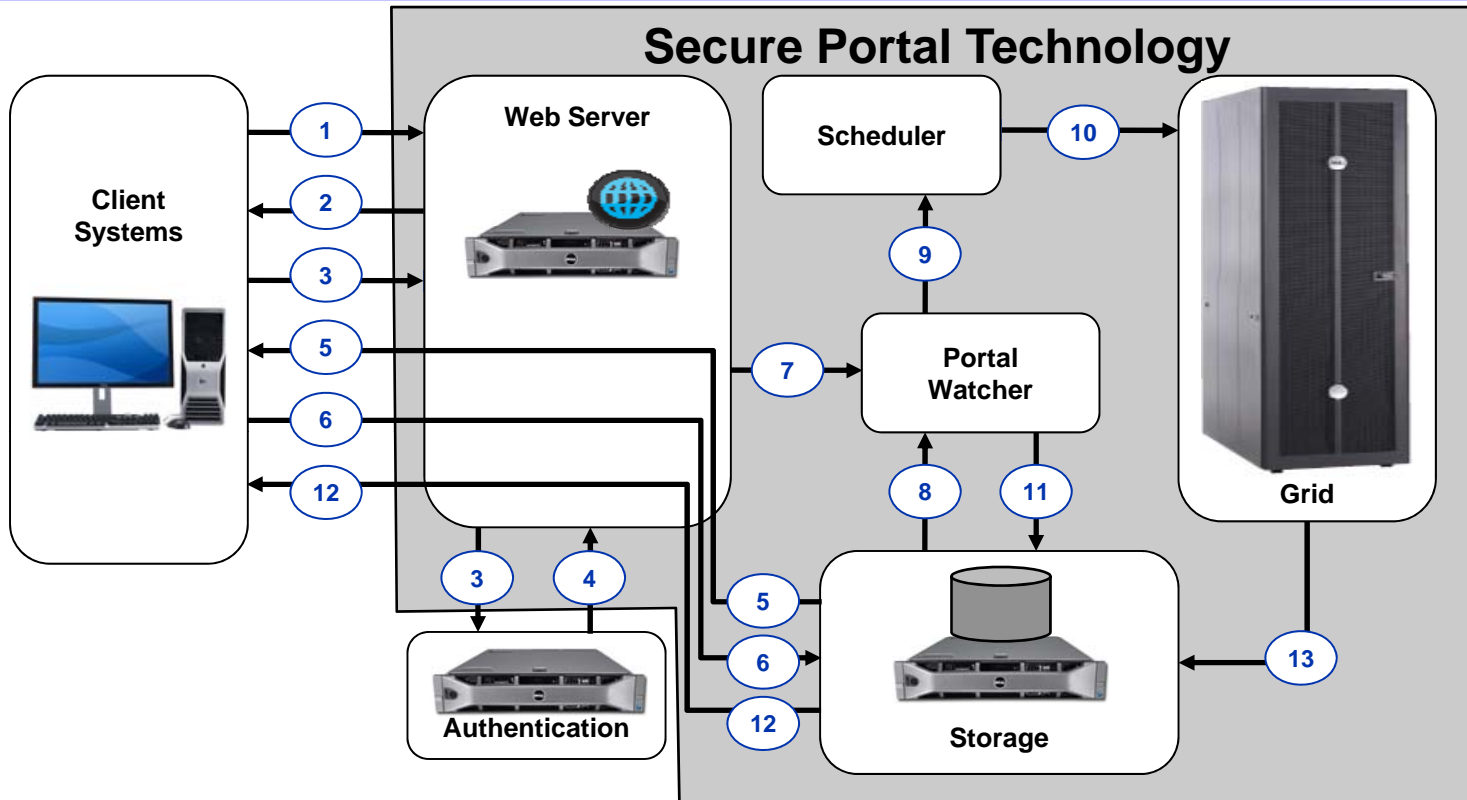
Cluster Parallel File System: Lustre 1.8.1

Scheduler: Sun Grid Engine (SGE)

Login and Compute Nodes (15 GB image size)

- last 5 versions of Matlab, Octave, pMatlab, GridMatlab,
- lammpi, mpich, mpich2, mvapich, openmpi

Prototype Architecture



1. Access Secure Portal
2. CAC Authentication Requested
3. Provide CAC with PIN
4. Credential Approved
5. Map User's Home
6. Submit a job with a protocol file
7. Portal Watcher gets notified

8. Read & parse job description in XML
9. Send the job to scheduler via DRMAA
10. Job scheduled and dispatched
11. Job ID returned in a protocol file
12. Job ID displayed on the client system
13. Output generated and stored

Outline

- Introduction

- Design Overview

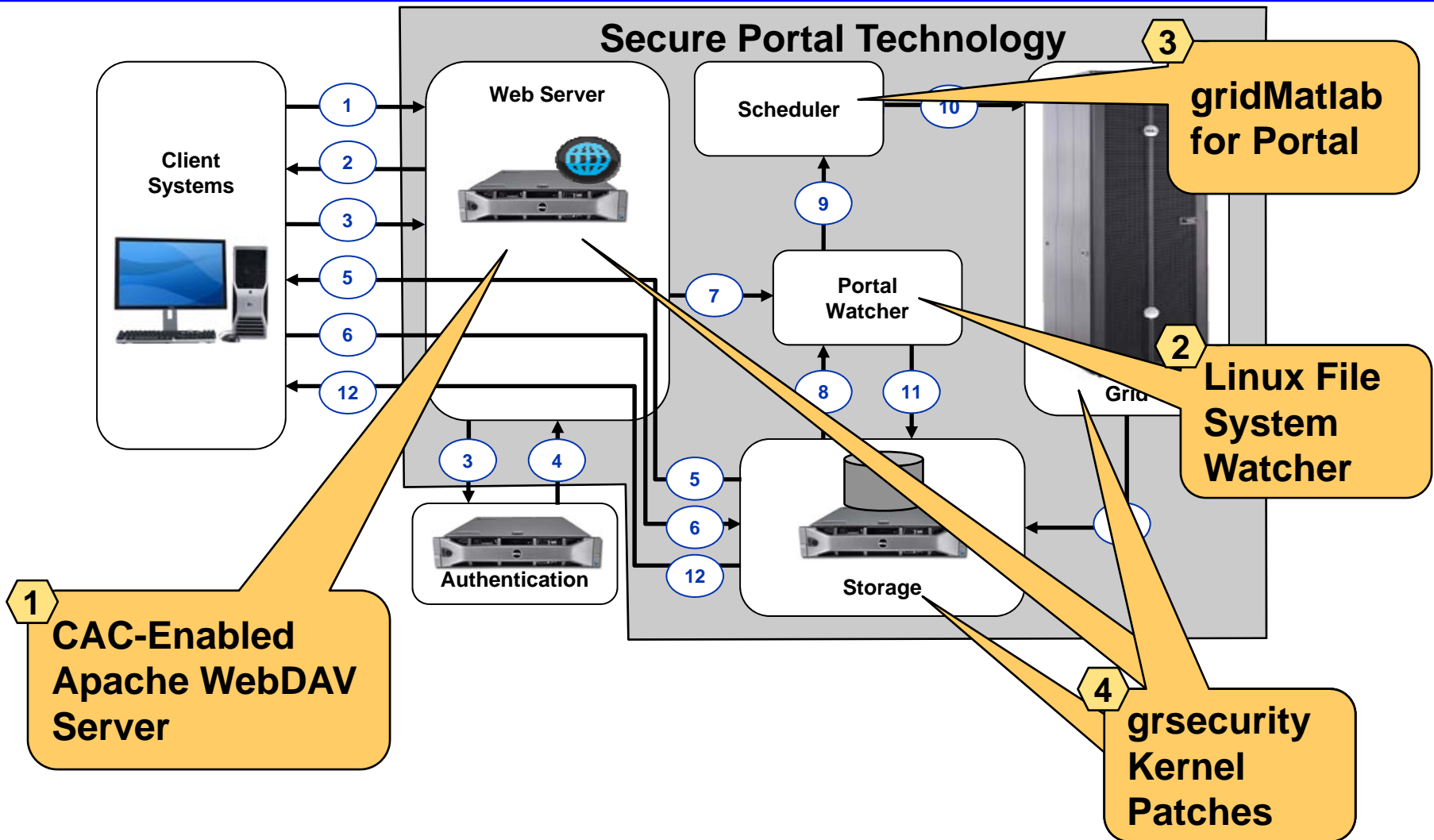
- **Technologies**

- *Key Components*
- *Component Descriptions*

- Summary

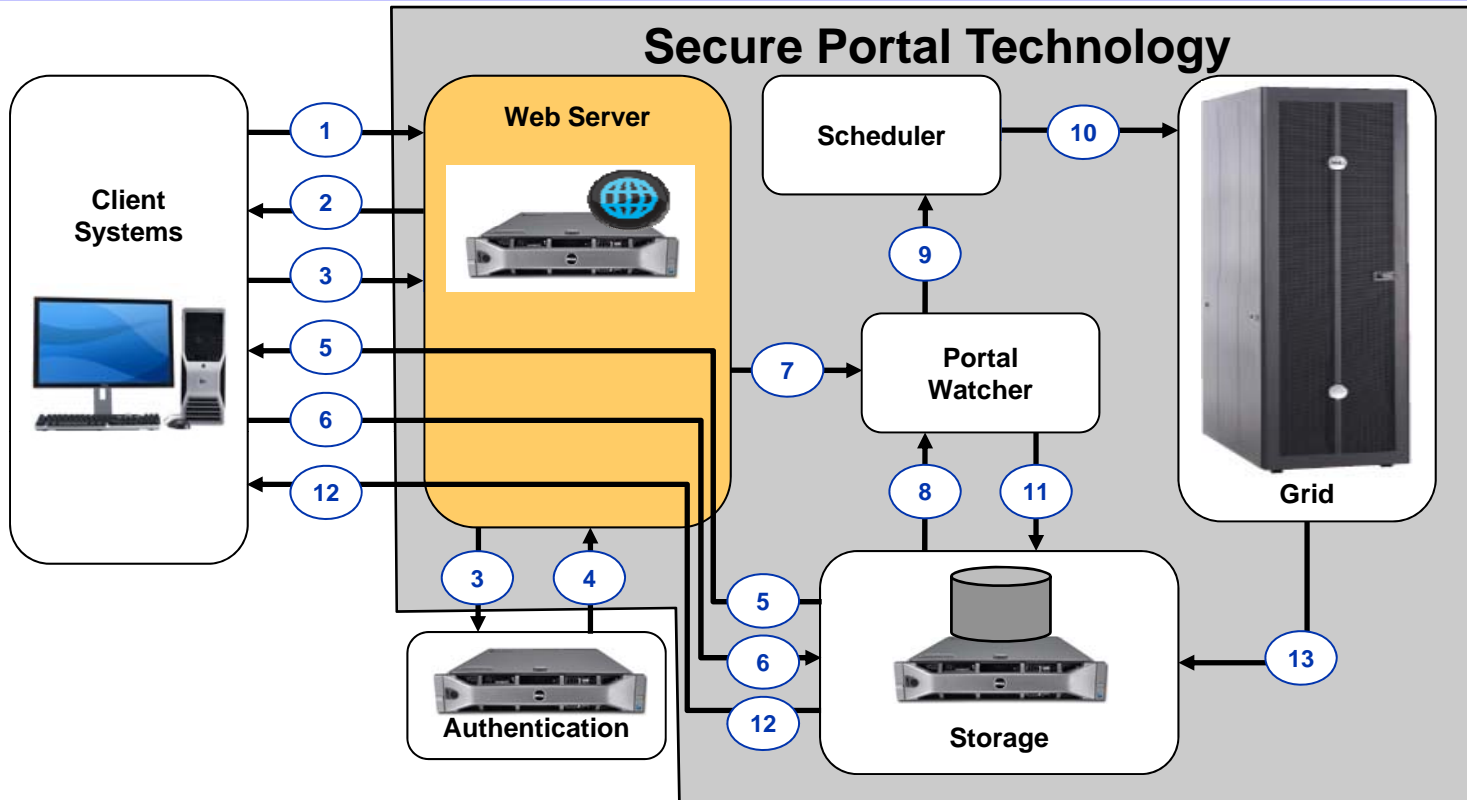
Prototype Architecture

Key Components



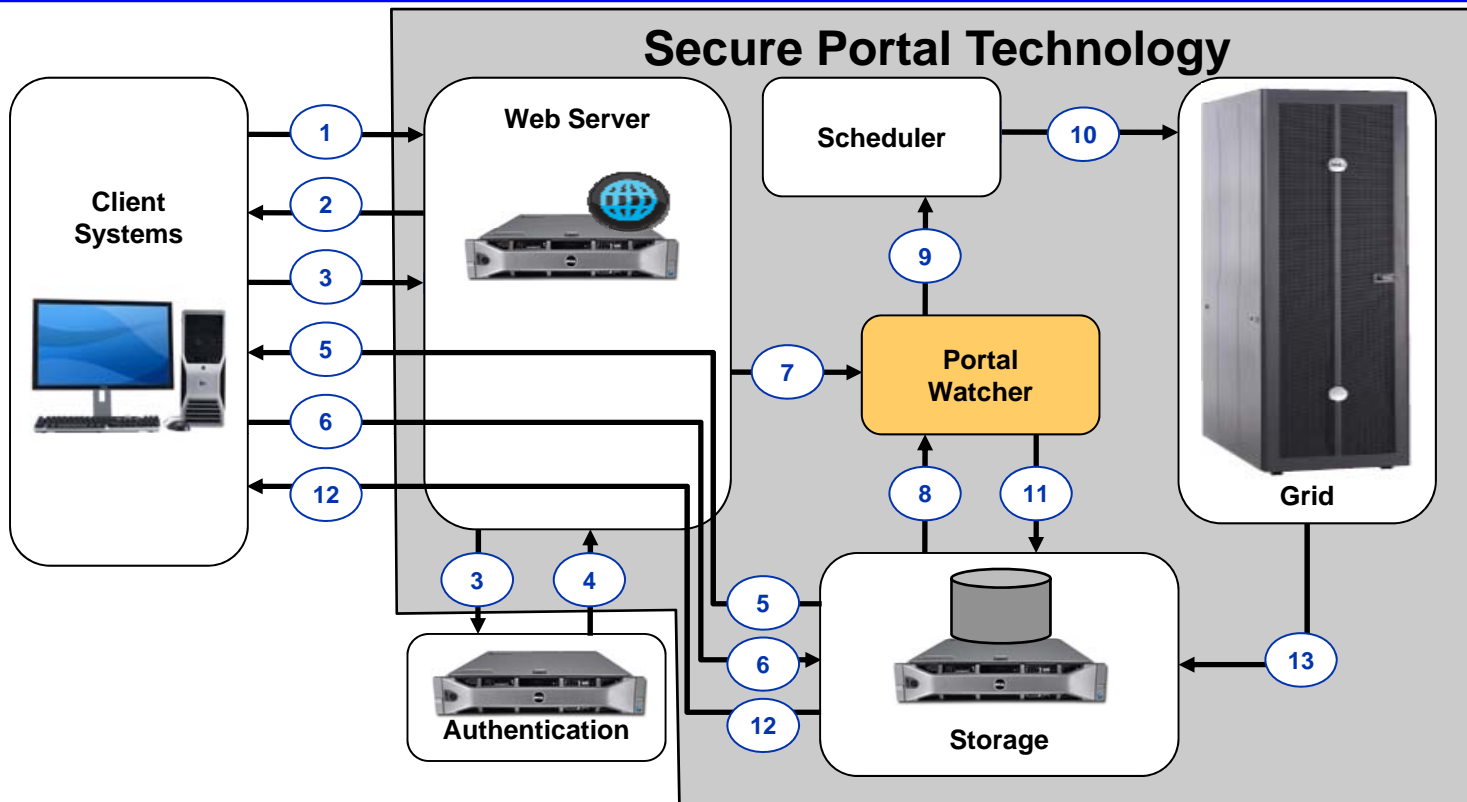
Prototype Architecture

CAC-Enabled Apache WebDAV Server



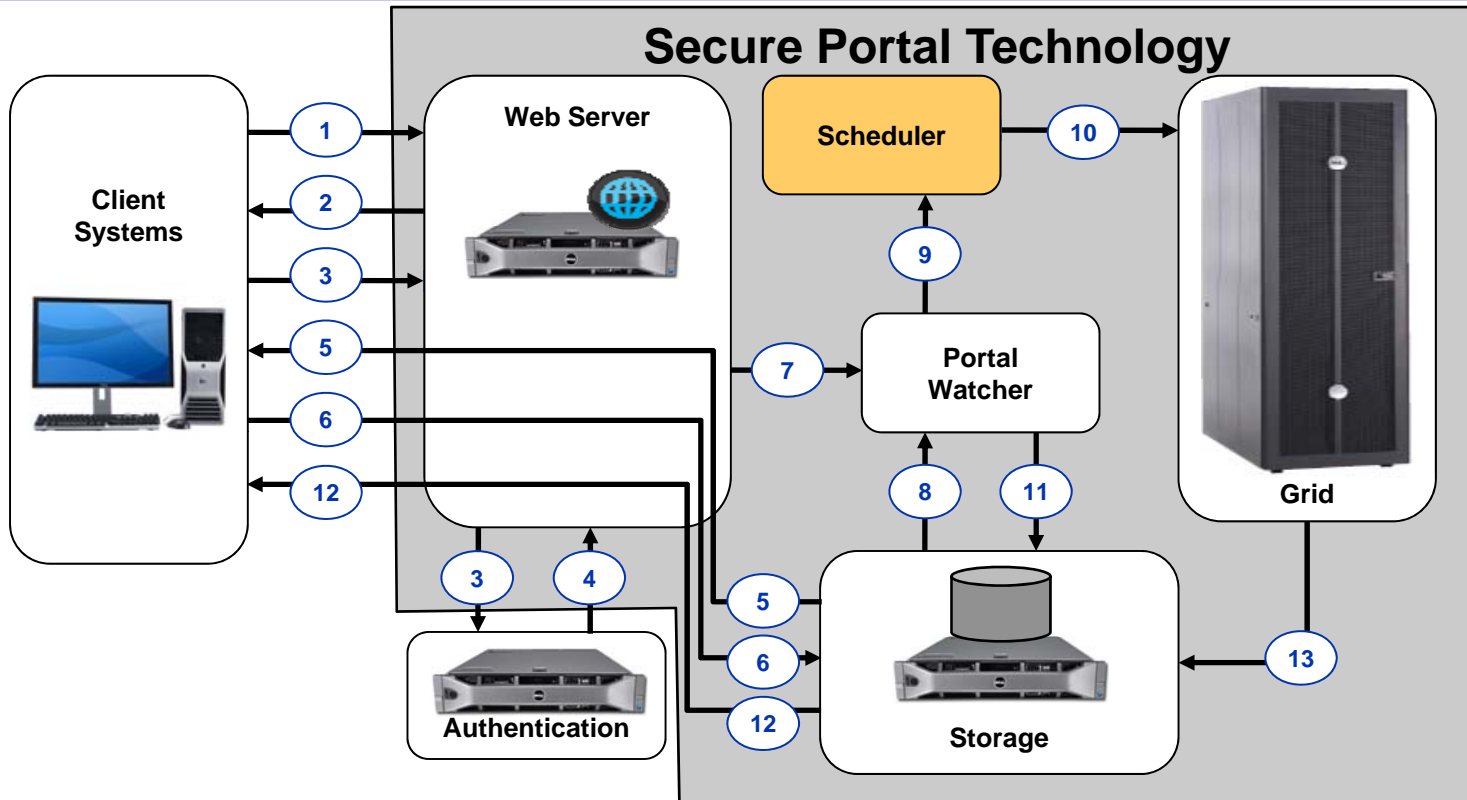
- **WebDAV provides file system services across HTTP (80)**
- **Apache server authenticates via CAC**
- **Required significant modification to Apache Web Server**

Prototype Architecture Linux File System Watcher



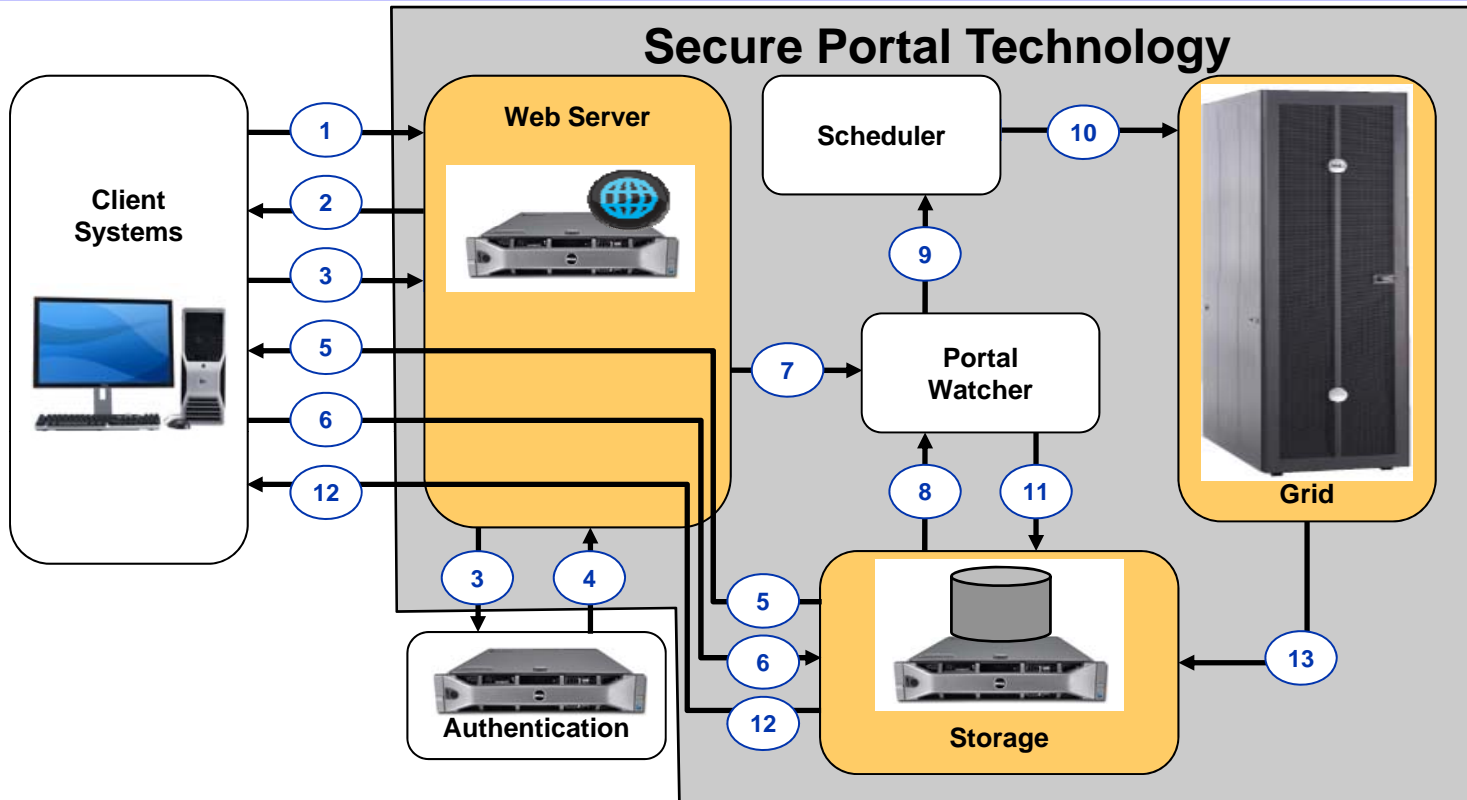
- **File Access Monitor in Linux kernel (2.6.25+)**
- **Receive event notification when file events occur**
- **Configure actions based on file name, directory, etc.**
- **Enables activities to launch jobs, abort jobs, etc.**

Prototype Architecture gridMatlab for Portal



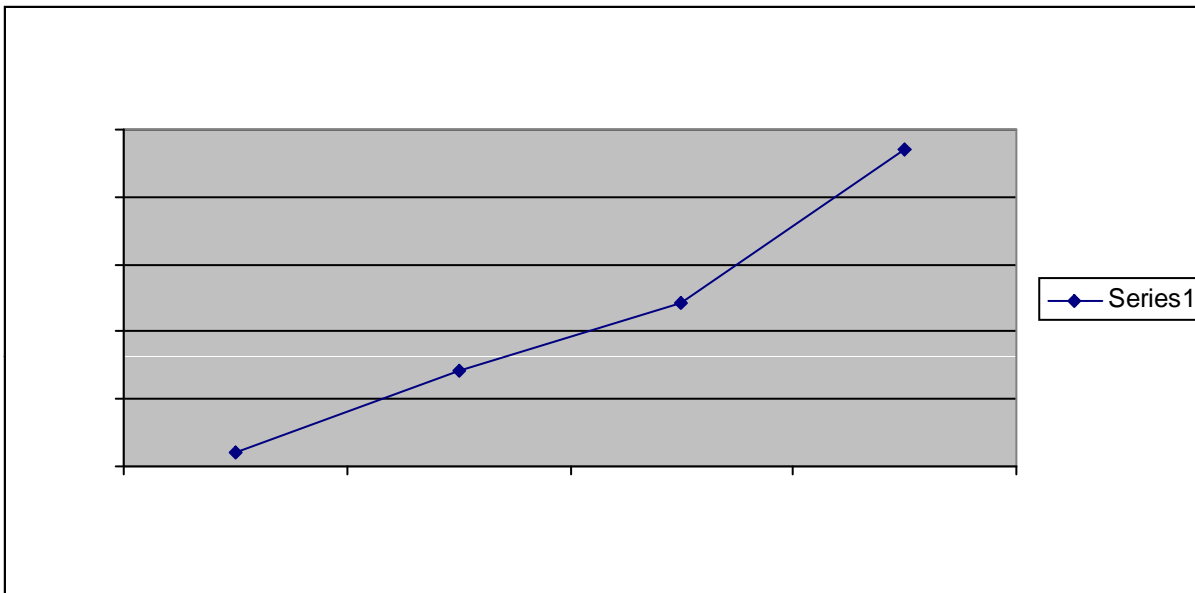
- Launch jobs, abort jobs, etc. by writing files to WebDAV file system
- Defined rich XML file formats for each action

Prototype Architecture grsecurity Kernel Patches



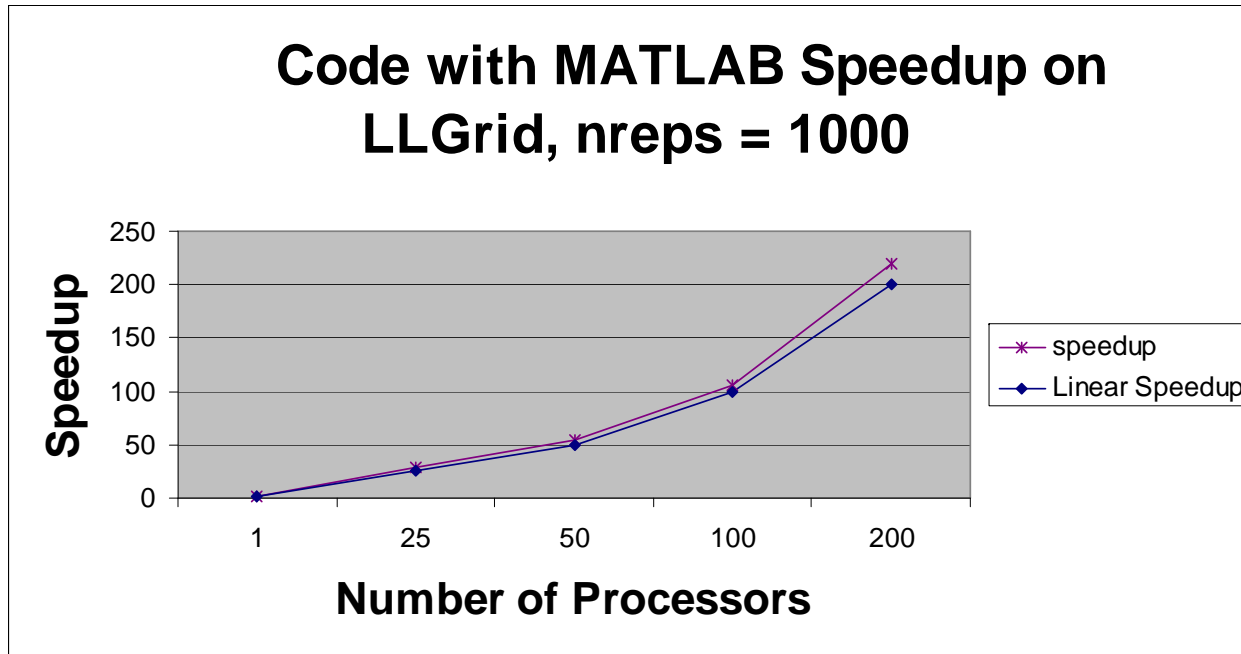
- **Role-Based Access Control (RBAC) system**
- **Users can only view own processes, files, etc.**
- **Extensive auditing and logging**
- **Randomization of the stack, library, heap and kernel bases**
- **Prevention of arbitrary code execution**

Speed-up for Example Code 1 running on Lincoln Laboratory Grid (LLGrid) (Matlab/pMatlab)



Nprocs	Max Time (secs)	Average Time (secs)	Speedup
1	178972.64	17897.64	1
10	25247.58	17448.12	7.08
20	14825.30	8767.93	12.1
36	7589.20	4832.97	23.6

Speed-up for Example Code 2 running on Lincoln Laboratory Grid (LLGrid) (Matlab/pMatlab)



Nprocs	Max Time (secs)	Average Time (secs)	Speedup
1	176344.0309	176344.0309	1
25	6088.6758	5471.0087	29
50	3245.6632	2699.6459	54
100	1673.5188	1341.6794	105
200	803.9898	658.7564	219

Outline

- Introduction
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Summary

- **DR&E Portal technology enables interactive, on-demand parallel Matlab from DoD desktops**
 - Required Zero Footprint LLGrid
 - Several phase rollout
- **Four key technologies**
 - CAC-enabled Apache WebDAV Server
 - Linux File System Watcher
 - gridMatlab for Portal
 - grsecurity Kernel Patches
- **Performance does not impede user experience**

Backups

HPCMP DR&E Portal Prototype Demo Using LLGridZF (zero footprint)

Steps:

Account use



Recycle Bin



MATLAB
R2010a



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- Portal Login
- Policies
- Hardware
- Documentation
- Software Support

DR&E Portal Login


Please insert

Return



Windows Security

Microsoft Smart Card Provider
Please enter your PIN.



PIN

[Click here for more information](#)

OK Cancel

New Users

- If you would like request an account simply click the the request button.

Request Account



- Portal Login
- Policies
- Hardware
- Documentation
- Software Support

Menu: [Login](#) | [Logout](#) | [Status](#)

Cookie set to: deb355cf48f8dd4af345accdea22fb06036f1b91
value=
 UserName=/C#US/O#U.S.
Government/OU#DoD/OU#PKI/OU#CONTRACTOR/CN#HUBBELL.MATTHEW.LANGAN.1391537654
 Groups=
 RemoteIP=140.31.214.115
 LoginTime=05/14/2010 18:07:46
 ClientCertDN=/C#US/O#U.S.
Government/OU#DoD/OU#PKI/OU#CONTRACTOR/CN#HUBBELL.MATTHEW.LANGAN.1391537654



Recycle Bin



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Computer > Search Computer

Organize Properties System properties Uninstall or change a program >>

- ★ Favorites
 - Desktop
 - Downloads
 - Recent Places
- Libraries
 - Documents
 - Music
 - Pictures
 - Videos
- Computer
- Network

Hard Disk Drives (1)

- Local Disk (C:)
 - 54.2 GB free of 74.4 GB

Devices with Removable Storage (1)

- DVD/CD-RW Drive (D:) Untitled Disc
 - 0 bytes free of 770 KB

Network Location (1)

- mhubbell
 - \\llgrid.mitll.hpc.mil@SSL\DavW...
 - Space used: [Progress Bar]
 - Space free: 54.2 GB

Network Drive





Recycle Bin



MATLAB R2010a



mhubbell (llgrid.mitll....)

Com... > mhubbell (\\llgrid.mitll.hpc.mil@SSL\DavWWWRo... > Search mhubbell (\\llgrid....

Organize Burn New folder

Name	Date modified	Type	Size
.matlab	4/30/2010 8:01 AM	File folder	
.ssh	4/28/2010 6:48 PM	File folder	
.t_coffee	4/28/2010 1:23 PM	File folder	
bio	4/28/2010 1:23 PM	File folder	
Examples	2/10/2010 1:53 PM	File folder	
matlab	4/29/2010 6:57 PM	File folder	
.bash_history	5/14/2010 12:09 PM	BASH_HISTORY File	4
.bash_logout	4/27/2010 4:08 PM	BASH_LOGOUT File	1
.bash_profile	4/27/2010 4:08 PM	BASH_PROFILE File	1
.bashrc	4/27/2010 4:08 PM	BASHRC File	1
.lessht	4/28/2010 6:50 PM	LESSHST File	1
.ncbirc	4/28/2010 1:23 PM	NCBIRC File	1
startup	4/2/2010 3:02 PM	MATLAB Code	2

13 items Offline status: Online Offline availability: Not available

Type: File folder
 Date modified: 4/29/2010 4:27/2010 4:08 PM
 Size: 6.17 KB
 Files: MatMPI_grid_config_local, startup, startup_local

Windows 7 Build 7600





Recycle Bin



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R2010a



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Windows 7
Build 7600





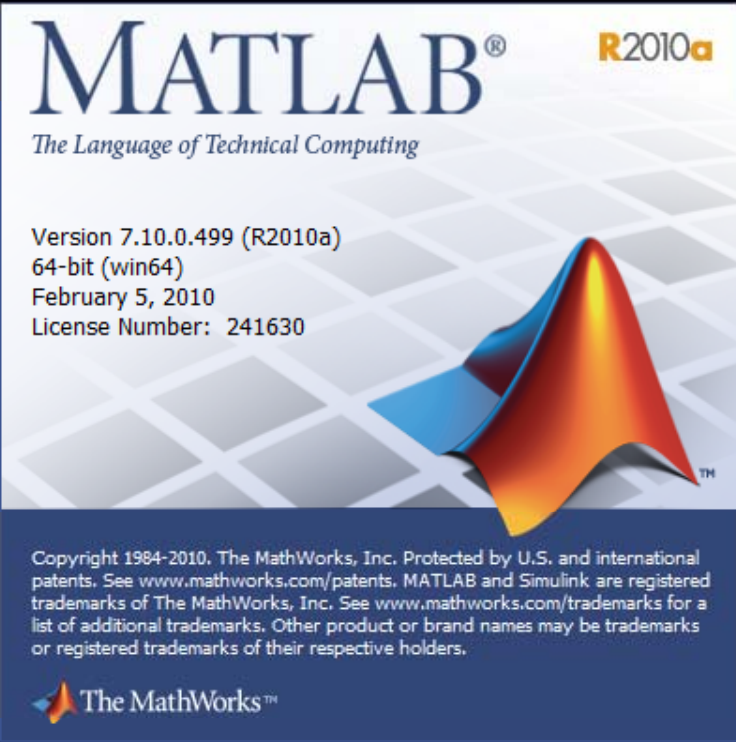
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February 5, 2010
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MATLAB 7.10.0 (R2010a)

File Edit Debug Parallel Desktop Window Help

Current Folder: C:\Users\mhubbell\Documents\MATLAB

Shortcuts How to Add What's New

Current Folder

< > << M... <> <> <>

Name
startup.m

Details

Command Window

New to MATLAB? Watch this [Video](#), see [Demos](#), or read [Getting Started](#).

MATLAB desktop keyboard shortcuts, such as Ctrl+S, are now cus
 In addition, many keyboard shortcuts have changed for improv
 across the desktop.

To customize keyboard shortcuts, use [Preferences](#). From there,
 restore previous default settings by selecting "R2009a Windows
 from the active settings drop-down list. For more information,
[Click here](#) if you do not want to see this message again.

fx >> |

Workspace

Name	Value
GRIDMATLAB_PA...	'X:\too
MATLABMPI_PATH	'X:\too
PMATLAB_PATH	'X:\too
PORTAL	1
ans	'once'
grid_config	<1x1 st
grid_path	'X:\ma
llgrid_startup	'X:\ma
mode	'produ
pMatlabOnly	'no'

Command History

```

$-- 5/11/10 4:34 E
  cd x:
  cd ..
  cd Examples\Blur
  eval (pRUN ('pBlur
$-- 5/11/10 4:39 E
  cd x:
  cd ..
  cd Examples\Blur
  eval (pRUN ('pBlur
$-- 5/14/10 4:55 E
  
```

Start Ready

OVR

Build 7600





Recycle Bin



MATLAB R2010a



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MATLAB 7.10.0 (R2010a)

File Edit Debug Parallel Desktop Window Help

Current Folder: C:\Users\mhubbell\Documents\MATLAB

Shortcuts How to Add What's New

Current Folder

Name

- startup.m

Details

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eval(pRUN('pBlur
5/14/10 4:55 E
```

Start Ready

OVR

Build 7600





MATLAB 7.10.0 (R2010a)

File Edit Debug Parallel Desktop Window Help

Current Folder: X:\matlab

Shortcuts How to Add What's New

Current Folder: m...

- MatMPI_grid_config_local.m
- startup.m
- startup_local.m

Command Window

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```
>> cd x:
fx >> cd ../Examples/Blurimage/
```

Workspace

Name	Value
GRIDMATLAB_PA...	'X:\too
MATLABMPI_PATH	'X:\too
PMATLAB_PATH	'X:\too
PORTAL	1
ans	'once'
grid_config	<1x1 st
grid_path	'X:\ma
llgrid_startup	'X:\ma
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Command History

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eval (pRUN ('pBlur:
$-- 5/11/10 4:39 E
cd x:
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eval (pRUN ('pBlur:
$-- 5/14/10 4:55 E
cd x:
```

Start

OVR

Build 7600



MATLAB 7.10.0 (R2010a)

File Edit Debug Parallel Desktop Window Help

Current Folder: X:\matlab

Shortcuts How to Add What's New

Current Folder

- MatMPI_grid_config_local.m
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cd x:
```

Start



MATLAB 7.10.0 (R2010a)

File Edit Debug Parallel Desktop Window Help

Current Folder: X:\Examples\Blurimage

Shortcuts How to Add What's New

Current Folder: Bl...

MatMPI
.pRUN_Parallel_Stub_pBluri...
pBlurimage.m

Command Window

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```
>> cd x:
>> cd ../Examples/Blurimage/
fx >> eval(pRUN('pBlurimage',4,'portal'))
```

Workspace

Name	Value
GRIDMATLAB_PA...	'X:\too
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PMATLAB_PATH	'X:\too
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ans	'once'
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cd Examples\Blur...
eval(pRUN('pBlur...
5/14/10 4:55 E
cd x:
cd ../Examples/B...
```

Start

OVR

Build 7600

- MatMPI
- .pRUN_Parallel_Stub_pBluri...
- pBlurimage.m

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MATLAB 7.10.0 (R2010a)

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[Click here](#) if you do not want to see this message again.

```
>> cd x:  
>> cd ../Examples/Blurimage/  
>> eval(pRUN('pBlurimage',4,'portal'))  
Submitting pBlurimage on 4 processor(s).  
MPI_Abort_portal: TODO: Wait until watcher confirms that all ta  
MPI_Abort_portal: TODO: Also need to print out the MPI_Abort st  
TODO: MPI_Abort_portal.m: Generate MatMPI_log_entry call
```

Workspace

Name	Value
GRIDMATLAB_PA...	'X:\too
MATLABMPI_PATH	'X:\too
PMATLAB_PATH	'X:\too
PORTAL	1
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cd x:  
cd ..  
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eval(pRUN('pBlur...  
5/14/10 4:55 E  
cd x:  
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eval(pRUN('pBlur...
```




MATLAB 7.10.0 (R2010a)

File Edit Debug Parallel Desktop Window Help

Current Folder: X:\Examples\Blurimage

Current Folder

Name

- MatMPI
- .pRUN_Parallel_Stub_pBluri...
- pBlurimage.m

Command Window

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Click here if you do not want to see this message again.

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Submitting pBlurimage on 4 processor(s).
MPI_Abort_portal: TODO: Wait until watcher confirms that all
MPI_Abort_portal: TODO: Also need to print out the MPI_Abort
TODO: MPI_Abort_portal.m: Generate MatMPI_log_entry call
Warning: Directory already exists.
> In MPI\_RunG at 105
   In MPI\_Run at 94
   In pRUN at 44
TODO: MatMPI_grid_resource_policy.m - Need to check grid availability
TODO: MatMPI_grid_resource_policy.m - Need to return total
TODO: MatMPI_grid_resource_policy.m - Need to return unclaimed
Launching MPI rank: 3 on: portal_03
Launching MPI rank: 2 on: portal_02
Launching MPI rank: 1 on: portal_01
Launching MPI rank: 0 on: DREN_PC

```

Workspace

Name	Value
GRIDMATLAB_PATH	'X:\too
MATLABMPI_PATH	'X:\too
PMATLAB_PATH	'X:\too
PORTAL	1
ans	'once'
grid_config	<1x1 st
grid_path	'X:\ma
llgrid_startup	'X:\ma
mode	'produ
pMatlabOnly	'no'

Command History

```

cd Examples\Blur...
eval(pRUN('pBlu...
5/11/10 4:39 E
cd x:
cd ..
cd Examples\Blur...
eval(pRUN('pBlu...
5/14/10 4:55 E
cd x:
cd ../Examples/B...
eval(pRUN('pBlu...

```

Start Busy

Build 7600



MATLAB 7.10.0 (R2010a)

File Edit Debug Parallel Desktop Window Help

Current Folder: X:\Examples\Blurimage

Shortcuts How to Add What's New

Current Folder

Name

- MatMPI
- .pRUN_Parallel_Stub_pBluri...
- pBlurimage.m

```

New to MATLAB? Watch this Video, see Demos, or read Getting Started.

>> eval(pRUN('pBlurimage',4,'portal'))
Submitting pBlurimage on 4 processor(s).
MPI_Abort_portal: TODO: Wait until watcher confirms that all
MPI_Abort_portal: TODO: Also need to print out the MPI_Abort
TODO: MPI_Abort_portal.m: Generate MatMPI_log_entry call
Warning: Directory already exists.
> In MPI_RunG at 105
   In MPI_Run at 94
   In pRUN at 44
TODO: MatMPI_grid_resource_policy.m - Need to check grid ava
TODO: MatMPI_grid_resource_policy.m - Need to return total
TODO: MatMPI_grid_resource_policy.m - Need to return unclaim
Launching MPI rank: 3 on: portal_03
Launching MPI rank: 2 on: portal_02
Launching MPI rank: 1 on: portal_01
Launching MPI rank: 0 on: DREN_PC
    Job <66> launched via SGE-HPC
Time to write XML file to notify a job submission = 0.8293
Time to confirm a job launch = 49.759
Job submitted to LLgrid via SGE-HPC resource manager
TODO: MatMPI_log_entry need to be update to log entries
TODO: MatMPI_log_entry need to be update to log entries
Launch Time (sec)           = 0.7072
Compute Time (sec)          = 7.6696
Performance (Gigaflops)     = 4.48

```

Workspace

Name	Value
GRIDMATLAB_PA...	'X:\too
MATLABMPI_PATH	'X:\too
PMATLAB_PATH	'X:\too
PORTAL	1
ans	'once'
grid_config	<1x1 st
grid_path	'X:\ma
llgrid_startup	'X:\ma
mode	'produ
pMatlabOnly	'no'

Command History

```

cd Examples\Blur...
eval(pRUN('pBlu...
$-- 5/11/10 4:39 E
cd x:
cd ..
cd Examples\Blur...
eval(pRUN('pBlu...
$-- 5/14/10 4:55 E
cd x:
cd ../Examples/B...
eval(pRUN('pBlu...

```

Details

Start Busy

OVR

Build 7600



MATLAB 7.10.0 (R2010a)

File Edit Debug P

Shortcuts How to A

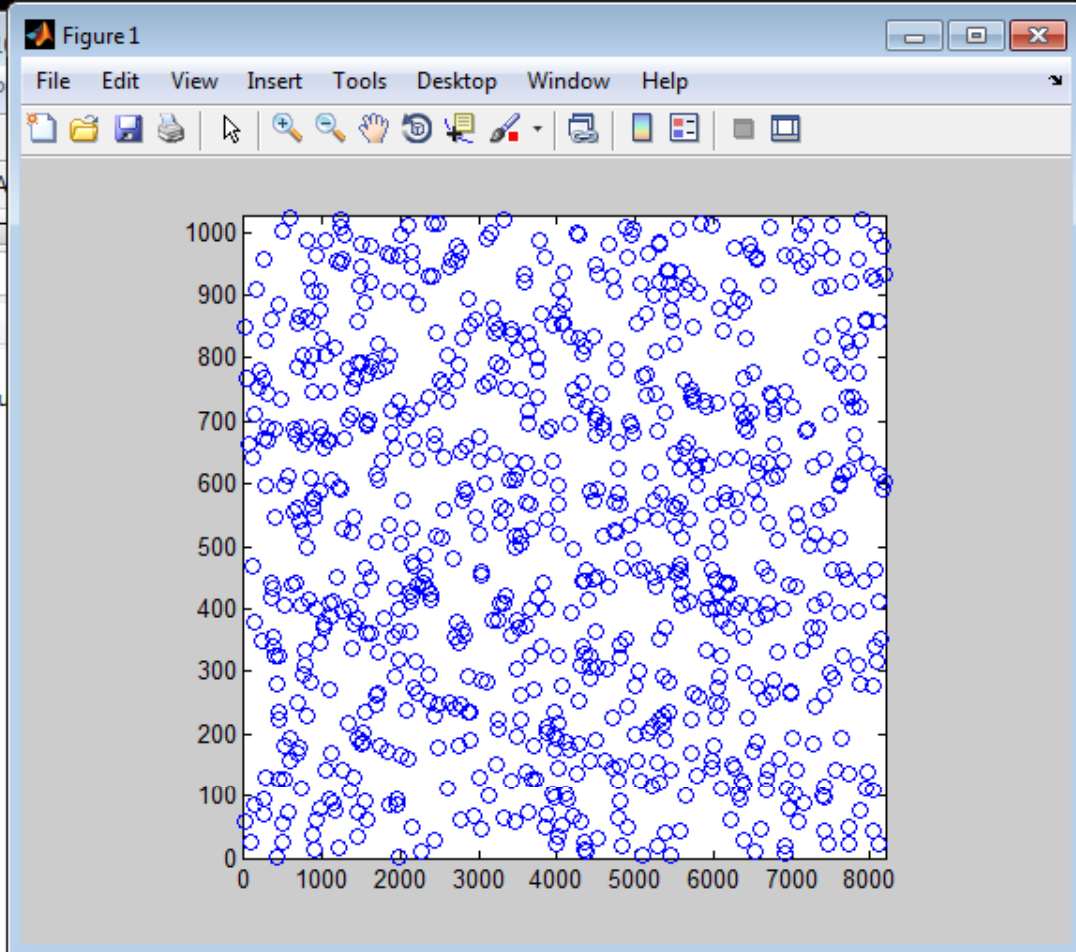
Current Folder

Bl...

Name
MatMPI
.pRUN_Parallel_Stu
pBlurimage.m

Details

Start



... submitted to llgrid via ... resource manager

TODO: MatMPI_log_entry need to be update to log entries

TODO: MatMPI_log_entry need to be update to log entries

Launch Time (sec) = 0.7072

Compute Time (sec) = 7.6696

Performance (Gigaflops) = 4.48

fx >>

Workspace

Name	Value
CHECK	0
GRIDMATLAB_PA...	'X:\too
MATLABMPI_PATH	'X:\too
MPI_COMM_WOR...	<1x1 st
Nblur	2
Nk	32
Nx	8192
Ny	1024
PARALLEL	1
PMATLAB_PATH	'X:\too

Command History

```
cd Examples\Blur...
eval(pRUN('pBlur...
5/11/10 4:39 E
cd x:
cd ..
cd Examples\Blur...
eval(pRUN('pBlur...
5/14/10 4:55 E
cd x:
cd ../Examples/B...
eval(pRUN('pBlur...
```



Recycle Bin

MATLAB R2010a

mhubbell (llgrid.mitl....)

MATLAB 7.10.0 (R2010a)

File Edit Debug P

Shortcuts How to A

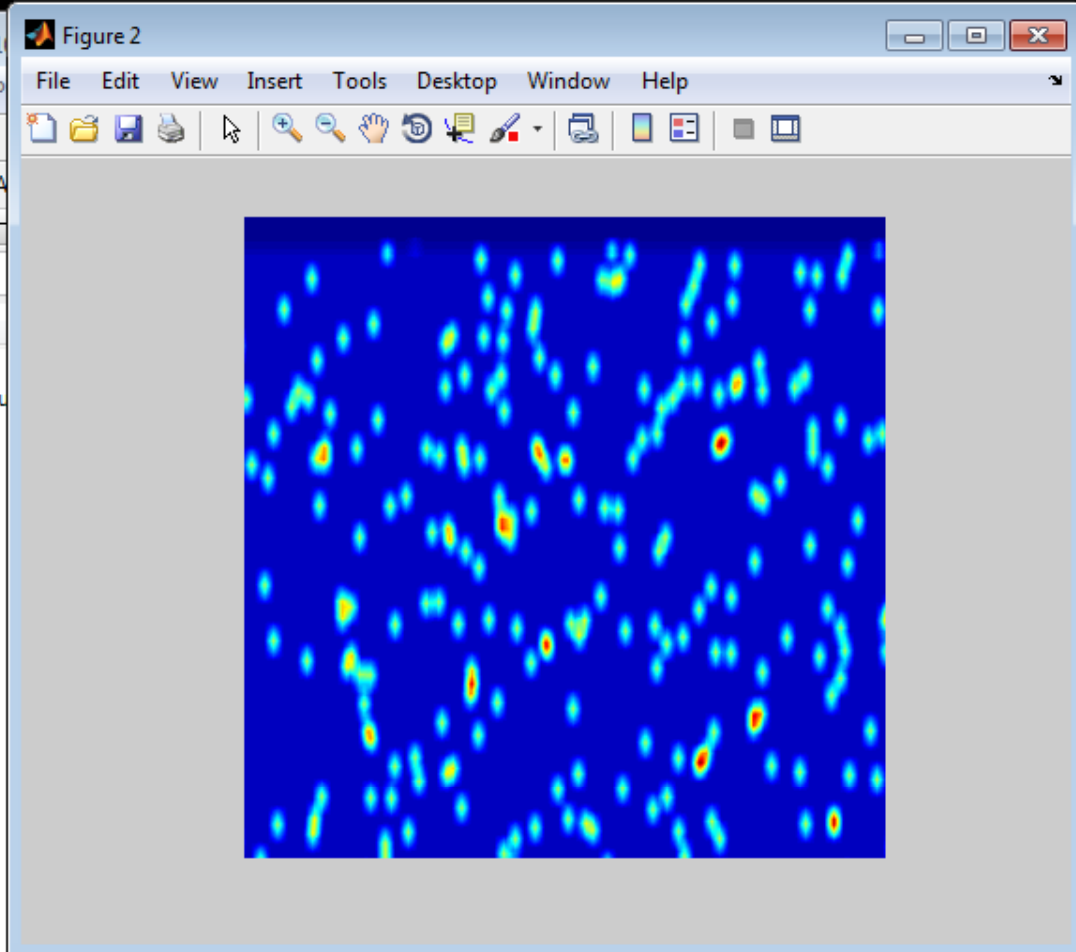
Current Folder

<< Bl... >>

Name
MatMPI
.pRUN_Parallel_Stu
pBlurimage.m

Details

Start



... submitted to llgrid via job resource manager

TODO: MatMPI_log_entry need to be update to log entries

TODO: MatMPI_log_entry need to be update to log entries

Launch Time (sec) = 0.7072

Compute Time (sec) = 7.6696

Performance (Gigaflops) = 4.48

fx >>

Workspace

Name	Value
CHECK	0
GRIDMATLAB_PA...	'X:\too
MATLABMPI_PATH	'X:\too
MPI_COMM_WOR...	<1x1 st
Nblur	2
Nk	32
Nx	8192
Ny	1024
PARALLEL	1
PMATLAB_PATH	'X:\too

Command History

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cd Examples\Blur...
eval (pRUN ('pBlur...
5/11/10 4:39 E
cd x:
cd ..
cd Examples\Blur...
eval (pRUN ('pBlur...
5/14/10 4:55 E
cd x:
cd ../Examples/B...
eval (pRUN ('pBlur...

```

Phases

- **Prototype**

- On-demand interactive parallel MATLAB delivered to alpha/beta users

- **Phase I**

- On-demand interactive parallel MATLAB delivered to DoD researchers and engineers

- **Phase II**

- A suite of on-demand interactive applications and an easy-to-use batch environment delivered to DoD researchers and engineers