Altair®

PBS Professional™ 7

Administrator's Guide

UNIX®, LINUX® and Windows®

Portable Batch System™ Administrator's Guide
Altair® PBS Professional™ 7, Service Pack 1, Updated: August 29, 2005
Edited by: Anne Urban

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The NASA version of PBS contained software developed by NASA Ames Research Center, Lawrence Livermore National Laboratory, and MRJ Technology Solutions. In addition, it included software developed by the NetBSD Foundation, Inc., and its contributors, as well as software developed by the University of California, Berkeley and its contributors.

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Preface

Intended Audience

This document provides the system administrator with the information required to install, configure, and manage the Portable Batch System (PBS). PBS is a workload management system that provides a unified batch queuing and job management interface to a set of computing resources.

Related Documents

The following publications contain information that may also be useful in the management and administration of PBS.

PBS Professional Quick Start Guide: Provides a quick overview of PBS Professional installation and license key generation.

PBS Professional User's Guide: Provides an overview of PBS Professional and serves as an introduction to the software, explaining how to use the user commands and graphical user interface to submit, monitor, track, delete, and manipulate jobs.

PBS Professional External Reference Specification: Discusses in detail the PBS application programming interface (API), security within PBS, and intra-component communication.

Ordering Software and Publications

To order additional copies of this manual and other PBS publications, or to purchase additional software licenses, contact your reseller or the PBS Products Department. Contact information is included on the copyright page of this document.

Document Conventions

PBS documentation uses the following typographic conventions.

abbreviation	If a PBS command can be abbreviated (such as subcommands to `qmgr`) the shortest acceptable abbreviation is underlined.
`command`	This fixed width font is used to denote literal commands, filenames, error messages, and program output.
input	Literal user input is shown in this bold, fixed-width font.
`manpage`(x)	Following UNIX tradition, manual page references include the corresponding section number in parentheses appended to the manual page name.
terms	Words or terms being defined, as well as variable names, are in italics.

Chapter 1
Introduction

This book, the **Administrator's Guide** to the Portable Batch System, Professional Edition (PBS Professional) is intended as your knowledgeable companion to the PBS Professional software. This edition pertains to PBS Professional in general, with specific information for version 7.0.

1.1 Book Organization

This book is organized into 13 chapters, plus three appendices. Depending on your intended use of PBS, some chapters will be critical to you, and others can be safely skipped.

Chapter 1	**Introduction**: Gives an overview of this book, PBS, and the PBS team.
Chapter 2	**Concepts and Terms**: Discusses the components of PBS and how they interact, followed by definitions of terms used in PBS.
Chapter 3	**Pre-Installation Planning**: Helps the reader plan for a new installation of PBS.
Chapter 4	**Installation**: Covers the installation of the PBS Professional software and licenses.
Chapter 5	**Upgrading PBS Professional**: Provides important information for sites that are upgrading from a previous version of PBS.

Chapter 6	**Configuring the Server**: Describes how to configure the PBS Server, and set up queues and nodes.
Chapter 7	**Configuring MOM**: Describes how to configure the PBS MOM processes.
Chapter 8	**Configuring the Scheduler**: Describes how to configure the PBS Scheduler.
Chapter 9	**Customizing PBS Resources**: Describes how to configure custom resources and dynamic consumable resources.
Chapter 10	**Administration**: Discusses PBS day-to-day administration and and related activities.
Chapter 11	**Administrator Commands**: Describes all PBS commands intended to be used by the Administrator.
Chapter 12	**Example Configurations**: Provides examples and sample configurations.
Chapter 13	**Problem Solving**: Discusses trouble-shooting, and describes the tools provided by PBS to assist with problem solving.
Appendix A	**Error Codes**: Provides a listing and description of the PBS error codes.
Appendix B	**Request Codes**: Provides a listing and description of the PBS request codes.
Appendix C	**File Listing**: Lists directories and files installed by this release of PBS Professional, with owner, permissions, and average size.

1.2 What is PBS Professional?

PBS Professional is the professional version of the Portable Batch System (PBS), a flexible resource and workload management system, originally developed to manage aerospace computing resources at NASA. PBS has since become the leader in supercomputer workload management and the *de facto* standard on Linux clusters.

Today, growing enterprises often support hundreds of users running thousands of jobs across different types of machines in different geographical locations. In this distributed heterogeneous environment, it can be extremely difficult for administrators to collect detailed, accurate usage data or to set system-wide resource priorities. As a result, many computing resource are left under-utilized, while others are over-utilized. At the same time, users are confronted with an ever expanding array of operating systems and platforms. Each year, scientists, engineers, designers, and analysts must waste countless hours learning the nuances of different computing environments, rather than being able to focus on their core priorities. PBS Professional addresses these problems for computing-inten-

sive enterprises such as science, engineering, finance, and entertainment.
Now you can use the power of PBS Professional to better control your computing resources. This product enables you to unlock the potential in the valuable assets you already have. By reducing dependency on system administrators and operators, you will free them to focus on other actives. PBS Professional can also help you to efficiently manage growth by tracking real usage levels across your systems and by enhancing effective utilization of future purchases.

1.2.1 History of PBS

In the past, UNIX systems were used in a completely interactive manner. Background jobs were just processes with their input disconnected from the terminal. However, as UNIX moved onto larger and larger processors, the need to be able to schedule tasks based on available resources increased in importance. The advent of networked compute servers, smaller general systems, and workstations led to the requirement of a networked batch scheduling capability. The first such UNIX-based system was the Network Queueing System (NQS) funded by NASA Ames Research Center in 1986. NQS quickly became the *de facto* standard for batch queueing.

Over time, distributed parallel systems began to emerge, and NQS was inadequate to handle the complex scheduling requirements presented by such systems. In addition, computer system managers wanted greater control over their compute resources, and users wanted a single interface to the systems. In the early 1990's NASA needed a solution to this problem, but found nothing on the market that adequately addressed their needs. So NASA led an international effort to gather requirements for a next-generation resource management system. The requirements and functional specification were later adopted as an IEEE POSIX standard (1003.2d). Next, NASA funded the development of a new resource management system compliant with the standard. Thus the Portable Batch System (PBS) was born.

PBS was quickly adopted on distributed parallel systems and replaced NQS on traditional supercomputers and server systems. Eventually the entire industry evolved toward distributed parallel systems, taking the form of both special purpose and commodity clusters. Managers of such systems found that the capabilities of PBS mapped well onto cluster computers. The PBS story continued when Veridian (the R&D contractor that developed PBS for NASA) released, in the year 2000, the Portable Batch System Professional Edition (PBS Professional), a commercial, enterprise-ready, workload management solution. Three years later, the Veridian PBS Products business unit was acquired by Altair Engineering, Inc. Altair set up the PBS Products unit as a subsidiary company named Altair Grid Technologies focused on PBS Professional and related Grid software.

1.3 About the PBS Team

The PBS Professional product is being developed by the same team that originally designed PBS for NASA. In addition to the core engineering team, Altair Grid Technologies includes individuals who have supported PBS on computers all around the world, including some of the largest supercomputers in existence. The staff includes internationally-recognized experts in resource-management and job-scheduling, supercomputer optimization, message-passing programming, parallel computation, and distributed high-performance computing. In addition, the PBS team includes co-architects of the NASA Metacenter (the first full-production geographically distributed meta-computing environment), co-architects of the Department of Defense MetaQueueing (prototype Grid) Project, co-architects of the NASA Information Power Grid, and co-chair of the Global Grid Forum's Scheduling Group.

1.4 About Altair Engineering

Through engineering, consulting and high performance computing technologies, Altair Engineering increases innovation for more than 1,500 clients around the globe. Founded in 1985, Altair's unparalleled knowledge and expertise in product development and manufacturing extend throughout North America, Europe and Asia. Altair specializes in the development of high-end, open CAE software solutions for modeling, visualization, optimization and process automation.

Chapter 2

Concepts and Terms

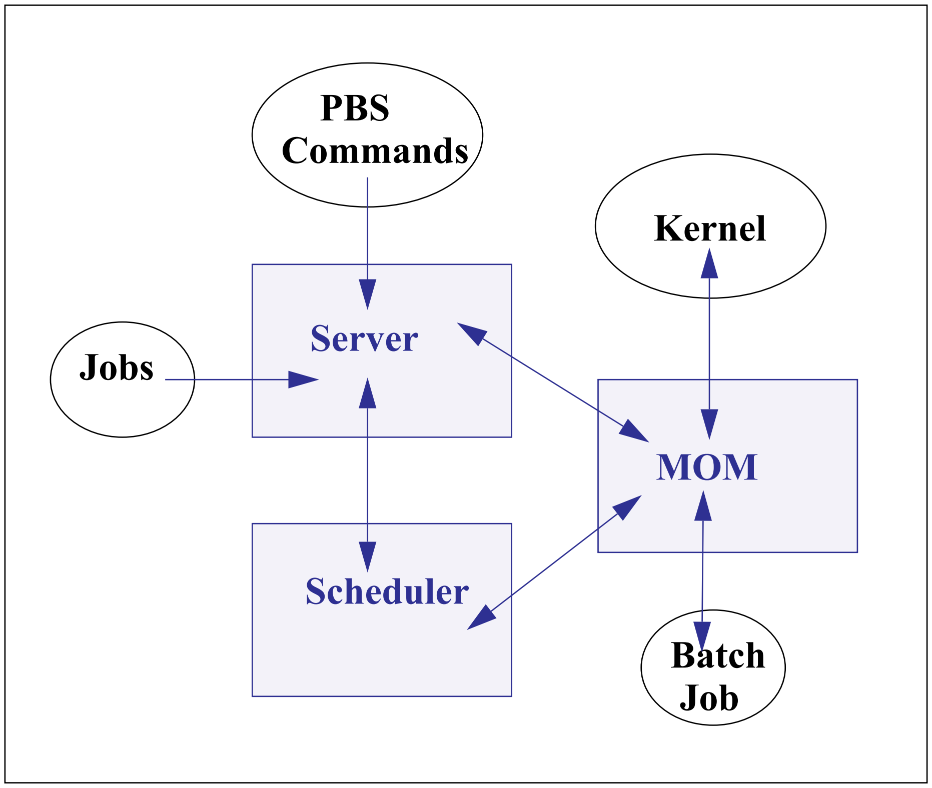
PBS is a distributed workload management system. As such, PBS handles the management and monitoring of the computational workload on a set of one or more computers. Modern workload/resource management solutions like PBS include the features of traditional batch queueing but offer greater flexibility and control than first generation batch systems (such as the original batch system NQS).

Workload management systems have three primary roles:

Queuing	The collecting together of work or tasks to be run on a computer. Users submit tasks or "jobs" to the resource management system where they are queued up until the system is ready to run them.
Scheduling	The process of selecting which jobs to run when and where, according to a predetermined policy. Sites balance competing needs and goals on the system(s) to maximize efficient use of resources (both computer time and people time).
Monitoring	The act of tracking and reserving system resources and enforcing usage policy. This covers both user-level and system-level monitoring as well as monitoring running jobs. Tools are provided to aid human monitoring of the PBS system as well.

2.1 PBS Components

PBS consist of two major component types: system processes and user-level commands. A brief description of each is given here to help you make decisions during the installation process.



Job Server The *Job Server* process is the central focus for PBS. Within this document, it is generally referred to as *the Server* or by the execution name *pbs_server.* All commands and communication with the Server are via an *Internet Protocol* (IP) network. The Server's main function is to provide the basic batch services such as receiving/creating a batch job, modifying the job, protecting the job against system crashes, and running the job. Typically there is one Server managing a given set of resources.

Job Executor (MOM) The *Job Executor* is the component that actually places the job into execution. This process, *pbs_mom,* is informally called *MOM* as it is the mother of all executing jobs. (MOM is a reverse-engineered acronym that stands for Machine Oriented Miniserver.) MOM places a job into execution when it receives a copy of the job from a Server. MOM creates a new session that is as identical to a user login session as is possible. For example, if the user's login shell is `csh`, then MOM creates a session in which `.login` is run as well as `.cshrc`. MOM also has the responsibility for returning the job's output to the user when directed to do so by the Server. One MOM runs on each computer which will execute PBS jobs.

A special version of MOM, called the *Globus MOM*, is available if it is enabled during the installation of PBS. It handles submission of jobs to the Globus environment. Globus is a software infrastructure that integrates geographically distributed computational and information resources. Usage of Globus is discussed in the "Globus Support" section of the **PBS Professional User's Guide**.

Job Scheduler The *Job Scheduler*, *pbs_sched*, implements the site's policy controlling when each job is run and on which resources. The Scheduler communicates with the various MOMs to query the state of system resources and with the Server to learn about the availability of jobs to execute. The interface to the Server is through the same API as used by the client commands. Note that the Scheduler communicates with the Server with the same privilege as the PBS Manager.

Commands PBS supplies both command line programs that are POSIX 1003.2d conforming and a graphical interface. These are used to submit, monitor, modify, and delete jobs. These *client commands* can be installed on any system type supported by PBS and do not require the local presence of any of the other components of PBS.

There are three classifications of commands: user commands (which any authorized user can use), operator commands, and manager (or administrator) commands. Operator and Manager commands require specific access privileges, as discussed in section 10.7.7 "External Security" on page 229.

2.2 Defining PBS Terms

The following section defines important terms and concepts of PBS. The reader should review these definitions before beginning the planning process prior to installation of PBS. The terms are defined in an order that best allows the definitions to build on previous terms.

Node A *node* to PBS is a computer system with a single *operating system* (OS) image, a unified virtual memory space, one or more CPUs and one or more IP addresses. Frequently, the term *execution host* is used for node. A computer such as the SGI Origin 3000, which contains multiple CPUs running under a single OS, is one node. Systems like Linux clusters, which contain separate computational units each with their own OS, are collections of nodes. A node **can** be over-committed if the local policy specifies to do so. (See also *virtual processors*.)

Cluster This is any collection of nodes controlled by a single instance of PBS (i.e., by one PBS Server). Also called a *complex*.

Load Balance A policy wherein jobs are distributed across multiple hosts to even out the workload on each host. Being a policy, the distribution of jobs across execution hosts is solely a function of the Job Scheduler.

Queue A *queue* is a named container for jobs within a Server. There are two types of queues defined by PBS, *routing* and *execution*. A *routing queue* is a queue used to move jobs to other queues including those that exist on different PBS Servers. A job must reside in an *execution queue* to be eligible to run and remains in an execution queue during the time it is running. In spite of the name, jobs in a queue need not be processed in queue order (first-come first-served or *FIFO*).

Node Attribute Nodes have attributes (characteristics) associated with them that provide control information. Such attributes include: `state`, the list of jobs to which the node is allocated, `bool-ean resources`, `max_running`, `max_user_run`, `max_group_run`, and both assigned and available resources (“`resources_assigned`” and “`resources_available`”).

Portable Batch System PBS consists of one Job Server (`pbs_server`), one or more Job Schedulers (`pbs_sched`), and one or more execution servers (`pbs_mom`). The PBS System can be set up to distribute the workload to one large system, multiple systems, a cluster of nodes, or any combination of these.

Virtual Processor (VP)	A node may be declared to consist of one or more *virtual processors (VPs)*. The term virtual is used because the number of VPs declared does not have to equal the number of real processors (CPUs) on the physical node. The default number of virtual processors on a node is the number of currently functioning physical processors; the PBS Manager can change the number of VPs as required by local policy.

The remainder of this chapter provides additional terms, listed in alphabetical order.

Account	An *account* is arbitrary character string, which may have meaning to one or more hosts in the batch system. Frequently, account is used as a grouping for charging for the use of resources.
Administrator	See Manager.
API	PBS provides an *Application Programming Interface (API)* which is used by the commands to communicate with the Server. This API is described in the **PBS Professional External Reference Specification**. A site may make use of the API to implement new commands if so desired.
Attribute	An *attribute* is a data item whose value affects the behavior of or provides information about the object and can be set by its owner. For example, the user can supply values for attributes of a job, or the administrator can set attributes of queues and nodes.
Batch or Batch Processing	This refers to the capability of running jobs outside of the interactive login environment.
Complex	A *complex* is a collection of hosts managed by one batch system. It may be made up of nodes that are allocated to only one job at a time or of nodes that have many jobs executing at once on each node or a combination of these two scenarios.
Destination	This is the location within PBS where a job is sent. A destination may uniquely define a single queue at a single Server or it may map into many locations.

Destination Identifier	This is a string that names the destination. It is composed two parts and has the format queue@server where server is the name of a PBS Server and queue is the string identifying a queue on that Server.
File Staging	*File staging* is the movement of files between a specified location and the execution host. See “Stage In” and “Stage Out” below.
Group ID (GID)	Numeric identifier uniquely assigned to each group (see Group).
Group	*Group* refers to collection of system users (see Users). A user must be a member of a group and may be a member of more than one. Within POSIX systems, membership in a group establishes one level of privilege. Group membership is also often used to control or limit access to system resources.
Hold	An restriction which prevents a job from being selected for processing. There are four types of holds. One is applied by the job owner (“user”), another is applied by a PBS *Operator*, a third is applied by the system itself or the PBS *Manager*; the fourth is set if the jobs fails due to an invalid password.
Job or Batch Job	The basic execution object managed by the batch subsystem. A job is a collection of related processes which is managed as a whole. A job can often be thought of as a shell script running in a POSIX session. (A session is a process group the member processes cannot leave.) A non-singleton job consists of multiple tasks of which each is a POSIX session. One *task* will run the job shell script.
Job Array	A job array is container for a collection of similar jobs. It can be submitted, queried, modified and displayed as a unit. For more on job arrays, see Job Arrays in the **PBS Professional User’s Guide**.
Job State	A job exists in one of the possible states throughout its existence within the PBS system. Possible states are: Queued, Running, Waiting, Transiting, Exiting, Suspended, Held, and Checkpointed. See also “Job States” on page 93 in the **PBS Professional User’s Guide**.
Manager	A *manager* is authorized to use all restricted capabilities of

	PBS. A PBS Manager may act upon the Server, queues, or jobs. The Manager is also called the Administrator.
Operator	A person authorized to use some but not all of the restricted capabilities of PBS is an *operator*.
Owner	The user who submitted a specific job to PBS.
PBS_HOME	Refers to the path under which PBS was installed on the local system. Your local system administrator can provide the specific location.
Parameter	A *parameter* provides control information for a component of PBS. Typically this is done by editing various configuration files.
POSIX	Refers to the various standards developed by the "Technical Committee on Operating Systems and Application Environments of the IEEE Computer Society" under standard P1003.
Requeue	The process of stopping a running (executing) job and putting it back into the queued ("Q") state. This includes placing the job as close as possible to its former position in that queue.
Rerunnable	If a PBS job can be terminated and its execution restarted from the beginning without harmful side effects, the job is rerunnable.
Stage In	This process refers to moving a file or files to the execution host prior to the PBS job beginning execution.
Stage Out	This process refers to moving a file or files off of the execution host after the PBS job completes execution.
State	See Job State.
User	Each system *user* is identified by a unique character string (the user name) and by a unique number (the user id).
Task	*Task* is a POSIX session started by MOM on behalf of a job.
User ID (UID)	Privilege to access system resources and services is typically established by the *user id*, which is a numeric identifier uniquely assigned to each user (see User).

Chapter 3
Pre-Installation Planning

This chapter presents information needed prior to installing PBS. First, a reference to new features in this release of PBS Professional is provided. Next is the information necessary to make certain planning decisions.

3.1 New Features in PBS Professional 7

PBS Professional has a major new feature. This is the enhancement to job resource requests and job placement on nodes. Several existing features are replaced by this new feature and are deprecated. All nodes are now treated alike with respect to allocating jobs and specifying resources. There is no distinction between time-shared and cluster nodes; all nodes are treated as time-shared, but are referred to as nodes. See “Enhanced Resource Requests and Job Placement” on page 14 for more information.

See the **PBS Professional User’s Guide** for information on using this new feature.

The *Release Notes* included with this release of PBS Professional lists all new features in this version of PBS Professional, and any warnings or caveats. Be sure to review the Release Notes, as they may contain information that was not available when this book was written. The following is a list of major new features.

Administrator’s & User’s Guides	Enhancement to job resource requests and placement. See “Requesting Resources” on page 32 of the **PBS Professional**

	User's Guide and "Enhanced Resource Requests and Job Placement" on page 14.
Administrator's Guide	Improved integration with LAM MPI. See "Integration with LAM MPI" on page 236.
Administrator's Guide	Improved integration with MPI for HP running HP-UX and Linux. See "Integration with HP MPI on HP-UX and Linux" on page 238.
User's Guide	Ability to convert a regular job into a reservation job that will run ASAP. See "Converting a Job into a Reservation Job that Will Run ASAP" on page 107 of the **PBS Professional User's Guide.**
Administrator's Guide	Ability to change the order in which jobs are preempted. See "Preemption Ordering by Start Time" on page 181.
Administrator's Guide	Enhancement to qrun command. See "The qrun Command" on page 270.
Administrator's Guide	Improved integration with MPICH. See "Interfacing MPICH with PBS Professional on UNIX" on page 232
Administrator's Guide	Improved integration with IBM AIX POE. "Integration with MPI under AIX" on page 234
Administrator's Guide	Improved integration with Comprehensive System Accounting on SGI Altix machines. See "Configuring MOM for Comprehensive System Accounting" on page 160.
Administrator's Guide	Enhanced support for SGI cpusets on Altix systems. See section 7.10 "Enhanced SGI cpusets Support" on page 153.
User's Guide	Job Arrays (See "Job Arrays" in the **PBS Professional User's Guide**.)

3.2 Enhanced Resource Requests and Job Placement

3.2.1 Major Changes

The way in which jobs request resources and placement on nodes has changed. All nodes are now treated alike with respect to allocating jobs and specifying resources. Node properties are replaced. The nodes file is changed. Several commands have different usage. There may be incompatibilities with prior versions when converting from the deprecated form to the current form. The scheduler groups nodes differently. The major changes and deprecations are listed below.

3.2.2 Resource Requests

Jobs now request resources in two ways. They can use the *select statement* to define *chunks* and specify the number of each chunk. A chunk is a set of resources that are to be allocated as a unit. Jobs can also use a job-wide resource request, which uses `resource=value` pairs. The `-l nodes=` form is deprecated, and if it is used, it will be converted into a request for chunks and job-wide resources.

The qsub, qalter and pbs_rsub commands are used to request resources.

For more information, see the **PBS Professional User's Guide** and the `qsub(1B)`, `qalter(1B)`, `pbs_rsub(1B)` and `pbs_resources(7B)` manual pages.

3.2.3 Placing Jobs on Nodes

All nodes are treated alike with respect to allocating jobs to nodes. Jobs are placed on nodes using the *place* statement. This allows specification of whether the job should run on a single host, or be scattered across hosts, or be grouped by a resource, or whether it should run anywhere available. It also allows specification of whether the job should have exclusive use of its node(s).

For more information, see the **PBS Professional User's Guide** and the `pbs_resources(7B)` manual page.

3.2.4 Node Types

All nodes are now treated alike, and are treated the same as what were called "time-shared" nodes. The types "time-shared" and "cluster" are deprecated. The `:ts` suffix is deprecated. The node attribute `ntype` will only be used to distinguish between PBS and Globus nodes. It is read-only.

3.2.5 Boolean Resources Replace Properties

What were properties are now *boolean resources*. These are treated like other resources except that they take on boolean values of “True” or “False”. The term “property” is **deprecated**. It will be accepted for the time being in a nodespec.

3.2.6 Nodes File

The server’s node definition file has changed due to the use of boolean resources and the change in node types. If an existing nodes file with deprecated forms is used, when it is written out, it will be in the new form. Properties will be written as boolean resources and any `:ts` suffixes will be dropped.

3.2.7 The qsub, qalter and pbs_rsub Commands

The `qsub, qalter and pbs_rsub` command usage has changed due to the change in resource requests and job placement. See the `qsub(1B), qalter(1B)` and `pbs_rsub(1B)` manual pages.

3.2.8 The qstat Command

The exec_host attribute displayed via qstat will be expanded to show the allocated resources on each node.

3.2.9 Warning About Conversion from nodespec

When a nodespec is converted into a select statement, the job will have the environment variables NCPUS and OMP_NUM_THREADS set to the value of ncpus in the first piece of the nodespec. This may produce incompatibilities with prior versions when a complex node specification using different values of ncpus and ppn in different pieces is converted.

For detailed information on conversion from `-l nodes=nodespec` to `-l select=` and `-l place=`, see the **PBS Professional User’s Guide.**

3.2.10 node Grouping Changes

If the complex-wide node grouping feature is enabled, i.e. the server attribute `node_group_enable=True`, then jobs that request *place=scatter* will be grouped according to the rules in use before 7.1. If however the job requests placement other than *scatter*, chunks will be allocated as if *place=scatter* were specified and a message entered into the scheduler's log.

If a job requests grouping by a resource, i.e. *place=group=resource*, then the chunks are placed as requested and complex-wide node grouping is ignored. If *scatter* is not also requested, the scheduler will log a message.

If a job is to use node grouping but the required number of nodes is not defined in any one group, grouping is ignored. This behavior is unchanged.

3.2.11 Administrator Can Set Chunk Defaults

The administrator can set server and queue defaults for resources used in chunks. See "Server Configuration Attributes" on page 76, "Attributes for execution queues only" on page 92 and the pbs_server_attributes(7B) and pbs_queue_attributes(7B) manual pages.

3.2.12 Deprecations

- The **-l nodes=nodespec** form is replaced by the -l select= and -l place= statements.
- The **nodes** resource is no longer used.
- The **-l resource=rescspec** form is replaced by the -l select= statement.
- The **time-shared** node type is no longer used.
- The **cluster** node type is no longer used.
- The resource **arch** is only used inside of a select statement.
- The resource **host** is only used inside of a select statement.
- The **nodect** resource is obsolete. The ncpus resource should be used instead. Sites which currently have default values or limits based on nodect should change them to be based on ncpus.
- The **neednodes** resource is obsolete.
- The **ssinodes** resource is obsolete.
- **Properties** are replaced by boolean resources.
- The **:ts** suffix is obsolete.

3.3 Planning

PBS is able to support a wide range of configurations. It may be installed and used to control jobs on a single system or to load balance jobs on a number of systems. It may be used to allocate nodes of a cluster or parallel system to both parallel and serial jobs. It can also deal with a mix of these situations. While this chapter gives a quick overview of different configurations for planning purposes, you may wish to read Chapter 12 Example Configurations, prior to installing PBS Professional. Also review the Glossary of terms prior to installation and configuration of PBS Professional. (See also “Concepts and Terms” on page 5.)

3.3.1 Network Configuration

Given that PBS is a distributed networked application, it is important that the network on which you will be deploying PBS is configured according to IETF standards. Specifically, forward and reverse name lookup should operate according to the standard.

3.3.2 Planning for File Access

In distributed environments it will be necessary to plan for how the users will access their input files, datasets, etc. Various options exist (such as NFS, `rcp`, `scp`, etc.). These need to be considered prior to installing PBS Professional, as such decisions can change which parameters are selected for tuning PBS. For details, see the MOM configuration parameter “$usecp” on page 135 and section 11.4 “The pbs_rcp vs. scp Command” on page 260. The impact of file location and delivery are discussed further in the **PBS Professional User’s Guide** under the heading “Delivery of Output Files” on page 113.

3.3.3 SGI Altix cpuset Feature Requires ProPack Library

Customers who intend to run PBS Professional on SGI Altix systems using cpusets should note that there are strict requirements for the SGI ProPack (containing the cpuset API). ProPack 2.4, 3.0 or 4.0 is required. The library is required on MOM nodes where cpuset functionality is desired. To test if the library is currently installed, execute the following command:

```
ls /usr/lib/libcpuset.so*
```

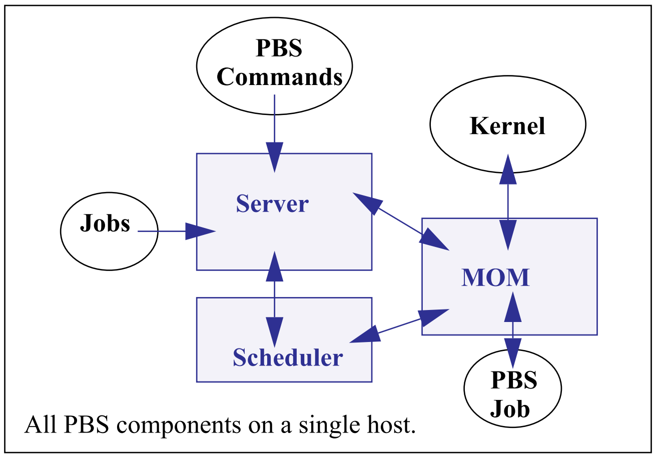
Important: The PBS Professional MOM binary for SGI’s ProPack 4.0 is pbs_mom.cpuset4, whereas for ProPack 2.4 and 3.0, it is pbs_mom.cpuset.

3.3.4 Using Comprehensive System Accounting on SGI Altix

Comprehensive System Accounting (CSA) on SGI Altix requires that both the Linux job container facility and CSA support be either built into the kernel or available as a loadable module. It also requires SGI ProPack 2.4 or greater. See “Configuring MOM for Comprehensive System Accounting” on page 160.

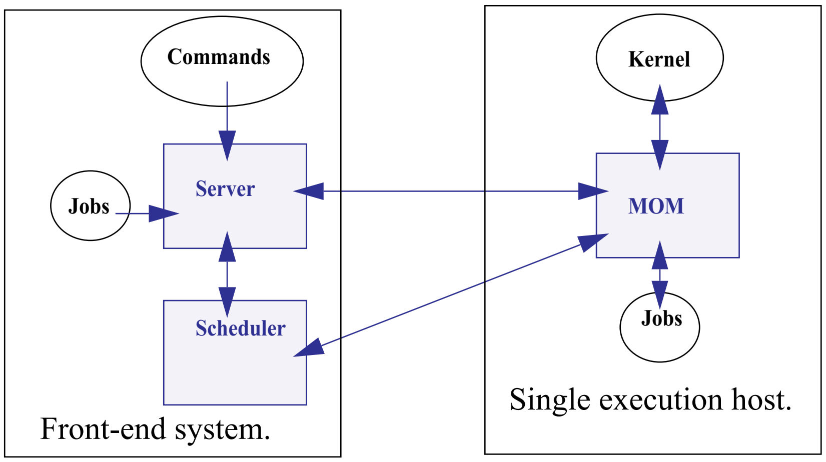
3.4 Single Execution System

If PBS is to be installed on a single system, all three components would normally be installed on that same system. During installation (as discussed in the next chapter) be sure to select option 1 (all components) from the PBS Installation tool.



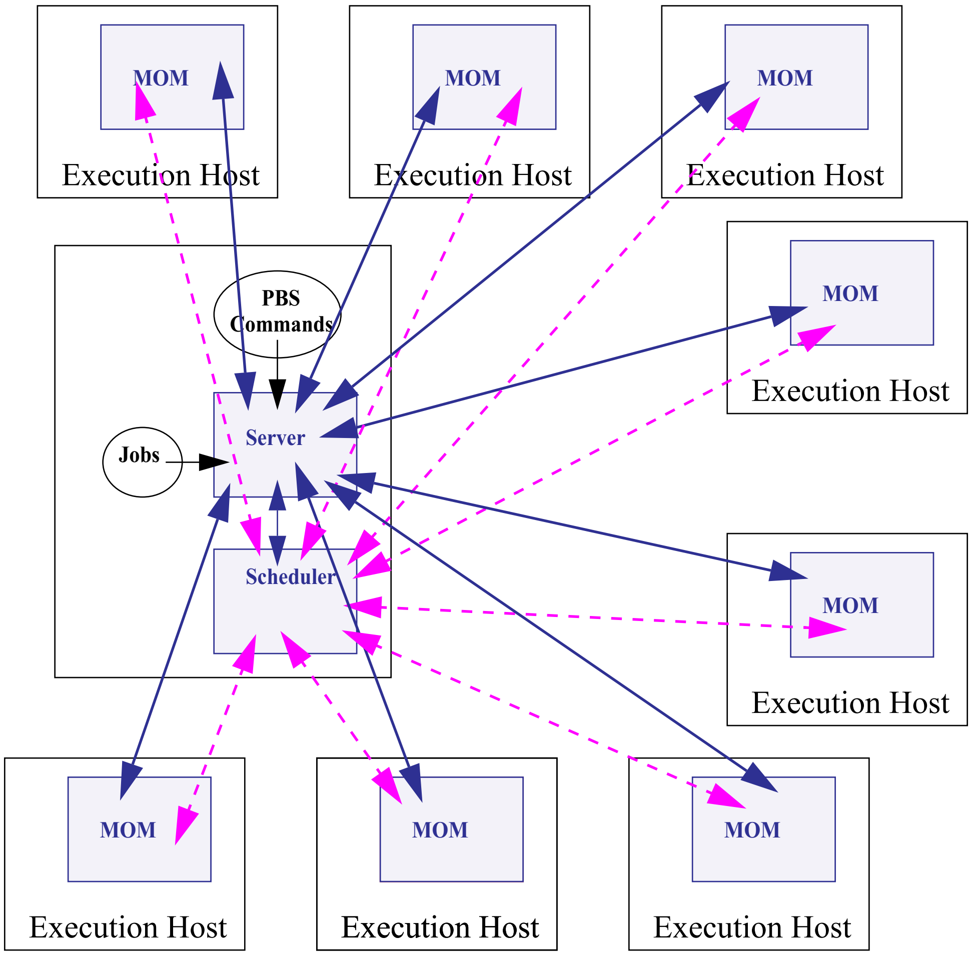
3.4.1 Single Execution System with Front-end

If you wish, the PBS Server and Scheduler (`pbs_server` and `pbs_sched`) can run on one system and jobs can execute on another.



3.5 Multiple Execution Systems

If PBS is to be installed on a collection (or cluster) of systems, normally the Server (pbs_server) and the Scheduler (pbs_sched) are installed on a “front end” system (option 1 from the PBS Installation tool), and a MOM (pbs_mom) is installed (option 2 from the Installation tool) and run on each execution node (i.e. each system where jobs are to be executed). The following diagram illustrates this for an eight node cluster.



3.6 UNIX User Authorization

When the user submits a job from a system other than the one on which the PBS Server is running, system-level user authorization is required. This authorization is needed for submitting the job and for PBS to return output files (see also "Delivery of Output Files" and "Input/Output File Staging" in the **PBS Professional User's Guide**).

Important: The username under which the job is to be executed is selected according to the rules listed under the "`-u`" option to `qsub` (as discussed in the **PBS Professional User's Guide**). The user submitting the job must be authorized to run the job under the execution user name (whether explicitly specified or not).

Such authorization is provided by any of the following three methods:

1. The host on which `qsub` is run (i.e. the submission host) is trusted by the server. This permission may be granted at the system level by having the submission host as one of the entries in the server's `host.equiv` file naming the submission host. For file delivery and file staging, the host representing the source of the file must be in the receiving host's `host.equiv` file. Such entries require system administrator access.

2. The host on which `qsub` is run (i.e. the submission host) is explicitly trusted by the server via the user's `.rhosts` file in his/her home directory. The `.rhosts` must contain an entry for the system from which the job is submitted, with the user name portion set to the name under which the job will run. For file delivery and file staging, the host representing the source of the file must be in the user's `.rhosts` file on the receiving host. It is recommended to have two lines per host, one with just the "base" host name and one with the full hostname, e.g.: `host.domain.name`.

3. PBS may be configured to use the Secure Copy (scp) for file transfers. The user should set up his/her SSH keys as described in "Enabling Hostbased Authentication on Linux" on page 229. See also "Delivery of Output Files" on page 113 of the **PBS Professional User's Guide**.

4. User authentication may also be enabled by setting the server's `flatuid` attribute to "True". See "flatuid" on page 79 and "User Authorization" on page 227.

3.7 Recommended PBS Configurations for Windows

This section presents the recommended configuration for running PBS Professional under Windows.

3.7.1 Primary Windows Configuration

The optimal configuration for running PBS Professional under Windows meets the following conditions:

- The PBS clients, Server, MOM, Scheduler, and `rshd` services are to be run on a set of Windows machines networked in a single domain, dependent upon a centralized database located on primary/secondary domain controllers.
- Domain controllers must be running on a Server type of Windows host, using Active Directory configured in "native" mode.
- The choice of DNS must be compatible with Active Directory.
- PBS Server and Scheduler must be run on a Server type of Windows machine that is not the domain controller and which is running Active Directory.
- PBS must not be installed nor run on a Windows system that is serving as the domain controller (running Active Directory) to the PBS hosts.
- All users must submit and run PBS jobs using only their domain accounts (no local accounts), and domain groups. If user has both a domain account and local account, then PBS will ensure that the job runs under the domain account.
- Each user must explicitly be assigned a HomeDirectory sitting on some network path. The HomeDirectory must be network-mounted. Currently supported are network-mounted directories using the Windows network share facility.
- Each user must always supply an initial password.

Important: Per Microsoft, access to network resources (such as a network drive), requires a password. This is particularly true in Windows 2000, XP, and 2000 Server.

When installing PBS Professional using this optimal, recommended configuration be aware that:

- The destination/installation path of PBS must be NTFS. All PBS configuration files, scripts, as well as input, output, error, intermediate files of a PBS job must reside in an NTFS directory.

- PBS must be installed from an account with domain administrator privileges (i.e. member of "Domain Admins" group). This must be the only account that will be used in all aspects of PBS installation including modifying configuration files, setting up failover, and so on. Do not use or create an account called "pbsadmin" (as such an account is created and used internally by PBS, as discussed below).

Important: If any of the PBS configuration files are modified by an account that is not the "installing" account, permissions/ownerships of the files could be altered, rendering them inaccessible to PBS.

The PBS services (`pbs_server`, `pbs_mom`, `pbs_sched`, `pbs_rshd`) will run under a special account called "pbsadmin", which will be created by the PBS installation program.

- The install program will require the installer to supply the password for the "pbsadmin" account. This same password must be supplied to future invocations of the install program on other Servers/hosts.

- The install program configures the "pbsadmin" account such that the password never expires, and should never be changed.

- The install program will make "pbsadmin" a member of the "Domain Admins" group. The "Domain Admins" group must always be a member of the local "Administrators" group.

Important: Be aware that the install program will also enable the following rights (Local Security Policy) to the "pbsadmin" account: "Create Token Object", "Replace Process Level Token", "Log On As a Service", and "Act As Part of the Operating System", and it will enable write permission to "pbsadmin" and "Domain Admins".

3.7.2 Secondary Windows Configuration

The following list of requirements represents an alternative, secondary configuration. Note that the installation program may not completely handle the following configuration without additional manual intervention.

- PBS is run on a set of machines that are not members of any domain (workgroup setup); that is, no domain controllers/ Active Directory are involved.
- As in the primary configuration, the destination/installation path of PBS as well as job intermediate, input, output, error files must reside on an NTFS filesystem.
- Each user must be assigned a local, NTFS HomeDirectory.
- Users must submit and run PBS jobs using their local accounts and local groups.
- A local account/group having the same name must exist for the user on all the execution nodes.
- If a user was not assigned a HomeDirectory, then PBS uses `PROFILE_PATH\My Documents\PBS Pro`, where `PROFILE_PATH` could be, for example, "`\Documents and Settings\`*`username`*".
- Users need not supply a password when submitting jobs. If user opts to submit a job with a password, then that password must be the same on all the execution hosts. (See also section 6.14 "Password Management for Windows" on page 112).

Important: Per Microsoft, access to network resources (such as a network drive), requires a password. This is particularly true in Windows 2000, XP, and 2000 Server.

For a password-less job, PBS will create a security authentication identifier for the user. This identifier will not be unique causing the job to not have access rights to some system resources like network shares. For a password-ed job, the authentication identifier will be unique so users can access (within his/her job script) folders in a network share. (See also the discussion of the single-signon feature in section 6.14 "Password Management for Windows" on page 112).

When installing PBS Professional under this alternative, secondary configuration, be aware that:

- PBS must be installed using an account with administrator privileges (i.e. a member of the local "Administrators" group). Do not use or create an account called "pbsadmin" as this is a special account which is discussed below.
- The PBS services will be run under a special account called "pbsadmin", which the PBS installation program creates.
- The install program will require the installer to supply the password for the "pbsadmin" account. The same password must be supplied to future invocations of the install program on other Servers/hosts.
- The install program configures the "pbsadmin" account such that the password never expires, and should never be changed.
- The install program will add "pbsadmin" to the local "Administrators" group.

Important: Be aware that the install program will also enable the following rights to the "pbsadmin" account: "Create Token Object", "Replace Process Level Token", "Log On As a Service", and "Act As Part of the Operating System", and it will enable write permission to "pbsadmin" and "Domain Admins".

3.7.3 Unsupported Windows Configurations

The following Windows configurations are currently unsupported:

- PBS running on a set of Windows 2000, Windows XP, Windows 2000 server hosts that are involved in several "domains" via any trust mechanism.

- Using NIS/NIS+ for authentication on non-domain accounts.
- Using RSA SecureID module with Windows logons as a means of authenticating non-domain accounts.

3.7.4 Sample Windows Deployment Scenario

For planning and illustrative purposes, this section describes deploying PBS Professional within a specific scenario: On a cluster of 20 machines networked in a single domain, with host 1 as the server host, and hosts 2 thru 20 as the execution hosts (nodes).

For this configuration, the installation program is initially run 20 times, invoked once per host. “All” mode (Server, Scheduler, MOM, and `rshd`) installation is done only on host 1, and “Execution” mode (MOM and `rshd`) installs are done on the other 19 hosts. On each invocation, the program will create the “pbsadmin” account if it doesn't exist in the Active Directory database. This account is used for running the PBS services.

The user that runs the `install` program will supply the password to the pbsadmin account. The password is set to be not expirable. The installation program will then propagate the password to the local Services Control Manager database.

Important: A reboot of each machine is necessary at the end of each install.

3.8 Windows User Authorization

When the user submits a job from a system other than the one on which the PBS Server is running, system-level user authorization is required. This authorization is needed for submitting the job and for PBS to return output files (see also “Delivery of Output Files” and “Input/Output File Staging” in the **PBS Professional User’s Guide**).

If running in the primary recommended configuration for Windows, then a password is also required for user authorization. See the discussion of single-signon in section 6.14 “Password Management for Windows” on page 112.

Important: The username under which the job is to be executed is selected according to the rules listed under the “`-u`” option to `qsub` (as discussed in the **PBS Professional User’s Guide**). The user submitting the job must be authorized to run the job under the execution user name (whether explicitly specified or not).

Such authorization is provided by any of the following three methods:

1. The host on which `qsub` is run (i.e. the submission host) is trusted by the execution host. This permission may be granted at the system level by having the submission host as one of the entries in the execution host's `host.equiv` file naming the submission host. For file delivery and file staging, the host representing the source of the file must be in the receiving host's `host.equiv` file. Such entries require system administrator access.

2. The host on which `qsub` is run (i.e. the submission host) is explicitly trusted by each execution host via the user's `.rhosts` file in his/her home directory. The `.rhosts` must contain an entry for the system on which the job will execute, with the user name portion set to the name under which the job will run. For file delivery and file staging, the host representing the source of the file must be in the user's `.rhosts` file on the receiving host. It is recommended to have two lines per host, one with just the "base" host name and one with the full hostname, e.g.: `host.domain.name`.

3. PBS may be configured to use the Secure Copy (`scp`) for file transfers. The user should set up his/her SSH keys See "Delivery of Output Files" on page 113 of the **PBS Professional User's Guide**.

3.8.1 Windows hosts.equiv File

The Windows `hosts.equiv` file determines the list of non-Administrator accounts that are allowed access to the local host, that is, the host containing this file. This file also determines whether a remote user is allowed to submit jobs to the local PBS Server, with the user on the local host being a non-Administrator account.

This file is usually: `%WINDIR%\system32\drivers\etc\hosts.equiv`.

The format of the `hosts.equiv` file is as follows:

```
[+|-] hostname username
```

'+' means enable access, whereas '-' means to disable access. If '+' or '-' is not specified, then this implies enabling of access. If only `hostname` is given, then users logged into that host are allowed access to like-named accounts on the local host. If only `username` is given, then that user has access to all accounts (except Administrator-type users) on the local host. Finally, if both `hostname` and `username` are given, then user at that host has access to like-named account on local host.

Important: The `hosts.equiv` file must be owned by an admin-type user or group, with write access granted to an admin-type user or group.

3.8.2 Windows User's HOMEDIR

Each Windows user is assumed to have a home directory (`HOMEDIR`) where his/her PBS job will initially be started. (The home directory is also the starting location of file transfers when users specify relative path arguments to `qsub/qalter -W stagein/stageout` options.)

The home directory can be configured by an Administrator via setting the user's HomeDirectory field in the user database, via the User Management Tool. It is important to include the drive letter when specifying the home directory path. The directory specified for the home folder must be accessible to the user. If the directory has incorrect permissions, PBS will be unable to run jobs for the user.

Important: You must specify an already existing directory for home folder. If you don't, the system will create it for you, but set the permissions to that which will make it inaccessible to the user.

If a user has not been explicitly assigned a home directory, then PBS will use this Windows-assigned default, local home directory as base location for its default home directory. More specifically, the actual home path will be:

```
[PROFILE_PATH]\My Documents\PBS Pro
```

For instance, if a *userA* has not been assigned a home directory, it will default to a local home directory of:

```
\Documents and Settings\userA\My Documents\PBS Pro
```

UserA's job will use the above path as working directory, and any relative pathnames in stagein, stageout, output, error file delivery will resolve to the above path.

Note that Windows can return as `PROFILE_PATH` one of the following forms:

`\Documents and Settings\`*`username`*
`\Documents and Settings\`*`username.local-hostname`*
`\Documents and Settings\`*`username.local-hostname`*`.00`*`N`* where *N* is a number
`\Documents and Settings\`*`username.domain-name`*

A user can be assigned a HomeDirectory that is network mounted. For instance, a user's directory can be: "`\\fileserver_host\sharename`". This would cause PBS to map this network path to a local drive, say `G:`, and allow the working directory of user's job to be on this drive. It is important that the network location (file server) for the home directory be on a Server-type of Windows machine like Windows 2000 Server or Windows 2000 Advanced Server. Workstation-type machines like Windows 2000 Professional or Windows XP Professional have an inherent limit on the maximum number of outgoing network connections (10) which can cause PBS to fail to map or even access the user's network HomeDirectory. The net effect is the job's working directory ends up in the user's default directory: `PROFILE_PATH\My Documents\PBS Pro`.

If a user has been set up with a home directory network mounted, such as referencing a mapped network drive in a HOMEDIR path, then the user must submit jobs with a password either via `qsub -Wpwd=""` (see the discussion of `qsub` in the **PBS Professional User's Guide**) or via the single-signon feature (see section 6.14 "Password Management for Windows" on page 112). When PBS runs the job, it will change directory to the user's home directory using his/her credential which must be unique (and passworded) when network resources are involved.

To avoid having to require passworded jobs, users must be set up to have a local home directory. Do this by accessing `Start Menu->Settings->Control Panel->Administrative Tools->Computer Management` (Win2000) or `Start Menu->Control Panel->Performance and Maintenance->Administrative Tools->Computer Management` (WinXP), and selecting `System Tools->Local Users and Groups`, double clicking `Users` on the right pane, double clicking on the *username* which brings up the user properties dialog from which you can select `Profile`, and specify an input for Local path (Home path). Be sure to include the drive information.

Chapter 4 Installation

This chapter discusses the installation procedures for PBS Professional. It is recommended that you read Chapter 3: Planning prior to beginning the installation.

Important: Be sure to read the Release Notes included in the PBS Professional distribution, as it will contain any information that was unavailable when this book went to press.

4.1 Overview

The PBS software can be installed from the PBS CD-ROM or downloaded from the Customer Login Area of the PBS website (http://www.pbspro.com). The installation procedure is slightly different depending on the distribution source. However, the basic steps of PBS installation are:

Step 1	Prepare distribution media
Step 2	Extract and install the software
Step 3	Acquire a PBS license

Step 4	Install the license

4.2 Default Install Options

The installation program installs the various PBS components into specific locations on the system. The installation program allows you to override these default locations if you wish. (Note that some operating systems' software installation programs do not permit software relocation, and thus you are not able to override the defaults on those systems.) The locations are written to the `pbs.conf` file created by the installation process. For details see the description of "pbs.conf" on page 209.

4.3 Pathname Conventions

During the installation process, you will be prompted for the location into which to install the various components of PBS. In this document, we use two abbreviations to correspond to installation locations. The term `PBS_HOME` refers to the location where the daemon/service configuration files, accounting logs, etc. are located. The term `PBS_EXEC` refers to the location where the executable programs were installed. Furthermore, directory and file pathnames used in this manual are written such that they can be interpreted on either UNIX or Windows systems. For example, the path reference "`PBS_HOME/bin/pbs_server`" represents either:

(UNIX) `$PBS_HOME/bin/pbs_server`
or
(Windows) `"%PBS_HOME%/bin/pbs_server"`

where the double quotes in the Windows case are necessary to handle both white space and the forward slash.

4.4 Installation on UNIX/Linux Systems

This section describes the installation process for PBS Professional on UNIX and Linux systems.

4.4.1 Media Setup

CD-ROM: If installing from the PBS CD-ROM, insert the PBS CD into the system CD-ROM drive, mount the CD-ROM device (if needed), then `cd` to the distribution directory.

```
mount /cdrom
cd /cdrom/PBSPro_7.0
```

Download: If not installing from CD-ROM, follow these instructions:

Step 1 Download the distribution file from the PBS website. (Follow the instructions you received with your order confirmation or the **PBS Professional Quick Start Guide**.)

Step 2 Move the distribution file to `/tmp` on the system on which you intend to install PBS,

Step 3 Uncompress and extract the distribution file

Step 4 Then `cd` to the distribution directory

```
cd /tmp
gunzip /tmp/pbspro_7.0-arch.tar.gz
tar -xvf /tmp/pbspro_7.0-arch.tar
cd PBSPro_7.0
```

4.4.2 Installation Overview

For a given system, the PBS install script uses the native package installer provided with that system. This means that the PBS package should install into what is considered the "normal" location for third-party software.

Important: Most operating systems allow you to specify an alternative location for the installation of the PBS Professional software binaries (`PBS_EXEC`) and private directories (`PBS_HOME`). Such locations should be owned and writable by root, and not writable by other users. (See Appendix C of this manual for a complete listing of all file permissions and ownerships.)

The following example shows a typical installation under the Sun Solaris operating system. The process is very similar for other operating systems, but may vary depending on the native package installer on each system. Launch the installation process by executing the `INSTALL` command, as shown below.

```
./INSTALL
Installation of PBS

The following directory will be the root of the
installation. Several subdirectories will be created if
they don't already exist: bin, sbin, lib, man and include.
Execution directory? [ /opt/pbs]

PBS needs to have a private directory (referred to as
"PBS_HOME" in the documentation) where it can permanently
store information.
Home directory? [ /usr/spool/PBS]
/usr/spool/PBS does not exist, I'll make it...done

[ Description of the different configuration options ]

PBS Installation:
        1. Server, execution and commands
        2. Execution only
        3. Commands only
(1|2|3)?
```

Next, you need to decide what kind of PBS installation you want for each machine in your cluster. There are three possibilities: a Server host, an execution host, or a client host. If you are going to run all the PBS components on a single timesharing host, install the full Server package (option 1). If you are going to have a cluster of machines, you need to pick one to be the front-end and install the Server package (option 1) there. Then, install the execution package (option 2) on all the compute nodes in the cluster. The client package (option 3) is for hosts which will not be used for execution but need to have access to PBS. It contains the commands, the GUIs and man pages. This gives the ability to submit jobs and check status of jobs as well as queues and multiple PBS Servers. The following sections illustrate the differences between installation on a single server system versus a cluster of workstations.

4.4.3 Installation on a (stand-alone) System

For the following examples, we will assume that you are installing PBS on a single large server or execution host, on which all the PBS components will run, and from which users will submit jobs. Examples of such a system include an SGI Altix or a Cray T90. To choose this, we select option **1** to the question shown in the example above.

Important: Some systems' installation programs (e.g. Solaris `pkgadd`) will ask you to confirm that it is acceptable to install setuid/setgid programs as well as to run installation sub-programs as root. You should answer yes (or "**y**") to either of these questions, if asked.

Next, the installation program will proceed to extract and install the PBS package(s) that you selected above. The process should look similar to the example below.

```
## Installing part 1 of 1.
/etc/init.d/pbs
[ listing of files not shown for brevity ]

## Executing postinstall script.
*** PBS Installation Summary
***
*** PBS Server has been installed in /opt/pbs/sbin.
*** PBS commands have been installed in /opt/pbs/bin.
***
*** This host has the PBS Server installed, so
*** the PBS commands will use the local server.
*** The PBS command server host is mars
***
*** PBS MOM has been installed in /opt/pbs/sbin.
*** PBS Scheduler has been installed in /opt/pbs/sbin.
***
Installation of <pbs64> was successful.
```

Finally, the installation program will request the license key for your system. Follow the instructions in section 4.6 "Installing the PBS License Key" on page 40 below.

4.4.4 Installing on a UNIX/Linux Cluster

A typical cluster of computers has a front-end system which (usually) manages the whole cluster. Most sites install the PBS Server and Scheduler on this front-end system, but not the MOM (as most sites tend *not* to want to run batch-jobs on the front-end node). The MOM is then installed on each computation node (execution host) within the cluster.

In either case, you will need to run the `INSTALL` program multiple times in order to install PBS Professional on your cluster system. (Alternatively, if all execution nodes are identical, you could install one of the execution nodes, and then distribute the installation to other nodes via a program such as `rdist`, or via `tar` plus `scp/rcp`.)

First, install PBS on the cluster's front-end machine, following the instructions given in section 4.4.3 "Installation on a (stand-alone) System" on page 36. Enter "**no**" when asked if you want to start PBS. Then, if you do *not* want to run batch jobs on the front-end node, edit the newly installed `/etc/pbs.conf` file, setting `PBS_START_MOM=0`, indicating that you do not want a PBS MOM started on this system.

Next, create the list of machines PBS will manage. Edit the file `PBS_HOME/server_priv/nodes`, adding one machine name per line for each execution machine in your cluster.

Lastly, start the PBS software on the Server machine by running the PBS startup script, the location for which varies depending on system type. (See "Starting and Stopping PBS: UNIX and Linux" on page 211.)

Now that the PBS Server has been installed and started, you need to install PBS on each execution node. Do this by running the `INSTALL` program on each node, selecting the execution package only (option **2**). When prompted if you wish to start PBS on that node, enter "**yes**".

4.4.5 Installing MOM with SGI cpuset Support

PBS Professional for SGI systems provides (site-selectable) support for IRIX and Altix cpusets. A cpuset in an SGI system is a named region containing a specific set of CPUs and associated memory. PBS has the ability to use the cpuset feature to "fence" PBS jobs into their own cpusets. This helps to prevent jobs from interfering with each other. To enable use of this feature, a different PBS MOM binary needs to be run. Stop the MOM process, follow the steps shown below, and then run this new `pbs_mom`. (See also section 10.3 "Starting and Stopping PBS: UNIX and Linux" on page 211.)

```
cd /usr/pbs/sbin
rm pbs_mom
ln -s pbs_mom.cpuset pbs_mom
```

Important: Job migration from ProPack 2.4 or 3.0 to ProPack 4.0 is not supported. When upgrading to ProPack 4.0, make sure that all jobs have finished running before stopping and restarting.

Additional information on configuring and using SGI cpusets can be found in section 7.10 "Enhanced SGI cpusets Support" on page 153.

4.4.6 PBS man Pages on SGI Irix Systems

If PBS is being installed on SGI systems, it is recommended that you verify that `/usr/bsd/` is in the `MANPATH` setting for users and administrators in order to locate and use the PBS `man` pages.

4.5 Network Addresses and Ports

PBS makes use of fully qualified host names for identifying the jobs and their location. A PBS installation is known by the host name on which the Server is running. The canonical host name is used to authenticate messages, and is taken from the primary name field, `h_name`, in the structure returned by the library call `gethostbyaddr`(). According to the IETF RFCs, this name must be fully qualified and consistent for any IP address assigned to that host.

The PBS components and the commands will attempt to use the system `services` file to identify the standard port numbers to use for communication. If the port number for a PBS service can't be found in the system file, a default value for that service will be used. The table below shows the valid PBS service names together with their default port numbers for that service:

Table 2:

Daemon	Port Number/ Protocol	Connection
pbs	15001/tcp	Client/Scheduler to Server
pbs_server	15001/udp	Server to MOM via RPP
pbs_mom	15002/tcp	MOM to/from Server
pbs_mom	15003/tcp	MOM resource requests
pbs_mom	15003/udp	MOM resource requests
pbs_sched	15004/tcp	PBS Scheduler
pbs_mom_globus	15005/tcp	MOM Globus

Table 2:

Daemon	Port Number/ Protocol	Connection
pbs_mom_globus	15006/tcp	MOM Globus resource requests
pbs_mom_globus	15006/udp	MOM Globus resource requests

Under UNIX, the `services` file is named `/etc/services`.
Under Windows, it is named `%WINDIR%\system32\drivers\etc\services`.

The port numbers listed are the default numbers used by PBS. If you change them, be careful to use the same numbers on all systems.

4.6 Installing the PBS License Key

In order to get PBS to run jobs, you need to have a valid PBS license key in the PBS license file: *`PBS_HOME`*`/server_priv/license_file`. The PBS license manager can handle multiple license keys in the PBS license file. This is useful when you expand your PBS configuration: you can simply add the additional licenses. This section describes adding a single license (such as is done following an initial installation of PBS Professional). The next section discusses adding multiple licenses. Optional “floating licenses” are discussed in section 4.6.2 “Using Floating Licenses” on page 42. Note that when requesting or generating your license key(s), the number of CPUs specified should correspond with the total number of CPUs on all the execution nodes (hosts where PBS jobs will be executed).

Important: The PBS license key is keyed to the hostid of the PBS Server host. If the hostid changes (such as by upgrading the Server hardware) then the license key will become invalid and jobs will be unable to run. A new license key will then need to be obtained.

When the installation of PBS is complete, you will need to install your PBS license key. If you already have your PBS license key, type it in when prompted by the license installation program, as shown below.

However, if you have not yet received your PBS license key, follow the instructions printed by the installation program (see example below) to obtain your key. (The **PBS**

Professional Quick Start Guide provides step-by-step instructions on generating your license key.) Then, as Administrator (root under UNIX), run the PBS license key installation program:

pbs_setlicense

.

```
PBS license installation

Using /usr/spool/PBS as PBS_HOME
To get a license, please visit
        www.pbspro.com/license.html
 or call PBSProfessional toll free at 877-905-4PBS
 and have the following information handy:

***     host name:      mars.domain.com
***     host id:        12927f28
***     site id from the PBSProfessional package
***     number of cpus you purchased

Please enter the license string(s) (^d to end).
? 5-00020-99999-3044-PfV/fjuivg-5Jz-agt-abc

Installing: 5-00020-99999-3044-PfV/fjuivg-5Jz-agt-abc
Please enter the next license string(s) (^d to end).
?
Would you like to start PBS now (y|[ n] )? n
```

4.6.1 Installing Multiple PBS Licenses

It is possible to add multiple licenses to the PBS License file. This can be done during installation of PBS Professional, or at some future time. If the installation program detects that you already have a PBS license file, it will prompt you as to what you want done: keep the file, replace the file, or append to it. Specify the option that corresponds to the action you wish to take. Then, if you have multiple license keys, simply type them in when prompted by the license installation program, as shown in the example below.

```
...
Please enter the license string(s) (^d to end).
? 5-00020-99999-0044-PfV/fjuivg-5Jz-agt-abc

Installing: 5-00020-99999-0044-PfV/fjuivg-5Jz-agt-abc
Please enter the next license string(s) (^d to end).
? 5-00020-99999-0010-XdsXdfssf-5Xj-agt-abc

Installing: 5-00020-99999-0010-XdsXdfssf-5Xj-agt-abc
Please enter the next license string(s) (^d to end).
?
Would you like to start PBS now (y|[n])? n
```

You can invoke the license key installation program directly (as may be needed following an increase in the size of the cluster managed by PBS), using the "-a" (append) option:

/usr/pbs/etc/pbs_setlicense -a

Alternatively, you can manually edit the license file, adding the new license as a separate line in the file. However you replace the license key, you will still need to shut down the Server with "`qterm -t quick`" and restart it for the new license to be recognized.

4.6.2 Using Floating Licenses

PBS can be purchased with *floating licenses*. When floating licenses are used, you may have more CPUs configured online than the number of licenses purchased. Nodes become licensed as they are needed to run jobs, up to the number of floating licenses purchased. The licenses are released from the node when no jobs remain running on that node.

The Server attribute "FLicense" shows the number of floating licenses currently available. The node attribute "pcpus" shows the number of physical CPUs on the node, which determines the number of licenses required for that node. Another node attribute "license" shows the node "license state", and can have one of the following three values
:

`u`	unlicensed
`l`	licensed with a node-locked license
`f`	licensed with a floating license

4.6.3 License Expiration Notice

If the PBS Professional software license that you install has an expiration date, you will be notified before the license expires. Email will be sent to the account that is defined by the Server attribute `mail_from` ("admin" by default), discussed in "Server Configuration Attributes" on page 76. Messages are sent 30 days in advance, 15 days in advance, and daily starting 7 days in advance. Upon expiration, the PBS Server will cease to run jobs.

4.6.4 Replacing Expired Licenses

If all of the licenses in the license file, `PBS_HOME/server_priv/license_file`, are expired and need to be replaced, do the following:

1. Obtain the new license key (s).
2. Run the `pbs_setlicense` program as root/administrator without any options:

```
pbs_setlicense
```

3. In response to the question about existing licenses, type '`r`' to replace (all) the existing licenses.
4. Enter the new license key(s).
5. Terminate input with `control-d`
6. Shut down the `pbs_server`:

```
qterm -t quick
```

7. Restart the Server

(UNIX): `PBS_EXEC/sbin/pbs_server`

(Windows): `net start pbs_server`

If only one of several keys has expired, the file must be manually edited. Using your favorite text editor, delete the expired keys and enter the new keys, then continue, starting with step 6 above.

4.7 Installation on Windows 2000 and XP Systems

When PBS is installed on a cluster, the MOM must be run on each execution host. The Server and Scheduler only need to be installed on one of the hosts or on a front-end system. For Windows 2000 and XP clusters, PBS is provided in a single package containing:

PBS Professional Quick Start Guide in PDF format,
PBS Professional Administrator's Guide in PDF format,
PBS Professional User's Guide in PDF format,
PBS Professional software, and
supporting text files (software license, README, release notes, etc.)

4.7.1 PBS Windows Considerations

PBS Professional is supported on the following operating systems: Windows 2000 Pro, Windows XP Pro, and both Windows 2000 Server and Windows 2003 Server if the domain controller server configured "native". While PBS Professional supports Active Directory Service domains, it does not support Windows NT domains. Running PBS in an environment where the domain controllers are configured in "mixed-mode" is not supported.

For Windows 2003 Server, because of its enhanced security, only jobs with passwords are allowed (see the discussion of Windows security in section 3.7.1 "Primary Windows Configuration" on page 23 and the single-signon feature discussed in section 6.14 "Password Management for Windows" on page 112).

Important: Install PBS Professional from an Administrator account.

When working with a Windows domain environment, be sure to install PBS using a domain, admin-type of account. That is, an account that is a member of "Domain Admins" group. Use this account in all aspects of PBS operation such as installing PBS, modifying PBS configuration files, and setting up network share directory for Server failover. Otherwise, PBS may encounter problems with file permissions.

PBS Professional requires that your C: drive be configured as an `NTFS` file system; PBS will not run on a `FAT` file system.

Before installing PBS Professional, be sure to uninstall any old PBS Professional files. For details see "Uninstalling PBS Professional on Windows" on page 55.

You can specify the destination folder for PBS using the "Ask Destination Path" dialog during setup. After installation, icons for the `xpbs` and `xpbsmon` GUIs will be placed on the desktop and a program file menu entry for PBS Professional will be added. You can use the GUIs to operate on PBS or use the command line interface via the command prompt.

This version of PBS Professional for Windows includes both `pbs_rcp` and `pbs_rshd` for allowing copy of output/error files from remote hosts to local Windows host.

4.7.2 Pre-installation Configuration

Before installing PBS Professional on a Windows 2000 or XP cluster, perform the following system configuration steps first.

The following discussion assumes that the `pbs_server` and `pbs_sched` services will be installed on a front-end host called "hostA", and the `pbs_mom` service will installed on all the nodes in the cluster that will be running jobs, "hostB ... hostZ".

1. Be sure that hostA, hostB, ..., hostZ consistently resolve to the correct IP addresses. A wrong IP address to hostname translation can cause errors for PBS. Make sure the following are done:

a. Configure your system to talk to a properly configured and functioning DNS server

b. Add the correct host entries to the following files:

win2000: `c:\winnt\system32\drivers\etc\hosts`

winXP: `c:\windows\system32\drivers\etc\hosts`

For example, if your Server is fifi.forway.com with address 192.0.0.231, then add the entry:

```
192.0.0.231 fifi.forway.com fifi
```

2. Set up any user accounts that will be used to run PBS jobs. They should not be Administrator-type of accounts, that is, not a member of the "Administrators" group so that basic authentication using `hosts.equiv` can be used.

The accounts can be set up using:

Start->Control Panel->Administrative Tools->Computer Management->Local Users & Groups

- or -

Start->Control Panel->User Manager

Once the accounts have been set up, edit the `hosts.equiv` file on all the hosts to include hostA, hostB, ..., hostZ to allow accounts on these hosts to access PBS services, such as job submission and remote file copying.

The `hosts.equiv` file can usually be found in either of the following locations:

```
C:\winnt\system32\drivers\etc\hosts.equiv
C:\windows\system32\drivers\etc\hosts.equiv
```

4.7.3 Installation Account vs. Service Account

New in PBS Professional 7, there are two accounts used when installing PBS: an *installation account*, and a *service account*. The installation account is that from which you will execute the PBS `install` program; the service account will actually run the PBS services: `pbs_server`, `pbs_mom`, `pbs_sched`, and `pbs_rshd`. The service account is also recommended for performing any updates of the PBS configuration files.

4.7.4 Passwords and the pbsadmin Account

During the installation process (as described in the next section), the install program will ask for the PBS service account password, and will take following actions with regards to the service account called "pbsadmin":

If the host where PBS is being installed is part of a domain, then the install program will check if pbsadmin domain account exists and validate the entered password against it. If no such account exists, then PBS will create one giving it the specified password.

If the installation host is not part of a domain, then the `install` program will check if a pbsadmin local account exists and validate the entered password against it. If no such account exists, then the program will create one giving it the specified password.

The install program will add the "pbsadmin" account to the "Domain Admins" group if it is a domain account. Otherwise, the program will add the account to the local "Administrators" group. During the installation process, the install program will create and secure PBS-related files to have the following permissions:

a. If domain environment, "pbsadmin" domain account is made the owner, "Full Control" permission is given to "pbsadmin" and "Domain Admins"

b. If non-domain environment, "pbsadmin" local account is made the owner, "Full Control" permission given to "pbsadmin" and local "Administrators"

The "pbsadmin" account will be initialized with a non-expirable password which should not be changed unless absolutely necessary (see also section 4.7.10 "Changing the pbsadmin Password" on page 54).

Important: Be sure that an account called "pbsadmin" does not exist both as a local account and a domain account. This account should never be removed nor its password changed while PBS is installed and running.

4.7.5 Software Installation

Next you will need to install the PBS software on each execution node of your cluster. The PBS Professional installation program will walk you through the installation process.

Important: If the installation host is a member of a domain, then the `install` program must be executed from a domain account which is a member of the "Domain Admins".

If the installation host is not a member of a domain, then the `install` program must be executed from a local account which is a member of the "Administrators" group.

1. If you are installing from the PBS Professional CD-ROM, insert the CD-ROM into your computer's CD-ROM drive, browse to your CD-ROM drive, and click on the PBS Professional program icon.

Alternatively, you can download the latest PBS Professional package from the PBS Web site, and save it to your hard drive. Run the self-extracting `pbspro.exe` package, and then the installation program, as shown below.

```
Admin> PBSpro_7.0-windows.exe
```

Important: On Windows XP, Service Pack 2 (SP2), upon launching the installer, a window may be displayed saying the program is from an unknown publisher. In order to proceed with the installation of PBS, click the “Run” button.

2. Review and accept the License Agreement, then click Next.

3. Supply your Customer Information, then click Next.

4. Review the installation destination location. You may change it to a location of your choice, provided the new location meets the requirements stipulated in section 3.7 “Recommended PBS Configurations for Windows” on page 23. Then click Next.

5. When installing on an execution node in the cluster, select the “Execution” node option from the `install` tool, then click Next.

6. You will then be prompted to enter a password for the special “pbsadmin” account (as discussed in the previous section). The password typed will be masked with “*”. An empty password will not be accepted. Enter your chosen password twice as prompted, then click Next.

   You may receive the following “error 2245" when PBS creates the pbsadmin account. This means “The password does not meet the password policy requirements. Check the minimum password length, password complexity and password history requirements.”

Important: You *must* use the same password when installing PBS on additional execution nodes as well as on the PBS Server node.

7. The installation tool will show two screens with informative messages. Read them; click Next on both.

8. On the "Editing PBS.CONF file" screen, specify the hostname on which the PBS Server service will run, then click Next.

9. On the "Editing HOSTS.EQUIV file" screen, follow the directions on the screen to enter any hosts and/or users that will need access to this local node. Then click Next.

10. On the "Editing PBS MOM config file" screen, follow the directions on the screen to enter any required MOM configuration entries (as discussed in section 7.2 "MOM Configuration Parameters" on page 130). Then click Next.

11. Lastly, when prompted, select Yes to restart the computer and click Finish.

Repeat the above steps for each execution node in your cluster. When complete you are ready to install PBS Professional on the host that will become the PBS Server node.

1. Install PBS Professional on hostA, selecting the "All" option. Next, you will be prompted for your software license key(s). Following this, the install program will prompt for information needed in setting up the `nodes` file, the `hosts.equiv` file, etc. Enter the information requested for hosts hostB, hostC, ..., hostZ, clicking Next to move between the different input screens.

2. Finally, run `pbsnodes -a` on hostA to see if it can communicate with the execution nodes in your cluster. If some of the nodes are seen to be down, then go to the problem node and restart the MOM, using the commands:

```
Admin> net stop pbs_mom
Admin> net start pbs_mom
```

4.7.6 Post Installation Considerations

The installation process will automatically create the following file,

```
[PBS Destination folder]\pbs.conf
```

containing at least the following entries:

```
PBS_EXEC=[PBS Destination Folder]\exec
PBS_HOME=[PBS Destination Folder]\home
PBS_SERVER=server-name
```

where `PBS_EXEC` will contain subdirectories where the executable and scripts reside, `PBS_HOME` will house the log files, job files, and other processing files, and *`server-name`* will reference the system running the PBS Server. The `pbs.conf` file can be edited by calling the PBS program "`pbs-config-add`". For example,

```
\Program Files\PBS Pro\exec\bin\pbs-config-add "PBS_SCP=\winnt\scp.exe"
```

Don't edit `pbs.conf` directly as the permission on the file could get reset causing other users to have a problem running PBS.
The auto-startup of the services is controlled by the PBS `pbs.conf` file as well as the Services dialog. This dialog can be invoked via selecting `Settings->Control Panel->Administrative Tools->Services`. If the services fail to start up with the message, "incorrect environment", it means that the *PBS_START_SERVER*, *PBS_START_MOM*, and *PBS_START_SCHED* `pbs.conf` variables are set to 0 (false).

Upon installation, special files in PBS home directory are set up so that some directories and files are restricted in access. The following directories will have files that will be readable by the \\Everyone group but writable only by Administrators-type accounts:

```
PBS_HOME/server_name
PBS_HOME/mom_logs/
PBS_HOME/sched_logs/
PBS_HOME/spool/
PBS_HOME/server_priv/accounting/
```

The following directories will have files that are only accessible to Administrators-type of accounts:

```
PBS_HOME/server_priv/
PBS_HOME/mom_priv/
PBS_HOME/sched_priv/
```

Important: The PBS administrator should review the recommended steps for setting up user accounts and home directories, as documented in section 3.8 "Windows User Authorization" on page 28, and Chapter 3 of the **PBS Professional User's Guide**.

4.7.7 Windows XP SP2 Firewall

Under Windows XP service pack 2 (SP2) the Windows Firewall may have been turned on by default. If so, it will block incoming network connections to all services including PBS. Therefore after installing PBS Professional, to allow `pbs_server`, `pbs_mom`, `pbs_sched`, and `pbs_rshd` to accept incoming connections:

Access `Settings->Control Panel->Security Center->Windows Firewall`, and verify that the Windows Firewall has been set to "ON" to block incoming network connections.

From this panel, you can either turn Windows Firewall "off", or click on the `Exceptions` tab and add the following to the list:

```
[INSTALL PATH]\exec\sbin\pbs_server.exe
[INSTALL PATH]\exec\sbin\pbs_mom.exe
[INSTALL PATH]\exec\sbin\pbs_sched.exe
[INSTALL PATH]\exec\sbin\pbs_rshd.exe
```

where `[INSTALL PATH]` is typically `C:\Program Files\PBS Pro`

4.7.8 Windows pbs_rshd

The Windows version of PBS contains a fourth service called `pbs_rshd` for supporting remote file copy requests issued by `pbs_rcp`, which is what PBS uses for delivering job output and error files to destination hosts. (Keep in mind that `pbs_rshd` does not allow normal `rsh` activities but only `rcp`.)

`pbs_rshd` will read either the `%WINDIR%\system32\drivers\etc\hosts.equiv` file or the user's `.rhosts` file for determining the list of accounts that are allowed access to the localhost during remote file copying. PBS uses this same mechanism for determining whether a remote user is allowed to submit jobs to the local Server. `pbs_rshd` is started automatically during installation but can also be started manually by typing either of the following two commands:

```
net start pbs_rshd
```

-or-

```
pbs_rshd -d
```

This latter form of invocation runs `pbs_rshd` in debug mode where logging output will be displayed on the command line.

If user on *hostA* uses `pbs_rcp` to copy a file to *hostB* (running `pbs_rshd`) as shown:

```
pbs_rcp file1 hostB:file2
```

the behavior will be as follows. If *userA* is a non-administrator account (e.g. not belonging to the Administrators group), then the copy will succeed in one of 2 ways: (1) *userA@hostA* is authenticated via *hostB's* `hosts.equiv` file; or (2) *userA@hostA* is authenticated via user's `[PROFILE_PATH]/.rhosts` on *hostB*. (See also section 3.8.2 “Windows User's HOMEDIR” on page 30.)

The format of the `hosts.equiv` file is:

```
[+|-] hostname username
```

'+' means enable access whereas '-' means to disable access. If '+' or '-' is not specified, then this implies enabling of access. If only *hostname* is given, then users logged into that host are allowed access to like-named accounts on the local host. If only *username* is given, then that user has access to all accounts (except Administrator-type users) on the local host. Finally, if both *hostname* and *username* are given, then user at that host has access to like-named account on local host.

The format of the user's `.rhosts` file is simply:

```
hostname username
```

The `hosts.equiv` file is consulted first and then, if necessary, the user's `.rhosts` file is checked. If *username* contains special characters like spaces, be sure to quote it so that it will be properly parsed by `pbs_rshd`:

```
hostname "username"
```

For the above `pbs_rcp` request, you will either need the system-wide `hosts.equiv` file on *hostB* to include as one of its entries:

```
hostA
```

or, `[PROFILE_PATH]\.rhosts` on *userA's* account on *hostB* to include:

```
hostA userA
```

If *userA* is an administrator account, or if a remote copy request looks like:

```
pbs_rcp file1 userB@hostB:file2
```

then use of the account's `[PROFILE_PATH]\.rhosts` file is the only way to authenticate, and it needs to have the entry:

```
hostA userA
```

These two methods of authentication are further discussed in the **PBS Professional User's Guide**.

4.7.9 Network Drives and File Delivery

If users require jobs to have output or error files going into some network location, and that network location is mapped to the same local drive (for instance drive `Q`), then you need to put the following two lines in MOM's config file. (For additional information on MOM configuration parameters, see section 7.2 "MOM Configuration Parameters" on page 130.)

```
$usecp *:Q: Q:
$usecp *:q: q:
```

The above causes any job output or error files having the form, "`<hostname>`: the letter "q": *`file-path`*" to be passed to `xcopy` as:

`Q:`*`file-path`* or `q:`*`file-path`*

instead of being passed to `pbs_rcp/pbs_rshd`.

The reason for putting a wildcard entry for *hostname* in `$usecp` is to get around the possibility of MOM seeing different permutations of hostname for the destination host. The upper and lower cases of “q” are needed in order to get a match in all possible situations.

The example above will result in the following translations:

```
pbs_rcp job_output_file host2:Q:\output
```

is translated to: `xcopy job_output_file Q:\output`

```
pbs_rcp job_output_file host3.test.domain.com:Q:\output
```

is translated to: `xcopy job_output_file Q:\output`

```
pbs_rcp job_output_file host4.domain.com:q:\output
```

is translated to: `xcopy job_output_file q:\output`

4.7.10 Changing the pbsadmin Password

Normally, the “pbsadmin” password must not be changed. But if it is deemed necessary to change it perhaps due to a security breach, then do so using the following steps:

First, change the “pbsadmin” service account's password on a machine in a command prompt from an admin-type of account by typing:

domain environments:

```
net user pbsadmin * /domain
```

non-domain environment:

```
net user pbsadmin *
```

Then the Service Control Manager (SCM) must be provided with the new password specified above. This can be done via the GUI-based Services application found as one of the Administrative Tools, or unregister and re-register the PBS services with password:

```
pbs_account --unreg "\Program Files\PBS Pro\exec\sbin\pbs_server.exe"
pbs_account --unreg "\Program Files\PBS Pro\exec\sbin\pbs_mom.exe"
pbs_account --unreg "\Program Files\PBS Pro\exec\sbin\pbs_sched.exe"
pbs_account --unreg "\Program Files\PBS Pro\exec\sbin\pbs_rshd.exe"

pbs_account --reg "\Program Files\PBS Pro\exec\sbin\pbs_server.exe"
pbs_account --reg "\Program Files\PBS Pro\exec\sbin\pbs_mom.exe"
pbs_account --reg "\Program Files\PBS Pro\exec\sbin\pbs_sched.exe"
pbs_account --reg "\Program Files\PBS Pro\exec\sbin\pbs_rshd.exe"
```

The register form (last four lines above) can take an additional argument `-p password` so that you can specify the password on the command line directly.

4.7.11 Uninstalling PBS Professional on Windows

To remove PBS from a Windows system, either (1) Go to `Start Menu->Settings->Control Panel->Add/Remove Program` (Win2000) or `Start Menu->Control Panel->Add/Remove Programs` (WinXP) menu and select the PBS Professional entry and click "Change/Remove"; or (2) double click on the PBS Windows installation package icon to execute. This will automatically delete any previous installation.

If the uninstallation process complains about not completely removing the PBS installation directory, then remove it manually, for example by typing:

```
cd \Program Files
rmdir /s "PBS Pro"
```

Under some conditions, if PBS is uninstalled by accessing the menu options (discussed above), the following error may occur:

```
...Ctor.dll: The specified module could not be found
```

To remedy this, do the uninstall by running the original PBS Windows installation executable (e.g. `PBSPro_7.0-windows.exe`), which will remove any existing instance of PBS.

During uninstallation, PBS will not delete the "pbsadmin" account because there may be other PBS installations on other hosts that could be depending on this account. However, the account can be deleted manually using an administrator-type of account as follows:

In a domain environment:

```
net user pbsadmin /delete /domain
```

In a non-domain environment:

```
     net user pbsadmin /delete
```

At the end of uninstallation, it is recommended to check that the PBS services have been completely removed from the system. This can be done by opening up the Services dialog:

(Windows 2000):

```
Start Menu->Settings->Control Panel->Administrative Tools->
Services
```

(Windows XP):

```
Start Menu->Control Panel->Performance and Maintenance->
Administrative Tools->Services
```

and check to make sure `PBS_SERVER`, `PBS_MOM`, `PBS_SCHED`, and `PBS_RSHD` entries are completely gone. If any one of them has a state of "DISABLED", then you must restart the system to get the service removed.

4.8 Post Installation Validation

If you wish to validate the installation of PBS Professional, at any time, run the `pbs_probe` command. It will review the installation (installed files, directory and file permissions, etc) and report any problems found. For details, see section 11.5 "The pbs_probe Command" on page 260. (The `pbs_probe` command is not available under Windows.)

Chapter 5

Upgrading PBS Professional

This chapter provides important information on upgrading from a previous version of PBS Professional. If PBS Professional is not currently installed on your system, you can safely skip this chapter at this time. However, be sure to refer to it before performing a future upgrade of PBS.

There are two types of upgrades available for PBS Professional:

overlay upgrade	(which installs the new binaries on top of the old ones)
migration upgrade	(which involves moving jobs from the old server to the new server).

One or the other of these needs to be used whenever there is a need to preserve existing jobs (migration won't preserve running jobs).

Important: Overlay upgrades are not supported in Microsoft Windows environments. For those environments you must use the migration upgrade, which is discussed in section 5.2 below.

On UNIX usually an overlay upgrade is needed. The migration upgrade is only necessary when the new release has a change to the Server's internal "JOB" data structure.

Important: Moving between 32-bit and 64-bit versions of PBS changes the "JOB" data structure and thus requires a migration upgrade.

Important: Some parameters that were settable are changed to being read-only in new releases. This will produce errors during a migration upgrade. For example, ntype is now read-only:

```
qmgr < /tmp/nodes.out.20050620    (done as root)

qmgr obj=sgi2 svr=default: Cannot set
   attribute, read only or insufficient
   permission  ntype

qmgr: Error (15003) returned from server
```

Note: In the scheduler's configuration file, PBS_HOME/sched_priv/sched_config, the default for `log_filter` has changed to DEBUG2 & DEBUG3. If you have altered your `log_filter` setting, you should add 1024 to its current value, in order to keep the current behavior. This is because you will want to filter out the new set of DEBUG3 messages.

Note: The `resources` attribute in the scheduler's configuration file should be changed to include the new defaults. It should have "`ncpus, mem, arch, host, software`".

5.1 Overlay Upgrade

Most new releases of PBS (especially minor versions and patch releases) will allow you to upgrade quickly. Except for the operating environments which are specifically singled out below, use the following steps to perform the overlay upgrade:

1 shut down PBS Professional by typing the command:

```
qterm -m -s        (PBS versions prior to PBSPro_5.4.0)
qterm -m -s -f     (PBS versions PBSPro_5.4.0 and later)
```

Also see "Starting and Stopping PBS: UNIX and Linux" on page 211, and section 10.3.6 "Impact of Shutdown / Restart on Running Jobs" on page 220.

2 Back up the Server's job directory (see details below).

3 Install the new version of PBS Professional on all nodes without uninstalling the previous installation.

4 Restart PBS Professional on all nodes, starting the execution hosts first.

The special case of overlay upgrade for Solaris environments:

1 shut down PBS Professional by typing the command:

```
qterm -m -s          (PBS versions prior to PBSPro_5.4.0)
qterm -m -s -f      (PBS versions PBSPro_5.4.0 and later)
```

2 Move the entire PBS home hierarchy to a temporary location:

```
mv /usr/spool/PBS /usr/spool/PBS.old
```
(this assumes the default location was used)

3 Remove the old PBS package:

("`pkginfo | grep -i pbs`" gets package name)

```
pkgrm  pbs64
  -or-
pkgrm  pbs32
```

4 Move PBS Professional home hierarchy back to its original location:

```
mv /usr/spool/PBS.old /usr/spool/pbs
```
(this assumes the default location was used)

5 Install the new PBS Professional version:

```
./INSTALL
```

6 Restart PBS Professional on all nodes, starting the execution hosts first.

You may use `tar` to perform the backup of the jobs directory. This backup step is precautionary only, allowing jobs to be restored should an error occur.

```
      cd $PBS_HOME/server_priv
      tar -cf /tmp/pbs_jobs_save.tar jobs
```

Follow the normal installation procedures for installing the new version. The installation program will pick up your existing installation parameters from the `pbs.conf` file, and prompt you to confirm that you wish to use them.

5.2 Migration Upgrade

A migration upgrade is more complicated than an overlay upgrade. It is needed whenever the internal PBS job structure is different between the version of PBS that is installed and that to which you are upgrading.

When the new version PBS is ready to be placed into service, you will probably want to move jobs from the old system to the new. The steps which follow form a procedure for carrying out this migration of jobs.

Important: In the examples below, all the file and directory pathnames are shown as the PBS defaults. If you changed the location to which PBS was installed, use your local locations instead.

All PBS Servers as well as the `qmgr` and `qmove` commands which follow need to be run by a user with Administrator privilege. Under UNIX, use “root”; under Windows, this Admin-type of account should be a member of "Domain Admins" group if migrating in a domain environment, or local "Administrators" group if in a standalone environment.

Step 1 Save a copy of the Server and nodes configuration to files, as this information will be necessary later on in the migration process. You should, as a precaution, check that these saved files really exist and appear to be correct in so far as size is concerned.

UNIX:

```
cd /tmp
qmgr -c “print server” > server.out
qmgr -c “print node @default” > nodes.out
```

WINDOWS:

```
Admin> cd C:\WINDOWS\TEMP        (Windows XP environments)
Admin> cd C:\WINNT\TEMP          (Windows 2000 environments)
Admin> qmgr -c “print server” > server.out
Admin> qmgr -c “print node @default” > nodes.out
```

Step 2 Stop any further scheduling cycles by setting the Server's `scheduling` attribute to false. Then disable the queues by setting all queues’ `enabled` attributes to false. This will prevent any new jobs from being accepted or started by PBS.

```
qmgr -c “set server scheduling = false”
qstat                            (check for any running jobs)
qrerun -W force jobIDs         (requeue running jobs if possible)
qstat                            (check that no jobs are running)

(If any jobs remain in state RUNNING, you either need to wait for their termination or use the qdel command to delete them.)

qmgr -c “set queue @default enabled = false”
```

Step 3 Shut down PBS.

If your version of the Server doesn't have the “fail over” feature, omit the “-f” option that appears in the `qterm` command below.

UNIX:

```
qterm -m -s          (PBS versions prior to PBSPro_5.4.0)
qterm -m -s -f      (PBS versions PBSPro_5.4.0 and later)
```

If the version of `qterm` does not have these options, do a shutdown with the init script.

```
/etc/init.d/pbs stop
     -or-
/etc/rc.d/init.d/pbs stop
```

WINDOWS:

```
Admin> qterm -m -s          (PBS versions prior to PBSPro_5.4.0)
Admin> qterm -m -s -f       (PBS versions PBSPro_5.4.0 and later)
Admin> net stop pbs_rshd
```

Step 4 Backup the Server's jobs directory, *PBS_HOME*/server_priv/jobs.

In the UNIX environment the value for PBS_HOME can be found in file /etc/pbs.conf, and in the Windows environment it is the value, \Program Files\PBS Pro\home.

Backup of the Server's jobs directory is only precautionary, but an extremely prudent step in the event of operator or other error.

UNIX:

```
cd PBS_HOME/server_priv
tar -cf /tmp/pbs_jobs_save.tar jobs
```

WINDOWS: In either case below, specify "D" for directory when prompted and subsequently verify that this backup of your PBS jobs seems successful.

For Windows-XP environments, type the following command on a single line:

```
xcopy /o /e "\Program Files\PBS Pro\home\server_priv\jobs"
 "\WINDOWS\TEMP\jobs"
```

For Windows-2K environments, type the following command on a single line:

```
xcopy /o /e "\Program Files\PBS Pro\home\server_priv\jobs"
 "\WINNT\TEMP\jobs"
```

Step 5 Install the new version of pbs_mom on each execution-only node. At the end of each installation, do not opt for restarting the MOM at this time. Wait until all jobs have been successfully moved over to the new Server.

UNIX: Select option #2 of the INSTALL program.

WINDOWS: Choose, on the relevant installation menu, the choice "execution". As this step will install and launch `pbs_mom`, follow this by the command:

```
net stop pbs_mom
```

Step 6 On the Server node, move the existing `PBS_HOME` and execution hierarchies to a temporary location.

LINUX:

```
mv /var/spool/PBS /var/spool/PBS.old
mv /usr/pbs /usr/pbs.old
```

UNIX:

```
mv /usr/spool/PBS /usr/spool/PBS.old

mv /usr/pbs /usr/pbs.old
-or-
mv /usr/local/pbs /usr/local/pbs.old
-or-
mv /opt/pbs /opt/pbs.old
```

WINDOWS: For the Windows environments do a `copy` operation rather than a `move`, since the install program contains a removal procedure that will take issue with the `PBS_HOME` hierarchy not being available for it to remove:

```
xcopy /o /e "\Program Files\PBS Pro" "\Program Files\PBS Pro.old"
```

In the above, specify "D" for directory when prompted. If you get an "access denied" error message while deleting a file in `\Program Files\PBS Pro\home\spool`, then bring up `Start menu->Programs->Accessories->Windows Explorer`, and right mouse click to select this file and bring up a pop-up menu, choose "Properties", select "Security" tab, then “Advanced”, then Owners tab, from which you can reset the ownership of the file to “Administrators”. Be sure also that “Administrators” has permission to read the file. Then rerun `xcopy`.

Step 7 Install the new version of PBS on the Server host.

UNIX: Perform the installation on the Server host using the `INSTALL` program, and then start PBS on that host.

WINDOWS: For Windows environments you need to run the PBS package executable twice. The first run attempts to remove the currently installed package. The second run does the actual install. Note that the uninstall process will require a system reboot after removing the PBS package, before installing the new version.

A word of caution is appropriate at this point. Make sure there isn't any access occurring on any file in the hierarchy

```
C:\Program Files\PBS Pro
```

when you do the uninstall of PBS Professional (e.g. don't have your current directory set to a subdirectory of the PBS directory hierarchy.) If there is access, you will be presented with a pop-up window stating that the above hierarchy could not be removed. This will force you to have to do the removal and the install manually.

The manual removal is done from a `cmd` shell window by typing:

```
rmdir /S /Q "C:\Program Files\PBS Pro"
```

Do not use the `del` command in place of `rmdir` as there may be circumstances where not everything is removed, which will later on cause problems in the migration procedure.

As the install also launches the PBS services, issue the following command to stop `pbs_mom` on the server node:

```
net stop pbs_mom
```

Step 8 Restart the Server in a way that it receives an empty configuration. Do this as follows:

UNIX:

```
qterm
```

Do the appropriate one of the following:

```
rm /usr/spool/PBS/server_priv/nodes
rm /var/spool/PBS/server_priv/nodes
```

Do the appropriate one of the following:

```
/usr/pbs/sbin/pbs_server -t create
/usr/local/pbs/sbin/pbs_server -t create
/opt/pbs/sbin/pbs_server -t create
```

Important: The following message will appear following a restart of the Server with the "`create`" option: "Create mode and server database exists, do you wish to continue?" Answer "y" to this question.

WINDOWS:

```
Admin> qterm
Admin> del "\Program Files\PBS Pro\home\server_priv\nodes"
Admin> "\Program Files\PBS Pro\exec\sbin\pbs_server" -C
Admin> net start pbs_server
```

Step 9 Now give to this new Server instance a duplicate of the queues and Server attributes that were saved in Step 1 (this assumes you want this new Server instance to have the same configuration as the old).

UNIX:

```
qmgr < /tmp/server.out
qmgr < /tmp/nodes.out
```

WINDOWS:

```
Admin> cd C:\WINDOWS\TEMP        (Windows XP environments)
Admin> cd C:\WINNT\TEMP          (Windows 2000 environments)
Admin> qmgr < server.out
Admin> qmgr < nodes.out
```

Step 10 Now start the original Server on different ports and direct it to take for the location of its database the location that you specified in Step 6.

UNIX:

```
/usr/pbs.old/sbin/pbs_server -p 13001 -M 13002 \
  -R 13003 -S 13004 -g 13005 -d /usr/spool/PBS.old
or
/usr/pbs.old/sbin/pbs_server -p 13001 -M 13002 \
  -R 13003 -S 13004 -g 13005 -d /var/spool/PBS.old
or
/usr/local/pbs.old/sbin/pbs_server -p 13001 -M 13002 \
  -R 13003 -S 13004 -g 13005 -d /usr/spool/PBS.old
or
/opt/pbs.old/sbin/pbs_server -p 13001 -M 13002 \
  -R 13003 -S 13004 -g 13005 -d /usr/spool/PBS.old
```

WINDOWS: Type the following command(s), without splitting across lines, all in the same command prompt window. Be sure that the command(s) reference the "old" Server and the "old" hierarchy.

You may omit the first command (`del`) if you are not upgrading from `PBSPro_5.3.3-wp1`

(Note that all of the following, except the second line, require quote marks as shown.)

```
Admin> del "\Program Files\PBS Pro.old\home\server_priv\server.lock"
Admin> set PBS_CONF_FILE=\Program Files\PBS Pro.old\pbs.conf
Admin> pbs-config-add "PBS_EXEC=\Program Files\PBS Pro.old\exec"
Admin> pbs-config-add "PBS_HOME=\Program Files\PBS Pro.old\home"
Admin> "\Program Files\PBS Pro.old\exec\sbin\pbs_server" -N -p 13001 -M
13002 -R 13003 -S 13004 -g 13005
```

Step 11 Verify that the old `pbs_server` is running on the alternate ports by going to another `cmd` prompt window and running:

```
qstat @hostname:13001
```

Step 12 This is a Windows-only step. If you are performing a migration on UNIX, skip this step.

WINDOWS: If `single_signon_password_enable` attribute of the old Server is false, unset or unavailable and in the new Server it is `true`, then, set the Server's single signon attribute to `false`:

```
Admin> qmgr host:15001
Qmgr: set server single_signon_password_enable=false
```

Otherwise, if `single_signon_password_enable` attribute of the old Server and new Server are both set to `true`, then, migrate user passwords from the old Server to the new Server as follows:

```
Admin> pbs_migrate_users host:13001 host:15001
```

Step 13 Now move the jobs from the old to the new Server. Note that the standard port number of the *new* Server (15001) needs to be part of the destination queue specification.

UNIX: The commands need to be run out of the old version of PBS which will be in `/usr/pbs.old/bin`, `/usr/local/pbs.old/bin` or `/opt/pbs.old/bin` depending on architecture (see step 6). Call this location `/oldpath/`.

This first step in the sequence is here to catch the special case where one is migrating jobs from a pre-`PBSPro_5.4.0` version of the Server and that Server's host happens to be also running a `pbs_mom`. The command will present a message about "no such node" if the host is not in the Server's nodes set. This is not a problem.

```
/oldpath/qmgr -c "d n serverhost" serverhost:13001
```

If the message "Cannot delete busy object" occurs, first use `qrerun -W force` or `qdel` to remove job(s) currently using the node, then rerun the `qmgr` command again

```
/oldpath/qstat @host:13001
/oldpath/qmove queue@host:15001 job_id1@host:13001
/oldpath/qmove queue@host:15001 job_id2@host:13001
...
/oldpath/qmove queue@host:15001 job_idN@host:13001
qstat
```

WINDOWS: On another command prompt window, type the following. (Note that the “for” statement should be typed all on one line.)

```
Admin> qstat @host:13001
Admin> for /F "usebackq" %j in (`qselect -q queue@host:1300
1`) do ( qmove queue@host:15001 %j@host:13001 )

Admin> qstat
```

Step 14 This is a Windows-only step. If you are performing a migration on UNIX, skip this step.

If `single_signon_password_enable` attribute of the old Server is false, unset, or unavailable and you intend to set it to “true” on the new Server, then first apply hold type “p” (bad password) to all jobs in new Server:

```
Admin> for /F "usebackq" %j in (`qselect -q
queue@host:15001`) do ( qhold -h p %j@host:15001 )
```

Then reset the Server’s single signon attribute to “true”:

```
Admin> qmgr host:15001
Qmgr:  set server single_signon_password_enable=True
```

Now each user with jobs on the new system must specify a password via `pbs_password` (see **PBS Professional User’s Guide** for usage details.)

Step 15 At this point, all of the jobs should be under control of the new Server and located in the new Server’s home. The old Server can now be shut down and the MOMs (`pbs_mom`) started.

Step 16 Lastly, scheduling should be turned back on in the Server.

UNIX:

```
qmgr -c "set server scheduling = True"
```

WINDOWS:

```
Admin> qmgr -c "set server scheduling = True"
```

Chapter 6
Configuring the Server

Now that PBS Professional has been installed, the Server and MOMs can be configured and the scheduling policy selected. The next three chapters will walk you through this process. Further configuration may not be required as the default configuration may completely meet your needs. However, you are advised to read this chapter to determine if the default configuration is indeed complete for you, or if any of the optional settings may apply.

6.1 The qmgr Command

The PBS manager command, `qmgr`, provides a command-line interface to the PBS Server. The qmgr command can be used by anyone to list or print attributes. Operator privilege is required to be able to set or unset node, queue or server attributes. Manager privilege is required to create or delete queues or nodes.

The `qmgr` command usage is:

```
qmgr [ -a] [ -c command] [ -e] [ -n] [ -z] [ server...]
```

The available options, and description of each, follows.

Option	Action
`-a`	Abort `qmgr` on any syntax errors or any requests rejected by a Server.
`-c command`	Execute a single command and exit `qmgr`. The command must be enclosed in quote marks, e.g. `qmgr -c "print server"`
`-e`	Echo all commands to standard output.
`-n`	No commands are executed, syntax checking only is performed.
`-z`	No errors are written to standard error.

If `qmgr` is invoked without the `-c` option and standard output is connected to a terminal, `qmgr` will write a prompt to standard output and read a directive from standard input.

Any qmgr setting containing commas, whitespace or the hashmark must be enclosed in double quotes. For example:

Qmgr: set node Node1 comment="Node will be taken offline Friday at 1:00 for memory upgrade."

A command is terminated by a new line character or a semicolon (";") character. Multiple commands may be entered on a single line. A command may extend across lines by escaping the new line character with a back-slash ("\"). Comments begin with the "#" character and continue to end of the line. Comments and blank lines are ignored by `qmgr`. The syntax of each directive is checked and the appropriate request is sent to the Server(s). A `qmgr` directive takes one of the following forms:

```
command server [ names] [ attr OP value[ ,...]]
command queue  [ names] [ attr OP value[ ,...]]
command node   [ names] [ attr OP value[ ,...]]
```

Where command is the sub-command to perform on an object.

Command	Explanation
`active`	Sets the active objects. If the active objects are specified, and the name is not given in a `qmgr` command the active object names will be used.

Command	**Explanation**
`create`	Create a new object, applies to queues and nodes.
`delete`	Destroy an existing object, applies to queues and nodes.
`help`	Prints command specific help and usage information
`list`	List the current attributes and associated values of the object.
`print`	Print settable queue and Server attributes in a format that will be usable as input to the `qmgr` command.
`set`	Define or alter attribute values of the object.
`unset`	Clear the value of the attributes of the object. Note, this form does not accept an OP and value, only the attribute name.

Other `qmgr` syntax definitions follow:

Variable	**`qmgr` Variable/Syntax Description**
`names`	List of one or more names of specific objects. The name list is in the form: `[ name][ @server][ ,name[ @server] ...]` with no intervening white space. The name of an object is declared when the object is first created. If the name is `@server`, then all the objects of specified type at the Server will be affected.
`attr`	Specifies the name of an attribute of the object which is to be set or modified. The attributes of objects are described on the relevant attribute man page (e.g. `pbs_node_attributes(3B)`). If the attribute is one which consists of a set of resources, then the attribute is specified in the form: `attribute_name.resource_name`
`OP`	An operation to be performed with the attribute and its value:
=	Set the value of the attribute. If the attribute has an existing value, the current value is replaced with the new value.

Variable	qmgr Variable/Syntax Description
+=	Increase the value of the attribute by the amount specified.
-=	Decrease the value of the attribute by the amount specified.
value	The value to assign to an attribute. If value includes white space, commas, or other special characters, such as "#", the value string must be inclosed in quote marks (" ").

A few examples of the qmgr command follow. Commands can be abbreviated. The underlined letters are there to show which abbreviations can be used in place of complete words.

```
qmgr
Qmgr: create node mars
Qmgr: set node mars resources_available.ncpus=2
Qmgr: create node venus
Qmgr: set node mars resources_available.inner = true
Qmgr: set node mars resources_available.haslife= true
Qmgr: delete node mars
Qmgr: d n venus
```

6.1.1 qmgr Help System

The qmgr built-in help function, invoked using the "help" sub-command, is illustrated by the next example which shows that requesting usage information on qmgr's set command produces the following output.

```
qmgr
Qmgr: help set
Syntax:
    set object [name][,name...] attribute[.resource] OP value
Objects can be "server" or "queue", "node"
The "set" command sets the value for an attribute on the spec-
ified object. If the object is "server" and name is not spec-
ified, the attribute will be set on all the servers specified
on the command line. For multiple names, use a comma separated
list with no intervening whitespace.
Examples:
set server s1 max_running = 5
set server managers = root
set server managers += susan
set node n1,n2 state=down
set queue q1@s3 resources_max.mem += 5mb
set queue @s3 default_queue = batch
```

6.2 Default Configuration

Server management consists of configuring the Server attributes, defining nodes, and establishing queues and their attributes. The default configuration from the binary installation sets the minimum Server settings, and some recommended settings for a typical PBS cluster. (The default Server configuration is shown below.) The subsequent sections in this chapter list, explain, and provide the default settings for all the Server's attributes for the default binary installation.

```
qmgr
Qmgr: print server
#
# Create queues and set their attributes.
#
#
# Create and define queue workq
#
create queue workq
set queue workq queue_type = Execution
set queue workq enabled = True
set queue workq started = True
#
# Set server attributes.
#
set server scheduling = True
set server default_queue = workq
set server log_events = 511
set server mail_from = adm
set server query_other_jobs = True
set server resources_default.ncpus = 1
set server scheduler_iteration = 600
set server resv_enable = True
set server node_fail_requeue = 310
set server max_array_size = 10000
```

6.2.1 PBS Levels of Privilege

The `qmgr` command is subject to the three levels of privilege in PBS: Manager, Operator, and user. In general, a "Manager" can do everything offered by `qmgr` (such as creating/deleting new objects like queues and nodes, modifying existing objects, and changing attributes that affect policy). The "Operator" level is more restrictive. Operators cannot create new objects nor modify any attribute that changes scheduling policy. A "user" can view, but cannot change, Server configuration information. For example, the `help`, `list` and `print` sub-commands of `qmgr` can be executed by the general user. Creating or deleting a queue requires PBS Manager privilege. Setting or unsetting `Server` or `queue` attributes (discussed below) requires PBS Operator or Manager privilege. Specifically, Manager privilege is required to create and delete queues or nodes, and set/alter/unset the following attributes:

server query_other_jobs	server acl_roots	server managers	all node boolean resources
server acl_user_enable	server acl_users	server operators	server default_node
server acl_host_enable	server acl_host_list	server mail_from	

For details on setting these levels of privilege, see the `managers` and `operators` Server attributes, discussed in "Server Configuration Attributes" on page 76; for security-related aspects of PBS privilege, see section 10.7.7 "External Security" on page 229.)

6.3 Hard versus Soft Limits

Hard limits cannot be exceeded. For example, if a user has reached a hard limit for `max_user_run` of 3, a fourth job will not run. A soft limit means that when that user has reached a `max_user_run_soft of 4`, their 5th and 6th jobs will still run. However, all of this user's jobs are now eligible to be preempted by another user who is under their limits. If it is necessary in order to run the other user's jobs, one of the first user's jobs will be preempted, then another, until the first user is no longer over their soft limit.

See also the discussion of scheduling parameters using soft limits in Chapter 8 .

Important: There are no soft limits attributes for nodes.

6.4 Server Configuration Attributes

This section explains all the available Server configuration attributes and gives the default values for each. Note that the possible values for the "boolean" format are any of:

"TRUE", "True", "true", "Y", "y", "1"; "FALSE", "False", "false", "N", "n", "0".

acl_host_enable

When `true` directs the Server to use the `acl_hosts` access control lists. Requires Manager privilege to set or alter.
Format: boolean
Default value: false = disabled

```
Qmgr: set server acl_host_enable=true
```

acl_hosts

List of hosts which may request services from this Server. This list contains the fully qualified network name of the hosts. Local requests, i.e. from the Server's host itself, are always accepted even if the host is not included in the list. Wildcards ("*") may be used in conjunction with host names, and subdomain and domain names. See also `acl_host_enable`.
Format: "[+|-]hostname.domain[,...]"
Default value: all hosts

```
Qmgr: set server acl_hosts=*.domain.com
Qmgr: set server acl_hosts="+*.domain.com,-*"
```

acl_resv_host_enable

When true directs the Server to use the `acl_resv_hosts` access control list. Requires Manager privilege to set or alter.
Format: boolean
Default value: false = disabled

```
Qmgr: set server acl_resv_host_enable=true
```

acl_resv_hosts

List of hosts which may request reservation services from this server. This list contains the network name of the hosts. Local requests, i.e. from the Server's host itself, are always accepted even if the host is not included in the list. Wildcards ("*") may be used in conjunction with host names and subdomain and domain names. Requires Manager privilege to set or alter. See also `acl_resv_enable`.
Format: "[+|-]hostname.domain[,...]"
Default value: all hosts

```
Qmgr: set server acl_resv_hosts=*.domain.com
```

acl_resv_group_enable

If true directs the Server to use the reservation group ACL `acl_resv_groups`. Requires Manager privilege to set or alter.
Format: boolean
Default value: false = disabled

```
Qmgr: set server acl_resv_group_enable=true
```

acl_resv_groups

List which allows or denies accepting reservations owned by members of the listed groups. The groups in the list are groups on the

Server host, not submitting hosts. See also `acl_resv_group_enable`.
Format: "[+|-]group_name[,...]"
Default value: all groups allowed
`Qmgr:` **`set server acl_resv_groups="blue,green"`**

acl_resv_user_enable

If true, directs the Server to use the `acl_resv_users` access list. Requires Manager privilege to set or alter.
Format: boolean
Default value: disabled
`Qmgr:` **`set server acl_resv_user_enable=true`**

acl_resv_users

A single list of users allowed or denied the ability to make reservation requests of this Server. Requires Manager privilege to set or alter. See also `acl_resv_user_enable`. Manager privilege overrides user access restrictions. The order of the elements in the list is important. The first match encountered in the list is accepted and terminates processing. Therefore, to allow all users except for some, the list of denied users should be put at the front of the list, followed by the set of allowed users. When usernames are added to the list, they are appended to the end of the list.
Format: "[+|-]user[@host][,...]"
Default value: all users allowed
To set list of allowed users:
`Qmgr:` **`set server acl_resv_users="-bob,-tom,joe,+"`**
To add to list of allowed users:
`Qmgr:` **`set server acl_resv_users+=nancy@terra`**
To remove from list of allowed users:
`Qmgr:` **`set server acl_resv_users-=joe`**
To add to list of disallowed users:
`Qmgr:` **`set server acl_resv_users+=-mary`**

acl_user_enable

When true directs the Server to use the Server level `acl_users` access list. Requires Manager privilege to set or alter.
Format: boolean
Default value: disabled
`Qmgr:` **`set server acl_user_enable=true`**

acl_users

A single list of users allowed or denied the ability to make any requests of this Server. Requires Manager privilege to set or alter. See also `acl_user_enable`. Manager privilege overrides user access restrictions. The order of the elements in the list is important. The first match encountered in the list is accepted and terminates processing. Therefore, to allow all users except for some, the list of denied users should be put at

the front of the list, followed by the set of allowed users. When usernames are added to the list, they are appended to the end of the list.
Format: "[+|-]user[@host][,...]"
Default value: all users allowed
To set list of allowed users:
`Qmgr: set server acl_users="-bob,-tom,joe,+"`
To add to list of allowed users:
`Qmgr: set server acl_users+=nancy@terra`
To remove from list of allowed users:
`Qmgr: set server acl_users-=joe`
To add to list of disallowed users:
`Qmgr: set server acl_users+=-mary`

acl_roots
: List of superusers who may submit to and execute jobs at this Server. If the job execution id would be zero (0), then the job owner, root@host, must be listed in this access control list or the job is rejected.
Format: "[+|-]user[@host][,...]"
Default value: no root jobs allowed
`Qmgr: set server acl_roots=host`

comment
: A text string which may be set by the Scheduler or other privileged client to provide information to PBS users.
Format: any string
Default value: none
`Qmgr: set server comment="Planets Cluster"`

default_chunk
: Defines default elements of chunks for all jobs on this server. All jobs will inherit default chunk elements for elements not set at submission time. Jobs moved to this server from another server will lose their old defaults and inherit these.
Format: resource specification format,
e.g. "default_chunk.resource=value,default_chunk.resource=value, ..."
`Qmgr: set server default_chunk.mem=100mb,default_chunk.ncpus=1`

default_queue
: The queue which is the target queue when a request does not specify a queue name.
Format: a queue name.
Default value: workq
`Qmgr: set server default_queue=workq`

flatuid
: Attribute which directs the Server to automatically grant authorization for a job to be run under the user name of the user who submitted the job even if the job was submitted from a different host. If not

set `true`, then the Server will check the authorization of the job owner to run under that name if not submitted from the Server's host. See section 10.7.5 “User Authorization” on page 227 for usage and important caveats.
Format: boolean
Default value: false = disabled

```
Qmgr: set server flatuid=True
```

log_events

A bit string which specifies the type of events which are logged; see also section 10.14 “Use and Maintenance of Logfiles” on page 250.
Format: integer
Default value: 511 (all events)

```
Qmgr: set server log_events=255
```

mail_from

The email address used as the “from” address for Server generated mail sent to users.
Format: string
Default value: adm

```
Qmgr: set server mail_from=boss@domain.com
```

Note: This email address will also be used by the Server as the “to” address to send important events and warnings. Currently, these are limited to warnings regarding expiration of PBS licenses. Therefore, this should be set to a valid address or alias to which mail, when sent, is actually read.

managers

List of users granted PBS Manager privileges. The host, subdomain, or domain name may be wild carded by the use of an * character. Requires Manager privilege to set or alter.
Format: “user@host.sub.domain[,user@host.sub.domain...]”
Default value: root on the local host

```
Qmgr: set server managers+=boss@sol.domain.com
```

max_array_size

The maximum number of subjobs (separate indices) that are allowed in an array job. Format: integer. Default value:10000.

max_running

The maximum number of jobs allowed to be selected for execution at any given time.
Format: integer
Default value: none

```
Qmgr: set server max_running=24
```

max_group_res
max_group_res_soft

The maximum amount of the specified resource that all members of the same group may consume simultaneously. The

named resource can be any valid PBS resource, such as "ncpus", "mem", "pmem", etc. This limit can be specified as either a *hard* or *soft* limit. (See also section 6.3 "Hard versus Soft Limits" on page 76.)
Format: "max_group_res.resource_name=value[,...]"
Format: "max_group_res_soft.resource_name=value[,...]"
Default value: none

```
Qmgr: set server max_group_res.ncpus=10
Qmgr: set server max_group_res_soft.mem=1GB
```

The first line in the example above sets a normal (e.g. *hard*) limit of 10 CPUs as the aggregate maximum that any group may consume. The second line in the example illustrates setting a group *soft* limit of 1GB of memory.

max_group_run
max_group_run_soft

The maximum number of jobs owned by a UNIX group that are allowed to be running from this server at one time.This limit can be specified as either a *hard* or *soft* limit. (See also section 6.3 "Hard versus Soft Limits" on page 76.)
Format: integer
Default value: none

```
Qmgr: set server max_group_run=10
Qmgr: set server max_group_run_soft=7
```

max_user_run
max_user_run_soft

The maximum number of jobs owned by a single user that are allowed to be running at one time. This limit can be specified as either a *hard* or *soft* limit. (See also section 6.3 "Hard versus Soft Limits" on page 76.)
Format: integer
Default value: none

```
Qmgr: set server max_user_run=6
Qmgr: set server max_user_run_soft=3
```

max_user_res
max_user_res_soft

The maximum amount of the specified resource that any single user may consume. The named resource can be any valid PBS resource, such as "ncpus", "mem", "pmem", etc. This limit can be specified as either a *hard* or *soft* limit. (See also section 6.3 "Hard versus Soft Limits" on page 76.)
Format: "max_user_res.resource_name=value[,...]"
Format: "max_user_res_soft.resource_name=value[,...]"
Default value: none

```
Qmgr: set server max_user_res.ncpus=6
Qmgr: set server max_user_res_soft.ncpus=3
```

The first line in the example above sets a normal (e.g. *hard*) limit of 3 CPUs as a maximum that any single user may consume. The second line in the example illustrates setting a *soft* limit of 6 CPUs on the same resource.

node_fail_requeue

Controls if running jobs are automatically requeued if the primary execution node fails (e.g. due to system crash or power failure). If this attribute is unset or set to a value of zero, PBS will leave the job in a Running state when the first node allocated to the job (Mother Superior node) is reported down. However, if this attribute is set to any non-zero positive integer ("N"), it defines the number of seconds that the PBS Server will wait for the node to come back online before the job is requeued or deleted. (If set to any negative non-zero value, N will be reset to 1.) If after *N* seconds the node is still down, any job which has that node as its first node will be (a) requeued if the job's rerun attribute is set to 'y' (yes); or (b) deleted if it is set to 'n' (no).

When a job is requeued for this reason, it will be requeued at the top of the queue with its former priority. In most circumstances, this job will be the next to be started. Exceptions are when another higher-priority job was submitted after the requeued job started, or when this user is over their fairshare limit.

(See also the "`-r y|n`" option to `qsub` in the **PBS Professional User's Guide**.) If a job is deleted, mail will be sent to the owner of the job. Requires either Manager or Operator privilege to set. The value selected for *N* should be long enough to exceed any transient non-node failures, but short enough to requeue the job in a timely fashion.
Format: integer
Default value: 310 (seconds)

```
Qmgr: set server node_fail_requeue=0
```

node_group_enable

When true directs the Server to enable node grouping. Requires Manager privilege to set or alter. See also `node_group_key`, and section 6.8 "Node Grouping" on page 101.
Format: boolean
Default value: disabled

```
Qmgr: set server node_group_enable=true
```

node_group_key

Specifies the resource to use for node grouping. Requires Manager privilege to set or alter. See also `node_group_enable`, and section 6.8 "Node Grouping" on page 101.

Format: string
Default value: disabled
```
Qmgr: set server node_group_key=resource
```

node_pack

Deprecated.

operators

List of users granted PBS Operator privileges.
Format of the list is identical with `managers` above. Requires Manager privilege to set or alter.
Default value: root on the local host.
```
Qmgr: set server operators="sue,bob,joe,tom"
```

query_other_jobs

The setting of this attribute controls whether or not general users, other than the job owner, are allowed to query the status of or select the job. Requires Manager privilege to set or alter.
Format: boolean
Default value: true (users may query or select jobs owned by other users)
```
Qmgr: set server query_other_jobs=false
```

require_cred_enable

When true directs the Server to use the credential authentication method specified by `require_cred`. Requires Manager privilege to set or alter. Depends on optional kerberos and DCE support.
Format: boolean
Default value: false = disabled
```
Qmgr: set server require_cred_enable=true
```

require_cred

Specifies the credential type required. All jobs submitted without the specified credential will be rejected. Requires Manager privilege to set or alter. See also `require_cred_enable`. Depends on optional kerberos and DCE support.
Format: string (`krb5` or `dce`)
Default value: unset
```
Qmgr: set server require_cred=krb5
```

The above example would cause the Server to reject all jobs that do not have a credential type of “`krb5`”.

resources_available

List of resources and amounts available to jobs on this Server. The sum of the resources of each type used by all jobs running by this Server cannot exceed the total amount listed here.
Format: “resources_available.resource_name=value[,...]”
Default value: unset
```
Qmgr: set server resources_available.ncpus=16
Qmgr: set server resources_available.mem=400mb
```

resources_default

The list of default resource values that are set as limits for a job exe-

cuting on this Server when the job does not specify a limit, and there is no queue default. See also section 6.10 “Resource Default/Min/Max Attributes” on page 108.
Format: “resources_default.resource_name=value[,...]
Default value: no limit

```
Qmgr: set server resources_default.mem=8mb
Qmgr: set server resources_default.ncpus=1
```

resources_max

Maximum amount of each resource which can be requested by a single job on this Server if there is not a `resources_max` valued defined for the queue in which the job resides. See section 6.10 “Resource Default/Min/Max Attributes” on page 108.
Format: “resources_max.resource_name=value[,...]
Default value: infinite usage

```
Qmgr: set server resources_max.mem=1gb
Qmgr: set server resources_max.ncpus=32
```

resv_enable

This attribute can be used as a master switch to turn on/off advance reservation capability on the Server. If set False, advance reservations are not accepted by the Server, however any already existing reservations will not be automatically removed. If this attribute is set True the Server will accept, for the Scheduler’s subsequent consideration, any reservation submission not otherwise rejected do to the functioning of some Administrator established ACL list controlling reservation submission. Requires Manager privilege to set or alter.
Format: boolean
Default value: True = enabled

```
Qmgr: set server resv_enable=true
```

scheduler_iteration

The time, in seconds, between iterations of attempts by the Server to schedule jobs. On each iteration, the Scheduler examines the available resources and runnable jobs to see if a job can be initiated. This examination also occurs whenever a running job terminates or a new job is placed in the queued state in an execution queue.
Format: integer seconds
Default value: 600

```
Qmgr: set server scheduler_iteration=300
```

scheduling

Controls if the Server will request job scheduling by the PBS Scheduler. If true, the Scheduler will be called as required; if false, the Scheduler will not be called and no job will be placed into execution unless the Server is directed to do so by a PBS Operator or Manager. Setting or resetting this attribute to `true` results in an immediate call to the Scheduler.
Format: boolean
Default value: value of `-a` option when Server is invoked; if `-a` is not specified, the value is recovered from the prior Server

run. If it has never been set, the value is "false".

```
Qmgr: set server scheduling=true
```

single_signon_password_enable
If enabled, this option allows users to specify their passwords only once, and PBS will remember them for future job executions. An unset value is treated as `false`. See discussion of use, and caveats, in section section 6.14 "Password Management for Windows" on page 112.
The feature can be enabled (set to True) only if no jobs exist, or if all jobs are of type "p" hold (bad password).
Format: boolean. It can be disabled only if there are no jobs currently in the system.
Default: false (UNIX), true (Windows)

```
Qmgr: set server single_signon_password_enable=true
```

The following attributes are read-only: they are maintained by the Server and cannot be changed by a client.

FLicenses	Shows the number of floating licenses currently available.
PBS_version	The release version number of the Server.
resources_assigned	The total amount of certain resources allocated to running jobs.
server_host	The name of the host on which the current (Primary or Secondary) Server is running, in failover mode.
server_name	The name of the Server as read from the `/etc/pbs.conf` file, or if unavailable, the local `hostname`. If the Server is listening to a non-standard port, the port number will be appended, with a colon, to the host name. For example: `host.domain:9999`.
state_count	Tracks the number of jobs in each state currently managed by the Server
server_state	The current state of the Server. Possible values are:

`Active`	The Server is running and will invoke the Scheduler as required to schedule jobs for execution.

`Hot_Start`	The Server may remain in this state for up to five minutes after being restarted with the “hot” option on the command line. Jobs that are already running will remain in that state and jobs that got requeued on shutdown will be rerun.
`Idle`	The Server is running but will not invoke the Scheduler.
`Scheduling`	The Server is running and there is an outstanding request to the Scheduler.
`Terminating`	The Server is terminating. No additional jobs will be scheduled.
`Terminating, Delayed`	The Server is terminating in delayed mode. The Server will not run any new jobs and will shut down when the last currently running job completes.

total_jobs The total number of jobs currently managed by the Server.

6.5 Queues within PBS Professional

Once you have the Server attributes set the way you want them, you will next want to review the queue settings. The default (binary) installation creates one queue with the attributes shown in the example below. You may wish to change these settings or add other attributes or add additional queues. The following discussion will be useful in modifying the PBS queue configuration to best meet your specific needs.

6.5.1 Execution and Routing Queues

There are two types of queues defined by PBS: routing and execution. A **routing queue** is a queue used to move jobs to other queues including those which exist on different PBS Servers. A job must reside in an **execution queue** to be eligible to run. The job remains in the execution queue during the time it is running. In spite of the name, jobs in a queue need not be processed in queue-order (first-come first-served or *FIFO*).

A Server may have multiple queues of either or both types, but there must be at least one queue defined. Typically it will be an execution queue; jobs cannot be executed while residing in a routing queue.

See the following sections for further discussion of execution and route queues:

section 6.5.4 “Attributes for execution queues only” on page 92
section 6.5.5 “Attributes for route queues only” on page 93
section 6.11 “Selective Routing of Jobs into Queues” on page 109
section 6.15.6 “Failover and Route Queues” on page 125
section 12.4 “Complex Multi-level Route Queues” on page 289.

6.5.2 Creating Queues

To create an execution queue:

```
#
# Create and define queue exec_queue
#
qmgr
Qmgr:
create queue exec_queue
set queue exec_queue queue_type = Execution
set queue exec_queue enabled = true
set queue exec_queue started = true
```

Now we will create a routing queue, which will send jobs to our execution queue:

```
qmgr
Qmgr:
create queue routing_queue
set queue routing_queue queue_type = Route
set queue routing_queue route_destinations += exec_queue
```

Note:
1. Destination queues must be created before being used as the routing queue's route_destination.
2. Routing queue's route_destinations must be set before enabling and starting the routing queue.

```
set queue routing_queue enabled = true
set queue routing_queue started = true
```

Note:

If we want the destination queue to accept jobs only from a routing queue, we set its from_route_only attribute to true:

```
set queue exec_queue from_route_only = True
```

6.5.3 Queue Configuration Attributes

Queue configuration attributes fall into three groups: those which are applicable to both types of queues, those applicable only to execution queues, and those applicable only to routing queues. If an "execution queue only" attribute is set for a routing queue, or vice versa, it is simply ignored by the system. However, as this situation might indicate the Administrator made a mistake, the Server will issue a warning message (on stderr) about the conflict. The same message will be issued if the queue type is changed and there are attributes that do not apply to the new type.

Queue public attributes are alterable on request by a client. The client must be acting for a user with Manager or Operator privilege. Certain attributes require the user to have full Administrator privilege before they can be modified. The following attributes apply to both queue types:

Important:	Note, an *unset* resource limit (i.e. a limit for which there is no default, minimum, nor maximum) is treated as an infinite limit.
acl_group_enable	When true directs the Server to use the queue's group access control list `acl_groups`. Format: boolean Default value: false = disabled `Qmgr:` **`set queue`** ***`QNAME`*** **`acl_group_enable=true`**
acl_groups	List which allows or denies enqueuing of jobs owned by members of the listed groups. The groups in the list are groups on the Server host, not submitting host. Note that the job's execution GID is evaluated (which is either the user's default group, or the group specified by the user via the `-Wgroup_list` option to `qsub`.) See also `acl_group_enable`. Format: "[+|-]group_name[,...]" Default value: unset `Qmgr:` **`set queue`** ***`QNAME`*** **`acl_groups="math,physics"`**
acl_host_enable	When true directs the Server to use the `acl_hosts` access list for the named queue. Format: boolean

Default value: disabled
`Qmgr: set queue QNAME acl_host_enable=true`

acl_hosts
: List of hosts which may enqueue jobs in the queue. See also `acl_host_enable`.
Format: "[+|-]hostname[,...]"
Default value: unset
`Qmgr: set queue QNAME acl_hosts="sol,star"`

acl_user_enable
: When true directs the Server to use the `acl_users` access list for this queue.
Format: boolean (see acl_group_enable)
Default value: disabled
`Qmgr: set queue QNAME acl_user_enable=true`

acl_users
: A single list of users allowed or denied the ability to enqueue jobs in this queue. Requires Manager privilege to set or alter. See also `acl_user_enable`. Manager privilege overrides user access restrictions. The order of the elements in the list is important. The first match encountered in the list is accepted and terminates processing. Therefore, to allow all users except for some, the list of denied users should be put at the front of the list, followed by the set of allowed users. When usernames are added to the list, they are appended to the end of the list.
Format: "[+|-]user[@host][,...]"
Default value: all users allowed
To set list of allowed users:
`Qmgr: set queue QNAME acl_users="-bob,-tom,joe,+"`
To add to list of allowed users:
`Qmgr: set queue QNAME acl_users+=nancy@terra`
To remove from list of allowed users:
`Qmgr: set queue QNAME acl_users-=joe`
To add to list of disallowed users:
`Qmgr: set queue QNAME acl_users+=-mary`

enabled
: When true, the queue will accept new jobs. When false, the queue is *disabled* and will not accept jobs.
Format: boolean
Default value: disabled
`Qmgr: set queue QNAME enabled=true`

from_route_only
: When true, this queue will accept jobs only when being routed by the Server from a local routing queue. This is used to force users to submit jobs into a routing queue used to distribute jobs to other

queues based on job resource limits.
Format: boolean
Default value: disabled

```
Qmgr: set queue QNAME from_route_only=true
```

max_array_size	The maximum number of subjobs that a job array in that queue can have. Job arrays with more than this number will be rejected at qsub time. Format: integer. Default: 10000. `Qmgr: set queue QNAME max_array_size = 5000`

max_group_res
max_group_res_soft
	The maximum amount of the specified resource that all members of the same group may consume simultaneously, in the specified queue. The named resource can be any valid PBS resource, such as “ncpus”, “mem”, “pmem”, etc. This limit can be specified as either a *hard* or *soft* limit. (See also section 6.3 “Hard versus Soft Limits” on page 76.)
	Format: “max_group_res.resource_name=value[,...]”
	Format: “max_group_res_soft.resource_name=value[,...]”
	Default value: none
	`Qmgr: set queue QNAME max_group_res.mem=1GB`
	`Qmgr: set queue QNAME max_group_res_soft.ncpus=10`
	
	The first line in the example above sets a normal (e.g. *hard*) limit of 1GB on memory as the aggregate maximum that any group in this queue may consume. The second line in the example illustrates setting a group *soft* limit of 10 CPUs.

max_queuable	The maximum number of jobs allowed to reside in the queue at any given time. Once this limit is reached, no new jobs will be accepted into the queue. Format: integer Default value: infinite `Qmgr: set queue QNAME max_queuable=200`
max_user_res max_user_res_soft	The maximum amount of the specified resource that any single user may consume. The named resource can be any valid PBS resource, such as “ncpus”, “mem”, “pmem”, etc. This limit can be specified as either a *hard* or *soft* limit. (See also section 6.3 “Hard versus Soft Limits” on page 76.) Format: “max_user_res.resource_name=value[,...]” Format: “max_user_res_soft.resource_name=value[,...]” Default value: none

```
Qmgr: set queue QNAME max_user_res.ncpus=6
Qmgr: set queue QNAME max_user_res_soft.ncpus=3
```

priority
: The priority of this queue against other queues of the same type on this Server. (A larger value is higher priority than a smaller value.) May affect job selection for execution/routing.
Format: integer in range of -1024 thru +1024, inclusive
Default value: 0

```
Qmgr: set queue QNAME priority=123
```

queue_type
: The type of the queue: execution or route. This attribute must be explicitly set.
Format: "execution", "e", "route", "r"
Default value: none, must be specified

```
Qmgr: set queue QNAME queue_type=route
Qmgr: set queue QNAME queue_type=execution
```

require_cred_enable
: Attribute which when true directs the Server to use the credential authentication method specified by `require_cred` for this queue. Requires full Manager privilege to set or alter.
Format: boolean
Default value: false = disabled

```
Qmgr: set queue QNAME require_cred_enable=true
```

require_cred
: Specifies the credential type required. All jobs submitted to the named queue without the specified credential will be rejected. Requires full Manager privilege to set or alter.
Format: string: "`krb5`" or "`dce`"
Default value: unset

```
Qmgr: set queue QNAME require_cred=krb5
```

resources_default
: The list of default resource values which are set as limits for a job residing in this queue and for which the job did not specify a limit. If not set, the default limit for a job is determined by the first of the following attributes which is set: Server's `resources_default`, queue's `resources_max`, Server's `resources_max`. An unset resource is viewed as unlimited. See also section 6.10 "Resource Default/Min/Max Attributes" on page 108.
Format: "resources_default.*resource_name*=*value*"
Default value: none

```
Qmgr: set queue QNAME resources_default.mem=1kb
Qmgr: set queue QNAME resources_default.ncpus=1
```

resources_max

The maximum amount of each resource which can be requested by a single job in this queue. The queue value supersedes any Server wide maximum limit. See also section 6.10 “Resource Default/Min/Max Attributes” on page 108.
Format: “resources_max.*resource_name*=*value*”
Default value: unset

```
Qmgr: set queue QNAME resources_max.mem=2gb
Qmgr: set queue QNAME resources_max.ncpus=32
```

resources_min

The minimum amount of each resource which can be requested by a single job in this queue. See also section 6.10 “Resource Default/Min/Max Attributes” on page 108.
Format: “resources_min.*resource_name*=*value*”
Default value: unset

```
Qmgr: set queue QNAME resources_min.mem=1kb
Qmgr: set queue QNAME resources_min.ncpus=1
```

started

When true, jobs may be scheduled for execution from this queue. When false, the queue is considered *stopped* and jobs will not be executed from this queue.
Format: boolean
Default value: unset

```
Qmgr: set queue QNAME started=true
```

6.5.4 Attributes for execution queues only

checkpoint_min

Specifies the minimum interval of CPU time, in minutes, which is allowed between checkpoints of a job. If a user specifies a time less than this value, this value is used instead.
Format: integer
Default value: unset

```
Qmgr: set queue QNAME checkpoint_min=5
```

default_chunk

Defines default elements of chunks for all jobs on this queue. All jobs will inherit default chunk elements for elements not set at submission time. Jobs moved to this queue from another queue will lose their old defaults and inherit these.
Format: resource specification format, e.g. “default_chunk.resource=value,default_chunk.resource=value, ...”

```
Qmgr: set queue QNAME default_chunk.mem=100mb
```

kill_delay

The amount of the time delay between the sending of SIGTERM and SIGKILL when a `qdel` command is issued against

a running job.
Format: integer seconds
Default value: 2 seconds
`Qmgr: set queue QNAME kill_delay=5`

max_running	The maximum number of jobs allowed to be selected from this queue for routing or execution at any given time. For a routing queue, this is enforced by the Server, if set. Format: integer Default value: infinite `Qmgr: set queue QNAME max_running=16`
max_user_run	The maximum number of jobs owned by a single user that are allowed to be running from this queue at one time. Format: integer Default value: unset `Qmgr: set queue QNAME max_user_run=5`
max_group_run	The maximum number of jobs owned by users in a single group that are allowed to be running from this queue at one time. Format: integer Default value: unset `Qmgr: set queue QNAME max_group_run=20`
resources_available	The list of resource and amounts available to jobs running in this queue. The sum of the resource of each type used by all jobs running from this queue cannot exceed the total amount listed here. Format: "resources_available.*resource_name*=*value*" Default value: unset `Qmgr: set queue QNAME resources_available.mem=1gb`

6.5.5 Attributes for route queues only

route_destinations	The list of destinations to which jobs may be routed, listed in the order that they should be tried. See also section 6.11 "Selective Routing of Jobs into Queues" on page 109. Format: queue_name[,...] Default value: none, should be set to at least one destination. `Qmgr: set queue QNAME route_destinations=QueueTwo`

route_held_jobs	If true, jobs with a hold type set may be routed from this queue. If false, held jobs are not to be routed. Format: boolean Default value: false = disabled `Qmgr: set queue QNAME route_held_jobs=true`
route_lifetime	The maximum time a job is allowed to exist in a routing queue. If the job cannot be routed in this amount of time, the job is aborted. If unset, the lifetime is infinite. Format: integer seconds Default value: infinite `Qmgr: set queue QNAME route_lifetime=600`
route_retry_time	Time delay between route retries. Typically used when the network between servers is down. Format: integer seconds Default value: 30 `Qmgr: set queue QNAME route_retry_time=120`
route_waiting_jobs	If true, jobs with a future `execution_time` attribute may be routed from this queue. If false, they are not to be routed. Format: boolean Default value: false = disabled `Qmgr: set queue QNAME route_waiting_jobs=true`

6.5.6 Read-only attributes of queues

These attributes are visible to client commands, but cannot be changed by them.

hasnodes	If true, indicates that the queue has nodes associated with it.
total_jobs	The number of jobs currently residing in the queue.
state_count	Lists the number of jobs in each state within the queue.
resources_assigned	Amount of resources allocated to jobs running in this queue.

6.6 Nodes

Where jobs will be run is determined by an interaction between the Scheduler and the Server. This interaction is affected by the contents of the PBS `nodes` file (*`PBS_HOME`*`/server_priv/nodes`), and the system configuration onto which you are deploying PBS. Without this list of nodes, the Server will not establish a communication stream with the MOM(s) and MOM will be unable to report information about running jobs or notify the Server when jobs complete. If the PBS configuration consists of a single host on which the Server and MOM are both running, all the jobs will run there.

If your complex has more than one execution host, then distributing jobs across the various hosts is a matter of the Scheduler determining on which host to place a selected job. By default, when the Scheduler seeks a node meeting the requirements of a job, it will select the first available node in the nodes list that meets those requirements. Thus the order of nodes in the nodes file has a direct impact on node selection for jobs. (This default behavior can be overridden by the various node-sorting options available in the Scheduler. For details, see the discussion of `node_sort_key` in section 8.3 "Scheduler Configuration Parameters" on page 166.)

Important: Each node must be defined in the Server's nodes file, *PBS_HOME*/`server_priv/nodes`.

6.6.1 PBS Nodes File

A basic nodes file is created for you by the install procedure. This file contains only the name of the host from which the install was run. If you have more than one host in your PBS cluster or you are not planning on running jobs on the Server's host, you need to change the list of nodes to reflect your site.

You may change the nodes list in one of two ways. If the Server is not running, you may directly edit the `nodes` file with a text editor. If the Server is running, you should use `qmgr` to edit the list of nodes (for details see section 6.6.2 "Creating or Modifying Nodes" on page 96. The Server's *node list* is in the file *PBS_HOME*/`server_priv/nodes`. This is a simple text file, where each line of the file has the form:

```
node_name [ attributes]
```

The *node name* is the network name of the node (host name), it does not have to be fully qualified (in fact it is best if it is as short as possible).

Nodes can have attributes associated with them. Attributes come in three types: boolean resources, name=value pairs, and name.resource=value pairs. A *boolean resource* is a string of alphanumeric characters (first character must be alphabetic) established by the Administrator. A user's job can specify that the node(s) used for the job have a certain set of boolean resources. Boolean resources are useful to create classes of nodes, which jobs can request.

Within the nodes file the expression `np=`*`NUMBER`* can be used in place of the cumbersome expression `resources_available.ncpus=NUMBER`, where *NUMBER* is an integer. This declares the number of virtual processors (VPs) associated with the node. This expression will allow the node to be allocated up to *NUMBER* times to one job or more than one job. If `np=`*`NUMBER`* is not specified for a cluster node, the number of VPs for the node defaults to “1”.

If the following resources are not explicitly set, they will take the value provided by MOM. But if they are explicitly set, that setting will be carried forth across Server restarts.

They are:

```
resources_available.ncpus
resources_available.arch
resources_available.mem
```

The following is an example of a `nodes` file for a cluster called “planets”. The nodes are given boolean resources, “inner” and “outer”, so that jobs may request nodes by those resources.

```
# Note that the boolean resources are
# provided to logically group certain nodes
# together.
#
mercury resources_available.inner=true
venus   resources_available.inner=true
earth   resources_available.inner=true
mars    resources_available.inner=true
jupiter resources_available.outer=true
saturn  resources_available.outer=true
uranus  resources_available.outer=true
neptune resources_available.outer=true
pluto
```

6.6.2 Creating or Modifying Nodes

After `pbs_server` is started, the node list may be entered or modified via the `qmgr` command. For example, to add a new node, use the “create” sub-command of `qmgr`:

```
create node node_name [ attribute=value]
```

where the attributes and their associated possible values are shown in the table below.

Important: All comma-separated attribute-value strings must be enclosed in quotes.

Below are several examples of creating nodes via `qmgr`.

```
qmgr
Qmgr: create node mars resources_available.ncpus=2
Qmgr: create node venus
```

Modify nodes: Once a node has been created, its attributes and/or boolean resources can be modified using the following `qmgr` syntax:

```
set node node_name [ attribute[ +|-] =value]
```

where attributes are the same as for `create`. For example:

```
qmgr
Qmgr:          set          node          mars
resources_available.resources_available.inner=true
```

Delete nodes: Nodes can be deleted via `qmgr` as well, using the `delete node` syntax, as the following example shows:

```
qmgr
Qmgr: delete node mars
Qmgr: delete node pluto
```

6.7 Node Configuration Attributes

A node has the following configuration attributes:

comment General comment; can be set by a PBS Manager or Operator. If this attribute is not explicitly set, the PBS Server will use it to display node status, specifically why the node is down. If explicitly set by the Administrator, it will not be modified by the Server.
Format: string
`Qmgr: set node MyNode comment="Down until 5pm"`

lictype	Controls whether the specific node should receive a node-locked versus a floating license. This attribute can be set to the single character '`f`' or '`l`' for floating or locked license. If set, only that type of license will be used for that node. Format: character `Qmgr:` **`set node`** ***`MyNode`*** **`lictype=f`**
max_running	The maximum number of jobs allowed to be run on this node at any given time. Format: integer `Qmgr:` **`set node`** ***`MyNode`*** **`max_running=22`**
max_user_run	The maximum number of jobs owned by a single user that are allowed to be run on this node at one time. Format: integer `Qmgr:` **`set node`** ***`MyNode`*** **`max_user_run=4`**
max_group_run	The maximum number of jobs owned by any users in a single group that are allowed to be run on this node at one time. Format: integer `Qmgr:` **`set node`** ***`MyNode`*** **`max_group_run=8`**
no_multinode_jobs	If this attribute is set true, jobs requesting more than one node will not be run on this node. This attribute can be used in conjunction with Cycle Harvesting on workstations to prevent a select set of workstations from being used when a busy workstation might interfere with the execution of jobs that require more than one node. Format: boolean `Qmgr:` **`set node`** ***`MyNode`*** **`no_multinode_jobs=true`**
priority	The priority of this node against other nodes of the same type on this Server. (A larger value is higher priority than a smaller value.) May be used in conjunction with `node_sort_key`. Format: integer in range of -1024 thru +1024, inclusive Default value: 0 `Qmgr:` **`set node`** ***`MyNode`*** **`priority=123`**
queue	Name of an execution queue (if any) associated with a node. Only jobs from the named queue will be run on the associated node, and jobs in that queue will only be run on the node or nodes associated with that queue. Note: a node can be associ-

ated with at most one queue. Note that if a node is associated with a queue, it will no longer be considered for advance reservations, nor for node grouping.
Format: queue specification
```
Qmgr: set node MyNode queue=MyQueue
```

resources_available List of resources available on node. Any valid PBS resources can be specified.
Format: resource list
```
Qmgr:set node MyNode resources_available.ncpus=2
Qmgr:set node MyNode resources_available.RES=xyz
```

resv_enable Whether or not the node can be used to satisfy advance reservation requests, including the case where the administrator has configured the node to do cycle harvesting. If there is no intervention by the administrator, the node is available for advance reservations, except for the special case where the administrator has configured the node for cycle harvesting. Any reservations that are already assigned to use this node will not be automatically removed if this attribute is subsequently set to false. Requires manager privilege to set or alter.
Format: True/False; default value: True (exception: default value is False if the node is marked for cycle harvesting.

state Shows or sets the state of the node. Certain state values, marked with an * in the following list, may be set by the Manager or Operator, the other states are set internally.

free *	Node is up and capable of accepting additional job(s).
offline *	Node has been marked by operator or administrator as unusable. Jobs currently running on this node will continue to run.
down	Node is not responding to queries from the Server.
job-busy	All CPUs on the node are allocated to jobs.
job-exclusive	The entire node has been exclusively allocated to one job at the job's request.

busy	The node is reporting a load average greater than the configured high water value.
state-unknown	The Server has never been able to contact the node. Either `pbs_mom` is not running on the node, the node hardware is down, or there is a network problem.

Format: string

`Qmgr: set node MyNode state=offline`

A node has the following read-only attributes:

pcpus	Shows the number of physical CPUs on the node, which determine the number of licenses required for that node.
license	Indicates the node “license state” as a single character, according to the following table:

`u`	unlicensed
`l`	licensed with a node lock (fixed) license
`f`	licensed with a floating license

ntype	No longer used to distinguish between node uses. The “time-shared” and “cluster” node types are **deprecated**.
resources_assigned	List of resources in use on node. Format: resource list
reservations	List of reservations pending on the node. Format: reservation specification
jobs	List of jobs executing on the node.

6.7.1 Node Comments

Nodes have a “comment” attribute which can be used to display information about that node. If the comment attribute has not been explicitly set by the PBS Manager and the node is down, it will be used by the PBS Server to display the reason the node was marked down. If the Manager has explicitly set the attribute, the Server will not overwrite the comment. The comment attribute may be set via the qmgr command:

```
qmgr
Qmgr: set node pluto comment="node will be up at 5pm"
```

Once set, node comments can be viewed via pbsnodes, xpbsmon (node detail page), and qmgr. (For details see "The pbsnodes Command" on page 264 and "The xpbsmon GUI Command" on page 283.)

6.8 Node Grouping

PBS has two mechanisms for grouping nodes. The first is complex-wide node grouping, whereby the PBS administrator can partition a complex into groups of nodes. The second is grouping the nodes used by a job using the place statement.

6.8.1 Complex-wide Node Grouping

The *complex-wide node grouping* feature allows the PBS Administrator to partition a PBS complex into logical node groups and have multi-node jobs run within one partition. (This assumes the job "fits" within at least one node-partition. However, if a job requires more nodes than are available in any node-grouping, then the Scheduler will select nodes regardless of node-grouping.)

In general, when a job is put into execution it will be assigned to nodes that all belong to the same partition, as chosen by the Scheduler. Similarly, when an advance reservation is confirmed, it is given a set of nodes all of which belong to a single partition. This is of particular interest to those sites which have multiple high-performance network switches within a large cluster. All of a job should be assigned to the same switch, rather than given nodes that span multiple switches (unless that is the only way to ever satisfy the job's or reservation's nodes request).

Important: Node grouping (which assigns specific nodes to a named set) cannot be combined with queue-node association (which assigns specific nodes to a particular queue).

In complex-wide node grouping, the Administrator defines a non-consumable string-valued node resource as the basis of the grouping. All nodes having the same value for the grouping resource are considered to be in the same partition. The Administrator enables node grouping via the `qmgr` command. There are two Server attributes associated with node grouping. One enables node grouping and the other specifies the name of the grouping resource.

```
set server node_group_enable = TRUE | FALSE
set server node_group_key = resource_name
```

If `node_group_enable` is not set it defaults to false. If `node_group_enable` is set and `node_group_key` is not, then node grouping will be disabled as well. It is not permitted to set `node_group_key` to an invalid resource name or a non-string resource.

Important: Note that these are Server object attributes only and therefore cannot be set at the queue level.

If the resource *`resource_name`* is not already defined, the Administrator must define this resource in the Server's *`PBS_HOME/server_priv/resourcedef`* file (and then restart the Server). The resource should be specified as type *`string`* and there should be no flags specified. Defining a new resource is discussed in detail in section 9.2 “Defining New Custom Resources” on page 192.

The nodes get partitioned according to the actual value given to the grouping resource on each node, i.e. the value of *`resources_available.RES`* on the node. This means that the Administrator needs to use `qmgr` to add the grouping resource to the node’s *`resources_available`* attribute and set its value (see below). Not all nodes need to have the node grouping resource appear in their **`resources_available`** attribute, just those that the Administrator wants to have participate in the node grouping.

In a cluster where some nodes are in node groups and some are not, boolean resources can be assigned to the nodes that make up each type (in node group vs not in node group) to control where a multi-node job will be run. If the nodes in node groups have a boolean resource such as in_node_group set to true, then if multinode jobs request that resource, they will stay in node groups even if they are too large for a single node group.

Single node jobs will not use node grouping to determine where to run. They will run on a node whether or not the node_group_key is defined.

For example, say you have a cluster with two high-performance switches each with half the nodes connected to it. Now you want to set up node grouping so that jobs will be scheduled only onto the same switch.

First, create a new resource called “switch”. See “Defining New Custom Resources” on page 192.

Next, we need to enable node grouping, specify the resource to use for node grouping (i.e. our new resource "switch"), and assign to "switch" a node-specific value. We can do all of this via the qmgr command, as the following example shows.

```
qmgr
Qmgr: set server node_group_enable=true
Qmgr: set server node_group_key=switch
Qmgr: set node node1 resources_available.switch=A
Qmgr: set node node2 resources_available.switch=A
Qmgr: set node node3 resources_available.switch=A
Qmgr: set node node4 resources_available.switch=B
Qmgr: set node node5 resources_available.switch=B
Qmgr: set node node6 resources_available.switch=B
```

For ease of use with qmgr, this attribute can be set on many nodes at once. This is done through the use of the "active" qmgr command. You can use this command to create a set of nodes, and after the set is created all node commands will act upon this set if no specific node name is specified. The usage is as following:

```
active node comma,separated,list,of,nodes
```

There can be no spaces between the list of nodes and commas. After the set is defined, you can type commands by leaving the node name off and the command will act upon the entire set. The following example is equivalent to the longer example above.

```
qmgr
Qmgr: active node node1,node2,node3
Qmgr: set node resources_available.switch=A
Qmgr: active node node4,node5,node6
Qmgr: set node resources_available.switch=B
```

6.8.2 Grouping the Nodes Used by a Job

The new enhancement to job resource requests and placement on nodes allows the user to specifiy how jobs will be placed on nodes using the `-l place` statement. For information on the -l `place` statement, see the **PBS Professional User's Guide** and the `pbs_resources(7B)` manual page.

If set, the complex-wide node grouping will take precedence over the `place` statement, unless the user groups by resource, i.e. `-l place=group=`*`resource_name`*.

If the complex-wide node grouping feature is enabled, i.e. the server attribute `node_group_enable=True`, then jobs that request *place=scatter* will be grouped according to the rules in use before 7.1. If however the job requests placement other than scatter, chunks will be allocated as if *place=scatter* were specified and a message entered into the scheduler's log.

If a job requests grouping by a resource, i.e. *place=group=resource*, then the chunks are placed as requested and complex-wide node grouping is ignored. If *scatter* is not also requested, the scheduler will log a message.

If a job is to use node grouping but the required number of nodes is not defined in any one group, grouping is ignored. This is unchanged.

6.9 PBS Resources

PBS has a standard set of "resources" which may be specified as a job requirement. Common examples of the predefined standard resources are:

cput	amount of CPU time
mem	amount of real memory
ncpus	number of CPUs
nodes	number and type of execution nodes
walltime	amount of real clock time

Important: A complete listing of available PBS resources is given in section 4.8 "PBS System Resources" of the **PBS Professional User's Guide**.

Depending on site policy, the required resources may be considered against the availability of the resources to determine ordering of jobs for execution and placement of jobs on an execution host.

6.9.1 PBS System Resources

Jobs can request a variety of resources that can be allocated and used by the job. For information on how to request resources, see the `pbs_resources(7B)` manual page, "Resource Requests" on page 15 and "Requesting Resources" on page 32 in the **PBS Professional User's Guide**.

The resource values are specified using the following data types:

time specifies a maximum time period the resource can be used. Time is expressed in seconds as an integer, or in the form:

```
[[hours:]minutes:]seconds[.milliseconds]
```

size specifies the maximum amount in terms of bytes (default) or words. It is expressed in the form `integer[suffix]`. The suffix is a multiplier defined in the following table. The size of a word is the word size on the execution host.

b or w	bytes or words.
kb or kw	Kilo (1024) bytes or words.
mb or mw	Mega (1,048,576) bytes or words.
gb or gw	Giga (1,073,741,824) bytes or words.

Different resources are available on different systems, often depending on the architecture of the computer itself. The table below lists the available resources that can be requested by PBS jobs on any system.

Resource	Description
arch	Required system architecture. For use inside chunks only. One architecture can be specified. Allowable values and effect on job placement are site-dependent. String.
cput	Maximum amount of CPU time used by the job for all processes on all nodes. Establishes a job resource limit. Units: time.
file	Limit on size of any single file that may be created by the job. Units: size.

Resource	Description
host	Name of execution host. For use inside chunks only. Site-dependent string.
mem	Maximum amount of physical memory i.e. workingset allocated to the job on any single node. Units: size.
ncpus	Number of processors requested. Integer.
nice	Nice value under which the job is to be run. Host-dependent integer.
pcput	Maximum amount of CPU time allocated to any single process in the job. Per-chunk limit. Units: time.
pmem	Maximum amount of physical memory (workingset) used by any single process of the job. Per-chunk limit. Units: size
pvmem	Maximum amount of virtual memory used by any single process in the job. Per-chunk limit. Units: size.
vmem	Maximum amount of virtual memory used by all concurrent processes in the job. Establishes a job resource limit. Units: size.
software	Site-specific software specification. Allowable values and effect on job placement are site-dependent. String.
walltime	Maximum amount of wall-clock time during which the job can be in the running state. Establishes a job resource limit. Units: time.
custom resources	Custom resources are site-dependent. If used for a floating license, must be specified outside of a selection statement, as a job-wide resource limit. If used for a node-locked license, must be specified inside a selection statement, in a chunk.

6.9.1.1 Specifying Architectures

The `resources_available.arch` resource is the value reported by MOM unless explicitly set by the Administrator. The values for `arch` are:

Table 3: Values for resources_available.arch

OS	Resource Label
AIX 4, AIX 5	aix4
HP-UX 10	hpux10
HP-UX 11	hpux11
IRIX	irix6
IRIX with cpusets	irix6cpuset
Linux	linux
Linux with cpusets	linux_cpuset
Mac OS X	bsd
Solaris	solaris7
Tru64	digitalunix
Unicos	unicos
Unicos MK2	unicosmk2
Unicos SMP	unicossmp

6.9.2 Setting Chunk Defaults

It is possible to set defaults on queues and the Server for resources used within a chunk. For example, the administrator could set the default for ncpus for chunks at the server. This means that if a job requests a certain chunk in which only mem and arch are defined, the default for ncpus will be added to that chunk.

Set the defaults for the server:

```
qmgr
Qmgr: set server  default_chunk.ncpus=1
Qmgr: set server  default_chunk.mem=1gb
```

Set the defaults for queue small:

```
qmgr
Qmgr: set queue small default_chunk.ncpus=1
Qmgr: set queue small default_chunk.mem=512mb
```

6.9.3 Defining New Resources

It is possible for the PBS Manager to define new resources within PBS Professional. Once created, jobs may request these new resources and the Scheduler can be directed to consider the new resources in the scheduling policy. For detailed discussion of this capability, see Chapter 9, “Customizing PBS Resources” on page 191.

6.10 Resource Default/Min/Max Attributes

Default, minimum and maximum queue and Server limits work with numeric valued resources, including time and size values. Generally, they do not work with string valued resources because of character comparison order. However, setting the `min` and `max` to the same value to force an exact match will work even for string valued resources, as the following example shows.

```
qmgr
Qmgr: set queue big resources_max.arch=unicos8
Qmgr: set queue big resources_min.arch=unicos8
```

The above example can be used to limit jobs entering queue `big` to those specifying `arch=unicos8`. Again, remember that if `arch` is not specified by the job, the tests pass automatically and the job will be accepted into the queue.
Note however that if a job does not request a specific resource, then the enforcement of the corresponding limit will not occur. To prevent such cases, the Administrator is advised to set queue and/or server defaults. The following example sets a maximum limit on the amount of cputime to 24 hours; but it also has a default of 1 hour, to catch any jobs that do not specify a `cput` resource request.

```
qmgr
Qmgr: set queue big resources_max.cput=24:00:00
Qmgr: set queue big resources_default.cput=1:00:00
```

With this configuration, any job that requests more than 24 hours will be rejected. Any job requesting 24 hours or less will be accepted, but will have this limit enforced. And any job that does not specify a `cput` request will receive a default of 1 hour, which will also be enforced.

6.11 Selective Routing of Jobs into Queues

Often it is desirable to route jobs to various queues on a Server, or even between Servers, based on the resource requirements of the jobs. The queue *resources_min* and *resources_max* attributes discussed above make this selective routing possible. As an example, let us assume you wish to establish two execution queues, one for short jobs of less than one minute CPU time, and the other for long running jobs of one minute or longer. Let's call them `short` and `long`. Apply the `resources_min` and `resources_max` attribute as follows:

```
qmgr
Qmgr: set queue short resources_max.cput=59
Qmgr: set queue long resources_min.cput=60
```

When a job is being enqueued, its requested resource list is tested against the queue limits: `resources_min` <= job_requirement <= `resources_max`. If the resource test fails, the job is not accepted into the queue. Hence, a job asking for 20 seconds of CPU time would be accepted into queue `short` but not into queue `long`.

Important: Note, if the `min` and `max` limits are equal, only that exact value will pass the test.

You may wish to set up a routing queue to direct jobs into the queues with resource limits. For example:

```
qmgr
Qmgr: create queue funnel queue_type=route
Qmgr: set queue funnel route_destinations ="short,long"
Qmgr: set server default_queue=funnel
```

A job will end up in either `short` or `long` depending on its cpu time request.

Important: You should always list the destination queues in order of the most restrictive first as the first queue which meets the job's requirements will be its destination (assuming that queue is enabled).

Extending the above example to three queues:

```
qmgr
Qmgr: set queue short resources_max.cput=59
Qmgr: set queue long resources_min.cput=1:00
Qmgr: set queue long resources_max.cput=1:00:00
Qmgr: create queue huge queue_type=execution
Qmgr: set queue funnel route_destinations="short,long,huge"
Qmgr: set server default_queue=funnel
```

A job asking for 20 minutes (20:00) of cpu time will be placed into queue `long`. A job asking for 1 hour and 10 minutes (1:10:00) will end up in queue `huge`, because it was not accepted into the first two queues, and nothing prevented it from being accepted into `huge`.

Important: If a test is being made on a resource as shown with `cput` above, and a job does not specify that resource item (it does not appear in the `-l resource=`*`valuelist`* on the `qsub` command, the test will pass. In the above case, a job without a CPU time limit will be allowed into queue `short`**.** For this reason, together with the fact that an unset limit is considered to be an infinite limit, you may wish to add a default value to the queues or to the Server.

```
qmgr
Qmgr: set queue short resources_default.cput=40
or
Qmgr: set server resources_default.cput=40
```

Either of these examples will ensure that a job without a cpu time specification is limited to 40 seconds. A `resources_default` attribute at a queue level only applies to jobs in that queue.

Important: Be aware of several important facts:

If a default value is assigned, it is done so after the tests against `min` and `max`. Default values assigned to a job from a queue `resources_default` are not carried with the job if the job moves to another queue. Those resource limits become unset as when the job was specified. If the new queue specifies default values, those values are assigned to the job while it is in the new queue. Server level default values are applied if there is no queue level default.

6.12 Overview of Advance Reservations

An *Advance Reservation* is a set of resources with availability limited to a specific user (or group of users), a specific start time, and a specified duration. Users submit reservation requests, and then PBS either confirms or rejects the reservation. Once the reservation is confirmed, the queue that was created to support this reservation will be enabled, allowing jobs to be submitted to it. The queue will have a user level access control list set to the user who submitted the reservation and any other users the owner specified. The queue will accept jobs in the same manner as normal queues. When the reservation start time is reached, the queue will be started. Once the reservation is complete, any jobs remaining in the queue or still running will be deleted, and the reservation removed. When a reservation is requested and confirmed, it means that a check was made to see if the reservation would conflict with currently running jobs, other confirmed reservations, and dedicated time. A reservation request that fails this check is denied.

Example: To submit a reservation for 1 node, with 100MB of memory at 3:30pm for 30 minutes with ncpus=2 and named MyResv:

```
    pbs_rsub -N MyResv -lncpus=2,mem=100mb -R 1530 -D 30
R456.myhost UNCONFIRMED
```

Important: Hosts/nodes that have been configured to accept jobs only from a specific queue (node-queue restrictions) cannot be used for advance reservations.

For additional information on configuring your system to use the advance reservation feature, see the various `acl_resv_*` Server configuration attributes in section 6.4 "Server Configuration Attributes" on page 76.

6.13 SGI Weightless CPU Support

Submitting a job and requesting `-l ncpus=0` is legal. In a non-cpuset SGI IRIX 6.x environment, the job's kernel scheduling priority will be set "weightless". There will be no allocation at the Server, Queue, or Node level of CPUs; i.e. `resources_assigned.ncpus` will not be incremented for this job.

Important: Because `ncpus=0` has no useful effect on any other system and can result in allowing too many jobs to be run, it is **strongly** recommended that jobs not be allowed to be submitted with `ncpus=0`. This may be done by setting a Server level resource default and a resources minimum via the `qmgr` command:

```
qmgr
Qmgr: set server resources_default.ncpus=1
Qmgr: set queue q1 resources_min.ncpus=1
Qmgr: set queue q2 resources_min.ncpus=1
```

6.14 Password Management for Windows

PBS Professional will allow users to specify two kinds of passwords: a per-user/per-server password, or a per-job password. The PBS administrator must choose which method is to be used. (Discussion of the difference between these two methods is given below; detailed usage instructions for both are given in the **PBS Professional User's Guide**.)

This feature is intended for Windows environments. It should *not* be enabled in UNIX since this feature requires the PBS_DES_CRED feature, which is not enabled in the normal binary UNIX version of PBS Professional. Setting this attribute to "true" in UNIX may cause users to be unable to submit jobs.

The per-user/per-server password was introduced as part of the single signon password scheme. The purpose is to allow a user to specify a password only once and have PBS remember this password to run the user's current and future jobs. A per-user/per-server password is specified by using the command:

```
pbs_password
```

The user must run this command before submitting jobs to the Server. The Server must have the `single_signon_password_enable` attribute set to "true".

Alternatively, one can configure PBS to use the current per-job password scheme. To do this, the Server configuration attribute `single_signon_password_enable` must be set to "false", and jobs must be submitted using:

```
qsub -Wpwd
```

You cannot mix the two schemes; PBS will not allow submission of jobs using `-Wpwd` when `single_signon_password_enable` is set to "true".

Important: If you wish to migrate from an older version of PBS Professional on Windows to the current version, be sure to review Chapter 5 of this document, as well as the discussion of `pbs_migrate_users` in Chapter 11.

6.14.1 Single Signon and the qmove Command

A job can be moved (via the `qmove` command) from a Server at hostA to a Server at hostB. If the Server on hostB has `single_signon_password_enable` set to `true`, then the user at hostB must have an associated per-user/per-server password. This requires that the user run `pbs_password` at least once on hostB.

6.14.2 Single Signon and Invalid Passwords

If a job's originating Server has `single_signon_password_enable` set to `true`, and the job fails to run due to a bad password, the Server will place a hold on the job of type "`p`" (bad password hold), update the job's comment with the reason for the hold, and email the user with possible remedy actions. The user (or a manager) can release this hold type via:

```
qrls -h p <jobid>
```

6.14.3 Single Signon and Peer Scheduling

In a peer scheduling environment, jobs could be moved from complex A to complex B by the Scheduler. If the Server in complex B has `single_signon_password_enable` attribute set to `true`, then users with jobs on complex A must make sure they have per-user/per-server passwords on complex B. This is done by issuing a `pbs_password` command on complex B.

6.15 Configuring PBS Redundancy and Failover

The redundancy-failover feature of PBS Professional provides the capability for a backup Server to assume the workload of a failed Server, thus eliminating the one single point of failure in PBS Professional. If the Primary Server fails due to a hardware or software error, the Secondary Server will take over the workload and communications automatically. No work is lost in the transition of control.

The following terms are used in this manual section: *Active Server* is the currently running PBS Professional Server process. *Primary Server* refers to the Server process which under normal circumstances is the active Server. *Secondary Server* is a Server which is inactive (idle) but which will become active if the Primary Server fails.

Important: Setting up the Server failover feature in Windows is known to have problems if done from a Remote Desktop environment. In particular starting of the Server in either the primary host or secondary host would lead to the error:

```
error 1056: Service already running
```

even though `PBS_HOME\server_priv\server.lock` and `PBS_HOME\server_priv\server.lock.secondary` files are non-existent.

To avoid these problems, configure Server failover from the console of the hosts or through VNC.

6.15.1 Failover Requirements

The following requirements must be met to provide a reliable failover service:

1. The Primary and Secondary Servers must be run on different hosts. Currently only one Secondary Server is permitted.

2. The Primary and Secondary Server hosts must be the same architecture, i.e. binary compatible.

3. Both the Primary and Secondary Server host must be able to communicate over the network with all execution hosts where `pbs_mom` is running.

4. The directory and subdirectories used by the Server, `PBS_HOME`, must be on a file system which is available to both the Primary and Secondary Servers. Both must have read/write access as root on UNIX, or "Domain Admins" group (if domain environment) or local "Administrators" group (standalone environment) on Windows.

   When selecting the failover device, both the hardware and the available file systems must be taken into consideration, as the solution needs to support concurrent read and write access from two hosts. The best solution is a high availability file server device (such as a dual ported RAID system) connected to both the Primary and Secondary Server hosts, used in conjunction with a file system that supports both multiple export/mounting and simultaneous read/write access from two or more hosts (such as SGI CFXS, IBM GPFS, or Red Hat GFS).

A workable, but not ideal, solution is to use an NFS file server with the file system exported to and *hard mounted* by both the Primary and Secondary Server hosts. The file server must not be either the Primary or Secondary Server host, as that introduces a single point of failure affecting both Servers.

In a Microsoft Windows environment, a workable solution is to use the network share facility; that is, use as `PBS_HOME` a directory on a remote Windows host that is shared among primary server and secondary hosts.

Important: Note that a failure of the NFS server will prevent PBS from being able to continue.

5. A MOM, `pbs_mom`, may run on either the Primary or the Secondary hosts, or both. It is strongly recommended that the directory used for "`mom_priv`" be on a local, non-shared, file system. It is critical that the two MOMs do not share the same directory. This can be accomplished by using the `-d` option when starting `pbs_mom`, or with the `PBS_MOM_HOME` entry in the `pbs.conf` file. The `PBS_MOM_HOME` entry specifies a directory which has the following contents:

UNIX:

Directory Contents	**Description**
`aux`	Directory with permission 0755
`checkpoint`	Directory with permission 0700

Directory Contents	Description
`mom_logs`	Directory with permission 0755
`mom_priv`	Directory with permission 0755
`mom_priv/jobs`	Subdirectory with permission 0755
`mom_priv/config`	File with permission 0644
`pbs_environment`	File with permission 0644
`spool`	Directory with permission 1777 (drwxrwxrwt)
`undelivered`	Directory with permission 1777 (drwxrwxrwt)

Windows:

Note: In the table below, references to “access to Admin-account” refer to access to “Domain Admins” in domain environments, or to “Administrators” in stand-alone environments.

Directory Contents	Description
`auxiliary`	Directory with full access to *Admin-account* and read-only access to Everyone
`checkpoint`	Directory with full access only to *Admin-account*
`mom_logs`	Directory with full access to *Admin-account* and read-only access to Everyone
`mom_priv`	Directory with full access to *Admin-account* and read-only access to Everyone
`mom_priv/jobs`	Subdirectory with full access to *Admin-account* and read-only access to Everyone
`mom_priv/config`	File with full access-only to *Admin-account*
`pbs_environment`	File with full access to *Admin-account* and read-only to Everyone
`spool`	Directory with full access to Everyone

Directory Contents	Description
`undelivered`	Directory with full access to Everyone

If `PBS_MOM_HOME` is present in the `pbs.conf` file, `pbs_mom` will use that directory for its "home" instead of `PBS_HOME`.

6. The version of the PBS Professional commands installed everywhere must match the version of the Server, in order to provide for automatic switching in case of failover.

6.15.2 Failover Configuration for UNIX/Linux

The steps below outline the process for general failover setup, and should be sufficient for configuration under UNIX. To configure PBS Professional for failover operation, follow these steps:

1. Select two systems of the same architecture to be the Primary and Secondary Server systems. They should be binary compatible.

2. Configure a file system (or at least a directory) that is read/write accessible by root (UNIX) from both systems. If an NFS file system is used, it must be "hard mounted" (UNIX) and root or Administrator must have access to read and write as "root" or as "Administrators" on both systems. Under UNIX, the NFS hard mount can be performed as follows:

```
mount -t nfs -o hard svr:/path /localpath
```

or, in `/etc/fstab`:

```
svr:/path /local/path nfs hard,intr 0 0
```

Under Unix, the directory tree must meet the security requirements of PBS. Each parent directory above `PBS_HOME` must be owned by "root" ("Administrators") and be writable only by "root" (Administrators").

3. Install PBS Professional on both systems, specifying the shared file system location for the `PBS_HOME` directory. DO NOT START ANY PBS DAEMONS.

4. Modify /etc/`pbs.conf` file on both systems, as follows:

5. Change `PBS_SERVER` on both systems to have the same value. The value must be a valid hostname. The short form (alias) of the Primary Server host name is preferred. Example: PBS_SERVER=<primary server hostname>

6. Add the following entries to `pbs.conf` files; they must have the same value in both files:

```
PBS_PRIMARY=primary_host
PBS_SECONDARY=secondary_host
```

where “primary_host” is the primary formal name of the Primary Server host, and “secondary_host” is the primary formal name of the Secondary Server host. It is important that these entries be correct and distinct as they are used by the Servers to determine their status at start up.

These entries must also be added to the `pbs.conf` file on any system on which the PBS commands are installed, and on all compute nodes in the cluster.

A sample /etc/pbs.conf file for each server:

Primary:
```
#PBS_START_SERVER=1
#PBS_START_MOM=0
#PBS_START_SCHED=1
#PBS_SERVER=primary_host
#PBS_PRIMARY=primary_host
#PBS_SECONDARY=secondary_host
```

Secondary:
```
#PBS_START_SERVER=1
#PBS_START_MOM=0
#PBS_START_SCHED=0
```

```
#PBS_SERVER=primary_host
#PBS_PRIMARY=primary_host
#PBS_SECONDARY=secondary_host
```

8. Ensure that the `PBS_HOME` entry on both systems names the shared PBS directory, using the specific path on that host.

9. On the Secondary host, modify the `pbs.conf` file to not start the Scheduler by setting

   ```
   PBS_START_SCHED=0
   ```

   If needed, the Secondary Server will start a Scheduler itself.

10. If you are running a **`pbs_mom`** on both the Primary and Secondary Server hosts, make sure that **`/etc/pbs.conf`** on each host has a **`PBS_MOM_HOME`** defined. This will be local to that host. You will need to replicate the `PBS_MOM_HOME` directory structure at the place specified by `PBS_MOM_HOME`. It is not recommended to run `pbs_mom` on both systems.

11. PBS has a standard delay time from detection of possible Primary Server failure until the Secondary Server takes over. This is discussed in more detail in the "Normal Operation" section below. If your network is very reliable, you may wish to decrease this delay. If your network is unreliable, you may wish to increase this delay. The default delay is 30 seconds. To change the delay, use the "`-F seconds`" option on the Secondary Server's command line.

12. The Job Scheduler, `pbs_sched`, is run on the same host as the PBS Server. The Secondary Server will start a Scheduler on its (secondary) host only if the Secondary Server cannot contact the Scheduler on the primary host. This is handled automatically; see the discussion under "Normal Operation" section below.

13. Once the Primary Server is started, use the `qmgr` command to set or modify the Server's "`mail_from`" attribute to an email address which is monitored. If the Primary Server fails and the

Secondary becomes active, an email notification of the event will be sent to the "`mail_from`" address.

14 Start up the primary and secondary servers in any order.

6.15.3 Failover Configuration for Windows

The following illustrates how PBS can be set up on Windows with the Server failover capability using the network share facility. That is, the primary and secondary Server/Scheduler will share a `PBS_HOME` directory that is located on a network share file system on a remote host. In this scenario a primary `pbs_server` is run on hostA, a secondary Server is run on hostB, and the shared `PBS_HOME` is set up on hostC using Windows network share facility.

Important: Note that hostC must be set up on a Windows 2000 Server, Windows 2000 Advanced Server, or Windows Server 2003 platform.

1. Install PBS Windows on hostA and hostB accepting the default destination location of "`C:\Program Files\PBS Pro`".

2. Next stop all the PBS services on both hostA and hostB:

```
net stop pbs_server
net stop pbs_mom
net stop pbs_sched
net stop pbs_rshd
```

3. Now configure a shared `PBS_HOME` by doing the following:

a. Go to hostC; create a folder named e.g., `C:\pbs_home.` If you installed PBS using a domain admin account, be sure to create the folder using the same account. Otherwise, PBS may have permission problems accessing this shared folder.

b. Using Windows Explorer, right click select the `C:\pbs_home` file, and choose "Properties".

c. Then select the "Sharing" tab, and click the checkbutton that says "Share this folder"; specify "Full Control" permissions for the "pbsadmin" domain account and "Domain Admins" group (if domain environment), or local "pbsadmin" account and "Administrators" group (if standalone environment).

4. Next specify `PBS_HOME` for primary `pbs_server` on hostA and secondary Server on hostB by running the following on both hosts:

```
pbs-config-add "PBS_HOME\\hostC\pbs_home"
```

Now on hostA, copy the files from the local PBS home directory onto the shared `PBS_HOME` as follows:

```
xcopy /o /e "\Program Files\PBS Pro\home \\hostC\pbs_home"
```

5. Set up a local `PBS_MOM_HOME` by running the following command on both hosts:

```
pbs-config-add "PBS_MOM_HOME=C:\Program Files\PBS Pro\home"
```

6. Now create references to primary Server name and secondary Server name in the `pbs.conf` file by running on both hosts:

```
pbs-config-add "PBS_SERVER=hostA"
pbs-config-add "PBS_PRIMARY=hostA"
pbs-config-add "PBS_SECONDARY=hostB"
```

On the secondary Server modify the `pbs.conf` file to not start the scheduler by running:

```
pbs-config-add "PBS_START_SCHED=0"
```

7. Now start all the PBS services on hostA:

```
net start pbs_mom
net start pbs_server
net start pbs_sched
net start pbs_rshd
```

8. Start the failover Server on hostB:

```
net start pbs_server
```

It's normal to get the following message:

```
"PBS_SERVER could not be started"
```

This is because the failover Server is inactive waiting for the primary Server to go down. If you need to specify a delay on how long the secondary Server will wait for the primary Server to be down before taking over, then you use `Start Menu->Control Panel->Administrative Tools->Services`, choosing `PBS_SERVER`, and specify under the "Start Parameters" entry box the value,

```
"-F <delay_secs>"
```

Then restart the secondary `pbs_server`. Keep in mind that the Services dialog does not remember the "Start Parameters" value for future restarts. The old default delay value will be in effect on the next restart.

9. Set the managers list on the primary Server so that when the secondary Server takes over, you can still do privileged tasks under the Administrator account or from a peer `pbs_server`:

```
Qmgr: set server managers="<account that installed PBS>@*,pbsadmin@*"
```

Important: set up of the Server failover feature in Windows may encounter problems if performed from a Remote Desktop environment. In particular, starting the Server on either the primary host or secondary host would lead to the error:

```
error 1056  Service already running
```

even though `PBS_HOME\server_priv\server.lock` and `PBS_HOME\server_priv\server.lock.secondary` files are non-existent. To avoid this, configure Server failover from the console of the hosts or through VNC.

Important: Under certain conditions under Windows, the primary Server fails to take over from the secondary even after it is returned into the network. The workaround, should this occur, is to reboot the primary Server machine.

6.15.4 Failover: Normal Operation

The Primary Server and the Secondary Server may be started by hand, or via the system `init.d` script under UNIX, or using the Services facility under Windows. If you are starting the Secondary Server from the `init.d` script (UNIX only) and wish the change the failover delay, be sure to add the `-F` option to the `pbs_server`'s entry in the `init.d` script. Under Windows, specify the -F as a start parameter given by the `Start-> Control Panel-> Administrator Tools-> Services-> PBS_SERVER` dialog.

It does not matter in which order the Primary and Secondary Servers are started.

Important: If the primary or secondary Server fails to start with the error:

```
another server running
```

then check for the following conditions:

1. There may be lock files (`server.lock`, `server.lock.secondary`) left in *PBS_HOME*/`server_priv` that need to be removed,

2 On UNIX, the RPC `lockd` daemon may not be running. For instance, on an IRIX system, you can manually start this daemon by running as root:

```
/usr/etc/rpc.lockd
```

When the Primary and Secondary Servers are initiated, the Secondary Server will periodically attempt to connect to the Primary. Once connected, it will send a request to "register" itself as the Secondary. The Primary will reply with information to allow the Secondary to use the license keys should it become active.

Important: Backup license keys or keys tied to the Secondary host are not required.

The Primary Server will then send "handshake" messages every few seconds to inform the Secondary Server that the Primary is alive. If the handshake messages are not received for the “take over” delay period, the Secondary will make one final attempt to reconnect to the Primary before becoming active. If the “take over” delay time is long, there may be a period, up to that amount of time, when clients cannot connect to either Server. If the delay is too short and there are transient network failures, then Secondary Server may attempt to take over while the Primary is still active.

While the Primary is active and the Secondary Server is inactive, the Secondary Server will not respond to any network connection attempts. Therefore, you cannot status the Secondary Server to determine if it is up.

If the Secondary Server becomes active, it will send email to the address specified in the Server attribute `mail_from`. The Secondary will inform the `pbs_mom` on the configured nodes that it has taken over. The Secondary will attempt to connect to the Scheduler on the Primary host. If it is unable to do so, the Secondary will start a Scheduler on its host. The Secondary Server will then start responding to network connections and accepting requests from client commands such as `qstat` and `qsub`.

JobIDs will be identical regardless of which Server was running when the job was created, and will contain the name specified by `PBS_SERVER` in `pbs.conf`.

In addition to the email sent when a Secondary Server becomes active, there is one other method to determine which Server is running. The output of a “`qstat -Bf`” command includes the “`server_host`” attribute whose value is the name of the host on which the Server is running.

When a user issues a PBS command directed to a Server that matches the name given by `PBS_SERVER`, the command will normally attempt to connect to the Primary Server. If it is unable to connect to the Primary Server, the command will attempt to connect to the Secondary Server (if one is configured). If this connection is successful, then the command will create a file referencing the user executing the command. (Under UNIX, the file is named “`/tmp/.pbsrc.UID`” where “UID” is the user id; under Windows the file is named `%TEMP\.pbsrc.USERNAME` where “USERNAME” is the user login name.) Any future command execution will detect the presence of that file and attempt to connect to the Secondary Server first. This eliminates the delay in attempting to connect to the down Server. If the command cannot connect to the Secondary Server, and can connect to the Primary, the command will remove the above referenced file.

6.15.5 Failover: Manual Shutdown

Any time the Primary Server exits, because of a fault, or because it was told to shut down by a signal or the `qterm` command, the Secondary Server will become active.

If you wish to shut down the Primary Server and not have the Secondary Server become active, you must either:

1 Use the `-f` option on the `qterm` command. This causes the Secondary Server to exit as well as the Primary; or

2 Use the `-i` option on the `qterm` command, this causes the Secondary Server to remain running but inactive (stand by state); or

3 Manually kill the Secondary Server before terminating the Primary Server (via sending any of `SIGKILL`, `SIGTERM`, or `SIGINT`).

If the Primary Server exits causing the Secondary Server to become active and you then restart the Primary Server, it will notify the Secondary Server to restart and become inactive. You need not terminate the active Secondary Server before restarting the Primary. However, be aware that if the Primary cannot contact the Secondary due to network outage, it will assume the Secondary is *not* running. The Secondary will remain active resulting in two active Servers.
If you need to shut down and restart the Secondary Server while it is active, and wish to keep it active, then use the `pbs_server` with the `-F` option and a delay value of "-1":

```
pbs_server -F -1
```

The negative one value directs the Secondary Server to become active immediately. It will still make one attempt to connect to the Primary Server in case the Primary is actually up.

6.15.6 Failover and Route Queues

When setting up a Server route queue whose destination is in a failover configuration, it is necessary to define a second destination that specifies the same queue on the Secondary Server.

For example, if you already have a routing queue created with a destination as shown:

```
Qmgr: set queue r66 route_destinations=workq@primary.xyz.com
```

you need to add the following additional destination, naming the secondary Server host:

```
Qmgr: set queue r66 route_destinations+=workq@secondary.xyz.com
```

6.15.7 Failover and Peer Scheduling

If the Server being configured is also participating in Peer Scheduling, both the Primary and Secondary Servers need to be identified as peers to the Scheduler. For details, see section 8.13.1 “Peer Scheduling and Failover Configuration” on page 189.

6.16 Recording Server Configuration

If you wish to record the configuration of a PBS Server for re-use later, you may use the `print` subcommand of `qmgr`(8B). For example,

```
qmgr -c "print server" > /tmp/server.out
qmgr -c "print node @default" > /tmp/nodes.out
```

will record in the file `/tmp/server.out` the `qmgr` subcommands required to recreate the current configuration including the queues. The second file generated above will contain the nodes and all the node properties. The commands could be read back into `qmgr` via standard input:

```
qmgr < /tmp/server.out
qmgr < /tmp/nodes.out
```

6.17 Server Support for Globus

If Globus support is enabled, then an entry must be manually entered into the PBS nodes file (*PBS_HOME*/`server_priv/nodes`) with `:gl` appended to the name. This is the only case in which two nodes may be defined with the same node name. One may be a Globus node (MOM), and the other a non-Globus node. If you run both a Globus MOM and a normal MOM on the same site, the normal PBS MOM must be listed first in your nodes file. If not, some scheduling anomalies could appear.

Important: Globus support is not currently available on Windows.

Chapter 7
Configuring MOM

The execution components, MOMs, require much less configuration than does the Server. The installation process creates a basic MOM configuration file which contains the minimum entries necessary in order to run PBS jobs. This chapter describes the MOM configuration file, and explains all the options available to customize the PBS installation to your site.

7.1 MOM Config File

The behavior of each MOM is controlled via its configuration file which is read upon initialization (start-up) and upon re-initialization (on UNIX, when `pbs_mom` receives a SIGHUP signal; on Windows, by starting and restarting MOM).

When MOM is started, it will open the `mom_priv/config` file in the path specified in `pbs.conf`, if the `config` file exists. If it does not, MOM will continue anyway. The `config` file may be placed elsewhere or given a different name, by starting `pbs_mom` using the `-c` option with the new file and path specified. (See also section 10.3.1 "Manually Starting MOM" on page 212.)

The configuration file provides several types of run time information to MOM: access control, static resource names and values, external resources provided by a program to be run on request via a shell escape, and values to pass to internal functions at initialization (and re-initialization). Each entry in the configuration file should be on a separate line with the component parts separated by white space. If the line starts with a pound sign ("#"), the line is considered to be a comment and is ignored.

The installation process creates a MOM configuration file with the following entries, which are explained in detail in the subsequent sections of this chapter.

```
$clienthost server-hostname
```

7.2 MOM Configuration Parameters

Most MOM configuration parameters have a name which starts with a dollar sign ("$"). Parameters that are specific to a single operating system, such as SGI IRIX, do not start with a dollar sign "$". Those that apply to all systems are first discussed below, followed by system-specific configuration parameters.

7.2.1 Standard Configuration Parameters

Important: Under Windows, if the pathname argument to any MOM option contains a space, be sure to enclose it in quotes as in the following:

```
hostn !"\Program Files\PBS Pro\exec\bin\hostn" host
```

`$action` *`action-to-modify timeout new-action`*

If present, directs MOM to replace the default action for a particular event with a site-specified action. The current list of modifiable actions are:

checkpoint	Run the specified program *`new-action`* in place of the "periodic" job checkpoint action (after which the job continues to run). For details see section 7.6 "Site-Specific Job Checkpoint and Restart" on page 141.
checkpoint_abort	Run the specified program *`new-action`* to checkpoint the job, after which the job is to be terminated. For details see section 7.6 "Site-Specific Job Checkpoint and Restart" on page 141.

multinodebusy	When cycle harvesting multi-node jobs, change the default action when a node become busy from "allow job to run" to "requeue job". For details, see section 7.7.4 "Cycle Harvesting: Serial vs Parallel Jobs" on page 149.
restart	Run the specified program `new-action` in place of the default job restart action. For details see section 7.6 "Site-Specific Job Checkpoint and Restart" on page 141.
terminate	Run the specified program `new-action` in place of the normal SIGTERM / SIGKILL action when MOM is terminating a job. For details, see section 7.5 "Site-specific Job Termination Action" on page 140.

`$checkpoint_path`

If present, directs MOM to use the pathname following this parameter as the location into which to write checkpoint files. (See also section 10.6 "Checkpoint / Restart Under PBS" on page 224.)

```
$checkpoint_path /path/to/ckpdevice
```

`$clienthost` Causes a host name to be added to the list of hosts which will be allowed to connect to MOM. Four host names are always allowed to connect to MOM: MOM herself (i.e. "localhost" and the name returned by the system call `gethostname()`), and the Server (both primary and secondary, if configured). These names need not be specified in the configuration file. Upon startup, MOM will send a restart notice to the Server. The IP addresses of all the hosts (nodes) in the Server `nodes` file will be forwarded by the Server to the MOM on each host listed in the `nodes` file. These hosts need not be in the various MOMs' configuration file as they will be added internally when the list is received from the Server.

The hosts which are provided by the Server to MOM comprise a *sisterhood* of hosts. Any one of the sisterhood will accept connections from a Scheduler [*Resource Monitor* (RM) requests] or Server [jobs to execute] from within the sisterhood. They will also accept *Internal MOM* (IM) messages from within the sisterhood. For a sisterhood to be able to communicate IM messages to each other, they must all share the same RM port. For example, here are two lines for the configuration file which will allow the hosts "phobos" and "deimos" to connect to MOM:

```
$clienthost phobos
$clienthost deimos
```

`$cputmult` Sets a factor used to adjust cpu time used by a job. This is provided to allow adjustment of time charged and limits enforced where the job might run on systems with different cpu performance. If MOM's system is faster than the reference system, set `$cputmult` to a decimal value greater than 1.0. If MOM's system is slower, set `$cputmult` to a value between 1.0 and 0.0. The value is given by

value = speed_of_this_system / speed_of_reference_system

For example:

```
$cputmult 1.5
or
$cputmult 0.75
```

`$enforce` *`arg`* Specifies site-specific resource enforcement behavior of `mem` or `ncpus`. (For details, see section 7.8 "Job Memory Limit Enforcement on UNIX" on page 150 and section 7.9 "Job NCPUS Limit Enforcement" on page 151.) Arguments to the `enforce` parameter take the form:

```
attribute [  value]
```

and include the following:

Attribute	Type	Description
`average_cpufactor`	float	ncpus factor to allow; default: 1.025
`average_percent_over`	int	percentage over the limit to allow; default: 50
`average_trialperiod`	int	minimum walltime before enforcement; default: 120 seconds
`cpuaverage`	boolean	if present, enforce this limit; default: off

`cpuburst`	boolean	if present, enforce this limit; default: off
`complexmem`	boolean	if present, enforce this limit; default: off Applies only to IRIX
`delta_cpufactor`	float	ncpus factor to allow; default: 1.5
`delta_percent_over`	int	percentage over the limit to allow; default: 50
`delta_weightup`	float	weighting when average is moving up; default: 0.4
`delta_weightdown`	float	weighting when average is moving down; default: 0.1
`mem`	boolean	if present, enforce this limit; default: off

`$ideal_load` Declares the low water mark for load on a node. It works in conjunction with a `$max_load` parameter. When the load average on the node drops below the `ideal_load`, MOM on that node will inform the Server that the node is no longer busy.

`$kbd_idle` Enables support for "idle workstation cycle harvesting" as described later in this chapter. Details are provided on page 144.

```
$kbd_idle 1800 10 5
```

`$logevent` Sets the mask that determines which event types are logged by `pbs_mom`. Default: 511. For example:

```
$logevent 0x1ff

$logevent 255
```

The first example would set the log event mask to 0x1ff (511) which enables logging of all events including debug events. The second example would set the mask to 0x0ff (255) which enables all events except debug events. The values of events are listed in section 10.14 "Use and Maintenance of Logfiles" on page 250.

`$max_load` Declares the high water mark for load on a node. It is used in conjunction with a `$ideal_load` parameter. When the load average exceeds the high water mark, MOM on that node will notify the Server that the node is busy. The state of the node will be shown as `busy`. A busy cluster node will not be allocated to jobs. This is useful in preventing allocation of jobs to nodes which are busy with interactive sessions.

A `busy` node may still run new jobs under the direction of the Scheduler. Both the `$ideal_load` and `$max_load` parameters add a static resource, `ideal_load` and `max_load`, which may be queried by the Scheduler. These static resources are supported by the Standard scheduler when load-balancing jobs. Note that the Scheduler will attempt to predict the load on the node prior to running a job, by taking the current load, and adding the number of CPUs requested by a job being considered. If the result is greater than `max_load`, then the job will not be run. For example:

```
$ideal_load 2.0
$max_load 3.5
```

`$prologalarm` Sets the time-out period in seconds for the prologue and epilogue scripts. (See discussion of the prologue and epilogue in section 10.12 “Job Prologue / Epilogue Programs” on page 239.) An alarm is set to prevent the script from locking up the job if the script hangs or takes a very long time to execute. The default value is 30 seconds. An example:

```
$prologalarm 60
```

`$restricted` Causes a host name to be added to the list of hosts which will be allowed to connect to MOM without needing to use a privileged port. The name specification allows for wildcard matching. Connections from the specified hosts are restricted in that only internal queries may be made. Only static resources from the config file will be reported and no control requests can be issued. This is to prevent any shell commands from being run by a non-root process.

This type of entry is typically used to specify hosts on which a monitoring tool, such as `xpbsmon`, can be run. `xpbsmon` will query MOM for general resource information.

For example, here is a configuration file line which will allow queries from any host from the domain "domain.com":

```
$restricted *.domain.com
```

`$suspendsig` Specify an alternate signal to be used for suspending jobs instead of using SIGSTOP. Optionally, can be used for specifying signal for resuming jobs which is SIGCONT.

```
$suspendsig signal_number [resume_signal]
```

`$usecp` Directs MOM to use `/bin/cp` (on UNIX) or `xcopy` (on Windows) instead of `rcp` or `scp` for delivery of output files. If MOM is to move a file to a host other than her own, MOM normally uses a remote copy command (`scp` or `rcp`) to transfer the file. This applies to stage-in/out and delivery of the job's standard output/error. The destination is recorded as `hostx:/full/path/name`. So if `hostx` is not the same system on which MOM is running, she uses `scp` or `rcp`; if it is the same system, MOM uses `cp/xcopy`. (To enable `scp`, set the `PBS_SCP` parameter as described in the discussion of "pbs.conf" on page 209.)

However, if the destination file system is NFS mounted among all the systems in the PBS environment (cluster), `cp/xcopy` may work better than `scp/rcp`. One or more `$usecp` parameters in the config file can be used to inform MOM about those file systems where the `cp/xcopy` command should be used instead of `scp/rcp`. The `$usecp` entry has the form:

$usecp *hostspec*:*path_prefix new_prefix*

The *hostspec* is either a fully qualified host–domain name or a wild-carded host–domain specification as used in the Server's host ACL parameter. The *path_prefix* is the leading (root) component of the fully qualified path for the NFS files as visible on the specified host. The *new_prefix* is the initial components of the path to the same files on MOM's host. If different mount points are used, the `path_prefix` and the `new_prefix` will be different. If the same mount points are used for the cross mounted file system, then the two prefixes will be the same. When given a file destination, MOM will:

Step 1 Match the `hostspec` against her host name. If they match, MOM will use the `cp/xcopy` command to move the file. If the `hostspec` is "`localhost`" then MOM will also use `cp/xcopy`.

Step 2 If the match in step one fails, MOM will match the host portion of the destination against each `$usecp hostspec` in turn. If the host matches, MOM matches the `path_prefix` against the initial segment of the destination name. If this matches, MOM will discard the host name, replace the initial segment of the path that matched against `path_prefix` with the `new_prefix` and use `cp/xcopy` with the resulting destination.

Step 3 If the host is neither the local host nor matches any of the `$usecp` parameters, MOM will use the `scp` or `rcp` command to move the file. For example, a user named Beth on host phobos.domain.com submits a job while her current working directory is:

```
/u/wk/beth/proj
```

The destination for her output would be given by PBS as:

`phobos.domain.com:/u/wk/beth/proj/123.OU`.

The job runs on node jupiter.domain.com which has the user's home file system cross mounted as `/r/home/beth`. Either of the following entries in the config file on node jupiter will result in a `cp/xcopy`-based copy to `/r/home/beth/proj/123.OU` instead of an `rcp`-based copy to `phobos.domain.com:/u/wk/beth/proj/123.OU`

```
$usecp phobos.domain.com:/u/wk/ /r/home/

$usecp *.domain.com:/u/wk/ /r/home/
```

Note that the destination is matched against the `$usecp` entries in the order listed in the config file. The first match of host and file prefix determines the substitution. Therefore, if you have the same physical file system mounted as `/scratch` on node mars and as `/workspace` on every other host, then the entries in the config file on jupiter should be in the following order:

```
$usecp mars.domain.com:/scratch /workspace
$usecp *.domain.com:/workspace /workspace
```

`$wallmult` Sets a factor used to adjust wall time usage by a job to a common reference system. The factor limits in the same way as `$cputmult` is used for cpu time.

`$tmpdir` Specifies the top level location under which each job will have its own directory set up, where the PATH argument names a secure directory. (This top-level directory should have full write/create permissions. Under UNIX, set the mode to `1777` with ownership `root` and GID of 10 or less. Any parent directory must not be world writable and also owned by root with a GID of 10 or less) The job-specific sub-directory will be named using the jobid of the job. In addition, the job's TMPDIR environment variable will be set to the full path of this job-specific sub-directory. When the epilogue completes after job termination, the subdirectory and its contents are deleted. See also usage discussion in the **PBS Professional User's Guide**.

```
$tmpdir PATH
```

7.2.2 SGI-Specific Configuration Parameters

This section discusses parameters that are specific to SGI systems. See also section 7.10 "Enhanced SGI cpusets Support" on page 153.

Important: SGI IRIX and Altix systems have different support for cpusets. The parameters below are all supported on IRIX. However, some are not supported on Altix (for details see "SGI Altix cpuset Caveats" on page 154).

`alloc_nodes_greedy` *arg*

On cpuset-enabled SGI IRIX systems, requests to allocate nodes close together (0) or anywhere (1, the default).

`checkpoint_upgrade`

If present, causes PBS to pass a special upgrade checkpoint flag to the SGI IRIX checkpoint system for use immediately prior to an IRIX operating system upgrade. For details on use, see section 10.6.4 “Checkpointing Jobs Prior to SGI IRIX Upgrade” on page 225.

`cpuset_create_flags` *arg*

On cpuset-enabled SGI systems, specifies system defined flags used in cpuset creation. For versions of ProPack < 4, the flag names are the same used in the SGI manual page for the `cpusetCreate()` function.

```
cpuset_create_flags CPUSET_CPU_EXCLUSIVE
cpuset_create_flags CPUSET_MEMORY_EXCLUSIVE
cpuset_create_flags CPUSET_POLICY_PAGE
```

Optionally, the list of flags can be “OR’d” together on a single line, as shown in the example below (but there can be no whitespace between the OR bars, i.e. “|”s).

cpuset_create_flags CPUSET_CPU_EXCLUSIVE|CPUSET_MEMORY_EXCLUSIVE

`cpuset_destroy_delay` *seconds*

On cpuset-enabled SGI systems, specifies the number of seconds to wait before tearing down (deleting) a cpuset.

`cpuset_small_mem` *arg*

On cpuset-enabled SGI systems, disables running jobs on shared cpusets when set to “0”. Otherwise, this sets the maximum amount of memory (in kilobytes) that a small job, which shares a cpuset, can request. Default: the maximum nodeboard size in kbytes.

`cpuset_small_ncpus` *arg*

On cpuset-enabled SGI systems, disables running jobs on shared cpusets when set to “0”. Otherwise, this sets the maximum number of CPUs that a small job, which shares a cpuset, can request. Default: 1

`max_shared_nodes` *arg*

Specifies the number of nodes that should be allocated to shared jobs with cpuset-enabled SGI systems.

`memreserved` *arg*

Specifies the number of megabytes of memory to reserve on each node for system use. This will reduce the system available memory.

`pbs_accounting_workload_mgmt` If present, controls whether CSA accounting is enabled. If not present, CSA accounting defaults to enabled. If present and set to 1 or "true", CSA accounting is enabled. If present and set to 0 or "false", CSA accounting is disabled. "true" and "false" are case-insensitive.

7.3 Static Resources

While it is possible to configure static (non-changing) resources in the MOM configuration file, it is generally recommended instead to configure such resources in the Server via `qmgr` by setting a `resources_available.`*RES* entry for the node in question. This is preferred because (1) the change takes effect immediately, as opposed to having to send a HUP signal to MOM; and (2) all such static resources can be centrally managed and viewed via `qmgr`.

That being said, to specify static resource names and values in the MOM configuration file, you can add a list of resource name/value pairs, one pair per line, separated by white space. These are most often used by the alternate schedulers, but are listed here for completeness. The names can be anything and are not restricted to actual hardware. For example the entry "`pongsoft 1`" could be used to indicate to the Scheduler that a certain piece of software ("pong") is available on this system. Another example could be the number of tape drives of different types.

```
pongsoft 1
tapedat  1
tape8mm  1
```

For more information on creating site-specific resources, see Chapter 9, "Customizing PBS Resources" on page 191.

7.4 Dynamic Resources

PBS provides the ability to extend the resource query capabilities of MOM by adding shell escapes to the MOM configuration file. The primary use of this feature is to add site-specific resources, such as to manage software application licenses. For a full discussion of this capability, and examples of use, see Chapter 9, "Customizing PBS Resources" on page 191.

7.5 Site-specific Job Termination Action

The default behavior of PBS is for MOM to terminate a job when the job's usage of a resource exceeds the limit requested or when the job is deleted by the Server on shutdown or because of a `qdel` command. However, a site may specify a script (or program) to be run by `pbs_mom` in place of the normal `SIGTERM/SIGKILL` action when MOM is terminating a job under the above conditions. This action takes place on terminate from exceeding resource limits or from usage of the `qdel` command. The script is defined by adding the following parameter to MOM's config file:

```
$action terminate TIME_OUT !SCRIPT_PATH [ARGS]
```

Where *`TIME_OUT`* is the time, in seconds, allowed for the script to complete.

`SCRIPT_PATH` is the path to the script. If it is a relative path, it is evaluated relative to the `PBS_HOME/mom_priv` directory.

Important: Under Windows, *`SCRIPT_PATH`* must have a "`.bat`" suffix since it will be executed under the Windows command prompt `cmd.exe`. If the *`SCRIPT_PATH`* specifies a full path, be sure to include the drive letter so that PBS can locate the file. For example, `C:\winnt\temp\terminate.bat`. The script must be writable by no one but an Administrator-type account.

`ARGS` are optional arguments to the script. Values for *`ARGS`* may be: any string not starting with '%'; or `%keyword`, which is replaced by MOM with the corresponding value:

`%jobid`	job id
`%sid`	session id of task (job)
`%uid`	execution uid of job
`%gid`	execution gid of job
`%login`	login name associated with uid
`%owner`	job owner "name@host"
`%auxid`	aux id (system dependent content)

If the script exits with a zero exit status (before the time-out period), PBS will not send any signals or attempt to terminate the job. It is the responsibility of the termination script in this situation to ensure that the job has been terminated. If the script exits with a non-zero exit status, the job will be sent `SIGKILL` by PBS. If the script does not complete in the time-out period, it is aborted and the job is sent `SIGKILL`. A *`TIME_OUT`* value of 0 is an infinite time-out.

A UNIX example:

```
$action terminate 60 !endjob.sh %sid %uid %jobid
or
$action terminate  0 !/bin/kill -13 %sid
```

A similar Windows example:

```
$action terminate 60 !endjob.bat %sid %uid %jobid
or
$action terminate  0 !"C:/Program Files/PBS Pro/exec/bin/pbskill" %sid
```

The first line in both examples above sets a 60 second time-out value, and specifies that `PBS_HOME/mom_priv/endjob.sh` (`endjob.bat` under Windows) should be executed with the arguments of the job's session ID, user ID, and PBS jobs ID. The third line in the first (UNIX) example simply calls the system `kill` command with a specific signal (13) and the session ID of the job. The third line of the Windows example calls the PBS-provided `pbskill` command to terminate a specific job, as specified by the session id (`%sid`) indicated.

7.6 Site-Specific Job Checkpoint and Restart

The PBS Professional site-specific job checkpoint facility allows an Administrator to replace the built-in checkpoint facilities of PBS Professional with a site-defined external command. This is most useful on computer systems that do not have OS-level checkpointing. This feature is used by setting five MOM configuration parameters.

```
$action checkpoint        TIME_OUT !SCRIPT_PATH ARGS [ ...]
```

```
$action checkpoint_abort  TIME_OUT !SCRIPT_PATH ARGS [ ...]
$action restart           TIME_OUT !SCRIPT_PATH [ ARGS ...]
```

The `checkpoint` parameter specifies that the script in `SCRIPT_PATH` is run, and the job is left running. This script is called once for each of the job's tasks, and is supplied by the site. The script must take care of everything necessary to checkpoint the job and restart it.

The `checkpoint_abort` parameter specifies that the script in `SCRIPT_PATH` is run, but the job is terminated. This script is called once for each of the job's tasks, and is supplied by the site. The script must handle everything necessary to checkpoint the job and restart it.

The `restart` parameter specifies the script to be used to restart the job. This script is called once for each of the job's tasks, and is supplied by the site. When the job is restarted, it will be running on the same machine as before, with the same priority.

`TIME_OUT` is the time (in seconds) allowed for the script (or program) to complete. If the script does not complete in this period, it is aborted and handled in the same way as if it returned a failure. This does not apply if `restart_transmogrify` is "true" (see below), in which case, no time check is performed.

`SCRIPT_PATH` is the path to the script. If it is a relative path, it is evaluated relative to the `PBS_HOME/mom_priv` directory.

`ARGS` are the arguments to pass to the script. The following *`ARGS`* are expanded by PBS:

`%globid`	Global ID
`%jobid`	Job ID
`%sid`	Session ID
`%taskid`	Task ID
`%path`	File or directory name to contain checkpoint files

```
$restart_background   (true|false)
$restart_transmogrify (true|false)
```

The MOM configuration parameter `restart_background` is a boolean flag that modifies how MOM performs a restart. When the flag is "false" (the default), MOM runs the restart operation and waits for the result. When the flag is "true", restart operations are done by a child of MOM which only returns when all the restarts for all the local tasks of a job are done. The parent (main) MOM can then continue processing without being blocked by the restart.

The MOM configuration parameter `restart_transmogrify` is a boolean flag that controls how MOM launches the restart script/program. When the flag is "false" (the default) MOM will run the restart script and block until the restart operation is complete (and return success or appropriate failure). In this case the restart action must restore the original session ID for all the processes of each task or MOM will no longer be able to track the job. Furthermore, if `restart_transmogrify` is "false" and restart is being done with an external command, the configuration parameter `restart_background` will be ignored and the restart will be done as if the setting of `restart_background` was "true". This is to prevent a script that hangs from causing MOM to block. If `restart_transmogrify` is "true", MOM will run the restart script/program in such a way that the script will "become" the task it is restarting. In this case the restart action script will replace the original task's top process. MOM will replace the session ID for the task with the session ID from this new process. If a task is checkpointed, restarted and checkpointed again when `restart_transmogrify` is "true", the session ID passed to the second checkpoint action will be from the new session ID.

7.6.1 Guidelines for Creating Local Checkpoint Action

This section provides a set of guidelines the Administrator should follow when creating a site-specific job checkpoint / restart program (or script). PBS will initiate the checkpoint program/script for each running task of a job. This includes all the nodes where the job is running. The following environment variables will be set:

GID	HOME	LOGNAME	PBS_GLOBID
PBS_JOBCOOKIE	PBS_JOBID	PBS_JOBNAME	PBS_MOMPORT
PBS_NODEFILE	PBS_NODENUM	PBS_QUEUE	PBS_SID
PBS_TASKNUM	SHELL	UID	USER

The checkpoint command should expect and handle the following inputs:

Global ID
Job ID
Session ID
Task ID
Filename or Directory name to contain checkpoint files

The restart command should return success or failure error codes, and expect and handle as input a file/directory name.

Both the checkpoint and restart scripts/programs should block until the checkpoint/restart operation is complete. When the script completes, it should indicate success or failure by returning an appropriate exit code and message. To PBS, an exit value of 0 indicates success, and a non-zero return indicates failure.

Note that when the MOM configuration parameter `restart_transmogrify` is set to "false" the restart action must restore the original session ID for all the processes of each task or MOM will no longer be able to track the job. If the parameter `restart_transmogrify` is set to "true", when the restart script for a task exits, the task will be considered done, and the restart action *`TIME_OUT`* will not be used.

Note: checkpointing is not supported for job arays. On systems that support checkpointing, subjobs are not checkpointed; instead they run to completion.

7.7 Idle Workstation Cycle Harvesting

"Harvesting" of idle workstations is a method of expanding the available computing resources of your site by automatically including in your cluster unused workstations that otherwise would have sat idle. This is particularly useful for sites that have a significant number of workstations that sit on researchers' desks and are unused during the nights and weekends. With this feature, when the "owner" of the workstation isn't using it, the machine can be configured to be used to run PBS jobs. Detection of "usage" can be configured to be based upon system load average or by keystroke activity (as discussed in the following two sections below). Furthermore, cycle harvesting can be configured for all jobs, single-node jobs only, and/or with special treatment for multi-node (parallel) jobs. See section 7.7.4 "Cycle Harvesting: Serial vs Parallel Jobs" on page 149 for details.

7.7.1 Cycle Harvesting Based on Load Average

To set up cycle harvesting of idle workstations based on load average, perform the following steps:

Step 1 If PBS is not already installed on the target execution workstations, do so now, selecting the execution-only install option. (See Chapter 4 of this manual for details.)

Step 2 Edit the `PBS_HOME/mom_priv/config` configuration file on each target execution workstation, adding the two load-specific configuration parameters with values appropriate to your site.

```
$max_load 5
$ideal_load 3
```

Step 3 Edit the `PBS_HOME/sched_priv/sched_config` configuration file to direct the Scheduler to perform scheduling based on `load_balancing`.

```
load_balancing:  true   ALL
```

It is also recommend to remove the `ncpus` entry from the Scheduler `resources` parameter, in order to allow more jobs to run than there are CPUs available on the workstation:

```
resources: "mem, arch"
```

7.7.2 Cycle Harvesting Based on Keyboard/Mouse Activity

If a system is configured for keyboard/mouse-based cycle harvesting, it becomes available for batch usage by PBS if its keyboard and mouse remain unused or idle for a certain period of time. The workstation will be shown in state "free" when the status of the node is queried. If the keyboard or mouse is used, the workstation becomes unavailable for batch work and PBS will suspend any running jobs on that workstation and not attempt to schedule any additional work on that workstation. The workstation will be shown in state "busy", and any suspended jobs will be shown in state "U".

Important: Jobs on workstations that become *busy* will not be migrated; they will remain on the workstation until they complete execution, are rerun, or are deleted.

Due to different operating system support for tracking mouse and keyboard activity, the availability and method of support for cycle harvesting varies based on the computer platform in question. The following table illustrates the method and support per system.

System	Status	Method	Reference
AIX	supported	pbs_idled	See section 7.7.3.
FreeBSD	unsupported	pbs_idled	See section 7.7.3.
HP-UX 10 and 11	supported	device	See below
IRIX	supported	pbs_idled	See section 7.7.3.
Linux	supported	device	See below
Mac OS X	unsupported	pbs_idled	See section 7.7.3.
Solaris	supported	device	See below
Tru64	supported	pbs_idled	See section 7.7.3.
Windows XP Pro	supported	other	See below
Windows 2003 Server	supported	other	See below
Windows 2000 Pro	supported	other	See below
Windows 2000 Server	supported	other	See below

The cycle harvesting feature is enabled via a single entry in `pbs_mom`'s `config` file, `$kbd_idle`, and takes up to three parameters, as shown below.

```
$kbd_idle idle_available [ idle_busy [ idle_poll ] ]
```

These three parameters, representing time specified in seconds, control the transitions between *free* and *busy* states. Definitions follow.

`idle_available`	time (in seconds) that the workstation keyboard and mouse must be idle before the workstation becomes available to PBS.
`idle_busy`	time period during which the keyboard or mouse must remain busy before the workstation "stays" unavailable. This is used to keep a single key stroke or mouse movement from keeping the workstation busy.
`idle_poll`	frequency of checking the state of the keyboard and mouse.

Let us consider the following example.

```
$kbd_idle 1800 10 5
```

Adding the above line to MOM's `config` file directs PBS to mark the workstation as *free* if the keyboard and mouse are idle for 30 minutes (1800 seconds), to mark the workstation as *busy* if the keyboard or mouse are used for 10 consecutive seconds, and the state of the keyboard/mouse is to be checked every 5 seconds.

The default value of *idle_busy* is 10 seconds, the default for *idle_poll* is 1 second. There is no default for *idle_available*; setting it to non-zero is required to activate the cycle harvesting feature.

Elaborating on the above example will help clarify the role of the various times. Let's start with a workstation that has been in use for some time by its owner. The workstation is shown in state *busy*. Now the owner goes to lunch. After 1800 seconds (30 minutes), the system will change state to *free* and PBS may start assigning jobs to run on the system. At some point after the workstation has become *free* and a job is started on it, someone walks by and moves the mouse or enters a command. Within the next 5 seconds (idle poll period), `pbs_mom` notes the activity. The job is suspended and shown being in state "U" and the workstation is marked *busy*. If, after 10 seconds have passed and there is no additional keyboard/mouse activity, the job is resumed and the workstation again is shown as *free*. However, if keyboard/mouse activity continued during that 10 seconds, then the workstation would remain *busy* and the job would remain suspended for at least the next 1800 seconds.

7.7.3 Cycle Harvesting on Machines with X-Windows

On some systems cycle harvesting is simple to implement as the console, keyboard, and mouse device access times are updated by the operating system periodically. The PBS MOM process takes note of that and marks the node busy if any of the input devices are in use. On other systems, however, this data is not available. (See table in section 7.7.2 above.) In such cases, PBS must monitor the X-Window System in order to obtain interactive idle time. To support this, there is a PBS X-Windows monitoring process called `pbs_idled`. This program runs in the background and monitors X and reports to the `pbs_mom` whether the node is idle or not.

Because of X-Windows security, running `pbs_idled` requires more modification than just installing PBS. First, a directory must be made for `pbs_idled`. This directory must have the same permissions as `/tmp` (i.e. mode 1777). This will allow the `pbs_idled` to create and update files as the user, which is necessary because the program will be running as the user. For example:

```
on Linux:
mkdir /var/spool/PBS/spool/idledir
chmod 1777 /var/spool/PBS/spool/idledir

on UNIX:
mkdir /usr/spool/PBS/spool/idledir
chmod 1777 /usr/spool/PBS/spool/idledir
```

Next, turn on keyboard idle detection in the MOM `config` file:

```
$kbd_idle 300
```

Lastly, `pbs_idled` needs to be started as part of the X-Windows startup sequence. The best and most secure method of installing `pbs_idled` is to insert it into the system wide `Xsession` file. This is the script which is run by `xdm` (the X login program) and sets up each user's X-Windows environment. The startup line for `pbs_idled` must be before the that of the window manager. It is also very important that `pbs_idled` is run in the background. On systems that use `Xsession` to start desktop sessions, a line invoking `pbs_idled` should be inserted near the top of the file. `pbs_idled` is located in `$PBS_EXEC/sbin`. For example, the following line should be inserted in a Linux `Xsession` file:

```
/usr/pbs/sbin/pbs_idled &
```

Important: On a Tru64 system running CDE, inserting `pbs_idled` into an Xsession file will *not* result in the executable starting. Rather, it needs to be added to the `dtsession_res` file. which typically has the following path:

```
/usr/dt/bin/dtsession_res
```

Note that if access to the system-wide `Xsession` file is not available, `pbs_idled` may be added to every user's personal `.xsession, .xinitrc, or .sgisession` file (depending on the local OS requirements for starting X-windows programs upon login).

Important: OS-X does not run X-Windows as its primary windowing system, and therefore does not support cycle harvesting.

7.7.4 Cycle Harvesting: Serial vs Parallel Jobs

Given local usage policy constraints, and the possible performance impact of running certain applications on desktop systems, a site may need to limit the usage of cycle harvesting to a subset of jobs. The most common restriction is on the use of multi-node jobs.

A site may wish to enable cycle harvesting, but only for single-node jobs. If this is the case, the `no_multinode_jobs` parameter can be set. For details, see the entry for `no_multinode_jobs` entry on page 98.

When a job is running on a workstation configured for cycle harvesting, and that node becomes "busy", the job is suspended. However, suspending a multi-node parallel job may have undesirable side effects because of the inter-process communications. Thus the default action for a job which uses multiple nodes when one or more of the nodes becomes busy, is to leave the job running.

It is possible, however, to specify that the job should be requeued (and subsequently rescheduled to run elsewhere) when any of the nodes on which the job is running becomes *busy*. To enable this action, the Administrator must add the following parameter to MOM's configuration file:

```
$action multinodebusy 0 requeue
```

where `multinodebusy` is the action to modify; "`0`" (zero) is the action time out value (it is ignored for this action); and `requeue` is the new action to perform.

Important: Jobs which are not rerunnable (i.e. those submitted with the `qsub -rn` option) will be killed if the requeue action is configured and a node becomes busy.

7.7.5 Cycle Harvesting and File Transfers

The cycle harvesting feature interacts with file transfers in one of two different ways, depending on the method of file transfer. If the user's job includes file transfer commands (such as `rcp` or `scp`)within the job script, and such a command is running when PBS decides to suspend the job on the node, then the file transfer will be suspended as well.

However, if the job has PBS file staging parameters (i.e. `stageout=file1`...), the file transfer will not be suspended. This is because the file staging occurs as part of the post-execution (or "`Exiting` state, after the `epilogue` is run), and is not subject to suspension. (For more information on PBS file staging, see the **PBS Professional User's Guide**.)

7.8 Job Memory Limit Enforcement on UNIX

Enforcement of the `mem` (physical memory) resource usage is available on all UNIX platforms, but not Windows. Enforcement is configurable by the `$enforce` entry in MOM's `config` file (see "$enforce arg" on page 132). By default, enforcement is off. If a `$enforce mem` statement appears in the `config` file, then jobs that exceed their specified amount of physical memory will be killed. The "mem" resource can be enforced at both the job level and the node level. The job level will be the smaller of a job-wide resource request and the sum of that for all chunks. The node level is the sum for all chunks on that node.

Important: "mem" enforcement is polled, therefore a job may exceed its limit for up to two minutes before it is detected.

7.8.1 SUN Solaris-specific Memory Enforcement

If a job is submitted with a `pmem` limit or without `pmem` and with a `mem` limit, PBS uses the `setrlimit`(2) call to set the limit. For most Operating Systems, `setrlimit`() is called with `RLIMIT_RSS` which limits the Resident Set (working set size). This is not a hard limit, but advice to the kernel. This process becomes a prime candidate to have memory pages reclaimed. Solaris does not support `RLIMIT_RSS`, but instead has `RLIMIT_DATA` and `RLIMIT_STACK`, which are hard limits. Therefore, under Solaris, a `malloc`() call that exceeds the limit will return `NULL`. This behavior is different than under other operating systems and may result in the program (such as a user's application) receiving a `SIGSEGV` signal.

7.8.2 SGI IRIX Non-cpuset Memory Enforcement

Under IRIX 6.5.x, there are two ways to determine the amount of real memory a set of processes are using. The "simple" way, as used by the `ps`(1) command, looks solely at the `pr_rssize` field of the `/proc/pinfo/` entry for each process. The "complex" method uses special SGI calls to determine the "shared" state of each memory segment in each process. This IRIX capability is not available on SGI Altix systems.

The "simple" method is quick and clean. However, this method does not factor in shared memory segments, so the resulting usage figure for processes that are started by the `sproc`(2) call is too high. The shared segments are counted fully against each process. This "apparent" over usage can result in under loading of the physical memory in the system.

The "complex" method correctly factors in the shared memory segments and yields a more accurate report on the amount of physical memory used. However, the SGI `ioctl(PIOCMAP_SGI)` call requires that the kernel look at each memory segment. This can result in the calling program, `pbs_mom`, being blocked for an extended period of time on larger systems. Systems smaller than 32 CPUs are not likely to see a problem.

By default, the "simple" option is enabled. With the addition of a `$enforce complexmem` statement in MOM's `config` file, the "complex" memory usage calculation is selected.

Important: If the "complex" method is selected, the Administrator needs to monitor the MOM logs for a warning of the form "time lag N secs" where N is a number of seconds greater than five. If this message appear frequently, it means the IRIX kernel is taking that long to respond to the `ioctl` call and the performance of `pbs_mom` may suffer. In that case, it is recommended that the site revert to the "simple" calculation or run the cpuset version of MOM.

7.9 Job NCPUS Limit Enforcement

Enforcement of the `ncpus` (number of CPUs used) is now available on all platforms. Enforcement is configurable by a set of entries in MOM's `config` file. (See description of `$enforce` on page 132.) By default, enforcement is off since it has not been enforced in the past.

Associated with this enforcement is the read-only resource `cpupercent`. This is a report of the average percentage usage of one CPU. For example, a value of 50 means that during a certain period, the job used 50 percent of one CPU. A value of 300 means over the period, the job used an average of three CPUs. Enforcement is based on two separate checks. The first check is based on the polled sum of CPU time for all processes in the job. Each poll period, the total CPU time used times 100, divided by the total walltime, is checked against the value specified for `ncpus` * 100. If this "average" value exceeds the number of CPUs requested and if the `cpuaverage` enforcement is turned on, the job is aborted. The second check during each poll period looks for sudden bursts of CPU activity. `cpupercent` is a moving weighted average based on the prior `cpupercent` and the amount of new CPU time used divided by the walltime for this period. This value can be weighted to ignore or punish sudden bursts of CPU activity. This enforcement is available if `cpuburst` is set in MOM's `config` file.

The following parameters, set via a `$enforce` statement in the `config` file, control the enforcement, weighting, and allowed overrun. (Types and description of each are given in the discussion of "$enforce arg" on page 132 above.)

For the absolute CPU time / walltime calculation, the following `enforce` arguments are used: `cpuaverage`, `average_trialperiod`, `average_percent_over`, `average_cpufactor`. Given the default values, a job will be killed if:

(cput / walltime) > (ncpus * average_cpufactor + average_percent_over / 100)

This enforcement only occurs after the job has had `average_trialperiod` seconds of walltime. For the weighted moving average, the following `enforce` arguments are used: `cpuburst`, `delta_percent_over`, `delta_cpufactor`, `delta_weightup`, `delta_weightdown`. The read-only `cpupercent` value is determined by weighing the new cput/walltime for the last measurement period and the old `cpupercent`:

new_percent = change_in_cpu_time / change_in_walltime
weight = delta_weight[up|down] * walltime/max_poll_period
new_cpupercent = (new_percent * weight) + (old_cpupercent * (1-weight))

`delta_weight_up` is used if the `new_percent` is higher than the old `cpupercent` value and `delta_weight_down` is used if `new_percent` is lower than the old value. If `delta_weight_`[up|down] is 0.0, then the value for `cpupercent` will not change with time. If it is 1.0, `cpupercent` will become the `new_percent` for the poll period; that means `cpupercent` changes quickly. (`max_poll_period` is the maximum time between samples, set to 120 seconds.) The job will be killed if

new_cpupercent > ((ncpus * 100 * delta_cpufactor) + delta_percent_over)

The following entries in MOM’s `config` file would turn on enforcement of both average and burst with the default values:

```
$enforce cpuaverage
$enforce cpuburst
$enforce delta_percent_over 50
$enforce delta_cpufactor 1.05
$enforce delta_weightup 0.4
$enforce delta_weightdown 0.1
$enforce average_percent_over 50
$enforce average_cpufactor 1.025
$enforce average_trialperiod 120
```

7.10 Enhanced SGI cpusets Support

PBS Professional includes enhancements for running PBS in conjunction with SGI cpusets. (An SGI cpuset is a named region of an SGI Origin or Altix system composed of one or more nodeboards, and associated memory and CPUs.) This section discusses these features in conjunction with previous versions’ support for cpusets.

Important: SGI cpuset support on Altix systems requires the SGI ProPack library. For details, see section 3.3.3 on page 18.

Important: Because cpusets cannot span systems, they can not be used by multi-node jobs.

Important: The PBS Professional MOM binary for SGI’s ProPack 2.4, 3.0 and 4.0 is pbs_mom.cpuset.

7.10.1 SGI IRIX cpuset Caveats

Users of irix6cpuset MOMs running under OS version 6.5.21 need to override the cpuset creation flags default by defining explicitly a flags set that doesn't contain `CPUSET_EVENT_NOTIFY`. This flag confuses the cpuset creation process. For example, the following can be added to MOM's config file (all on one line, without the “\”s):

```
cpuset_create_flags CPUSET_CPU_EXCLUSIVE|\
CPUSET_POLICY_KILL|CPUSET_MEMORY_LOCAL|\
CPUSET_MEMORY_EXCLUSIVE|\
CPUSET_MEMORY_MANDATORY|\
```

7.10.2 SGI Altix cpuset Caveats

The SGI Altix machine is supported with and without cpusets. The interface is similar to what is used for IRIX cpuset machines. The known differences follow:

The `alt_id` returned by MOM has the form `cpuset=name` where the cpuset name follows the equal sign. There is no walltime associated with a shared cpuset. Once the last job using a shared cpuset exits (or is suspended), the shared cpuset is cleared. There are fewer flags that can be specified in the `cpuset_create_flags` MOM configuration parameter. For ProPack4, the choice is either don't set the flag, or set it to 0. The available flags are shown below; those marked with * are on by default:

```
*   CPUSET_CPU_EXCLUSIVE
*   CPUSET_MEMORY_LOCAL
*   CPUSET_MEMORY_EXCLUSIVE
    CPUSET_MEMORY_KERNEL_AVOID
*   CPUSET_MEMORY_MANDATORY
    CPUSET_POLICY_PAGE
*   CPUSET_POLICY_KILL
*   CPUSET_EVENT_NOTIFY
```

The missing flag is:

```
CPUSET_KERN
```

For ProPack 4, only CPUSET_CPU_EXCLUSIVE is used.

Several IRIX cpuset-specific MOM configuration parameters are not available. The parameters that are available are:

```
cpuset_create_flags
cpuset_destroy_delay
cpuset_small_ncpus
cpuset_small_mem
max_shared_nodes
memreserved
```

The "small cpuset" functionality is on by default and requires a job have both ncpus and mem set so the MOM can decide if it will fit into a small cpuset.

7.10.3 SGI Altix and Origin Caveats

On SGI Altix and Origin systems running with cpusets, array jobs whose ncpus and mem resource requirements would exceed the shared cpuset size will fail unless the user specifies an exact multiple of node boards for the number of cpus (ncpus) and memory (mem) requested for each subjob in the array.

To prevent the adverse effects caused by such "large" subjobs, the administrator should use a combination of the following: queue restrictions on the number of ncpus, amount of mem requested by an array job, and whether array jobs themselves can be enqueued.

For example, to establish one queue for array jobs: set the `resources_max.ncpus` and `resources_max.mem` on the queue to the maximum size of a job that uses a shared cpuset, and set on the queue the maximum number of subjobs allowed in an array job to your site's limit. Set `max_array_size` on the queue to a non-zero, positive number.

For other queues, intended to accept normal (non array) jobs with larger ncpus and memory requirements, set `max_array_size` on the queue to zero.

The attribute `max_array_size` may be set on any queue to restrict the size of an array job that can be enqueued into that queue. The value of `max_array_size` specifies the maximum number of subjobs allowed within an acceptable array job.

If `max_array_size` is set to one or less, array jobs cannot be enqueued into that queue.

7.10.4 IRIX OS-Level Checkpoint With cpusets

MOM supports use of new IRIX checkpointing features to allow the checkpointing and restart of jobs running within SGI cpusets. This requires SGI IRIX version 6.5.16 or later.

7.10.5 SGI Shared cpusets for Small Jobs

MOM supports two classes of jobs running within cpusets: a *small* job and a *normal* job. The small job, which is usually a single CPU job with memory requirements such that it will fit on a single nodeboard, will allow itself to be run within a cpuset where other similar jobs run. Normal jobs are those that require more resources than are available on a single nodeboard or which need to run exclusively within a cpuset for repeatability of performance. The small job runs on a shared cpuset whereas the normal job runs on an exclusive cpuset. Up to `max_shared_nodes` (set in MOM's `config` file) will be allowed to be assigned to shared cpusets. To find out which cpuset is assigned to a running job, the `alt_id` job attribute has a field called `cpuset` that will show this information. Note that shared cpusets can be more than one nodeboard.

Important: The SGI Altix system has shared cpuset support enabled by default. It is recommended, therefore to set the Server configuration parameters `resources_default.mem`, and `resources_default.ncpus`.

To set a threshold as to the number of nodeboards that can be assigned to shared cpusets, set the following in MOM's `config` file (see also section 7.2.2 "SGI-Specific Configuration Parameters" on page 137):

```
max_shared_nodes #-of-nodeboards
```

To define the maximum number of CPUs and amount of memory (in kb) that a job can request and still be considered a small job, specify those amounts using the following parameters in MOM's config file:

```
cpuset_small_ncpus 3
cpuset_small_mem 1024
```

If you do not want MOM to run small jobs within a shared cpuset, set the following in MOM's config file:

```
cpuset_small_ncpus 0
cpuset_small_mem 0
```

7.10.6 MOM cpuset Configuration Options

In order to make MOM `config` file options consistent, the format of `cpuset_create_flags` for specifying the flags to pass to `cpusetCreate()` is changed from

```
    $cpuset_create_flags <flags>
```

to

```
    cpuset_create_flags <flags>
```

Similarly, the format for `cpuset_destroy_delay` for setting the number of seconds to sleep before tearing down (deleting) a cpuset is changed from

```
    $cpuset_destroy_delay <secs>
```

to

```
    cpuset_destroy_delay <secs>
```

In addition, a new option is available for IRIX only:

```
    alloc_nodes_greedy <0 or 1>
```

If set to 0, for job requests of 64 or fewer nodeboards, MOM will only allocate eligible nodes that are within one router hop in the hypercube architecture, that is, those nodes that are physically sitting close to each other. Otherwise if set to 1, MOM will allocate nodes from all those available regardless of the distance (number of router hops) between them. This latter case is the default behavior.

Important: Upon startup, MOM will not use or remove any cpusets that it did not create. The nodes in these cpusets will be removed from MOM's available nodepool.

7.10.7 Enhanced cpuset Resource Reporting

MOM will report to the Server the actual number of CPUs and memory that are under the control of PBS. This allows the node's `resources_available.{ncpus,mem}` to reflect the amount of resources that come from nodeboards that are not part of the reserved and system cpusets (e.g. `boot`); (and on IRIX systems, stuck cpusets). Be sure to `unset` any manual settings of `resources_available.{ncpus,mem}` in both the node and the Server to get this count automatically updated by MOM. Manual settings (i.e. those either put in the server's `nodes` file or via the `qmgr set node` construct) take precedence. If manually setting the server's `resources_available.ncpus` parameter, be sure to use a value that is a multiple of the nodeboard size. This value should not be less than one nodeboard size, otherwise no jobs (including shareable jobs) will run. For example, if there are four cpus per nodeboard, don't set `resources_available.ncpus=3`, instead set `resources_available.ncpus=4` (8, 12, 16, and so on).

7.10.8 CPU 0 Allocation with cpusets

Some special node and CPU allocation rules are enforced by MOM on cpuset enabled systems. If `cpuset_create_flags` set during `cpusetCreate()` contains a flag for `CPUSET_CPU_EXCLUSIVE` then CPU 0 will not be allowed to be part of a cpuset. This is the default setting. (On an IRIX system, nodeboard 0 will only be allocated if no other nodeboards are available to satisfy the request. For Altix default settings, see section 7.10.2 “SGI Altix cpuset Caveats” on page 154.) Use of nodeboard 0 for jobs can be a source of performance degradation as the kernel heavily uses this node for system daemons. Usually, PBS with cpusets is used in conjunction with a boot cpuset which the system administrator creates which includes nodeboard 0. To use the default setting for `cpuset_create_flags` except that CPU 0 is to be used by PBS, the following can be added to MOM's config file (all on one line, without the “\”s):

```
cpuset_create_flags CPUSET_MEMORY_LOCAL|\
CPUSET_MEMORY_MANDATORY|\
CPUSET_MEMORY_EXCLUSIVE|\
CPUSET_POLICY_KILL|CPUSET_EVENT_NOTIFY
```

For ProPack4, **`cpuset_create_flags`** should be set to 0:

```
cpuset_create_flags 0
```

Note: The ProPack4 cpuset-enabled mom, if asked to allocate a set for a job whose requirements exceed a single node board, may allocate CPUs and memory from node boards that are not necessarily adjacent.

7.10.9Troubleshooting ProPack4 cpusets

The ProPack4 cpuset-enabled mom may occasionally encounter errors during startup from which it cannot recover without help. If pbs_mom was started without the -p flag, one may see

```
"/PBSPro hierarchy cleanup failed in <dir> -
   restart pbs_mom with '-p'"
```

where <dir> is one of /PBSPro, /PBSPro/shared, or /PBSPro/suspended. If this occurs, try restarting pbs_mom with the -p flag. If this succeeds, no further action will be necessary to fix this problem. However, it is possible that if pbs_mom is started with the -p flag, one may then see any of these messages:

```
"cpuset_query for / failed - manual intervention
   is needed"
"/PBSPro query failed - manual intervention is needed"
"/PBSPro cpuset_getmems failed - manual intervention
   is needed"
```

In this case, there is likely to be something wrong with the PBSPro cpuset hierarchy. First, use the `cpuset(1)` utility to test it:

```
# cpuset -s /PBSPro -r | while read set
    do
       cpuset -d $set > /dev/null
    done
```

If cpuset detects no problems, no output is expected. If a problem is seen, expect output of the form

```
cpuset </badset> query failed
/badset: Unknown error
```

In this case, try to remove the offending cpuset by hand, using the cpuset(1) utility,

```
# cpuset -x badset
cpuset <badset> removed.
```

This may fail because the named cpuset contains other cpusets, because tasks are still running attached to the named set, or other unanticipated reasons. If the set has subsets,

```
# cpuset -x nonempty
cpuset <nonempty> remove failed
/nonempty: Device or resource busy
```

first remove any CPU sets it contains:

```
# cpuset -s nonempty -r
/nonempty
/nonempty/subset
...

# cpuset -s nonempty -r | tac | while read set
   do
       cpuset -x $set
   done
...
cpuset </nonempty/subset> removed.
cpuset </nonempty> removed.
```

Note that output is previous output, reversed.

If the set has processes that are still attached,

```
# cpuset -x busy
cpuset <busy> remove failed
/busy: Device or resource busy
```

one can choose to either kill off the processes,

```
# kill `cpuset -p busy`
# cpuset -x busy
cpuset <busy> removed.
```

or wait for them to exit. In the latter case, be sure to restart pbs_mom using the -p flag to prevent it from terminating the running processes.

Finally, note that if removing a cpuset with cpuset -x should fail, one may also try to remove it with rmdir(1), provided one takes care to prepend the cpuset file system mount point first. For example,

```
# mount | egrep cpuset
cpuset on /dev/cpuset type cpuset (rw)
# find /dev/cpuset/nonempty -type d -print |
     tac | while read set
   do
      rmdir $set
   done
```

7.11 Configuring MOM for Comprehensive System Accounting

7.11.1 Requirements for CSA

CSA can be used on SGI Altix machines running SGI's ProPack 2.4 or greater, and having library (not system) call interfaces to the kernel's job container and CSA facilities. Both the Linux job container facility and CSA support must either be built into the kernel or available as loadable modules.

For information on getting Linux job container software configured and functioning, go to http://www.ciemat.es/informatica/gsc/perfdoc/007-4413-003/sgi_html/index.html and see "Linux Resource Administration Guide", subsection "Linux Kernel Jobs".

See the Release Notes for information on which versions of ProPack provide support for CSA with PBS.

If CSA is enabled, the PBS user can request the kernel to write user job accounting data to accounting records. These records can then be used to produce reports for the user. If workload management is enabled, the kernel will write workload management accounting records associated with the PBS job to the system-wide process accounting file. The default for this file is /var/csa/day/pacct.

There are two pbs_mom daemons for the Altix, one for cpusets and the standard daemon. The downloadable PBS binary for the Altix is built so that if job container and CSA facilities are available in the kernel, then both CSA user job accounting and CSA workload management accounting are available in either of the pbs_mom daemons.

In order for CSA user job accounting and workload management accounting requests to be acted on by the kernel, the administrator needs to make sure that the parameters CSA_START and WKMG_START in the /etc/csa.conf configuration file are set to "on" and that the system reflects this. You can check this by running the command:

```
csaswitch -c status
```

To set CSA_START to "on", use the command:

```
csaswitch -c on -n csa
```

To set WKMG_START to "on", use:

```
csaswitch -c on -n wkmg
```

Alternatively, you can use the CSA startup script /etc/init.d/csa with the desired argument (on/off) - see the system's manpage for csaswitch and how it is used in the /etc/init.d/csa startup script.

7.11.2 Configuration for CSA

If MOM is configured for CSA support, MOM can issue CSA workload management record requests to the kernel. To configure MOM for CSA support, modify $PBS_HOME/mom_priv/config, by adding a line for the parameter `pbs_accounting_workload_mgmt`. Set this parameter to "on"/"true"/"1" to enable CSA support, and “off”/”false”/”0” to disable it. If the parameter is absent, CSA support is enabled by default.

After modifying the MOM config file, either restart pbs_mom or send it SIGHUP.

For information on using CSA, see “Using Comprehesive System Accounting on SGI Altix Machines” on page 126 of the **PBS Professional User’s Guide**.

For information on SGI Job Containers, see “SGI Job Container / Limits Support” on page 239.

7.12 MOM Globus Configuration

For the optional Globus MOM, the same configuration mechanism applies as with the regular MOM except only three initiation value parameters are applicable: `$clienthost`, `$restricted`, `$logevent`. For details, see the description of these configuration parameters earlier in this chapter.

7.13 Examples

Examples of different MOM configurations are included in Chapter 12 “Example Configurations” on page 285.

Chapter 8
Configuring the Scheduler

Now that the Server and MOMs have been configured, we turn our attention to the Scheduler. As mentioned previously, the Scheduler is responsible for implementing the local site policy by which jobs are run, and on what resources. This chapter discusses the default configuration created in the installation process, and describes the full list of tunable parameters available for the PBS Standard Scheduler.

8.1 Default Configuration

This Standard Scheduler provides a wide range of scheduling policies. It provides the ability to sort the jobs in several different ways, in addition to FIFO order, such as on user and group priority, fairshare, and preemption. As distributed, it is configured with the following options (which are described in detail below).

1. Specific system resources are checked to make sure they are available: `mem` (memory requested), `ncpus` (number of CPUs requested), `arch` (architecture requested), **`host`**, and **`software`**.

2. Queues are sorted into descending order by queue `priority` attribute to determine the order in which their jobs are to be considered. Jobs in the highest priority queue will be considered for execution before jobs from the next highest priority queue.

3. Jobs within queues of priority 150 or higher will preempt jobs in lower priority queues.

4. The jobs within each queue are sorted into ascending order by requested CPU time (`cput`). The shortest job is placed first.

5. Jobs which have been queued for more than one day will be considered *starving* and extra measures will be taken to attempt to run them.

6. Any queue whose name starts with "`ded`" is treated as a dedicated time queue (see discussion below). Sample dedicated time file (*`PBS_HOME`*`/sched_priv/dedicated_time`) is included in the installation.

7. Prime time is set to 6:00 AM - 5:30 PM. Any holiday is considered non-prime. Standard U.S. Federal holidays for the year 2005 are provided in the file *`PBS_HOME`*`/sched_priv/holidays`. These dates should be adjusted yearly to reflect your local holidays.

8. In addition, the Scheduler utilizes the following parameters and resources in making scheduling decisions:

Object	**Attribute/Resource**	**Comparison**
server, queue & node	`resources_available`	>= resources requested by job
server, queue & node	`max_running`	>= number of jobs running
server, queue & node	`max_user_run`	>= number of jobs running for a user
server, queue & node	`max_group_run`	>= number of jobs running for a group

Object	Attribute/Resource	Comparison
server & queue	`max_group_res`	>= usage of specified resource by group
server & queue	`max_user_res`	>= usage of specified resource by user
server & queue	`max_user_res_soft`	>= usage of specified resource by user (see "Hard versus Soft Limits" on page 76) Not enabled by default.
server & queue	`max_user_run_soft`	>= maximum running jobs for a user (see "Hard versus Soft Limits" on page 76) Not enabled by default.
server & queue	`max_group_res_soft`	>= usage of specified resource by group (see "Hard versus Soft Limits" on page 76) Not enabled by default.
server & queue	`max_group_run_soft`	>= maximum running jobs for a group (see "Hard versus Soft Limits" on page 76) Not enabled by default.
queue	`started`	= true
queue	`queue_type`	= execution
job	`job_state`	= queued / suspended
node	`loadave`	< configured limit (default: not enabled)
node	`arch`	= type requested by job
node	`host`	= name requested by job

8.2 Scheduler Features

8.2.1 Preemption Ordering Change

This new feature provides a way to order jobs selected for preemption. When set, jobs with the most recent start time are chosen, instead of the default oldest start time. This feature uses the new scheduler option:

`preempt_sort`.

8.2.2 Option to Make anytime Queues Unaffected by backfill_prime

The new scheduler option, `prime_exempt_anytime_queues`, allows the administrator to exempt anytime queues from limits imposed by `backfill_prime`. See "prime_exempt_anytime_queues" on page 173.

8.3 Scheduler Configuration Parameters

To tune the behavior of the Standard Scheduler, change directory to *`PBS_HOME`*`/sched_priv` and edit the scheduling policy configuration file `sched_config`. This file controls the scheduling policy (the order in which jobs run). The format of the `sched_config` file is:

```
name: value [ prime | non_prime | all | none]
```

`name` cannot contain any whitespace, but *`value`* may if the string is double-quoted. *`value`* can be: true | false | number | string. Any line starting with a "#" is a comment, and is ignored. The third field allows you to specify that the setting is to apply during primetime, non-prime-time, or all the time. A blank third field is equivalent to "`all`" which is both prime- and non-primetime. Note that the *value* and *all* are case-sensitive, but common cases are accepted, e.g. "`TRUE`", "`True`", and "`true`".

Important: Note that some Scheduler parameters have been deprecated, either due to new features replacing the old functionality, or due to automatic detection and configuration. Such deprecated parameters are no longer supported, and should ***not*** be used as they may cause conflicts with other parameters.

The available options for the Standard Scheduler, and the default values, are as follows.

`assign_ssinodes`
Deprecated. Such configuration now occurs automatically.

`backfill` boolean. If this is set to "True", the scheduler will attempt to schedule smaller jobs around starving jobs, as long as running the smaller jobs won't change the start time of the starving jobs. The scheduler chooses jobs in the standard order, so other starv-

ing jobs will be considered first in the set to fit around the most starving job. It only has an effect if the paramenter "`help_starving_jobs`" is true. If backfill is "False", the scheduler will idle the system to run starving jobs.
Default: `true all`

`backfill_prime`

boolean: Directs the Scheduler not to run jobs which will overlap the boundary between primetime and non-primetime. This assures that jobs restricted to running in either primetime or non-primetime can start as soon as the time boundary happens. See also `prime_spill`, prime_exempt_anytime_queues.
Default: `false all`

`by_queue` boolean: If `true`, the jobs will be run queue by queue; if `false`, and `round_robin` is enabled, then `round_robin` is enforced, otherwise the entire job pool in the Server is looked at as one large queue. See also `round_robin`.
Default: `true all`

`cpus_per_ssinode`

Deprecated. Such configuration now occurs automatically.

`dedicated_prefix`

string: Queue names with this prefix will be treated as dedicated queues, meaning jobs in that queue will only be considered for execution if the system is in dedicated time as specified in the configuration file *PBS_HOME*`/sched_priv/dedicated_time`. See also section 8.6 "Defining Dedicated Time" on page 176.
Default: `ded`

`fair_share` boolean: This will enable the fairshare algorithm. It will also turn on usage collecting and jobs will be selected based on a function of their recent usage and priority (shares). See also section 8.11 "Using Fairshare" on page 181.
Default: `false all`

`fairshare_entity`

string: Specifies the job attribute to use as the "entity" for which fairshare usage data will be collected. (Can be any valid PBS job attribute, such as "euser", "egroup", "Account_Name", or "queue".)
Default: `euser`

`fairshare_enforce_no_shares`

boolean: If this option is enabled, jobs whose entity has zero shares will never run. Requires `fair_share` to be enabled.
Default: `false`

`fairshare_usage_res`
string: Specifies the resource to collect and use in fairshare calculations and can be any valid PBS resource, including user-defined resources. See also section 8.11.4 “Tracking Resource Usage” on page 184. A special case resource is the exact string “ncpus*walltime”. The number of cpus used is multiplied by the walltime used by the job to determine the usage.
Default: “`cput`”.

`half_life`
time: The half life for fairshare usage; after the amount of time specified, the fairshare usage will be halved. Requires that `fair_share` be enabled. See also section 8.11 “Using Fairshare” on page 181.
Default: `24:00:00`

`help_starving_jobs`
boolean: Setting this option will enable starving jobs support. Once jobs have waited for the amount of time given by `max_starve` they are considered starving. If a job is considered starving, then no jobs will run until the starving job can be run, unless backfilling is also specified. To use this option, the `max_starve` configuration parameter needs to be set as well. See also `backfill, max_starve`.
Default: `true all`

`job_sort_key`
string: Selects how the jobs should be sorted. (Replaced `sort_by` from previous versions of PBS Professional.) `job_sort_key` can be used to sort by either resources or by special case sorting routines. Multiple `job_sort_key` entries can be used, in which case the first entry will be the primary sort key, the second will be used to sort equivalent items from the first sort, etc. The `HIGH` option implies descending sorting, `LOW` implies ascending. See example for details.
Syntax: `job_sort_key: “PBS_resource HIGH|LOW”`
Default: “`cput low`”

There are three special case sorting routines, that can be used instead of a specific PBS resource:

Special Sort	Description
`fair_share_perc HIGH`	Sort based on the values in the resource group file. This should only used if strict priority sorting is needed. **Do not enable `fair_share_perc` sorting if using the `fair_share` scheduling option.** (This option was previously named "`fair_share`" in the deprecated `sort_by` parameter). See also section 8.12 "Enabling Strict Priority" on page 187
`preempt_priority HIGH`	Sort jobs by preemption priority. Recommended that this be used when soft user limits are used. Also recommended that this be the primary sort key.
`sort_priority HIGH|LOW`	Sort jobs by the job `priority` attribute regardless of job owner. (The `priority` attribute can be set during job submission via the "`-p`" option to the `qsub` command, as discussed in the **PBS Professional User's Guide**.)

The following example illustrates using resources as a sorting parameter. Note that for each, you need to specify HIGH (descending) or LOW (ascending). Also, note that *resources* must be a quoted string.

```
job_sort_key: "ncpus HIGH" all
job_sort_key: "mem LOW" prime
```

`key` Deprecated. Use `job_sort_key`.

`load_balancing`

boolean: If set, the Scheduler will balance the computational load of single-node jobs across a cluster. The load balancing takes into consideration the load on each node as well as all resources specified in the "resource" list. See `smp_cluster_dist`, and section 8.9 "Enabling Load Balancing" on page 179.
Default: `false all`

`load_balancing_rr`

Deprecated. To duplicate this setting, enable `load_balancing` and set `smp_cluster_dist` to `round_robin`. See also section 8.9 “Enabling Load Balancing” on page 179.

`log_filter`	integer: Defines which event types to filter from the component logfile. The value should be set to the bitwise OR of the event classes which should be filtered. (A value of 0 specifies maximum logging.) See also section 10.14 “Use and Maintenance of Logfiles” on page 250. Default: `1280` (DEBUG2 & DEBUG3)
`max_starve`	time: The amount of time before a job is considered starving. This variable is used only if `help_starving_jobs` is set. Format: HH:MM:SS Default: `24:00:00`
`mem_per_ssinode`	Deprecated. Such configuration now occurs automatically.
`mom_resources`	string: This option is used to be able to query the MOMs to set the value `resources_available.res` where res is a site-defined resource. Each MOM is queried with the resource name and the return value is used to replace `resources_available.res` on that node. See also section 9.3 “Configuring Node-level Custom Resources” on page 194.
`node_sort_key`	string: Defines sorting on `resources_available` values on nodes (i.e. total amounts, not free amounts). Options and usage are the same as for `job_sort_key`, except there is only one special case sorting algorithm (`sort_priority`) which is used for sorting based on the node’s `priority` value. Note that multiple `node_sort_key` entries can be used, in which case the first entry will be the primary sort key, the second will be used to sort equivalent items from the first sort, etc. Syntax: `node_sort_key:“sort_priority HIGH|LOW”` Default: “`sort_priority HIGH`”
`nonprimetime_prefix`	string: Queue names which start with this prefix will be treated as non-primetime queues. Jobs within these queues will only run during non-primetime. Primetime and nonprimetime are defined in the `holidays` file. See also “Defining Primetime

and Holidays" on page 176.
Default: `np_`

`peer_queue` string: Defines the mapping of a remote queue to a local queue for Peer Scheduling. For details, see section 8.13 "Enabling Peer Scheduling" on page 187.
Default: unset

`preemptive_sched`
string: Enable job preemption. See section 8.10 "Enabling Preemptive Scheduling" on page 179 for details.
Default: `true all`

`preempt_checkpoint`
Deprecated. Add "C" to `preempt_order` parameter.

`preempt_fairshare`
Deprecated. Add "fairshare" to `preempt_prio` parameter.

`preempt_order`
quoted list: Defines the order of preemption methods which the Scheduler will use on jobs. This order can change depending on the percentage of time remaining on the job. The ordering can be any combination of S C and R (for suspend, checkpoint, and requeue). The usage is an ordering (SCR) optionally followed by a percentage of time remaining and another ordering. Note, this has to be a quoted list("").
Default: `SCR`

```
preempt_order: "SR"
# or
preempt_order: "SCR 80 SC 50 S"
```

The first example above specifies that PBS should first attempt to use suspension to preempt a job, and if that is unsuccessful, then requeue the job. The second example says if the job has between 100-81% of requested time remaining, first try to suspend the job, then try checkpoint then requeue. If the job has between 80-51% of requested time remaining, then attempt suspend then checkpoint; and between 50% and 0% time remaining just attempt to suspend the job.

`preempt_prio` quoted list: Specifies the ordering of priority of different preemption levels. Two or more job types may be combined at the *same* priority level with a "+" between them (no whitespace). Comma-

separated preemption levels are evaluated left to right, with each having lower priority than the preemption level preceding it. The table below lists the six preemption levels. Note that any level not specified in the `preempt_prio` list will be ignored.
Default: `“express_queue, normal_jobs”`

express_queue	Jobs in the preemption (e.g. “express”) queue(s) preempt other jobs (see also `preempt_queue_prio`).
starving_jobs	When a job becomes starving it can preempt other jobs (requires `preempt_starving` be set to `true`).
fairshare	When a job exceeds its fairshare.
queue_softlimits	Jobs which are over their queue soft limits
server_softlimits	Jobs which are over their server soft limits
normal_jobs	The preemption level into which a job falls if it does not fit into any other specified level.

For example, the first line below states that starving jobs have the highest priority, then normal jobs, and jobs over their fairshare limit are third highest. The second example shows that starving jobs that are also over their fairshare limit are lower priority than normal jobs.

```
preempt_prio: “starving_jobs, normal_jobs, fairshare”
# or
preempt_prio: “normal_jobs, starving_jobs+fairshare”
```

`preempt_queue_prio`

integer: Specifies the minimum queue priority required for a queue to be classified as an express queue.
Default: `150`

`preempt_requeue`

Deprecated. Add an “R” to `preempt_order` parameter.

`preempt_sort` Whether jobs most eligible for preemption will be sorted according to their start times. If set to “min_time_since_start”, first job preempted will be that with most recent start time. If not set, job will be that with longest running time. See “Preemption Ordering by Start Time” on page 181.

`preempt_starving`

Deprecated. Add “starving_jobs” `preempt_prio` parameter.

`preempt_suspend`	Deprecated. Add an "S" to `preempt_order` parameter.
`primetime_prefix`	string: Queue names starting with this prefix are treated as primetime queues. Jobs will only run in these queues during primetime. Primetime and non-primetime are defined in the `holidays` file. See also "Defining Primetime and Holidays" on page 176. Default: `p_`
`prime_exempt_anytime_queues`	Determines whether anytime queues are controlled by **`backfill_prime`**. If set to true, jobs in an anytime queue will not be prevented from running across a primetime/non-primetime or non-primetime/primetime boundary. If set to false, the jobs in an anytime queue may not cross this boundary, except for the amount specified by their **`prime_spill`** setting. See also **`backfill_prime, prime_spill`**. Boolean. Default: false.
`prime_spill`	Specifies the amount of time a job can spill over from non-primetime into primetime or from primetime into non-primetime. Can be set to a different value for each execution queue. This option is only meaningful if `backfill_prime` is true. Also note that this option can be separately specified for prime- and non-primetime. See also **`backfill_prime, prime_exempt_anytime_queues`**. Units: time. Default: `00:00:00` For example, the first setting below means that non-primetime jobs can spill into prime time by 1 hour. However the second setting means that jobs in either prime/non-prime can spill into the other by 1 hour.

```
prime_spill: 1:00:00 prime
# or
prime_spill: 1:00:00 all
```

`resources`	string: Specifies those resources which are to be enforced when scheduling jobs. Boolean resources are automatically enforced and do not need to be listed here. Limits are set by setting `resources_available.`**`resourceName`** on the Server

	objects (nodes, queues, and servers). The Scheduler will consider numeric (integer or float) items as consumable resources and ensure that no more are assigned than are available (e.g. `ncpus` or `mem`). Any string resources will be compared using string comparisons (e.g. `arch`). See the description of the Server parameter `resources`; see also section “Dynamic Consumable Resources” on page 175. Default: “`ncpus, mem, arch, host, software`” (number CPUs, memory, architecture). If host is not added to the resources line, when the user submits a job requesting a specific node in the following syntax: qsub -l select=host=NodeName the job will run on any host.
`round_robin`	boolean: If `true`, the queues will be cycled through in a circular fashion, attempting to run one job at a time from each queue per scheduling cycle. Each scheduling cycle starts with the same queue, which will therefore get preferential treatment. If `false`, attempts to run all jobs from the current queue before processing the next queue. See `by_queue`. Default: `false all`
`server_dyn_res`	string: Directs the Scheduler to replace the Server’s `resources_available` values with new values returned by a site-specific external program. See section 8.4 “Dynamic Consumable Resources” on page 175 for details of usage.
`smp_cluster_dist`	string: Specifies how single-node jobs should be distributed to all nodes of the cluster. Options are: `pack`, `round_robin`, and `lowest_load`. `pack` means keep putting jobs onto one node until it is “full” and then move onto the next. `round_robin` is to put one job on each node in turn before cycling back to the first one. `lowest_load` means to put the job on the lowest loaded node. See also section 8.8 “Configuring SMP Cluster Scheduling” on page 177, and section 8.9 “Enabling Load Balancing” on page 179. Default: `pack all`
`sort_by`	Deprecated. Use `job_sort_key`.
`strict_fifo`	boolean: specifies that jobs must be run in the order determined by whatever sorting parameters are being used. This means that

a job cannot be skipped due to resources required not being available. If a job due to run next cannot run, no job will run. For details, see section 8.14 "Enabling True FIFO Scheduling" on page 190 and section 8.15 "Combining strict_fifo with Other Parameters" on page 190.
Default: `false all`

`sync_time`	time: The amount of time between writing the fairshare usage data to disk. Requires `fair_share` to be enabled. Default: `1:00:00`
`unknown_shares`	integer: The amount of shares for the "unknown" group. Requires `fair_share` to be enabled. See also section 8.11 "Using Fairshare" on page 181. The "unknown" group gets 0 shares unless set.

8.4 Dynamic Consumable Resources

It is possible to schedule resources where the number or amount available is outside of PBS's control. Such resources are called "dynamic consumable resources", and are discussed in detail, with examples, in Chapter 9 "Customizing PBS Resources" on page 191.

8.5 Job Priorities in PBS Professional

There are various classes of job priorities within PBS Professional, which can be enabled and combined based upon customer needs. The following table illustrates the inherent ranking of these different classes of priorities. A higher ranking class always takes precedence over lower ranking classes, but within a given class the jobs are ranked according to the attributes specific to that class. For example, since the Reservation class is the highest ranking class, jobs in that class will be run (if at all possible) before jobs from other classes.

Rank	Class	Description
1	Reservation	Jobs submitted to an Advance Reservation, thus resources are already reserved for the job.
2	Express	High-priority ("express" jobs). See discussion in section 8.10 "Enabling Preemptive Scheduling" on page 179.

Rank	Class	Description
3	Starving	Jobs that have waited longer than the starving job threshold. See also the Scheduler configuration parameters `help_starving_jobs`, `max_starve`, and `backfill`.
4	Suspended	Jobs that have been suspended by higher priority work.
5	round_robin or by_queue	Queue-based scheduling may affect order of jobs depending if these options are enabled.
6	fairshare or job_sort_key	Jobs will be sorted as specified by job_sort_key. If fairshare is enabled, it will become the primary sort key.

8.6 Defining Dedicated Time

The file *PBS_HOME*/sched_priv/dedicated_time defines the dedicated times for the Scheduler. During dedicated time, only jobs in the dedicated time queues can be run (see dedicated_prefix in section 8.3 “Scheduler Configuration Parameters” on page 166). The format of entries is:

```
# From Date-Time   To Date-Time
# MM/DD/YYYY HH:MM MM/DD/YYYY HH:MM
# For example
04/15/2005 12:00 04/15/2005 15:30
```

Important: To force the Scheduler to re-read the dedicated time file (needed after modifying the file), restart or reinitialize the Scheduler. (For details, see “Starting and Stopping PBS: UNIX and Linux” on page 211 and “Starting and Stopping PBS: Windows 2000 / XP” on page 222.)

8.7 Defining Primetime and Holidays

To have the Scheduler enforce a distinction between primetime (usually, the normal work day) and non-primetime (usually nights and weekends), as well as enforcing non-primetime scheduling policy during holidays, edit the *PBS_HOME*/sched_priv/holidays file to specify the appropriate values for the begin and end of prime time, and any holidays. The ordering is important. Any line that begins with a “*” or a “#” is considered a comment. The format of the holidays file is:

```
YEAR YYYY      This is the current year.
<day> <prime> <nonprime>
<day> <prime> <nonprime>
```

Day can be `weekday`, `saturday`, or `sunday.` *Prime* and *nonprime* are times when prime or non-prime time start. Times can either be HHMM with no colons(:) or the word "`all`" or "`none`"

```
<day> <date> <holiday>
```

PBS Professional uses the <day> field and ignores the <date> string. *Day* is the julian day of the year between 1 and 365 (e.g. "1"). *Date* is the calendar date (e.g. "Jan 1"). *Holiday* is the name of the holiday (e.g. "New Year's Day").

```
HOLIDAYFILE_VERSION1
YEAR    2005
*             Prime   Non-Prime
* Day         Start   Start
*
  weekday     0600    1730
  saturday    none    all
  sunday      none    all
*
* Day of     Calendar      Company Holiday
* Year        Date          Holiday
    1         Jan 1         New Year's Day
   17         Jan 17        Dr. M.L. King Day
   52         Feb 21        President's Day
  150         May 30        Memorial Day
  185         Jul 4         Independence Day
  248         Sep 5         Labor Day
  283        Oct 10         Columbus Day
  315         Nov 11        Veteran's Day
  328         Nov 24        Thanksgiving
  359         Dec 25        Christmas Day
```

8.8 Configuring SMP Cluster Scheduling

The Standard Scheduler schedules SMP clusters in an efficient manner. Instead of scheduling only via load average of nodes, it takes into consideration the resources specified at the server, queue, and node level. Furthermore, the Administrator can explicitly select the resources to be considered in scheduling via an option in the Scheduler's configuration file (`resources`). The configuration parameter `smp_cluster_dist` allows you to specify how nodes are selected.

The available choices are `pack` (pack one node until full), `round_robin` (put one job on each node in turn), or `lowest_load` (put one job on the lowest loaded node). The `smp_cluster_dist` parameter should be used in conjunction with `node_sort_key` to ensure efficient scheduling. (Optionally, you may wish to enable "load balancing" in conjunction with SMP cluster scheduling. For details, see section 8.9 "Enabling Load Balancing" on page 179.)

Important: This feature only applies to single-node jobs where the number of chunks is 1, and *place=pack* has been specified.

To use these features requires two steps: setting resource limits via the Server, and specifying the scheduling options. Resource limits are set using the `resources_available` parameter of nodes via `qmgr` just like on the server or queues. For example, to set maximum limits on a node called "node1" to 10 CPUs and 2 GB of memory:

```
Qmgr: set node node1 resources_available.ncpus=10
Qmgr: set node node1 resources_available.mem=2GB
```

Important: Note that by default both `resources_available.ncpus` and `resources_available.mem` are set to the physical number reported by MOM on the node. Typically, you do not need to set these values, unless you do not want to use the actual values reported by MOM.

Next, the Scheduler options need to be set. For example, to enable SMP cluster Scheduler to use the "round robin" algorithm during primetime, and the "pack" algorithm during non-primetime, set the following in the Scheduler's configuration file:

```
smp_cluster_dist: round_robin prime
smp_cluster_dist: pack non_prime
```

Finally, specify the resources to use during scheduling:

```
resources: "ncpus, mem, arch, host"
```

8.9 Enabling Load Balancing

The load balancing scheduling algorithm will balance the computational load of single-node jobs (i.e. not multi-node jobs) across a cluster. The load balancing takes into consideration the load on each node as well as all resources specified in the "resource" list.

To configure load balancing, first enable the option in the Scheduler's configuration file:

```
load_balancing: True ALL
```

Next, configure SMP scheduling as discussed in the previous section, section 8.8 "Configuring SMP Cluster Scheduling" on page 177.
Lastly, configure the target and maximum desired load in each node's MOM configuration file. (See also the discussion of these two MOM options in section 7.2.1 "Standard Configuration Parameters" on page 130.)

```
$ideal_load: 30
$max_load:   32
```

8.10 Enabling Preemptive Scheduling

PBS provides the ability to preempt currently running jobs in order to run higher priority work. Preemptive scheduling is enabled by setting several parameters in the Scheduler's configuration file (discussed below, and in "Scheduler Configuration Parameters" on page 166). Jobs utilizing advance reservations are not preemptable. If high priority jobs (as defined by your settings on the preemption parameters) can not run immediately, the Scheduler looks for jobs to preempt, in order to run the higher priority job. A job can be preempted in several ways. The Scheduler can suspend the job (i.e. sending a SIGSTOP signal), checkpoint the job (if supported by the underlying operating system, or if the Administrator configures site-specific checkpointing, as described in "Site-Specific Job Checkpoint and Restart" on page 141), or requeue the job (a requeue of the job terminates the job and places it back into the queued state). The Administrator can choose the order of these attempts via the `preempt_order` parameter.

Important: If the Scheduler cannot find enough work to preempt in order to run a given job, it will not preempt any work.

There are several Scheduler parameters to control preemption. The `preemptive_sched` parameter turns preemptive scheduling on and off. You can set the minimum queue priority needed to identify a queue as an express queue via the `preempt_queue_prio` parameter. The `preempt_prio` parameter provides a means of specifying the order of precedence that preemption should take. The ordering is evaluated from left to right. One special name (`normal_jobs`) is the default (If a job does not fall into any of the specified levels, it will be placed into `normal_jobs`.). If you want normal jobs to preempt other lower priority jobs, put `normal_job` before them in the `preempt_prio` list. If two or more levels are desired for one priority setting, the multiple levels may be indicated by putting a '+' between them. A complete listing of the preemption levels is provided in the Scheduler tunable parameters section above. The `preempt_order` parameter can be used to specify the preemption method(s) to be used. If one listed method fails, the next one will be attempted.
Soft run limits can be set or unset via `qmgr`. If unset, the limit will not be applied to the job. However if soft run limits are specified on the Server, either of `queue_softlimits` or `server_softlimits` need to be added to the `preempt_prio` line of the Scheduler's configuration file in order to have soft limits enforced by the Scheduler.

The job sort `preempt_priority` will sort jobs by their preemption priority. Note: It is a good idea to put `preempt_priority` as the primary sort key (i.e. `job_sort_key`) if the `preempt_prio` parameter has been modified. This is especially necessary in cases of when soft limits are used.

Important: Note that any queue with a priority 150 (default value) or higher is treated as an express (i.e. high priority) queue.

Below is an example of (part of) the Scheduler's configuration file showing how to enable preemptive scheduling and related parameters. Explanatory comments precede each configuration parameter.

```
# turn on preemptive scheduling
preemptive_sched:       TRUE ALL

# set the queue priority level for express queues
preempt_queue_prio:     150

# specify the priority of jobs as: express queue (highest)
# then starving jobs, then normal jobs, followed by jobs
# who are starving but the user/group is over a soft limit,
# followed by users/groups over their soft limit but not
# starving
#
preempt_prio: "express_queue, starving_jobs, normal_jobs, sta
rving_jobs+server_softlimits, server_softlimits"

# specify when to use each preemption method. If the first
# method fails, try the next method. If a job has
# between 100-81% time remaining, try to suspend, then
# checkpoint then requeue. From 80-51% suspend and then
# checkpoint, but don't requeue. If between 50-0% time
# remaining, then just suspend it.
preempt_order: "SCR 80 SC 50 S"
```

8.10.1 Preemption Ordering by Start Time

PBS has a new feature that allows a different ordering of preemption of jobs. The new default behaviour will order preemption of jobs by most recent start time. If "preempt_sort" is disabled, then the first submitted job will be preempted.

For example, if we have two jobs, job A submitted at 10:00 and job B submitted at 10:30, the default behavior will preempt job A, and the new behavior will preempt job B.

In PBS_HOME/sched_priv/sched_config, the keyword preempt_sort can be set to "min_time_since_start" to enable this behavior.

8.11 Using Fairshare

Fairshare provides a way to enforce a site's resource usage policy. It is a method for ordering the start times of jobs based on two things: how a site's resources are apportioned, and the resource usage history of site members. Fairshare ensures that jobs are run in the order of how deserving they are. The scheduler performs the fairshare calculations each scheduling cycle. All jobs can have fairshare applied to them; there is no exemption from fairshare.

The administrator can employ basic fairshare behavior, or can apply a policy of the desired complexity.

8.11.1 The Fairshare Tree

Fairshare uses a tree structure, where each node in the tree represents some set of job owners and is assigned usage *shares*. Shares are used to apportion the site's resources. The default tree always has a root node and an *unknown* node. In order to apportion a site's resources according to a policy other than equal shares for each user, the administrator creates a fairshare tree to reflect that policy. To do this, the administrator edits the file `PBS_HOME/sched_priv/resource_group`, which describes the fairshare tree.

8.11.2Enabling Basic Fairshare

If the default fairshare behavior is enabled, all users with queued jobs will get an equal share of CPU time. The root node of the tree will have one child, the `unknown` node. All users will be put under the unknown node, and appear as children of the `unknown` node.

Basic fairshare is enabled by doing two things: in `PBS_HOME/sched_priv/sched_config`, set the scheduler configuration parameter `fair_share` to true, and uncomment the `unknown_shares` setting so that it is set to `unknown_shares: 10`.

Note that a variant of basic fairshare has all users listed in the tree as children of root. Each user can be assigned a different number of shares. This must be explicity created by the administrator.

8.11.3Using Fairshare to Enforce Policy

The administrator sets up a hierarchical tree structure made up of interior nodes and leaf nodes. Interior nodes are *departments*, which can contain both departments and leaf nodes. Leaf nodes are for *fairshare entities*, defined by setting `fairshare_entity` to one of the following: `eusers`, `egroups`, `egroup:eusers`, `account_string`, or queues. Apportioning of resources for the site is among these entities. These entities' usage of resources is used in determining the start times of the jobs associated with them. All fairshare entities must be the same type. If you wish to have a user appear in more than one department, you can use `egroup:euser` to distinguish between that user's different resource allotments.

8.11.3.1 Shares in the Tree

The administrator assigns shares to each node in the tree. The actual number of shares given to a node or assigned in the tree is not important. What is important is the ratio of shares among each set of sibling nodes. Competition for resources is between siblings only. The sibling with the most shares gets the most resources.

8.11.3.2 Format for Describing the Tree

The file describing the fairshare tree contains four columns to describe the nodes in the tree. The columns are for a node's name, its fairshare ID, the name of its parent node, and the number of shares assigned to that node. Node names and IDs must be unique. Node IDs are integers. Neither the root node nor the `unknown` node is described in this file. They are always added automatically, and `unknown` is always a child of root. The `unknown` node's shares default to 10. Any entites not listed in this file will end up as children of the `unknown` node. Parent nodes must be listed before their children.

For example, we have a tree with two top-level departments, Math and Phys. Under math are the users Bob and Tom as well as the department Applied. Under Applied are the users Mary and Sally. Under Phys are the users John and Joe. Our PBS_HOME/sched_priv/resource_group looks like this:

```
Math      100   Root      30
Phys      200   Root      20
Applied   110   Math      20
Bob       101   Math      20
Tom       102   Math      10
Mary      111   Applied   1
Sally     112   Applied   2
John      201   Phys      2
Joe       202   Phys      2
```

8.11.3.3 Computing How Much Each Node Deserves

How much resource usage each entity deserves is its portion of all the shares in the tree, divided by its past and current resource usage.

A node's portion of all the shares in the tree is called *tree percentage*. It is computed for all of the nodes in the tree. Since the leaves of the tree represent the entities among which resources are to be shared, their tree percentage sums to 100 percent.

The scheduler computes the tree percentage for the nodes this way:

First, it gives the root of the tree a tree percentage of 100 percent. It proceeds down the tree, finding the tree percentage first for immediate children of root, then their children, ending with leaves.

```
For each internal node A:
    sum the shares of its children;
    For each child J of Node A:
        divide J's shares by the sum to normalize the shares;
        multiply J's normalized shares by node A's tree percentage to find J's tree
        percentage.
```

8.11.4Tracking Resource Usage

The administrator selects a resource to be tracked for fairshare purposes by setting the scheduler configuration parameter `fairshare_usage_res` in `PBS_HOME/sched_priv/sched_config`. The default for this resource is `cput`, CPU time. Another resource is the exact string "`ncpus*walltime`" which multiplies the number of cpus used by the walltime. An entity's usage always starts at 1.

Each entity's current usage of the designated resource is combined with its previous usage. Each scheduler cycle, the scheduler adds the usage increment between this cycle and the previous cycle to its sum for the entity. Each entity's usage is *decayed*, or cut in half periodically, at the interval set in the `half_life` parameter in `PBS_HOME/sched_priv/sched_config`. This interval defaults to 24 hours.

This means that an entity with a lot of current or recent usage will have low priority for starting jobs, but if the entity cuts resource usage, its priority will go back up after a few decay cycles.

Note that if a job ends between two scheduling cycles, its resource usage between the end of the job and the following scheduling cycle will not be recorded. The scheduler's default cycle interval is 10 minutes.

The scheduling cycle can be adjusted via the `qmgr` command. Use `qmgr:` **`set server scheduler_iteration=<new value>`**

8.11.5Finding the Most Deserving Entity

The most deserving entity is found by starting at the root of the tree, comparing its immediate children, finding the most deserving, then looking among that node's children for the most deserving child. This continues until a leaf is found. In a set of siblings, the most deserving node will be the node with the lowest ratio of resource usage divided by tree percentage.

8.11.6Choosing Which Job to Run

The job to be run next will be selected from the set of jobs belonging to the most deserving entity. The jobs belonging to the most deserving entity are sorted according to the methods the scheduler normally uses. This means that fairshare effectively becomes the primary sort key. If the most deserving job cannot run, then the next most is selected to run, and so forth. All of the most deserving entity's jobs would be examined first, then those of the next most deserving entity, et cetera.

At each scheduling cycle, the scheduler attempts to run as many jobs as possible. It selects the most deserving job, then recalculates to find the next most deserving job, runs it, and so on.

When the scheduler starts a job, all of the job's requested usage is added to the sum for the owner of the job for one scheduling cycle. This is to keep one entity from using up all of the resource in one scheduling cycle.

8.11.7Files and Parameters Used in Fairshare

`PBS_HOME/sched_priv/sched_config`

fair_share	[true/false] Enable or disable fairshare
fairshare_usage_res	Resource whose usage is to be tracked; default is cput
half_life	Decay time period; default is 24 hours
sync_time	Time between writing all data to disk; default 1 hour
unknown_shares	Number of shares for unknown node; default 10, 0 if commented out
fairshare_entity	What can be a leaf node; default euser.
fairshare_enforce_no_shares	If an entity has no shares, this controls whether it can run jobs. T: an entity with no shares cannot run jobs. F: an entity with no shares can only run jobs when no other jobs

	are available to run.
by_queue	If on, queues cannot be designated as fairshare entities, and fairshare will work queue by queue instead of on all jobs at once.

`PBS_HOME/sched_priv/resource_group`
Contains the description of the fairshare tree.

`PBS_HOME/sched_priv/usage`
Contains the usage database.

qmgr
Used to set scheduler cycle frequency; default is 10 minutes.

```
Qmgr: set server scheduler_iteration=<new value>
```

job attributes
Used to track resource usage:
`resources_used.<resource>`
Default is `cput`.

8.11.8Fairshare and Queues

The scheduler configuration parameter `by_queue` in the file `PBS_HOME/sched_priv/sched_config` is set to on by default. When `by_queue` is on, fairshare cycles through queues, not overall jobs. So first fairshare is applied to Queue1, then Queue2, etc. If `by_queue` is on, queues cannot be designated as fairshare entities.

8.11.9Viewing and Managing Fairshare Data

The `pbsfs` command provides a command-line tool for viewing and managing some fairshare data. You can display the tree in tree form or in list form. You can print all information about an entity, or set an entity's usage to a new value. You can force an immediate decay of all the usage values in the tree. You can compare two fairshare entities. You can also remove all entities from the `unknown` department. This makes the tree easier to read. The tree can become unwieldy because entities not listed in the file `PBS_HOME/sched_priv/resource_group` all land in the `unknown` group.

The fairshare usage data is written to the file `PBS_HOME/sched_priv/usage` at an interval set in the scheduler configuration parameter `sync_time`. The default interval is one hour. To have the scheduler write out usage date prior to being killed, issue a **`kill -HUP`**. Otherwise, any usage data acquired since the last write will be lost.

See the `pbsfs(8B)` manual page for more information on using the `pbsfs` command.

8.12 Enabling Strict Priority

Not to be confused with fairshare (which considers past usage of each entity in the selection of jobs), the Standard Scheduler offers a sorting key called "`fair_share_perc`" (see also section 8.3 "Scheduler Configuration Parameters" on page 166). Selecting this option enables the sorting of jobs based on the priorities specified in the fairshare tree (as defined above in the `resource_group` file). A simple share tree will suffice. Every user's `parent_group` should be `root`. The amount of shares should be their desired priority. `unknown_shares` (in the Scheduler's configuration file) should be set to one. Doing so will cause everyone who is not in the tree to share one share between them, making sure everyone else in the tree will have priority over them. Lastly, `job_sort_key` must be set to "`fair_share_perc HIGH`". This will sort by the fairshare tree which was just set up. For example:

```
usr1    60      root    5
usr2    61      root    15
usr3    62      root    15
usr4    63      root    10
usr5    64      root    25
usr6    65      root    30
```

8.13 Enabling Peer Scheduling

PBS Professional includes a feature to have different PBS installations automatically run jobs from each other's queues. This provides the ability to dynamically load-balance across multiple, separate PBS installations. (These cooperating PBS installations are referred to as "Peers".) When this feature is enabled and resources are available, PBS can "pull" jobs from one or more (remote) Peer Servers and run them locally. No job will be moved if it cannot run immediately.

Important: When configuring Peer Scheduling, it is *strongly* recommended to use the same versions of PBS Professional at all Peer locations.

This functionality is implemented by mapping a remote Peer's queue to a local queue. When the Scheduler determines that a remote job can run locally, it will move the job to the specified queue on the local Server and then run the job.

Important: Note that the Peer queue mapping must be between *execution* queues, not *route* queues.

Peer Scheduling features requires a flat user namespace, meaning that there is an assumption that user “joe” on the remote Peer system(s) is the same as user “joe” on the local system.

To configure Peer Scheduling, the following setting needs to be made in the local Server and all Peer Servers, via `qmgr`:

```
Qmgr: set server flatuid = true
```

Furthermore, in order to pull jobs from a remote Peer to the local Server, the remote Peer Server needs to grant manager access to the local Peer Server (and *vice versa* if you wish to permit jobs to move in the opposite direction).

For UNIX:

```
Qmgr: set server managers += root@localServer.domain.com
```

For Windows:

```
Qmgr: set server managers += pbsadmin@*
```

Important: Under Windows, if `single_signon_password_enable` is set to "true" among all peer Servers, then users must have their password cached on each Server. For details see section 6.14.3 “Single Signon and Peer Scheduling” on page 113.

Lastly, you need to configure the local Scheduler to pull jobs from the remote server onto the local server. Add one or more `peer_queue` entries to the local Scheduler’s configuration file, mapping a remote queue to a local queue. The format is:

```
peer_queue: "local_queue remote_queue@remote_server.domain"
```

```
peer_queue: “workq workq@remote_server.domain.com”
peer_queue: “peerq workq@other_server.different.com”
```

Since the Scheduler maps the remote jobs to a local queue, any moved jobs are subject to the policies of the queue they are moved into. If remote jobs are to be treated differently from local jobs, this can be done on the queue level. A queue can be created exclusively for remote jobs and this will allow queue level policy to be set for remote jobs. For example, you can set a priority value on your queues, and enable sorting by priority to ensure that remotely queued jobs are always lower (or higher!) priority than locally queued jobs.

8.13.1 Peer Scheduling and Failover Configuration

When setting up the Scheduler for Peer Scheduling, and the peer is in a Failover Server configuration, it is necessary to define two remote peer queues. For example, say the Scheduler is set to pull jobs into local queue `workq` from the peer `workq@SVR1.example.com`. The `sched_config` file would have the following entry:

```
peer_queue: “workq workq@SVR1.example.com”
```

Now if you configure host SVR1 into a Failover configuration, where SVR1 is the Primary and the Secondary is SVR2, you will need to add an additional entry (for SVR2) to the Scheduler `sched_config` file, as follows:

```
peer_queue: “workq workq@SVR1.example.com”
peer_queue: “workq workq@SVR2.example.com”
```

8.13.2 Peer Scheduling and Group Limit Enforcement

There is a condition when using Peer Scheduling in which group hard limits could be exceeded. The situation occurs when the `egroup` attribute of the job changes when a job is moved from a remote (peer) system to the local system. All the hard limit checking is performed on the old system prior to moving the job, and not on the new (local group). This means that if a job is in group `foo` on the remote system and group `foo` on the local system has not exceeded its limit, the job may be selected to run. But if it is selected to run, *and* the job’s default group on the local system is different (let’s say it is `bar`), the job will be run even if the limit on group `bar` has been exceeded. This situation can also occur if the user explicitly specifies a group via `qsub -W group_list`.

Important: Thus, it is recommended to advise users to *not* use the `qsub` options "`-u` *`user_list`*" or "`-W group_list=`*`groups`*" in conjunction with Peer Scheduling.

8.14 Enabling True FIFO Scheduling

True first-in, first-out (FIFO) scheduling means sorting jobs into the order submitted, and then running jobs in that order. Furthermore, it means that when the Scheduler reaches a job in the sorted list that cannot run, then no other jobs will be considered until that job can run. In many situations, this results in an undesirably low level of system utilization. However, some customers have a job-mix or a usage policy for which FIFO scheduling is appropriate.

Because true FIFO runs counter to many of the efficiency algorithms in PBS Professional, several options must be set in order to achieve true FIFO scheduling within a given queue. In order to have jobs within individual queues be run in true FIFO order, set the following parameters to the indicated values in the Scheduler's configuration file:

```
strict_fifo:         True   ALL
round_robin:         False  ALL
job_sort_key:        False  ALL
fairshare:           False  ALL
help_starving_jobs:  False  ALL
```

8.15 Combining strict_fifo with Other Parameters

If the `strict_fifo` scheduling parameter is enabled in conjunction with other scheduling parameters, "strict ordering" of jobs can be achieved. This combination can be used with most scheduling strategies. If so configured, when the Scheduler reviews the (possibly sorted) list of queued jobs and it reaches one which can not run, the Scheduler will not attempt to run any more jobs in that queue. The list of jobs is dependent upon the other scheduling algorithms enabled, such as sorting resulting from the `job_sort_key` or `fairshare` parameters.

Note that parameters `backfill` and `strict_fifo` are mutually exclusive.

Chapter 9

Customizing PBS Resources

It is possible for the PBS Manager to define new resources within PBS. The primary use of this feature is to add site-specific resources, such as to manage software application licenses. This chapter discusses the steps involved in specifying such new resources to PBS, followed by several detailed examples of use.

Once new resources are defined, jobs may request these new resources and the Scheduler will consider the new resources in the scheduling policy. Using this feature, it is possible to schedule resources where the number or amount available is outside of PBS's control.

9.1 Custom Resources

There are two types of custom resources: static and dynamic. Dynamic custom resources can be defined at the server or node level. Static custom resources are defined ahead of time, at the server, queue or node level. Dynamic resources are tracked in order to determine their availability. Custom resources are defined to the server, then set on one or more nodes.

For static custom resources the Server maintains the status of the custom resource (either reporting a static setting specified via `qmgr` or the results of querying an external source), and the Scheduler queries the Server for the resource.

For dynamic server-level custom resources the scheduler uses a script to get resource availability.

For dynamic node-level custom resources, the Scheduler will send a resource query to each MOM to get the current availability for the resource and use that value for scheduling. If the MOM returns a value it will replace the `resources_available` value reported by the Server. If the MOM returns no value, the value from the Server is kept. If neither specify a value, the Scheduler sets the resource value to 0.

Static custom resource values at node, queue and server level can be established via qmgr, setting resources_available.<custom resource name> = <some value>. For a static node-level resource, values can be established by a MOM directive in `PBS_HOME/mom_priv/config` that defines the resource as a static-valued resource and gives its value.

For a dynamic node-level resource, values are established by a MOM directive which defines a script which returns a dynamic value when executed. For a dynamic server-level custom resource, the value is established by the script defined in the `server_dyn_res` line in `PBS_HOME/sched_priv/sched_config`.

9.2 Defining New Custom Resources

To define one or more new resources, the Administrator creates the Server resource definition file, *PBS_HOME*`/server_priv/resourcedef`. Each line in the file defines a new resource. The format of each line is:

```
RESOURCE_NAME [ type=RTYPE] [ flag=FLAGS]
```

`RESOURCE_NAME` is any string made up of alphanumeric characters, starting with an alphabetic character. The underscore character, "_", and the hyphen, "-", are also allowed.

The length of each line in `PBS_HOME/server_priv/resourcedef` file should not be not more than 254 characters.

`RTYPE` is the type of the resource value, which must be one of the following keywords:

long	the value is a long integer
float	the value is a floating point number
size	the value is an integer number following by a suffix denoting magnitude `k`, `m`, `g`, `t` and `b` for bytes or `w` for words.

string	a null terminated string. The value of the string custom resource should not start with a number
boolean	boolean-valued resource

If not specified, the resource will default to type `long`.

9.2.1 Resource Flags

`FLAGS` is a set of characters which indicate if and how the Server should accumulate the requested amounts of the resource in the attribute `resources_assigned` when the job is run.

For example, when defining a static consumable resource that is tracked at the node level, such as a node-locked license, you would use the "n" flag. However, when defining a dynamic resource such as a floating license, no flag would be used.

The value of `flag` is the concatenation of one or more of the following letters:

q	the amount is tracked at the Queue and Server level
n	the amount is tracked at the Node level, for all nodes assigned to the job
f	the amount is tracked at the Node level for only the first node allocated to the job

If FLAGS is not specified, the resource will not be accumulated in `resources_assigned`.

Important: Flags should not be used if a custom resource is of type "string"

Important: If you are defining a new static resource, e.g. node-locked license, the `flag` option is required. However, if you are defining a dynamic resource, the `flag` option should not be set.

Examples are provided in section 9.7 "Examples" on page 199 and in section 9.7.4 "Complex External Licenses Example" on page 203.

Once you have defined the new resource(s), you must restart the Server in order for these changes to take effect (see section 9.6 on page 198). When the Server restarts, users will be able to submit jobs requesting the new resource, using the normal syntax to which they are accustomed. See also section 9.7 “Examples” on page 199.

Important: You may wish to set limits on these new resources via `qmgr`. Such limits might be to indicate the quantity of the resource available (either cluster-wide or on a given node), or they might be to restrict user’s use of these new resources. See also section 9.7.4 “Complex External Licenses Example” on page 203 and section 6.4 “Server Configuration Attributes” on page 76.

9.3 Configuring Node-level Custom Resources

If the new resource you are adding is a node-level resource, then you will also need to configure each MOM such that she will be able to answer the resource query requests from the Scheduler.

Each MOM can be instructed in how to respond to a Scheduler resource query by adding shell escapes to the MOM configuration file *PBS_HOME*`/mom_priv/config`. The shell escape provides a means for the resource monitor to yield arbitrary information to the Scheduler and other client commands. The format of a shell escape line is:

```
RESOURCE_NAME !path-to-command
```

The `RESOURCE_NAME` specified should be the same as the corresponding entry in the Server’s *PBS_HOME*`/server_priv/resourcedef` file. The rest of the line, following the exclamation mark (“!”), is saved to be executed through the services of the `system`(3) standard library routine. The first line of output from the shell command is returned as the response to the resource query.

Important: On Windows, be sure to place double-quote (“ “) marks around the *path-to-command* if it contains any whitespace characters.

Typically, what follows the shell escape (i.e. “!”) is the full path to the script or program that you wish to be executed, in order to determine the status and/or availability of the new resource you have added. Once the shell escape script/program is started, MOM waits for output. The wait is by default five seconds, but can be changed via the `-a alarm` command line start option. (For details of use, see section 10.3.1 “Manually Starting MOM” on page 212 and section 10.4.1 “Startup Options to PBS Windows Services” on page 223.) If the alarm time passes and the shell escape process has not finished, a log message, “resource read alarm” is written to the MOM’s log file. The process is given another alarm period to finish and if it does not, an error is returned, usually to the scheduler, in the form of "`? 15205`". Another log message is written. The `?` indicates an error condition and the value 15205 is `PBSE_RMSYSTEM`. The user's job may not run.

In order for the changes to the MOM `config` file to take effect, the `pbs_mom` process must be either restarted or reinitialized (see section 9.6 on page 198). Examples are provided in section 9.7 "Examples" on page 199 and in section 9.7.4 "Complex External Licenses Example" on page 203.

9.4 Using a Custom Resource for Scheduling

In order for a new resource to be used for scheduling, it must be defined to the server and set either via qmgr or by adding it to the correct line. In this example, we add five custom resources: a static and a dynamic node-level resource, and a static and a dynamic server-level resource, and a static queue-level resource.

1. The resource must be defined to the server, with appropriate flags set:
   Add resource to `PBS_HOME/server_priv/resourcedef`

```
staticserverresource      type=long flag=q
staticnoderesource      type=long flag=n
dynamicserverresource      type=long
dynamicnoderesource     type=long
staticqueueresource     type=long flag=q
```

2. The resource must be added to the list of resources:
   Add resource to "resources" line in
   `PBS_HOME/sched_priv/sched_config`

```
resources:  "staticserverresource,staticnoderesource,
   dynamicserverresource, dynamicnoderesource,
   staticqueueresource"
```

3. If the resource is static, use `qmgr` to set it at the node, queue or server level.

```
Qmgr: set node Node1
   resources_available.staticnoderesource=1
Qmgr: set queue Queue1
   resources_available.staticqueueresource=1
Qmgr: set server Server1
   resources_available.staticserverresource=1
```

See “The qmgr Command” on page 71.

4. If the resource is dy namic:
   a. If it’s a node-level resource, add it to the “mom_resources” line in `PBS_HOME/sched_priv/sched_config`:
   `mom_resources “dynamicnoderesource”`
   b. If it’s a server-level resource, add it to the “server_dyn_res” line in `PBS_HOME/sched_priv/sched_config`:
   server_dyn_res “dynamicserverresource”

To use a static custom resource for scheduling purposes, the resource must be tracked in `resources_assigned`. This is accomplished by setting the appropriate flags. See “Resource Flags” on page 193.

Table 4: Adding Custom Resources

Resourc e Type	Node-level	Queue-level	Server-level
static	Set via qmgr	Set via qmgr	Set via qmgr
dynamic	Add to mom_resources line in PBS_HOME/ sched_priv/sched_config	Cannot be used.	Add to server_dyn_res line in PBS_HOME/ sched_priv/sched_config

9.5 Scheduling Custom Resources

The last step in creating a new custom resource is configuring the Scheduler to (a) query your new resource, and (b) include the new resource in each scheduling cycle. Whether you set up server-level or node-level resources, the external site-provided script/program is run once per scheduling cycle. Multiple jobs may be started during a cycle. For any job started that requests the resource, the Scheduler maintains an internal count, initialized when the script is run, and decremented for each job started that required the resource.

To direct the Scheduler to use a new server-level custom resource, add the `server_dyn_res` configuration parameter to the Scheduler *`PBS_HOME/`* `sched_priv/sched_config` file:

```
server_dyn_res: “RESOURCE_NAME !path-to-command”
```

where RESOURCE_NAME should be the same as used in the Server's *PBS_HOME*/ server_priv/resourcedef file. (See also section 8.3 "Scheduler Configuration Parameters" on page 166).

Alternatively, to direct the Scheduler to use a new node-level custom resource, add the mom_resources configuration parameter to the Scheduler sched_config file:

```
mom_resources: "RESOURCE_NAME"
```

where RESOURCE_NAME should be the same as used in the Server's resourcedef file and the MOM's config file. (see also section 7.2 "MOM Configuration Parameters" on page 130).

Next, tell the Scheduler to include the custom resource as a constraint in each scheduling cycle by appending the new resource to the resources configuration parameter in the Scheduler sched_config file:

```
resources: "ncpus, mem, arch, RESOURCE_NAME"
```

Examples are provided in section 9.7 "Examples" on page 199 and in section 9.7.4 "Complex External Licenses Example" on page 203.

Once you have defined the new resource(s), you must restart/reinitialize the Scheduler in order for these changes to take effect (see section 9.6 on page 198).

Important: Because custom resources are external to PBS, they are not completely under PBS' control. Therefore it is possible for PBS to query and find a resource available, schedule a job to run to use that job, only to have an outside entity take that resource before the job is able to use it. For example, say you had an external resource of "scratch space" and your local query script simply checked to see how much disk space was free. It would be possible for a job to be started on a node with the requested space, but for another application to use the free space before the job did. A solution would be to have your local query script invoke the local disk quota system to reserve the specific amount of space for the user. That way no programs outside of PBS would be able to use the space either. (In such an example, you'd need to be sure to release the space when the job was free. The PBS epilogue would be a possible place to do that.)

9.6 PBS Restart Steps for Custom Resources

In order to have new custom resources recognized by PBS, the individual PBS components must either be restarted or reinitialized for the changes to take effect. The subsequent sections of this chapter will indicate when this is necessary, and refer to the details of this section for the actual commands to type.

Important: The procedures below apply to the specific circumstances of defining custom resources. For general restart procedures, see section 10.3 “Starting and Stopping PBS: UNIX and Linux” on page 211 and section 10.4 “Starting and Stopping PBS: Windows 2000 / XP” on page 222.

Server restart procedures are:

On UNIX:

```
qterm -t quick
PBS_EXEC/sbin/pbs_server
```

On Windows:

```
Admin> qterm -t quick
Admin> net start pbs_server
```

MOM restart / reinitialization procedures are:

On UNIX: Use the “`ps`” command to determine the process ID of current instance of PBS MOM, and then terminate MOM via `kill` using the PID returned by `ps`. Note that `ps` arguments vary among UNIX systems, thus “`-ef`” may need to be replaced by “`-aux`”. (Note that if your custom resource gathering script/ program takes longer than the default five seconds, you can change the alarm timeout via the `-a alarm` command line start option as discussed in section 10.3.1 “Manually Starting

MOM" on page 212.)

```
ps -ef | grep pbs_mom
kill -HUP <MOM PID>
PBS_EXEC/sbin/pbs_mom [-a 30 options]
```

On Windows:

```
Admin> net stop pbs_mom
Admin> net start pbs_mom
```

If your custom resource gathering script/program takes longer than the default five seconds, you can change the alarm timeout via the `-a alarm` command line start option as discussed in section 10.4.1 "Startup Options to PBS Windows Services" on page 223.)

Scheduler restart / reinitialization procedures are:

On UNIX:

```
ps -ef | grep pbs_sched
kill -HUP <Scheduler PID>
PBS_EXEC/sbin/pbs_sched
```

On Windows:

```
Admin> net stop pbs_sched
Admin> net start pbs_sched
```

9.7 Examples

This section provides several examples (first simple, then complex) which illustrate how to implement custom resources in PBS.

9.7.1 Node-level "scratchspace" Example

Say you have jobs that require a large amount of scratch disk space during their execution.

To ensure that sufficient space is available when starting the job, you first write a script that returns as a single line (with new-line) the amount of space available. This script is placed in `/usr/local/bin/scratchspace` on each node. Next, edit the Server's resource definition file, (`PBS_HOME/server_priv/resourcedef`) adding a definition for the new resource. (See also "Defining New Resources" on page 108.) For this example, let's call our new resource "scratchspace":

```
scratchspace    type=size
```

Important: Note that the optional "flags" is not specified, since this is a node-level resource.

Also note that in Windows, if you use Notepad to create the file, be sure to explicitly put a newline at the end of the line, otherwise none will appear, causing PBS to be unable to properly parse the file.

Now restart the Server (see section 9.6 on page 198).

Once the Server recognizes the new resources, you may optionally specify any limits on that resource via `qmgr`, such as the maximum amount available of the new resources, or the maximum that a single user can request. For example, at the `qmgr` prompt you could type:.

```
set server resources_max.scratchspace=1gb
```

Next, configure MOM to use the `scratchspace` script by entering one line into the `PBS_HOME/mom_priv/config` file:

On UNIX:.

```
scratchspace !/usr/local/bin/scratchspace
```

On Windows:.

```
scratchspace !"c:\Program Files\PBS Pro\scratchspace"
```

Then, restart / reinitialize the MOM (see section 9.6 on page 198).

Finally, edit the Scheduler configuration file (`PBS_HOME/sched_priv/`

sched_config), specifying this new resource that you want queried and used for scheduling:

```
mom_resources:  "scratchspace"
resources: "ncpus, mem, arch, scratchspace"
```

Then, restart / reinitialize the Scheduler (see section 9.6 on page 198).

Now users will be able to submit jobs which request this new "scratchspace" resource using the normal `qsub -l` syntax to which they are accustomed.

```
% qsub -l scratchspace=100mb ...
```

The Scheduler will see this new resource, and know that it must query the different MOMs when it is searching for the best node on which to run this job.

9.7.2 Note About Licenses

Different licenses use different license units to track whether an application is allowed to run. Some licenses track the number of CPUs an application is allowed to run on. Some licenses use tokens, requiring that a certain number of tokens be available in order to run. After you have defined *license_name* to the server, be sure to set `resources_available.`*`license_name`* to the correct number of units.

9.7.3 Server-level External Licenses Example

A common question that arises among PBS Professional customers is regarding how to use the dynamic resources to coordinate external license checking for applications. This occurs frequently in FlexLM deployments. This example illustrates how to implement such a custom resource. Before starting you should consider and have answers to the following questions:

How many units of a feature does the application require?
How many features are required to execute the application?
How do I query the license manager to obtain the available licenses of particular features?

With these questions answered you can begin configuring PBS Professional to query the license manager servers for the availability of application licenses. Think of a license manager feature as a resource. Therefore, you should associate a resource with each feature. Thus, if you need four features to run an application, then you need four custom resources.

To continue with the example, there are four features required to execute an application, thus *PBS_HOME*/server_priv/resourcedef needs to be modified:

```
feature1   type=long
feature3   type=long
feature6   type=long
feature8   type=long
```

Important: Note that in the above example the optional FLAG (third column of the resourcedef file) is not shown because it is not needed for server-level resources.

Once these resources have been defined, you will need to restart the PBS Server (see section 9.6 on page 198).

Once the Server recognizes the new resources, you may optionally specify any limits on that resource via qmgr, such as the maximum amount available of the new resources, or the maximum that a single user can request. For example, at the qmgr prompt you could type:

```
set server resources_max.scratchspace=1gb
```

Now that PBS is aware of the new custom resources we can begin configuring the Scheduler to query the license manager server, and schedule based on the availability of the licenses.

Within *PBS_HOME*/sched_priv/sched_config the following parameters will need to be updated, or introduced depending on your site configuration. The 'resources:' parameter should already exist with some default PBS resources declared, and therefore you will want to append your new custom resources to this line, as shown below.

```
resources: "ncpus, mem, arch, feature1, feature3, feature6, feature8"
```

You will also need to add the parameter 'server_dyn_res which allows the Scheduler to execute a program or script, that will need to be created, to query your license manager server for available licenses. For example.

UNIX:

```
server_dyn_res: "feature1 !/path/to/script [ argN] "
server_dyn_res: "feature3 !/path/to/script [ argN] "
server_dyn_res: "feature6 !/path/to/script [ argN] "
server_dyn_res: "feature8 !/path/to/script [ argN] "
```

Windows:

```
server_dyn_res: "feature1 !c:\Program Files\PBS Pro\script [ argN] "
server_dyn_res: "feature3 !c:\Program Files\PBS Pro\script [ argN] "
server_dyn_res: "feature6 !c:\Program Files\PBS Pro\script [ argN] "
server_dyn_res: "feature8 !c:\Program Files\PBS Pro\script [ argN] "
```

Once the `PBS_HOME/sched_priv/sched_config` has been updated, you will need to restart/reinitialize the `pbs_sched` process.

Essentially, the provided `script` needs to report the number of available licenses to the Scheduler via an echo to `stdout`. Complexity of the script is entirely site-specific due to the nature of how applications are licensed. For instance, an application may require `N+8` units, where `N` is number of CPUs, to run one job. Thus, the script could perform a conversion so that the user will not need to remember how many units are required to execute a `N` CPU application.

9.7.4 Complex External Licenses Example

This section presents a complex example of configuring PBS Professional to schedule and enforce several different application-specific licenses as custom resources.

For this example, we have a 10-node cluster, with one CPU per node. The nodes are numbered 01 through 10. On this cluster we have four licensed applications: one with a local node-locked license; two which draw licenses from an external license manager (such as FlexLM); and one whose node-locked license is served via an external license manager. Furthermore we want to limit use of the applications only to specific nodes. The table below shows the four applications, the number of licenses for each, the nodes on which the licenses should be used, and a description of the type of license used by the application.

Application	Licenses	Nodes	DESCRIPTION
AppA	8	01-08	uses a local node-locked application license
AppB	4	03-10	uses licenses from an externally managed pool
AppC	2	09-10	uses licenses from an externally managed pool
AppD_smp	2	09-10	uses externally managed node-locked licenses

Below is the step by step process for setting up the above described custom resources.

Server Configuration

1. Define the new resource in the Server's `resourcedef` file. Create a new file if one does not already exist by adding the resource names, type, and flag as discussed above.

```
cd $PBS_HOME/server_priv/
[edit] resourcedef
```

Example `resourcedef` file with new resources added:

```
AppA type=long flag=q
AppB type=long
AppC type=long
AppD_smp type=long flag=n
```

Note that since `AppA` has a node-locked license, it is shown in the `resourcedef` file with "`flag=q`" meaning that its value is maintained by the Server. Application `AppD_smp` is node-locked as well, but controlled by an external license manager, thus the Server tracks the usage at the node level ("`flag=n`").

2. Restart the Server (see section 9.6 on page 198).

3. Specify the available amount of any new resource whose value is maintained by the Server. In this example, only the node-locked application `AppA` needs this step.

```
qmgr: set server resources_available.AppA=8
```

Node Configuration

4. Direct the nodes, via `qmgr`, to accept the new resource. Where applicable, specify the maximum number of such licenses available on each node. (Ensure that each `qmgr` directive is typed on a single line.)

```
     qmgr: active node node01,node02,node03,node04,node05,
node06,node07,node08
     qmgr: set node resources_available.AppA = 1

     qmgr: active node node03,node04,node05,node06,node07,
node08,node09,node10
     qmgr: set node resources_available.AppB = 1

     qmgr: active node node09,node10
     qmgr: set node resources_available.AppC = 1

     qmgr: active node node09,node10
     qmgr: set node resources_available.AppD_smp=1
     qmgr: active node node01,node02,node03,node04,node05,
node06,node07,node08
     qmgr: set node resources_available.AppD_smp=0

     qmgr: quit
```

Scheduler Configuration

5. Edit the Scheduler configuration file, appending the new resource names to the "`resources:`" and "`server_dyn_res:`" lines.

```
cd $PBS_HOME/sched_priv/
[edit] sched_config
```

Example `sched_config` file with new resources added:

UNIX:

```
resources: "ncpus, mem, arch, AppA, AppB, AppC, AppD_smp"
server_dyn_res: "AppB !/local/flex_AppB"
server_dyn_res: "AppC !/local/flex_AppC"
server_dyn_res: "AppD_smp !/local/flex_AppD_smp"
```

Windows:

```
resources: "ncpus, mem, arch, AppA, AppB, AppC, AppD_smp"
server_dyn_res: "AppB !c:\Program Files\PBS Pro\flex_AppB"
server_dyn_res: "AppC !c:\Program Files\PBS Pro\flex_AppC"
server_dyn_res: "AppD_smp !c:\Program Files\PBS Pro\flex_AppD_smp"
```

6. Restart or reinitialize the Scheduler (see section 9.6 on page 198).

The following examples illustrates how the users could request the new resources in conjunction with their `nodes` request:

```
qsub -l nodes=8:AppA:ppn=1 -l AppA=8

qsub -l nodes=4:AppB:ppn=1 -l AppB=4
```

The example below shows what the node configuration would look like after configuration. What is shown is actually truncated output from the `pbsnodes -a` command. Similar information could be printed via the `qmgr -c "print node @default"` command as well.

```
node1
     properties = AppA
     resources_available.AppD_smp = 0
node2
     properties = AppA
     resources_available.AppD_smp = 0
node3
     properties = AppA,AppB
     resources_available.AppD_smp = 0
node4
     properties = AppA,AppB
     resources_available.AppD_smp = 0
node5
     properties = AppA,AppB
     resources_available.AppD_smp = 0
node6
     properties = AppA,AppB
     resources_available.AppD_smp = 0
node7
     properties = AppA,AppB
     resources_available.AppD_smp = 0
node8
     properties = AppA,AppB
     resources_available.AppD_smp = 0
node9
     properties = AppB,AppC
     resources_available.AppD_smp = 1
node10
     properties = AppB,AppC
     resources_available.AppD_smp = 1
```

Chapter 10 Administration

This chapter covers information on the maintenance and administration of PBS, and as such is intended for the PBS Manager. Topics covered include: starting and stopping PBS, security within PBS, prologue/epilogue scripts, accounting, configuration of the PBS GUIs, and using PBS with other products such as Globus.

10.1 pbs.conf

During the installation of PBS Professional, the `pbs.conf` file was created as either `/etc/pbs.conf` (UNIX) or `[PBS Destination Folder]\pbs.conf` (Windows, where [PBS Destination Folder] is the path specified when PBS was installed on the Windows platform, e.g., "`C:\Program Files\PBS Pro\pbs.conf`".) The installed copy of `pbs.conf` is similar to the one below.

```
PBS_EXEC=/usr/pbs
PBS_HOME=/var/spool/PBS
PBS_START_SERVER=1
PBS_START_MOM=1
PBS_START_SCHED=1
PBS_SERVER=hostname.domain
```

This configuration file controls which components are to be running on the local system, directory tree location, and various runtime configuration options. Each node in a cluster should have its own `pbs.conf` file. The following table describes the available parameters :

Parameters	Meaning
`PBS_BATCH_SERVICE_PORT`	Port Server listens on
`PBS_BATCH_SERVICE_PORT_DIS`	DIS Port Server listens on
`PBS_SYSLOG`	Controls use of syslog facility
`PBS_SYSLOGSEVR`	Filters syslog messages by severity
`PBS_ENVIRONMENT`	Location of `pbs_environment` file
`PBS_EXEC`	Location of PBS bin and sbin directories
`PBS_HOME`	Location of PBS working directories
`PBS_LOCALLOG`	Enables logging to local PBS log files
`PBS_MANAGER_GLOBUS_SERVICE_PORT`	Port Globus Manager listens on
`PBS_MANAGER_SERVICE_PORT`	Port MOM Manager listens on
`PBS_MOM_GLOBUS_SERVICE_PORT`	Port Globus MOM listens on
`PBS_MOM_HOME`	Location of MOM working directories
`PBS_MOM_SERVICE_PORT`	Port MOM listens on
`PBS_PRIMARY`	Hostname of primary Server
`PBS_RCP`	Location of `rcp` command if `rcp` is used
`PBS_SCP`	Location of `scp` command if `scp` is used; setting this parameter directs PBS to use `scp` rather than `rcp` for file transport.
`PBS_SCHEDULER_SERVICE_PORT`	Port Scheduler listens on
`PBS_SECONDARY`	Hostname of secondary Server
`PBS_SERVER`	Hostname of host running the Server
`PBS_START_SERVER`	Set to 1 if Server is to run on this host

Parameters	**Meaning**
`PBS_START_MOM`	Set to 1 if a MOM is to run on this host
`PBS_START_SCHED`	Set to 1 if Scheduler is to run on this node

10.2 Ports

PBS daemons listen for connections at specific network ports. These ports have defaults, but can be configured if necessary. For the list of default ports and information on configuring ports, see "Network Addresses and Ports" on page 39

10.3 Starting and Stopping PBS: UNIX and Linux

The Server, Scheduler, MOM and the optional MOM Globus processes must run with the real and effective uid of root. Typically the components are started automatically by the system upon reboot. The location of the boot-time start/stop script for PBS varies by OS, as the following table shows.

OS	**Location of PBS Startup Script**
AIX	`/etc/rc.d/rc2.d/S90pbs`
HP-UX	`/sbin/init.d/pbs`
IRIX	`/etc/init.d/pbs`
Linux	`/etc/init.d/pbs` `/etc/rc.d/init.d/pbs` (on some older linux versions)
Mac OS	`/Library/StartupItems/PBS`
OSF1	`/sbin/init.d/pbs`
Solaris	`/etc/init.d/pbs`
Tru64	`/sbin/init.d/pbs`

UNICOS	`/etc/config/daemons entry:`
	`SYS2 pbs YES /opt/pbs/etc/pbs_stop /opt/pbs/etc/pbs_start`

The PBS startup script reads the `pbs.conf` file to determine which components should be started. The startup script can also be run by hand to get status of the PBS components, and to start/stop PBS on a given host. The command line syntax for the startup script is:

```
STARTUP_SCRIPT [ status | stop | start | restart ]
```

Alternatively, you can start the individual PBS components manually, as discussed in the following sections. Furthermore, you may wish to change the start-up options, as discussed below.

Important: The method by which the Server and MOMs are shut down and restarted has different effects on running jobs; review section 10.3.6 "Impact of Shutdown / Restart on Running Jobs" on page 213.

10.3.1 Manually Starting MOM

MOM should be started at boot time. Typically there are no required options. It is recommended to start MOM before the Server so she will be ready to respond to the Server's "are you there?" ping. Start MOM with the command line:

```
PBS_EXEC/sbin/pbs_mom [ options]
```

If MOM is taken down and the host system continues to run, MOM should be restarted with either of the following options:

`-p` This directs MOM to let running jobs continue to run. Because MOM is no longer the parent of the jobs, she will not be notified (**SIGCHLD**) when they die and so must poll to determine when the jobs complete. The resource usage information therefore may not be completely accurate.

`-r` This directs MOM to kill off any jobs which were left running.

Without either the -p or the -r option, MOM will assume the jobs' processes no longer exist due to a system restart. This is called a cold start. She will not attempt to kill the processes and will request that any jobs which where running before the system restart be requeued.

Other command line options for MOM include:

`-a alarm`	Used to specify the alarm timeout in seconds for computing a resource. Every time a resource request is processed, an alarm is set for the given amount of time. If the request has not completed before the given time, an alarm signal is generated. The default is 5 seconds.
`-C chkdir`	Specifies the path of the directory used to hold checkpoint files. The default directory is `PBS_HOME/spool/checkpoint`; see the `-d` option. The directory specified with the `-C` option must be owned by root and accessible (rwx) only by root to protect the security of the checkpoint files. (See also "Site-Specific Job Checkpoint and Restart" on page 136.)
`-c config`	Specifies an alternate configuration file; see description below. If this is a relative filename it will be relative to `PBS_HOME/mom_priv`; see the `-d` option. If the specified file cannot be opened, `pbs_mom` will abort. If the `-c` option is not supplied, `pbs_mom` will attempt to open the default configuration file "config" in `PBS_HOME/mom_priv`. If this file is not present, `pbs_mom` will log the fact and continue.
`-d directory`	Specifies the path of the directory which is the home of the server's working files, `PBS_HOME`. This option is typically used along with `-M` when debugging MOM. The default directory is given by `PBS_HOME` which is typically `/usr/spool/PBS`.
`-L logfile`	Specify an absolute path name for use as the log file. If not specified, MOM will open a file named for the current date in the `PBS_HOME/mom_logs` directory; see the `-d` option.
`-M port`	Specifies the port number on which MOM will listen for batch requests. Default is 15002.
`-n nice_val`	Specifies the priority value of MOM when it executes. Note that this will set the priority of MOM herself, but any spawned processes will have a nice value of zero. (If instead you want all processes to have the specified nice value, use the UNIX nice command instead: "`nice -19 pbs_mom`".)

`-R port`	Specifies the port number on which MOM will listen for resource monitor requests, task manager requests and inter-MOM messages. Both a UDP and a TCP port of this number will be used. Default is 15003.
`-S port`	Specifies the port number on which MOM will communicate with the Server.
`-x`	Disables the check for privileged port resource monitor connections. This is used mainly for testing since the privileged port is the only mechanism used to prevent any ordinary user from connecting.

10.3.2 Manually Starting the Server

Normally the PBS Server is started from the system boot file via a line such as:

```
PBS_EXEC/sbin/pbs_server [ options]
```

The command line options for the Server include:

`-A acctfile`	Specifies an absolute pathname of the file to use as the accounting file. If not specified, the file is named for the current date in the `PBS_HOME/server_priv/accounting` directory.
`-a active`	Specifies if scheduling is active or not. This sets the Server attribute `scheduling`. If the option argument is “true” (“True”, “t”, “T”, or “1”), the server is *active* and the PBS job Scheduler will be called. If the argument is “false” (“False”, “f”, “F”, or “0), the server is *idle*, and the Scheduler will not be called and no jobs will be run. If this option is not specified, the server will retain the prior value of the `scheduling` attribute.
`-d serverhome`	Specifies the path of the directory which is home to the Server’s configuration files, `PBS_HOME`. The default configuration directory is `PBS_HOME` which is defined in `/etc/pbs.conf`.

`-e mask` Specifies a log event mask to be used when logging. See "log_events" on page 79.

`-F seconds` Specifies the delay time (in seconds) from detection of possible Primary Server failure until the Secondary Server takes over.

`-G globus_RPP`

Specifies the port number on which the Server should query the status of PBS MOM Globus process. Default is 15006.

`-g globus_port`

Specifies the host name and/or port number on which the Server should connect the PBS MOM Globus process. The option argument, *globus_port*, has one of the forms: `host_name`, `[:]port_number`, or `host_name:port_number`. If `host_name` not specified, the local host is assumed. If `port_number` is not specified, the default port is assumed. Default is 15005.

`-L logfile` Specifies an absolute pathname of the file to use as the log file. If not specified, the file is one named for the current date in the `PBS_HOME/server_logs directory`; see the `-d` option.

`-M mom_port` Specifies the host name and/or port number on which the server should connect to the MOMs. The option argument, *mom_port*, has one of the forms: `host_name`, `[:]port_number`, or `host_name:port_number`. If `host_name` not specified, the local host is assumed. If `port_number` is not specified, the default port is assumed. See the `-M` option for `pbs_mom`. Default is 15002.

`-p port` Specifies the port number on which the Server will listen for batch requests. Default is 15001.

`-R RPPport` Specifies the port number on which the Server should query the status of MOM. See the `-R` option for `pbs_mom`. Default is 15003.

`-S sched_port`

Specifies the port number to which the Server should connect when contacting the Scheduler. The option argument, *sched_port*, is of the same syntax as under the `-M` option. Default is 13004.

`-t type`	Specifies the impact on jobs when the Server restarts. The *type* argument can be one of the following four options:

Option	Effect Upon Job Running Prior to Server Shutdown
`cold`	All jobs are purged. Positive confirmation is required before this direction is accepted.
`create`	The Server will discard any existing queues (including jobs in those queues) and re-initialize the Server configuration to the default values. In addition, the Server is idled (scheduling set false). Positive confirmation is required before this direction is accepted.
`hot`	All jobs in the Running state are retained in that state. Any job that was requeued into the Queued state from the Running state when the server last shut down will be run immediately, assuming the required resources are available. This returns the server to the same state as when it went down. After those jobs are restarted, then normal scheduling takes place for all remaining queued jobs. All other jobs are retained in their current state. If a job cannot be restarted immediately because of a missing resource, such as a node being down, the server will attempt to restart it periodically for up to 5 minutes. After that period, the server will revert to a normal state, as if warm started, and will no longer attempt to restart any remaining jobs which were running prior to the shutdown.
`warm`	All jobs in the Running state are retained in that state. All other jobs are maintained in their current state. The job Scheduler will typically make new selections for which jobs are placed into execution. Warm is the default if `-t` is not specified.

10.3.3 Manually Starting the Scheduler

The Scheduler should also be started at boot time. If starting by hand, use the following command line:

```
PBS_EXEC/sbin/pbs_sched [ options]
```

There are no required options for the Standard Scheduler. Available options are listed below.

`-a alarm`	This specifies the time in seconds to wait for a scheduling run to finish. If a script takes too long to finish, an alarm signal is sent, and the Scheduler is restarted. If a core file does not exist in the current directory, `abort`() is called and a core file is generated. The default for *alarm* is 180 seconds.
`-d home`	This specifies the PBS home directory, `PBS_HOME`. The current working directory of the Scheduler is `PBS_HOME/sched_priv`. If this option is not given, `PBS_HOME` defaults to `PBS_HOME` as defined in the `pbs.conf` file.
`-L logfile`	Specifies an absolute path name of the file to use as the log file. If not specified, the Scheduler will open a file named for the current date in the `PBS_HOME/sched_logs` directory; see the `-d` option.
`-p file`	This specifies the "print" file. Any output from the Scheduler which is written to standard out or standard error will be written to this file. If this option is not given, the file used will be `PBS_HOME/sched_priv/sched_out`. See the `-d` option.
`-R port`	This specifies the resource monitor port to use. If this option is not given, the default port for the PBS MOM is used. Default is 15003.
`-S port`	This specifies the port for the scheduler to use. If this option is not given, the default port for the PBS Scheduler is used. Default is 13004.

The options that specify file names may be absolute or relative. If they are relative, their root directory will be `PBS_HOME/sched_priv`.

10.3.4 Manually Starting Globus MOM

The optional Globus MOM should be started at boot time if Globus support is desired. Note that the provided startup script does not start the Globus MOM. There are no required options. If starting manually, run it with the line:

```
PBS_EXEC/sbin/pbs_mom_globus [ options]
```

If Globus MOM is taken down and the host system continues to run, the Globus MOM should be restarted with the `-r` option. This directs Globus MOM to kill off processes running on behalf of a Globus job. See the **PBS Professional External Reference Specification** (or the `pbs_mom_globus`(1B) manual page) for a more complete explanation.

If the `pbs_mom_globus` process is restarted without the `-r` option, the assumption that will be made is that jobs have become disconnected from the Globus gatekeeper due to a system restart (cold start). Consequently, `pbs_mom_globus` will request that any Globus jobs that were being tracked and which where running be canceled and requeued.

10.3.5 Stopping PBS

The `qterm` command is used to shut down, selectively or inclusively, the various PBS components. The command usage is:

```
qterm [ -f | -i | -F] [ -m] [ -s] [ -t type] [ server...]
```

The available options, and description of each, follows.

Option	Description
`default (no option)`	Used without options, `qterm` will shut down the Primary Server.
`-f`	Specifies that the Secondary Server, in a Server failover configuration, should be shut down as well as the Primary Server. If this option is not used in a failover configuration, the Secondary Server will become active when the Primary Server exits. The `-f` and `-i` options cannot be used together
`-F`	Specifies that the Secondary Server (only) should be shut down. The Primary Server will remain active. The `-F` and `-i` or `-f` options cannot be used together.
`-i`	Specifies that the Secondary Server, in a Server failover configuration, should return to an idle state and wait for the Primary Server to be restarted. The `-i` and `-f` options cannot be used together.
`-m`	Specifies that all known `pbs_mom` components should also be told to shut down. This request is relayed by the Server to each MOM. Jobs are left running subject to other options to `qterm`.

Option	**Description**
`-s`	Specifies that the Job Scheduler, `pbs_sched`, should also be terminated.
`-t type`	Specifies the type of shutdown.

The `-t type` option takes one of three arguments for the *type* of shutdown you wish to perform. The three types are:

***type* of shutdown**	**Description**
`immediate`	All running jobs are to immediately stop execution. If checkpoint is supported, running jobs that can be checkpointed are checkpointed, terminated, and requeued. If checkpoint is not supported or the job cannot be checkpointed, running jobs are requeued if the rerunnable attribute is true. Otherwise, jobs are killed. Normally the Server will not shut down until there are no jobs in the running state. If the Server is unable to contact the MOM of a running job, the job is still listed as running. The Server may be forced down by a second "qterm `-t immediate"` command.
`delay`	If checkpoint is supported, running jobs that can be checkpointed are checkpointed, terminated, and requeued. If a job cannot be checkpointed, but can be rerun, the job is terminated and requeued. Otherwise, running jobs are allowed to continue to run. Note, the operator or Administrator may use the `qrerun` and `qdel` commands to remove running jobs.
`quick`	This is the default action if the `-t` option is not specified. This option is used when you wish that running jobs be left running when the Server shuts down. The Server will cleanly shut down and can be restarted when desired. Upon restart of the Server, jobs that continue to run are shown as running; jobs that terminated during the Server's absence will be placed into the exiting state.

If you are not running in Server Failover mode, then the following command will shut down the entire PBS complex:

```
qterm -s -m
```

However, if Server Failover is enabled, the above command will result in the Secondary Server becoming active after the Primary has shut down. Therefore, in a Server Failover configuration, the "`-f`" (or the "`-i`") option should be added:

```
qterm -s -m -f
```

Important: Note that `qterm` defaults to `qterm -t quick`. Also, note that the Server does a quick shutdown upon receiving `SIGTERM`.

Important: Should you ever have the need to stop a single MOM but leave jobs managed by her running, you have two options. The first is to send MOM a SIGINT. This will cause her to shut down in an orderly fashion. The second is to kill MOM with a `SIGKILL` (`-9`). Note that MOM will need to be restarted with the `-p` option in order reattach to the jobs.

10.3.6 Impact of Shutdown / Restart on Running Jobs

The method of how PBS is shut down (and which components are stopped) will affect running jobs differently. The impact of a shutdown (and subsequent restart) on running jobs depends on three things:

1 How the Server (`pbs_server`) is shut down,
2 How MOM (`pbs_mom`) is shut down,
3 How MOM is restarted.

Choose one of the following recommended sequences, based on the desired impact on jobs, to stop and restart PBS:

1. To allow running jobs to continue to run:

Shutdown: `qterm -t quick -m -s`

Restart:
```
pbs_server -t warm
pbs_mom -p
```

```
pbs_sched
```

2. To requeue the jobs and immediately rerun the ones that were running:

Shutdown: qterm `-t immediate -m -s`

Restart: pbs_mom
pbs_server -t hot
pbs_sched

3. To requeue the jobs and ignore what was running before:

Shutdown: `qterm -t immediate -m -s`

Restart:
```
pbs_mom
pbs_server -t warm
pbs_sched
```

10.3.7 Stopping / Restarting a Single MOM

If you wish to shut down and restart a single MOM, be aware of the following effects on jobs.
Methods of manual shutdown of a single MOM:

`SIGTERM`	If a MOM is killed with the signal `SIGTERM`, jobs are killed before MOM exits. Notification of the terminated jobs is not sent to the Server until the MOM is restarted. Jobs will still appear to be in the "R" (running) state.
`SIGINT` `SIGKILL`	If a MOM is killed with either of these signals, jobs are not killed before the MOM exits. With `SIGINT`, MOM exits after cleanly closing network connections.

A MOM may be restarted with the following options:

`pbs_mom`	Running jobs are returned to the Server to be requeued or deleted (if not rerunnable). Processes associated with the job are not killed (signaled).

`pbs_mom -r`	Processes associated with the job are killed. Running jobs are returned to the Server to be requeued or deleted. This option should not be used if the system has just been rebooted as the process numbers will be incorrect and a process not related to the job would be killed.
`pbs_mom -p`	Jobs which were running when MOM terminated remain running.

10.4 Starting and Stopping PBS: Windows 2000 / XP

When PBS Professional is installed on either Microsoft Windows XP or 2000, the PBS processes are registered as system services. As such, they will be automatically started and stopped when the systems boots and shuts down. However, there may come a time when you need to manually stop or restart the PBS services (such as shutting them down prior to a PBS software upgrade). The following example illustrates how to manually stop and restart the PBS services. (These lines must be typed at a Command Prompt with Administrator prilevege.)

```
net stop pbs_sched
net stop pbs_mom
net stop pbs_server
net stop pbs_rshd
    and to restart PBS:
net start pbs_server
net start pbs_mom
net start pbs_sched
net start pbs_rshd
```

It is possible to run (Administrator privilege) the PBS services manually, in standalone mode, as follows:

```
Admin> pbs_server -N <options>
Admin> pbs_mom -N <options>
Admin> pbs_sched -N <options>
Admin> pbs_rshd -N <options>
```

10.4.1 Startup Options to PBS Windows Services

The procedure to specify startup options to the PBS Windows Services is as follows:

1. Go to `Start Menu->Settings->Control Panel->Administrative Tools->Services` (in Win2000) or `Start Menu->Control Panel->Performance and Maintenance->AdministrativeTools->Services` (in WinXP).

2. Select the PBS Service you which to alter. For example, if you select "PBS_MOM", the MOM service dialog box will come up.

3. Enter in the "Start parameters" entry line as required. For example, to specify an alternate MOM configuration file, you might specify the following input:

```
-c "\Program Files\PBS Pro\home\mom_priv\config2"
```

4. Lastly, click on "Start" to start the specified Service.

Keep in mind that the Windows services dialog does not remember the "Start parameters" value when you close the dialog. For future restarts, you need to always specify the "Start parameters" value.

10.5 UNIX and Windows Interoperability Issues

This section discusses some of the issues related to mixing UNIX (or Linux) systems with Windows 2000/XP systems in the same PBS Professional cluster.

10.5.1 User Name Length Issues

Windows and UNIX systems have different maximum user login name lengths. In particular, most UNIX systems will not support a login name that is longer than 8 characters. Therefore, if your Windows usernames are longer than permitted by UNIX, either shorten the Windows names, or you cannot combine the systems in the same cluster.

10.6 Checkpoint / Restart Under PBS

PBS Professional supports two methods of checkpoint/restart: OS-specific and a generic site-specific method. Operating system checkpoint-restart is supported where provided by the system. Currently both SGI IRIX and Cray UNICOS provide OS-level checkpoint packages, which PBS uses. Alternatively, a site may configure the generic checkpointing feature of PBS Professional to use any method of checkpoint and restart. For details see "Site-Specific Job Checkpoint and Restart" on page 136. (In addition, users may manage their own checkpointing from within their application. This is discussed further in the **PBS Professional User's Guide**.) The location of the directory into which jobs are checkpointed can now be specified in a number of ways. In order of preference:

1. "`-C path`" command line option to `pbs_mom`
2. **`PBS_CHECKPOINT_PATH`** environment variable
3. "`$checkpoint_path path`" option in MOM's config file
4. default value

Note: checkpointing is not supported for job arrays. On systems that support checkpointing, subjobs are not checkpointed; instead they run to completion.

10.6.1 Manually Checkpointing a Job

On systems which provide OS-level checkpointing, the PBS Administrator may manually force a running job to be checkpointed. This is done by using the `qhold` command. (Discussed in detail in the **PBS Professional Users Guide**).

10.6.2 Checkpointing Jobs During PBS Shutdown

The PBS start/stop script will not result in PBS checkpointing jobs (on systems which provide OS-level checkpointing). This behavior allows for a faster shutdown of the batch system at the expense of rerunning jobs from the beginning. If you prefer jobs to be checkpointed, then append the `-t immediate` option to the `qterm` statement in the script.

10.6.3 Suspending/Checkpointing Multi-node Jobs

The PBS suspend/resume and checkpoint/restart capabilities are supported for multi-node jobs. With checkpoint (on systems which provide OS-level checkpointing), the system must be able to save the complete session state in a file. This means any open socket will cause the operation to fail. PBS normally sets up a socket connection to a process (`pbs_demux`) which collects stdio streams from all tasks. If this is not turned off, the checkpoint cannot work. Therefore, a new job attribute has been added: `no_stdio_sockets`. See the `pbs_job_attributes(7B)` manual page for more details. If this attribute is true, the `pbs_demux` process will not be started and no open socket will prevent the checkpoint from working. The other place where PBS will use a socket that must be addressed is if the program `pbsdsh` is used to spawn tasks. There is a new option for `pbsdsh` '`-o`' that is used to prevent it from waiting for the spawned tasks to finish. This is done so no socket will be left open to the MOM to receive task manager events. If this is used, the shell must use some other method to wait for the tasks to finish.

10.6.4 Checkpointing Jobs Prior to SGI IRIX Upgrade

Under the SGI IRIX operating system, the normal checkpoint procedure does not save shared libraries in the restart image in order to reduce the image size and time required to write it. This type of image cannot be restarted following an IRIX operating system upgrade. In order to produce an image which can be restarted following an upgrade, a special flag is required when calling checkpoint. MOM has a `config` file option `$checkpoint_upgrade` which if present causes PBS to use the special upgrade checkpoint flag. It is recommended that this flag be set (and `pbs_mom` be restarted via `SIGHUP`) only when shutting down PBS just prior to upgrading your system.

10.7 Security

There are three parts to security in the PBS system:

Internal security	Can the component itself be trusted?
Authentication	How do we believe a client about who it is?
Authorization	Is the client entitled to have the requested action performed?

10.7.1 Internal Security

A significant effort has been made to ensure the various PBS components themselves cannot be a target of opportunity in an attack on the system. The two major parts of this effort are the security of files used by PBS and the security of the environment. Any file used by PBS, especially files that specify configuration or other programs to be run, must be secure. The files must be owned by root and in general cannot be writable by anyone other than root.

A corrupted environment is another source of attack on a system. To prevent this type of attack, each component resets its environment when it starts. If it does not already exist, the `environment` file is created during the install process. As built by the install process, it will contain a very basic path and, if found in root's environment, the following variables: **TZ**, **LANG**, **LC_ALL**, **LC_COLLATE**, **LC_CTYPE**, **LC_MONETARY**, **LC_NUMERIC**, and **LC_TIME**. The `environment` file may be edited to include the other variables required on your system.

Important: Note that **PATH** must be included. This value of **PATH** will be passed on to batch jobs. To maintain security, it is important that **PATH** be restricted to known, safe directories. Do NOT include "." in **PATH**. Another variable which can be dangerous and should not be set is **IFS**.

The entries in the **`PBS_ENVIRONMENT`** file can take two possible forms:

```
variable_name=value
variable_name
```

In the latter case, the value for the variable is obtained before the environment is reset.

10.7.2 Host Authentication

PBS uses a combination of information to authenticate a host. If a request is made from a client whose socket is bound to a privileged port (less than 1024, which requires root privilege), PBS believes the IP (Internet Protocol) network layer as to whom the host is. If the client request is from a non-privileged port, the name of the host which is making a client request must be included in the credential sent with the request and it must match the IP network layer opinion as to the host's identity.

10.7.3 Host Authorization

Access to the Server from another system may be controlled by an access control list (ACL). Access to `pbs_mom` is controlled through a list of hosts specified in the `pbs_mom`'s configuration file. By default, only "localhost", the name returned by `gethostname`(2), and the host named by `PBS_SERVER` from `/etc/pbs.conf` are allowed. See the man page for `pbs_mom`(8B) for more information on the configuration file. Access to `pbs_sched` is not limited other than it must be from a privileged port.

10.7.4 User Authentication

The PBS Server authenticates the user name included in a request using the supplied PBS credential. This credential is supplied by `pbs_iff`.

10.7.5 User Authorization

PBS as shipped does not assume a consistent user name space within the set of systems which make up a PBS cluster. However, the Administrator can enable this assumption, if desired. By default, the routine `site_map_user`() is called twice, once to map the name of the requester and again to map the job owner to a name on the Server's (local) system. If the two mappings agree, the requester is considered the job owner.

If running PBS in an environment that *does* have a flat user namespace, the Administrator can disable these checks by setting the `flatuid` Server attribute to `True` via `qmgr`:

```
qmgr
Qmgr: set server flatuid=True
```

If `flatuid` is set to `true`, a UserA on HostX who submits a job to the PBS Server on HostY will *not* require an entry in the `/etc/passwd` file (UNIX) or the User Database (Windows), nor a `.rhosts` entry on HostY for HostX, nor must HostX appear in HostY's `hosts.equiv` file. In either case, if a job is submitted by *UserA@HostA,* PBS will allow the job to be deleted or altered by *UserA@HostB*.

Important: When `flatuid` is true, a password entry for the submitting user is not required on the server system. But, without the password entry, the Server does not know the user's group (it is not passed implicitly from `qsub`). Without knowing the group, the `acl_group` attribute on a queue cannot be checked. The error of "not allowed" will be returned. This applies to `acl_group` on the Server or Queue level.

If `flatuid` is *not* set to `true`, a user may supply a name under which the job is to be executed on a certain system (via the `-u user_list` option of the `qsub`(1B) command). If one is not supplied, the name of the job owner is chosen to be the execution name. Authorization to execute the job under the chosen name is granted under the following conditions:

1. The job was submitted on the Server's (local) host and the submitter's name is the same as the selected execution name.

2. The host from which the job was submitted is declared trusted by the execution host in the system `hosts.equiv` file or the submitting host and submitting user's name are listed in the execution users' `.rhosts` file. The system-supplied library function, `ruserok`*()*, is used to make these checks.

   The `hosts.equiv` file is located in `/etc` under UNIX, and in `%WINDIR%\system32\drivers\etc\` under Windows).

Additional information on user authorization is given in section 3.6 "UNIX User Authorization" on page 21 and section 3.8 "Windows User Authorization" on page 28, as well as in the **PBS Professional User's Guide**.

In addition to the above checks, access to a PBS Server and queues within that Server may be controlled by access control lists. (For details see "Server Configuration Attributes" on page 76 and "Queue Configuration Attributes" on page 87.)

10.7.6 Group Authorization

PBS allows a user to submit jobs and specify under which group the job should be executed. The user specifies a `group_list` attribute for the job which contains a list of group@host similar to the user list. See the `group_list` attribute under the -W option of `qsub`(1B). The PBS Server will ensure the user is a member of the specified group by:

1. Checking if the specified group is the user's primary group in the password entry on the execution host. In this case the user's name does not have to appear in the group entry for his primary group.

2. Checking on the execution host for the user's name in the specified group entry in `/etc/group` (under UNIX) or in the group membership field of the user's account profile (under Windows).

The job will be aborted if both checks fail. The checks are skipped if the user does not supply a `group_list` attribute (and the user's default/primary group will be used).

Under UNIX, when staging files in or out, PBS also uses the selected execution group for the copy operation. This provides normal UNIX access security to the files. Since all group information is passed as a string of characters, PBS cannot determine if a numeric string is intended to be a group name or GID. Therefore when a group list is specified by the user, PBS places one requirement on the groups within a system: each and every group in which a user might execute a job MUST have a group name and an entry in `/etc/group`. If no `group_list` is used, PBS will use the login group and will accept it even if the group is not listed in `/etc/group`. Note, in this latter case, the `egroup` attribute value is a numeric string representing the GID rather than the group "name".

10.7.7 External Security

In addition to the security measures discussed above, PBS provides three levels of privilege: user, Operator, and Manager. Users have user privilege which allows them to manipulate their own jobs. Manager or Operator privilege is required to set or unset attributes of the Server, queues, nodes, and to act on other people's jobs. For specific limitations on "user" privilege, and additional attributes available to Managers and Operators, review the following: "The qmgr Command" on page 71; the introduction to Chapter 11 "Administrator Commands" on page 244; and the discussion of user commands in the **PBS Professional User's Guide**.

10.7.8 Enabling Hostbased Authentication on Linux

Hostbased authentication will allow users within your cluster to execute commands or transfer files on/to remote machines. This can be accomplished for both the r-commands (e.g., rsh, rcp), and secure-commands (e.g., ssh, scp).

10.7.8.1 RSH/RCP

1 Verify that the rsh-server and rsh-client packages are installed on each node within the cluster.

2 Verify that the rsh and rlogin services are on on each node within the cluster.
Example:
```
chkconfig --list | grep -e rsh -e rlogin
rlogin: on
rsh:    on
```

3 On the headnode (for simplicity) add the hostname of each node within the cluster to `/etc/hosts.equiv`, and distribute it to each node within the cluster.
Example file (filename: `/etc/hosts.equiv`):
```
headnode
node01
node02
```

```
node03
node04
node05
```

10.7.8.2 SSH/SCP

1 Verify that the openSSH package is installed on each node within the cluster.

2 Verify that the openSSH service is on on each node within the cluster.
Example:

```
chkconfig --list | grep ssh
sshd        0:off  1:off  2:on   3:on   4:on   5:on   6:off
```

3 Modify the following `ssh config` files on each node within the cluster to enable the hostbased authentication. These options may be commented out, and therefore require to be uncommented and set.

a. `/etc/ssh/sshd_config`

```
HostbasedAuthentication yes
```

b. `/etc/ssh/ssh_config`

```
HostbasedAuthentication yes
```

4 Restart the openSSH service on each node within the cluster.

```
/etc/init.d/sshd restart
```

5 On the headnode (for simplicity) create a file which contains the hostname and IP address of each node within the cluster, where the hostname and IP address are comma delimited.
Example file (filename: `ssh_hosts`):

```
headnode,192.168.1.100
node01,192.168.1.1
node02,192.168.1.2
node03,192.168.1.3
node04,192.168.1.4
node05,192.168.1.5
```

6 Gather each node's public ssh host key within the cluster by executing `ssh-keyscan` and the `ssh_hosts` file created in Step 5, and distribute the file to each node within the cluster.

```
ssh-keyscan -t rsa -f ssh_hosts > \
        /etc/ssh/ssh_known_hosts2
```

7 Create the `/etc/ssh/shosts.equiv` file for all of the machines in the

cluster.

.

8 Every machine in the cluster will need to have `ssh_config` and `sshd_config` updated. These files can be copied out to each machine.

SPECIAL NOTES:
The configurations of OpenSSH change (frequently). Therefore, it is important to understand what you need to set up. Here are some tips on some versions.

OpenSSH_3.5p1:
Procedure above should work.

OpenSSH_3.6.1p2:
Procedure above should work with the following additional step:
1. Define "EnableSSHKeysign yes" in the `/etc/ssh/ssh_config` file

OpenSSH_3.9p1:
Procedure above should work with the following two additional steps:
1. Define "EnableSSHKeysign yes" in the `/etc/ssh/ssh_config` file
2. **`chmod 4755 /usr/lib/ssh/ssh-keysign`**
   Was 0755 before chmod.
   This file is required to be setuid to work.

NOTE for LAM:
Might be worth noting that if you want to use SSH that you enable 'PermitUserEnvironment yes' so that the user's environment will be passed onto the other nodes within the cluster. Otherwise, you will see an issue with tkill not being in the user's PATH when executing across the nodes.

10.8 Root-owned Jobs

The Server will reject any job which would execute under the UID of zero unless the owner of the job, typically root/Administrator, is listed in the Server attribute `acl_roots`.

The Windows version of PBS considers as a "root" account the following:

Administrator account
SYSTEM account

account that is a member of the Administrators group
account that is a member of the Domain Admins group

In order to submit a job from this "root" account on the local host, be sure to set acl_roots. For instance, if user foo is a member of the Administrators group, then you need to set:

```
qmgr:  set server acl_roots += foo
```

in order to submit jobs and not get a "bad uid for job execution" message.

Important: Allowing "root" jobs means that they can run on a configured node host under the same account which could also be a privileged account on that node.

10.9 Managing PBS and Multi-node Parallel Jobs

Many customers use PBS Professional in cluster configurations for the purpose of managing multi-node parallel applications. This section provides the PBS Administrator with information specific to this situation.

10.9.1 The PBS_NODEFILE

For each job, PBS will create a job-specific "host file" or "node file"—a text file containing the name of the node(s) allocated to that job, listed one per line. The file will be created by the MOM on the first node in `PBS_HOME/aux/`*`JOB_ID`*, where *`JOB_ID`* is the actual job identifier for that job. The full path and name for this file is written to the job's environment via the variable `PBS_NODEFILE`. (See also details on using this environment variable in Chapter 9 of the **PBS Professional User's Guide**.) For more on node files, see "PBS Nodes File" on page 95.

10.10 Support for MPI

Some of the MPI integrations use pbs_attach, which means MOM polls for usage information like CPU time. Since MOM only polls every 2 minutes, up to 2 minutes' data may be lost for each process.

10.10.1 Interfacing MPICH with PBS Professional on UNIX

The existing mpirun command can be modified to check for the PBS environment and use the PBS-supplied host file. Do this by editing the `.../mpich/bin/mpirun.args` file and adding the following near line 40 (depending on the version being used):

```
if [  "$PBS_NODEFILE" != "" ]
then
     machineFile=$PBS_NODEFILE
fi
```

Important: Additional information regarding checkpointing of parallel jobs is given in "Suspending/Checkpointing Multi-node Jobs" on page 217.

10.10.1.1 MPICH on Linux

On Linux systems running MPICH with P4, the existing `mpirun` command is replaced with `pbs_mpirun` The `pbs_mpirun` command is a shell script which attaches a user's MPI tasks to the PBS job.

10.10.1.2 The `pbs_mpirun` command

The PBS command `pbs_mpirun` replaces the standard `mpirun` command in a PBS MPICH job using P4. The usage is the same as `mpirun` except for the `-machinefile` option. The value for this option is generated by `pbs_mpirun`. All other options are passed directly to `mpirun`. The value used for the `-machinefile` option is a temporary file created from the PBS_NODEFILE in the format expected by `mpirun`. If the `-machinefile` option is specified on the command line, a warning will be output saying "Warning, -machinefile value replaced by PBS".

10.10.1.3 Transparency to the User

Users should be able to continue to run existing scripts. To be transparent to the user, `pbs_mpirun` should replace standard `mpirun`. To do this, the link for `mpirun` should be changed to point to `pbs_mpirun`:

* install MPICH into /usr/local/mpich (or note path for mpirun)
* mv /usr/local/mpich/bin/mpirun /usr/local/mpich/bin/mpirun.std
* create link called "mpirun" pointing to pbs_mpirun in /usr/local/mpich/bin/

* edit pbs_mpirun to change "mpirun" call to "mpirun.std"

At this point, using "mpirun" will actually invoke pbs_mpirun.

When `pbs_mpirun` is run, it runs `pbs_attach`, which attaches the user's MPI process to the job.

.

10.10.1.4 Environment Variables and PATHs

The PBS_RSHCOMMAND environment variable should not be set by the user. For `pbs_mpirun` to function correctly for users who require the use of `ssh` instead of `rsh`, several approaches are possible:

1 Set P4_RSHCOMMAND in the login environment.

2 Set P4_RSHCOMMAND externally to the login environment, then pass the value to PBS via qsub(1)'s -v or -V arguments:

```
qsub -vP4_RSHCOMMAND=ssh ...
```

or

```
qsub -V ...
```

3 A PBS administrator may set P4_RSHCOMMAND in the `pbs_environment` file in `PBS_HOME` and advise users to not set `P4_RSHCOMMAND` in the login environment

PATH on remote machines must contain PBS_EXEC/bin. Remote machines must all have pbs_attach in the PATH.

10.10.1.5 Notes

Usernames must be identical across nodes.

10.10.2 Integration with MPI under AIX

MPI is supported under IBM's Parallel Operating Environment (POE) on AIX. Under AIX, the program `poe` is used to start user processes on remote machines.

10.10.2.1 PBS with POE

The PBS command `pbs_poe` replaces the standard `poe` command in a PBS MPI job. The usage is the same as `poe` except for the `-procs` and `-hostfile` options. Values for these options are generated by `pbs_poe`. All other options are passed directly to `poe`. The value generated for the `-procs` option is the count of nodes in PBS_NODEFILE. The value used for the `-hostfile` option is the value of PBS_NODEFILE. If the `-hostfile` option is specified on the command line, a warning will be output saying "hostfile value replaced by PBS". The `-procs` option may be specified with a value smaller than the count of nodes in PBS_NODEFILE to limit the number of nodes used. If the `-procs` option specifies a value larger than the count of nodes in PBS_NODEFILE, a warning is output saying "(number of host nodes) < (number of procs) -- assigning multiple processes per node".

When `pbs_poe` is run, it invokes `poe` with several arguments including `pbs_attach`, the job id, and the arguments to `pbs_poe`. The command `pbs_attach` attaches the user's MPI process to the job.

10.10.2.2 Transparency to the User

Users should be able to continue to run existing scripts. To be transparent to the user, `pbs_poe` should replace standard `poe`. To do this, the link for `/usr/bin/poe` should be changed to point to `pbs_poe`.

* note path for poe (typically /usr/bin/poe)
* confirm this is a link to poe (/usr/lpp/ppe.poe/bin/poe)
* remove poe link (rm /usr/bin/poe).
* create pbs_poe link (ln -s /usr/pbs/bin/pbs_poe /usr/bin/poe)

At this point, using "poe" will actually invoke `pbs_poe`.

10.10.2.3 Environment Variables

The environment variables LANG and NLSPATH must be copied from the file `/etc/environment` into the `pbs_environment` file so they are available to jobs. This is done by `pbs_postinstall`.

An error saying, "NLSPATH is not set" can occur if the user uses `su` to switch users. Both the environment variables NLSPATH and LANG must be set when `poe` or `pbs_poe` is run. AIX sets them when the user logs in, taking settings from the file `/etc/environment`. PBS sets them for a job, using settings from `/usr/local/`

`spool/PBS/pbs_environment`.

Using the program `su` to switch user can cause NLSPATH to become unset. If this happens, running `poe` or `pbs_poe` will result in an error. To avoid this problem, use *`su -`* to set a full login environment for the new shell. For more information, see the AIX man page for `su`.

10.10.2.4 Paths

Remote machines must all have `pbs_attach` available in the same path.
The path to the “real” poe must be `/usr/lpp/ppe.poe/bin/poe`.
The path to the "real" pdbx must be `/usr/lpp/ppe.poe/bin/pdbx`.

10.10.2.5 Using the `pdbx` Debugger

The debugger `pdbx` may also be relinked as follows:

* note path for pdbx (typically /usr/bin/pdbx)
* confirm this is a link to pdbx (/usr/lpp/ppe.poe/bin/pdbx)
* remove pdbx link (rm /usr/bin/pdbx).
* create pbs_poe link (ln -s /usr/pbs/bin/pbs_poe /usr/bin/pdbx)

At this point, using "pdbx" will actually invoke `pbs_poe`. The path to the "real" pdbx must be `/usr/lpp/ppe.poe/bin/pdbx`.

10.10.2.6 Notes

Usernames must be identical across nodes.

It is possible to run an MPI program compiled with `mpcc_r` without using `poe`. For example, an MPI program called mpihw that prints the hostname can be run on 2 hosts, host-1 and host-2, as follows:

```
$ ./mpihw -procs 2
 hithere host-1
 hithere host-2
```

All the options permitted with poe may be used with an MPI program.

10.10.3 Integration with LAM MPI

10.10.3.1 The pbs_lamboot Command

The PBS command `pbs_lamboot` replaces the standard `lamboot` command in a PBS LAM MPI job, for starting LAM software on each of the PBS execution hosts.

Usage is the same as for LAM's lamboot. All arguments except for `bhost` are passed directly to `lamboot`. PBS will issue a warning saying that the `bhost` argument is ignored by PBS since input is taken automatically from $PBS_NODEFILE. The `pbs_lamboot` program will not redundantly consult the $PBS_NODEFILE if it has been instructed to boot the nodes using the `tm` module. This instruction happens when an argument is passed to `pbs_lamboot` containing "-ssi boot tm" or when the `LAM_MPI_SSI_boot` environment variable exists with the value `tm`.

10.10.3.2 The pbs_mpilam Command

The PBS command pbs_mpilam replaces the standard mpirun command in a PBS LAM MPI job, for executing programs. It attaches the user's processes to the PBS job. This allows PBS to collect accounting information, and to manage the processes.

Usage is the same as for LAM mpirun. All options are passed directly to mpirun. If the where argument is not specified, pbs_mpilam will try to run the user's program on all available CPUs using the C keyword.

10.10.3.3 PATH

The PATH for `pbs_lamboot` and `pbs_mpilam` on all remote machines must contain PBS_EXEC/bin.

10.10.3.4 Transparency to the User

Both pbs_lamboot and pbs_mpilam should be transparent to the user. Users should be able to run existing scripts.

To be transparent to the user, pbs_lamboot should replace LAM lamboot. The link for lamboot should be changed to point to pbs_lamboot.

- Install LAM MPI into `/usr/local/lam-<version>`
- **`mv /usr/local/lam-<version>/bin/lamboot /user/local/lam-<version>/bin/lamboot.lam`**
- Edit `pbs_lamboot` to change "lamboot" call to "lamboot.lam"

•Rename `pbs_lamboot` to `lamboot`:

```
   cd /usr/local/lam-<version>/bin
   ln  -s PBS_EXEC/bin/pbs_lamboot lamboot
```

At this point, using “lamboot” will actually invoke `pbs_lamboot`.

To be transparent to the user, `pbs_mpilam` should replace `LAM mpirun`. The link for `mpirun` should be changed to point to `pbs_mpilam`.

•Install LAM MPI into `/usr/local/lam-<version>`

```
·mv  /usr/local/lam-<version>/bing/mpirun
   /user/local/lam-<version>/bin/mpirun.lam
```

•Edit `pbs_mpirun` to change “mpirun” call to “mpirun.lam”

•Rename `pbs_mpilam` to `mpirun`:

```
   cd /usr/local/lam-<version>/bin
   ln -s PBS_EXEC/.bin/pbs_mpilam mpirun
```

10.10.4 Integration with HP MPI on HP-UX and Linux

10.10.4.1 The pbs_mpihp Command

The PBS command pbs_mpihp replaces the standard mpirun and mpiexec commands in a PBS HP MPI job on HP-UX and Linux, for executing programs. It attaches the user’s processes to the PBS job. This allows PBS to collect accounting information, and to manage the processes.

10.10.4.2 Transparency to the User

To be transparent to the user, `pbs_mpihp` should replace HP `mpirun`. The recommended steps for making `pbs_mpihp` transparent to the user are:

Rename HP’s `mpirun`:

```
   cd <MPI installation location>/bin
   mv mpirun mpirun.hp
```

Link the user-callable “mpirun” to `pbs_mpihp`:

```
   cd <MPI installation location>/bin
   ln -s $PBS_EXEC/bin/pbs_mpihp mpirun
```

Create a link to `mpirun.hp` from `PBS_EXEC/etc/pbs_mpihp`. `pbs_mpihp` will call the real HP `mpirun`:

```
cd $PBS_EXEC/etc
ln -s <MPI installation location>/bin/mpirun.hp
    pbs_mpihp
```

10.11 SGI Job Container / Limits Support

PBS Professional supports the SGI Job Container/Limit feature. Each PBS job is placed in its own SGI Job container. Limits on the job are set as the `MIN(ULDB limit, PBS Resource_List limit)`. The ULDB domains are set in the following order:

PBS_{queue name}
PBS
batch

Limits are set for the following resources: `cput` and `vmem`. A job limit is *not* set for `mem` because the kernel does not factor in shared memory segments among `sproc`() processes, thus the system reported usage is too high.

For information on using Comprehensive System Accounting, see "Configuring MOM for Comprehensive System Accounting" on page 155.

10.12 Job Prologue / Epilogue Programs

PBS provides the ability for the Administrator to run a site-supplied script (or program) before (`prologue`) and/or after (`epilogue`) each job runs. This provides the capability to perform initialization or cleanup of resources, such as temporary directories or scratch files. The scripts may also be used to write "banners" on the job's output files. When multiple nodes are allocated to a job, these scripts are run only by the "Mother Superior", the `pbs_mom` on the first node allocated. This is also where the job shell script is run. Note that both the `prologue` and `epilogue` are run under root (on UNIX) or an Admin-type account (on Windows), and neither is included in the job session, thus the `prologue` cannot be used to modify the job environment or change limits on the job.

10.12.1 Sequence of Events for End of Job

This is the order in which events take place at the end of a job:

1 The job script finishes
2 The epilogue is run

3 The obit is sent to the server
4 File staging out takes place, including stdout and stderr
5 Files staged in and out are removed
6 Job files are deleted

If a `prologue` or `epilogue` script is not present, MOM continues in a normal manner. If present, the script is run with root/Administrator privilege. In order to be run, the script must adhere to the following rules:

- The script must be in the *`PBS_HOME`*`/mom_priv` directory with the exact name "`prologue`" (under UNIX) or "`prologue.bat`" (under Windows) for the script to be run before the job and the name "`epilogue`" (under UNIX) or "`epilogue.bat`" (under Windows) for the script to be run after the job.
- Under UNIX, the script must be owned by root, be readable and executable by root, and cannot be writable by anyone but root.
- Under Windows, the script's permissions must give "Full Access" to the "Domain Admins" group (domain environment) or the "Administrators" group (stand-alone environments).

The "script" may be either a shell script or an executable object file.

The `prologue` will be run immediately prior to executing the job. When that execution completes for any reason (normal termination, job deleted while running, error exit, or even if `pbs_mom` detects an error and cannot completely start the job), the `epilogue` script will be run. If the job is deleted while it is queued, then neither the `prologue` nor the `epilogue` is run.

If a job is rerun or requeued as the result of being checkpointed, the exit status passed to the `epilogue` (and recorded in the accounting record) will have one of the following special values:

-11 - Job was rerun
-12 - Job was checkpointed and aborted

10.12.2 Prologue and Epilogue Arguments

When invoked, the `prologue` is called with the following arguments:

argv[1]	the job id.
argv[2]	the user name under which the job executes.
argv[3]	the group name under which the job executes.

The `epilogue` is called with the above, plus:

argv[4]	the job name.
argv[5]	the session id.
argv[6]	the requested resource limits (list).
argv[7]	the list of resources used
argv[8]	the name of the queue in which the job resides.
argv[9]	the account string, if one exists.
argv[10]	the exit status of the job.

For both the `prologue` and `epilogue`:

envp	The environment passed to the script is null.
cwd	The current working directory is `PBS_HOME/mom_priv` (`prologue`) or the user's home directory (`epilogue`).
input	When invoked, both scripts have standard input connected to a system dependent file. The default for this file is `/dev/null`.
output	The standard output and standard error of the scripts are connected to the files which contain the standard output and error of the job. (Under UNIX, there is one exception: if a job is an interactive PBS job, the standard output and error of the `epilogue` is pointed to `/dev/null` because the pseudo terminal connection used was released by the system when the job terminated. Interactive jobs are only supported on UNIX.)

Important: Under Windows, accessing **`arg[10]`** in the epilogue requires a shift in positional parameters. The script must call the arguments with indices 0 through 8, then perform a shift /8, then access the last argument using %9%.

10.12.3 Prologue and Epilogue Time Out

To prevent an error condition within the `prologue` or `epilogue` from delaying PBS, MOM places an alarm around the script's/program's execution. This is currently set to 30 seconds. If the alarm sounds before the script has terminated, MOM will kill the script.

The alarm value can be changed via `$prologalarm` MOM configuration parameter.

10.12.4 Prologue and Epilogue Error Processing

Normally, the `prologue` and `epilogue` programs should exit with a zero exit status. MOM will record in her log any case of a non-zero exit codes. Exit status values and their impact on the job are:

Exit Code	Meaning	Prologue	Epilogue
-4	The script timed out (took too long).	The job will be requeued.	Ignored
-3	The `wait`(2) call waiting for the script to exit returned with an error.	The job will be requeued	Ignored
-2	The input file to be passed to the script could not be opened.	The job will be requeued.	Ignored
-1	The script has a permission error, is not owned by root, and/or is writable by others than root.	The job will be requeued.	Ignored
0	The script was successful.	The job will run.	Ignored
1	The script returned an exit value of 1.	The job will be aborted.	Ignored
>1	The script returned a value greater than one.	The job will be requeued.	Ignored

The above apply to normal batch jobs. Under UNIX which supports interactive-batch jobs (`qsub -I` option), such jobs cannot be requeued on a non-zero status, and will therefore be aborted on any non-zero `prologue` exit.

Important: The Administrator must exercise great caution in setting up the `prologue` to prevent jobs from being flushed from the system.

`Epilogue` script exit values which are non-zero are logged, but have no impact on the state of the job. Neither prologue nor epilogue exit values are passed along as the job's exit value.

10.13 The Accounting Log

The PBS Server maintains an accounting log. The log name defaults to *PBS_HOME*/server_priv/accounting/*ccyymmdd* where *ccyymmdd* is the date. The accounting log files may be placed elsewhere by specifying the -A option on the pbs_server command line. The option argument is the full (absolute) path name of the file to be used. If a null string is given, then the accounting log will not be opened and no accounting records will be recorded. For example

```
pbs_server -A ""
```

The accounting file is changed according to the same rules as the event log files. If the default file is used, named for the date, the file will be closed and a new one opened every day on the first event (write to the file) after midnight. With either the default file or a file named with the -A option, the Server will close the accounting log and reopen it upon daemon/service shutdown.

On UNIX the Server will also close and reopen the account log file upon the receipt of a **SIGHUP** signal. This allows you to rename the old log and start recording again on an empty file. For example, if the current date is February 9, 2005 the Server will be writing in the file 20050209. The following actions will cause the current accounting file to be renamed feb9 and the Server to close the file and starting writing a new 20050209.

```
cd $PBS_HOME/server_priv/accounting
mv 20050209 feb9
kill -HUP 1234     (the Server's pid)
```

On Windows, to manually rotate the account log file, shut down the Server, move or rename the accounting file, and restart the Server. For example, to cause the current accounting file to be renamed feb9 and the Server to close the file and start writing a new 20050209:

```
cd "%PBS_HOME%\server_priv\accounting"
net stop pbs_server
move 20050209 feb9
net start pbs_server
```

10.13.1 Accounting Log Format

The PBS accounting file is a text file with each entry terminated by a newline. The format of an entry is:

```
date time;record_type;id_string;message_text
```

The `date time` field is a date and time stamp in the format:

```
mm/dd/yyyy hh:mm:ss
```

The `id_string` is the job, reservation, or reservation-job identifier. The `message_text` is ascii text. The content depends on the record type. The message text format is blank-separated keyword=value fields. The `record_type` is a single character indicating the type of record. The types are:

`A`	Job was aborted by the server.
`B`	Beginning of reservation period. The `message_text` field contains details about the specified advance reservation. Possible attributes include:

Table 5:

Attribute	Explanation
`owner=`ownername	Name of party who submitted the resource reservation request.
`name=`reservation_name	If submitter supplied a name string for the reservation.
`account=`account_string	If submitter supplied a string to be recorded in accounting.
`queue=`queue_name	The name of the instantiated reservation queue if this is a general resource reservation. If the resources reservation is for a reservation job, this is the name of the queue to which the reservation-job belongs.
`ctime=`creation_time	Time at which the resource reservation was created; seconds since the epoch.
`start=`period_start	Time at which the reservation period is to start, in seconds since the epoch.
`end=`period_end	Time at which the reservation period is to end, in seconds since the epoch.

Table 5:

Attribute	Explanation
`duration`=reservation_duration	The duration specified or computed for the resource reservation, in seconds.
`exec_host`=node_list	Nodes and node-associated resources are listed . Format is the same as for qrun -H: exec_host=NodeA:mem=X+NodeB:mem=Y:ncpus=Z
`authorized_users`=users_list	The list of acl_users on the queue that is instantiated to service the reservation.
`authorized_groups`=groups_list	If specified, the list of acl_groups on the queue that is instantiated to service the reservation.
`authorized_hosts`=hosts_list	If specified, the list of acl_hosts on the queue that is instantiated to service the reservation.
`Resource_List`=resources_list	List of resources requested by the reservation. Resources are listed individually as, for example: Resource_List.ncpus=16 Resource_List.mem=1048676.

`C` Job was checkpointed and held.

`D` Job was deleted by request. The `message_text` will contain `requester=user@host` to identify who deleted the job.

`E` Job ended (terminated execution). The `message_text` field contains detailed information about the job. Possible attributes include:

Attribute	Explanation
`user`=username	The user name under which the job executed.

Attribute	Explanation
`group`=groupname	The group name under which the job executed.
`account`=account_string	If job has an "account name" string.
`jobname`=job_name	The name of the job.
`queue`=queue_name	The name of the queue in which the job executed.
`resvname`=reservation_name	The name of the resource reservation, if applicable.
`resvID`=reservation_ID_string	The ID of the resource reservation, if applicable.
`ctime`=time	Time in seconds when job was created (first submitted).
`qtime`=time	Time in seconds when job was queued into current queue.
`etime`=time	Time in seconds when job became eligible to run.
`start`=time	Time in seconds when job execution started.
`exec_host`=host	Name of host on which the job is being executed.
`Resource_List.`resource=limit	List of the specified resource limits.
`session`=sessionID	Session number of job.

Attribute	Explanation
`alt_id`=id	Optional alternate job identifier. Included only for certain systems: IRIX 6.x with Array Services - The alternate id is the Array Session Handle (ASH) assigned to the job. For SGI irix6cpuset MOM and the Altix Pro-Pack 2.4 or 3.0 MOM, the alternate id holds the name of the cpuset assigned to the job as well as resources assigned to the job. For example, alt_id=cpuset=357.sgi3:1024kb/1p On Altix machines with ProPack 4, the alternate id will show the path to the job, starting with /PBSPro/.
`end`=time	Time in seconds when job ended execution.
`Exit_status`=value	The exit status of the job. If the value is less than 10000 (decimal) it is the exit value of the top level process of the job, typically the shell. If the value is greater than 10000, the top process exited on a signal whose number is given by subtracting 10000 from the exit value.
`resources_used.`*RES*=*value*	Provides the aggregate amount (*value*) of specified resource *RES* used during the duration of the job.
accounting_id=jidvalue	CSA JID, job ID

F Resource reservation period finished.

`K` Scheduler or server requested removal of the reservation. The `message_text` field contains: `requester=user@host` to identify who deleted the resource reservation.

`k` Resource reservation terminated by ordinary client - e.g. an owner issuing a `pbs_rdel` command. The `message_text` field contains: `requester=user@host` to identify who deleted the resource reservation.

Q Job entered a queue. The message_text contains queue=name identifying the queue into which the job was placed. There will be a new Q record each time the job is routed or moved to a new (or the same) queue.

R Job was rerun.

S Job execution started. The message_text field contains:

Attribute	Explanation
user=username	The user name under which the job will execute.
group=groupname	The group name under which the job will execute.
jobname=job_name	The name of the job.
queue=queue_name	The name of the queue in which the job resides.
ctime=time	Time in seconds when job was created (first submitted).
qtime=time	Time in seconds when job was queued into current queue.
etime=time	Time in seconds when job became eligible to run; no holds, etc.
start=time	Time in seconds when job execution started.
exec_host=host	Name of host on which the job is being executed.
Resource_List.resource=limit	List of the specified resource limits.
session=sessionID	Session number of job.
accounting_id=identifier_string	An identifier that is associated with system-generated accounting data. In the case where accounting is CSA on Altix, identifier_string is a job container identifier or JID created for the PBS job.

T Job was restarted from a checkpoint file.

`U` Created unconfirmed resources reservation on Server. The `message_text` field contains `requester=user@host` to identify who requested the resources reservation.

`Y` Resources reservation confirmed by the Scheduler. The `message_text` field contains the same item (items) as in a `U` record type.

For `Resource_List` and `resources_used`, there is one entry per resource, corresponding to the resources requested and used, respectively.

Important: If a job ends between MOM poll cycles, `resources_used.`*`RES`* numbers will be slightly lower than they are in reality. For long-running jobs, the error percentage will be minor.

10.13.2 PBS Accounting and Windows

PBS will save information such as user name, group name, and account name in the accounting logs found in `PBS_HOME\server_priv\accounting`. Under Windows, these entities can contain space characters, thus PBS will put a quote around string values containing spaces in them. For example,

```
user=pbstest group=None account="Power Users"
```

Otherwise, one can specify the replacement for the space character by adding the `-s` option to the `pbs_server` command line option. This can be set as follows:

1. Bring up the `Start Menu->Settings->Control Panel->Administrative Tools->Services` dialog box (Windows 2000) or `Start Menu->Control Panel ->Performance and Maintenance->Administrative Tools->Services` dialog box (Windows XP).
2. Select `PBS_SERVER`.
3. Stop the Server
4. Specify in start parameters the option for example "`-s %20`".
5. Start the Server

This will replace space characters as "`%20`" in `user=, group=, account=` entries in accounting log file:

```
user=pbstest group=None account=Power%20Users
```

Important: If the first character of the replacement string argument to `-s` option appears in the input string itself, then that character will be replaced by its hex representation prefixed by `%`. For example, given:

```
account=Po%wer Users
```

Since `%` also appears the above entry and our replacement string is "`%20`", then replace this `%` with its hex representation (`%25`):

```
account="Po%25wer%20Users"
```

10.14 Use and Maintenance of Logfiles

The PBS system tends to produce a large number of logfile entries. There are two types of logfiles: the event logs which record events from each PBS component (`pbs_server`, `pbs_mom`, and `pbs_sched`) and the PBS accounting log.

10.14.1 PBS Events

The amount of output in the PBS event logfiles depends on the specified log filters for each component. All three PBS components can be directed to record only messages pertaining to certain event types. The specified events are logically "or-ed" to produce a mask representing the events the local site wishes to have logged. The available events, and corresponding decimal and hexadecimal values are shown below.

Value	Hex	Event Description
1	0x1	Internal PBS errors.
2	0x2	System (OS) errors, such as malloc failure.
4	0x4	Administrator-controlled events, such as changing queue attributes.

Value	Hex	Event Description
8	0x8	Job related events: submitted, ran, deleted, ...
16	0x10	Job resource usage.
32	0x20	Security related, e.g. attempts to connect from an unknown host.
64	0x40	When the Scheduler was called and why.
128	0x80	First level, common, debug messages.
256	0x100	Second level, more rare, debug messages.

Everything turned on is of course 511. 127 is a good value to use. The event logging mask is controlled differently for the different components. The following table shows the log event parameter for each, and page reference for details.

PBS	Attribute and Reference	Notes
Server	See "log_events" on page 79.	Takes effect immediately with `qmgr`
MOM	See "$logevent" on page 128.	Requires `SIGHUP` to MOM
Scheduler	See "log_filter" on page 165.	Requires `SIGHUP` to Scheduler

When reading the PBS event logfiles, you may see messages of the form "Type 19 request received from PBS_Server...". These "type codes" correspond to different PBS batch requests. Appendix B contains a listing of all "types" and each corresponding batch request.

10.14.2 Event Logfiles

Each PBS component maintains separate event logfiles. The logfiles default to a file with the current date as the name in the *`PBS_HOME/`*`(`*`component`*`)_logs` directory. This location can be overridden with the "`-L pathname`" option where pathname must be an absolute path.

If the default logfile name is used (no `-L` option), the log will be closed and reopened with the current date daily. This happens on the first message after midnight. If a path is given with the `-L` option, the automatic close/reopen does not take place.

On UNIX, all components will close and reopen the same named log file on receipt of **SIGHUP**. The process identifier (PID) of the component is available in its lock file in its home directory. Thus it is possible to move the current log file to a new name and send **SIGHUP** to restart the file thusly:

```
cd $PBS_HOME/component_logs
mv current archive
kill -HUP `cat ../component_priv/component.lock`
```

On Windows, manual rotation of the event log files can be accomplished by stopping the particular PBS service component for which you want to rotate the logfile, moving the file, and then restarting that component. For example:

```
cd "%PBS_HOME%\component_logs"
net stop pbs_component
move current archive
net start pbs_component
```

10.14.3 Event Logfile Format

Each component event logfile is a text file with each entry terminated by a new line. The format of an entry is:

```
date-time;event_code;server_name;object_type;object_name;message
```

The `date-time` field is a date and time stamp in the format:

```
mm/dd/yyyy hh:mm:ss.
```

The `event_code` is the type of event which triggered the event logging. It corresponding to the bit position, 0 to n, in the event mask (discussed above) of the PBS component writing the event record.

The `server_name` is the name of the Server which logged the message. This is recorded in case a site wishes to merge and sort the various logs in a single file.

The `object_type` is the type of object which the message is about:

`Svr`	for server
`Que`	for queue
`Job`	for job
`Req`	for request

`Fil` for file

The `object_name` is the name of the specific object. `message_text` field is the text of the log message.

10.15 Using the UNIX syslog Facility

Each PBS component logs various levels of information about events in its own log file. While having the advantage of a concise location for the information from each component, the disadvantage is that in a cluster, the logged information is scattered across each execution host. The UNIX syslog facility can be useful.

If your site uses the `syslog` subsystem, PBS may be configured to make full use of it. The following entries in `pbs.conf` control the use of `syslog` by the PBS components:

`PBS_LOCALLOG=x`	Enables logging to local PBS log files. Only possible when logging via syslog feature is enabled. 0 = no local logging 1 = local logging enabled
`PBS_SYSLOG=x`	Controls the use of syslog and syslog "facility" under which the entries are logged. If x is: 0 - no syslogging 1 - logged via `LOG_DAEMON` facility 2 - logged via `LOG_LOCAL0` facility 3 - logged via `LOG_LOCAL1` facility ... 9 - logged via `LOG_LOCAL7` facility
`PBS_SYSLOGSEVR=y`	Controls the severity level of messages that are logged; see `/usr/include/sys/syslog.h`. If y is: 0 - only `LOG_EMERG` messages are logged 1 - messages up to `LOG_ALERT` are logged ... 7 - messages up to `LOG_DEBUG` are logged

Important: `PBS_SYSLOGSEVR` is used in addition to PBS's `log_event` mask which controls the class of events (job, node, ...) that are logged.

10.16 Interpreting PBS Exit Codes

The PBS Server logs and accounting logs record the exit status of jobs. Zero or positive exit status is the status of the top level shell. Certain negative exit codes are used internally and will never be reported to the user. The positive exit status values indicate which signal killed the job. Depending on the system, values greater than 128 (or on some systems 256; see wait(2) or waitpid(2) for more information) are the value of the signal that killed the job. To interpret (or "decode") the signal contained in the exit status value, subtract the base value from the exit status. For example, if a job had an exit status of 143, that indicates the job was killed via a `SIGTERM` (e.g. 143 - 128 = 15, signal 15 is `SIGTERM`). See the `kill`(1) manual page for a mapping of signal numbers to signal name on your operating system.

10.17 UNIX Shell Invocation

When PBS starts a job, it invokes the user's login shell (unless the user submitted the job with the `-S` option). PBS passes the job script which is a shell script to the login process.

PBS passes the name of the job script to the shell program. This is equivalent to typing the script name as a command to an interactive shell. Since this is the only line passed to the script, standard input will be empty to any commands. This approach offers both advantages and disadvantages:

+ Any command which reads from standard input without redirection will get an EOF.

+ The shell syntax can vary from script to script. It does not have to match the syntax for the user's login shell. The first line of the script, even before any #PBS directives, should be

`#!/`*`shell`* where *`shell`* is the full path to the shell of choice, `/bin/sh, /bin/csh`, ...

The login shell will interpret the `#!` line and invoke that shell to process the script.

- An extra shell process is run to process the job script.

- If the script does start with a `#!` line, the wrong shell may be used to interpret the script and thus produce errors.

- If a non-standard shell is used via the `-S` option, it will not receive the script, but its name, on its standard input.

Chapter 11
Administrator Commands

There are two types of commands in PBS: those that users use to manipulate their own jobs, and those that the PBS Administrator uses to manage the PBS system. This chapter covers the various PBS administrator commands.

The table below lists all the PBS commands; the left column identities all the user commands, and the right column identifies all the administrator commands. (The user commands are described in detail in the **PBS Professional User's Guide**.)

Important: Individuals with PBS Operator or Manager privilege can use the user commands to act on any user job. For example, a PBS Operator can delete or move any user job. (Detailed discussion of privilege within PBS is discussed under the heading of section 10.7.7 "External Security" on page 229.)

Some of the PBS commands are intended to be used by the PBS Operator or Manager. These are the administrator commands, which are described in detail in this chapter. Some administrator commands can be executed by normal users but with limited results. The `qmgr` command can be run by a normal user, who can view but cannot alter any Server configuration information. If you want normal users to be able to run the `pbs-report` command, you can add read access to the `server_priv/accounting` directory, enabling the command to report job-specific information. Be cautioned that all job information will then be available to all users. Likewise, opening access to the accounting records will permit additional information to be printed by the tracejob command, which normal users would not have permissions to view. In either case, an administrator-type user (or UNIX root) always has read access to these data.

Table 6: PBS Professional User and Manager Commands

User Commands		Administrator Commands	
Command	**Purpose**	**Command**	**Purpose**
nqs2pbs	Convert from NQS	pbs-report	Report job statistics
pbs_rdel	Delete Adv. Reservation	pbs_hostid	Report host identifier
pbs_rstat	Status Adv. Reservation	pbs_hostn	Report host name(s)
pbs_password	Update per user / per server password[1]	pbs_migrate_users	Migrate per user / per server passwords [1]
pbs_rsub	Submit Adv.Reservation	pbs_probe	PBS diagnostic tool
pbsdsh	PBS distributed shell	pbs_rcp	File transfer tool
qalter	Alter job	pbs_tclsh	TCL with PBS API
qdel	Delete job	pbsfs	Show fairshare usage
qhold	Hold a job	pbsnodes	Node manipulation
qmove	Move job	printjob	Report job details
qmsg	Send message to job	qdisable	Disable a queue
qorder	Reorder jobs	qenable	Enable a queue
qrls	Release hold on job	qmgr	Manager interface
qselect	Select jobs by criteria	qrerun	Requeue running job
qsig	Send signal to job	qrun	Manually start a job
qstat	Status job, queue, Server	qstart	Start a queue
qsub	Submit a job	qstop	Stop a queue
tracejob	Report job history	qterm	Shut down PBS
xpbs	Graphical User Interface	xpbsmon	GUI monitoring tool

Notes: 1 Available on Windows only.

11.1 The pbs_hostid Command

The **`pbs_hostid`** command reports the host identifier (hostID) of the current host. This hostID is used by the PBS license manager to enforce node-locked and floating licenses. The `pbs_hostid` command may be needed if you change your Server hardware and need to generate a new license key. The command usage is:

```
pbs_hostid [  -i | -n | -v]
```

The available options, and description of each, follows.

Option	Description
`-i`	Prints the host identifier of the system
`-n`	Prints the primary hostname of the system
`-v`	Prints the version number of the PBS Professional Server

11.2 The pbs_hostn Command

The **`pbs_hostn`** command takes a hostname, and reports the results of both `gethost-byname(3)` and `gethostbyaddr(3)` system calls. Both forward and reverse lookup of hostname and network addresses need to succeed in order for PBS to authenticate a host and function properly. Running this command can assist in troubleshooting problems related to incorrect or non-standard network configuration, especially within clusters. The command usage is:

```
pbs_hostn [  -v]  hostname
```

The available options, and description of each, follows.

Option	Description
`-v`	Turns on verbose mode

11.3 The pbs_migrate_users Command

During a migration upgrade in Windows environments, if the Server attribute `single_signon_password_enable` is set to "true" in both the old Server and the new Server, the per-user/per-server passwords are not automatically transferred from an old Server to the new Server. The `pbs_migrate_users` command is provided for migrating the passwords. (Note that users' passwords on the old Server are not deleted.) The command usage is:

```
pbs_migrate_users old_server[ :port] new_server[ :port]
```

The exit values and their meanings are:

0	success
-1	writing of passwords to files failed.
-2	communication failures between old Server and new Server
-3	`single_signon_password_enable` not set in either old Server or new Server.
-4	the current user is not authorized to migrate users

11.4 The pbs_rcp vs. scp Command

The **`pbs_rcp`** command is used internally by PBS as the default file delivery mechanism. PBS can be directed to use Secure Copy (**`scp`**) by so specifying in the PBS global configuration file. Specifically, to enable `scp`, set the `PBS_SCP` parameter to the full path of the local `scp` command, as described in the discussion of "pbs.conf" on page 209.) This should be set on all nodes where there is or will be a PBS MOM running. MOMs already running will need to be stopped and restarted.

11.5 The pbs_probe Command

The **`pbs_probe`** command reports post-installation information that is useful for PBS diagnostics. Aside from the direct information that is supplied on the command line, `pbs_probe` reads basic information from the `pbs.conf` file, and the values of any of the following environment variables that may be set in the environment in which `pbs_probe` is run: `PBS_CONF`, `PBS_HOME`, `PBS_EXEC`, `PBS_START_SERVER`, `PBS_START_MOM`, and `PBS_START_SCHED`.

Important: The `pbs_probe` command is currently only available on

UNIX; in Windows environments, use the `pbs_mkdirs` command instead.

The `pbs_probe` command usage is:

```
pbs_probe [  -f | -v ]
```

If no options are specified, `pbs_probe` runs in "report" mode, in which it will report on any errors in the PBS infrastructure files that it detects. The problems are categorized, and a list of the problem messages in each category are output. Those categories which are empty do not show in the output.

The available options, and description of each, follows.

Option	Description
`-f`	Run in "fix" mode. In this mode `pbs_probe` will examine each of the relevant infrastructure files and, where possible, fix any errors that it detects, and print a message of what got changed. If it is unable to fix a problem, it will simply print a message regarding what was detected.
`-v`	Run in "verbose" mode. If the verbose option is turned on, `pbs_probe` will also output a complete list of the infrastructure files that it checked.

11.6 The pbsfs (PBS Fairshare) Command

The **`pbsfs`** command allows the Administrator to display or manipulate PBS fairshare usage data. The `pbsfs` command can only be run as root (UNIX) or a user with Administrator privilege (Windows). If the command is to be run with options to alter/update the fairshare data, the Scheduler must not be running. If you terminate the Scheduler, be sure to restart it after using the `pbsfs` command.

For printing, the scheduler can be running, but the data may be stale. To make sure the data isn't stale when being printed, sending a kill -HUP to the scheduler will force the scheduler to write out its internal cache.

Important: If the Scheduler is killed, it will lose any new fairshare data since the last synchronization. For suggestions on minimizing or eliminating possible data loss, see section 8.11.9 "Viewing and Managing Fairshare Data" on page 186.

The command usage is:

```
pbsfs [ -d | -e | -p | -t ]
pbsfs [ -c entity1 entity2 ] [ -g entity ]
      [ -s entity usage_value ]
```

The available options, and description of each, follows.

Option	Description	Scheduler: Up/Down
`-c` *`entity1 entity2`*	Compare two *entities* and print the most deserving entity.	Up
`-d`	Decay the fairshare tree (divide all values in half)	Down
`-e`	Trim fairshare tree to include only entries in `resource_group` file	Down
`-g` *`entity`*	Print all data for *entity* and path from the root of tree to node.	Up
`-p`	Print the fairshare tree in a flat format (default format).	Up
`-s` *`entity usage_value`*	Set *entity's* usage value to *usage_value*. Note that editing a non-leaf node is ignored. All non-leaf node usage values are calculated each time the Scheduler is run or HUPed.	Down
`-t`	Print the fairshare tree in a hierarchical format.	Up

There are multiple parts to a fairshare node and you can print these data in different formats.The data displayed is:

Data	Description
entity	the name of the entity to use in the fairshare tree
group	the group ID the entity is in (i.e. the entity's parent)
cgroup	the group ID of this entity
shares	the number of shares the entity has

usage	the amount of usage
percentage	the percentage the entity has of the tree. Note that only the leaf nodes sum to 100%. If all of the nodes are summed, the result will be greater then 100%. Only the leaf nodes of the tree are fairshare entities.
usage / perc	The value the Scheduler will use to pick which entity has priority over another. The smaller the number the higher the priority.
path from root	The path from the root of the tree to the leaf node. This is useful because the Scheduler will compare two entities by starting at the root, and working toward the leaf nodes, to determine which has the higher priority.
resource	Resource for which usage is accumulated for the fairshare calculations. Default is `cput` (cpu seconds) but can be changed in `sched_config` .

Whenever the fairshare usage database is changed, the original database is saved with the name "`usage.bak`". Only one backup will be made.

Subjobs are treated as regular jobs in the case of fairshare. Fairshare data may not be accurate for job arrays, because subjobs are typically shorter than the scheduler cycle, and data for them can be lost.

11.6.1 Trimming the Faireshare Data

Fairshare usage data may need to be trimmed because of the way the scheduler deals with unknown entities which have usage data. If the scheduler finds an entity which has usage data, but is not in the resource_group file, it will add it to the "unknown" group. This is sometimes the result of a typo. It will also be be what happens to accounts that are no longer in a group. Trimming the fairshare tree is a good way to get rid of these.

The recommended set of steps to use `pbsfs` to trim fairshare data are as follows:

UNIX:

First send a HUP signal to the Scheduler to force current fairshare usage data to be written, then terminate the Scheduler:

```
kill -HUP pbs_sched_PID
kill pbs_sched_PID
```

Windows:

```
net stop pbs_sched
```

Now you can modify the `$PBS_HOME/sched_priv/resource_group` file if needed. When satisfied with it, run the `pbsfs` command to trim the fairshare tree:

```
pbsfs -e
```

Lastly, restart the Scheduler:

UNIX:

```
$PBS_EXEC/sbin/pbs_sched
```

Windows:

```
net start pbs_sched
```

11.7 The pbs_tclsh Command

The **`pbs_tclsh`** command is a version of the TCL shell (tclsh) linked with special TCL-wrapped versions of the PBS Professional external API library calls. This enables the user to write TCL scripts which utilize the PBS Professional API to query information. For usage see the `pbs_tclapi(3B)` manual page, and the **PBS Professional External Reference Specification.**

11.8 The pbsnodes Command

The **`pbsnodes`** command is used to query the status of nodes, or mark nodes down, free or off-line. (For detailed discussion of nodes and node states, see “Node Configuration Attributes” on page 97.) Node information is obtained by sending a request to the PBS Server. The command usage is:

```
pbsnodes [-a|-l|-s][-c node][-d node][-o node][-r node]
```

The available options, and description of each, follows.

Option	Description
`(no option)`	Prints the command usage syntax.

Option	Description
node1 node2	Prints the status of nodes `node1` and `node2`.
`-a`	Lists all nodes and all their attributes.
`-c` *nodes*	Clear OFFLINE or DOWN from listed nodes. The listed nodes are "free" to be allocated to jobs.
`-d` *nodes*	The nodes specified as operands are marked DOWN and unavailable to run jobs. It is important that all the nodes known to be down are given as arguments on the command line. This is because nodes which are not listed are assumed to be UP and will be indicated as such if they were previously marked DOWN. I.e., "*pbsnodes -d*" will mark all nodes as free.
`-l`	List all nodes marked in any way.
`-o` *nodes*	Mark listed nodes as OFFLINE even if currently in use. This gives the Administrator a tool to hold a node out of service without changing the automatic script.
`-r` *nodes*	Clear OFFLINE from listed nodes.
`-s`	Specify the PBS Server to which to connect.

Important: Only the `-d` option will change the marking for nodes which are not given on the command line.

11.9 The printjob Command

The **`printjob`** command is used to print the contents of the binary file representing a PBS batch job saved within the PBS system. By default all the job data including job attributes are printed. This command is useful for troubleshooting, as during normal operation, the `qstat` command is the preferred method for displaying job-specific data and attributes. The command usage is:

```
printjob [ -a] file [ file...]
```

The available options, and description of each, follows.

Option	Description
`-a`	Suppresses the printing of job attributes.

11.10 The tracejob Command

PBS includes the **`tracejob`** utility to extract daemon/service logfile messages for a particular job (from all log files available on the local host) and print them sorted into chronological order.

Important: By default a normal user does not have access to the accounting records, and so information contained therein will not be displayed. However, if an administrator or UNIX root runs the tracejob command, this data will be included.

Usage for the `tracejob` command is:

```
tracejob [ -a|s|l|m|v][ -w cols][ -p path][ -n days][ -f filter]
         [ -c count] jobid
```

Note: for an array job, the job ID must be enclosed in double quotes.

The available options, and description of each, follows.

Option	Description
`-a`	Do not report accounting information.
`-c <count>`	Set excessive message limit to count. If a message is logged at least count times, only the most recent message is printed. Default for count is 15.
`-f <filter>`	Do not include logs of type filter. The -f option can be used more than once on the command line. filter: error, system, admin, job, job_usage, security, sched, debug, debug2
`-l`	Do not report scheduler information.

Option	Description
`-m`	Do not report MOM information.
`-n <days>`	Report information from up to days days in the past. Default is 1 = today.
`-p <path>`	`Use path as path to PBS_HOME on machine being queried.`
`-s`	Do not report server information.
`-w <cols>`	Width of current terminal. If not specified by the user, tracejob queries OS to get terminal width. If OS doesn't return anything, default is 80.
`-v`	Verbose. Report more of tracejob's errors than default.
`-z`	Disable excessive message limit. Excessive message limit is enabled by default.

For more information, see man(8) tracejob.

The following example requests all log message for a particular job from today's (the default date) log file. Note that the third column of the display contains a single letter (S, M, A, or L) indicating the source of the log message (**S**erver, **M**OM, **A**ccounting, or schedu**L**er log files).

```
tracejob 475
Job: 475.pluto.domain.com
03/10/2005 14:29:15 S enqueuing into workq, state 1 hop 1
03/10/2005 14:29:15 S Job Queued at request of james, owner=
      james@mars.domain.com, job name = STDIN
03/10/2005 15:06:30 S Job Modified at request of Scheduler
03/10/2005 15:06:30 L Considering job to run
03/10/2005 15:06:30 S Job Run at request of Scheduler
03/10/2005 15:06:32 L Job run on node mars
03/10/2005 15:06:32 M Started, pid = 25282
03/10/2005 15:06:32 M Terminated
03/10/2005 15:06:32 M task 1 terminated
03/10/2005 15:06:32 M kill_job
03/10/2005 15:06:32 S Obit received
03/10/2005 15:06:32 S dequeuing from workq, state 5
03/10/2005 15:06:32 A user=jwang group=mygroup jobname=subrun
      queue=workq ctime=1026928565 qtime=1026928565
         etime=1026928565 start=1026928848 exec_host=south/0
      Resource_List.arch=linux Resource_List.ncpus=1
      Resource_List.walltime=00:10:00 session=6022
      end=1026929149 Exit_status=0 resources_used.ncpus=1
      resources_used.cpupercent=0 resources_used.vmem=498kb
      resources_used.cput=00:00:00 resources_used.mem=224kb
      resources_used.walltime=00:05:01
```

11.11 The qdisable Command

The `qdisable` command directs that the designated queue should no longer accept batch jobs. If the command is asuccessful, the queue will no longer accept Queue Job requests which specified the now-disabled queue. Jobs which already reside in the queue will continue to be processed. This allows a queue to be “drained.” The command usage is:

```
qdisable destination ...
```

11.12 The qenable Command

The `qenable` command directs that the designated queue should accept batch jobs. This command sends a Manage request to the batch Server specified on the command line. If the command is accepted, the now-enabled queue will accept Queue Job requests which specify the queue. The command usage is:

```
qenable destination ...
```

11.13 The qstart Command

The `qstart` command directs that the designated queue should process batch jobs. If the queue is an execution queue, the Server will begin to schedule jobs that reside in the queue for execution. If the designated queue is a routing queue, the Server will begin to route jobs from that queue. The command usage is:

```
qstart destination ...
```

11.14 The qstop Command

The `qstop` command directs that the designated queue should stop processing batch jobs. If the designated queue is an execution queue, the Server will cease scheduling jobs that reside in the queue for execution. If the queue is a routing queue, the Server will cease routing jobs from that queue. The command usage is:

```
qstop destination ...
```

11.15 The qrerun Command

The **`qrerun`** command directs that the specified jobs are to be rerun if possible. To rerun a job is to terminate the session leader of the job and return the job to the queued state in the execution queue in which the job currently resides. If a job is marked as not rerunnable then the rerun request will fail for that job. (See also the discussion of the `-r` option to `qsub` in the **PBS Professional User's Guide**.) The command usage is:

```
qrerun [ -W force ] jobID [ jobID ...]
```

Note: for array jobs, the job IDs must be enclosed in double quotes.

The available options, and description of each, follows.

Option	Description
`-W force`	This option, where `force` is the literal character string "force", directs that the job is to be requeued even if the node on which the job is executing is unreachable.

The qrerun command can be used on a job array, a subjob, or a range of subjobs. If the qrerun command is used on a job array, all of that array's currently running subjobs and all of its completed and deleted subjobs are requeued.

11.16 The qrun Command

The **`qrun`** command is used to force a Server to initiate the execution of a batch job. The job is run regardless of scheduling position, resource requirements and availability, or state. The command usage is:

```
qrun [ -a ] [ -H host-spec ] jobID [ jobID ...]
```

Note: for array jobs, job IDs should be enclosed in double quotes.

The available options, and description of each, follows.

Option	Description
`-a`	Specifies that the `qrun` command will exit before the job actually starts execution.
`-H host-spec`	Specifies the host(s) within the complex on which the job(s) are to be run. The *host-spec* argument is a plus-separated list of node names, e.g. NodeA+NodeB+NodeC. Resources can be specified in this fashion: NodeA:mem=100kb:ncpus=1+NodeB:mem=100kb:ncpus=2

See "Requesting Resources" on page 32 of the **PBS Professional User's Guide** for detailed information on requesting resources and placing jobs on nodes.

No -H hosts option	If the operator issues a qrun request of a job without -H hosts, the server will make a request of the scheduler to run the job

immediately. The scheduler will run the job if the job is otherwise runnable by the scheduler:

The queue in which the job resides is an execution queue and is started.

The job is in the queued state.

Either the resources required by the job are available, or preemption is enabled and the required resources can be made available by preempting jobs that are running.

-H hosts option	If the -H hosts option is used, the Server will immediately run the job on the named hosts, regardless of current usage on those nodes.
-H hosts option with list of nodes	If a "+" separated list of hosts is specified in the Run Job request, e.g. NodeA+NodeB+... the Scheduler will apply one requested chunk from the select directive in round-robin fashion to each node in the list.
-H hosts option with list of nodes and resource specification	If a "+" separated list of hosts is specified in the Run Job request, and resources are specified with node names, e.g. NodeA:mem=100kb:ncpus=1+NodeB:mem=100kb:ncpus=2, the Scheduler will apply the specified allocations and the select directive will be ignored. Any single resource specification will result in the job's select directive being ignored.

The qrun command can be used on a subjob or a range of subjobs, but not on a job array. When it is used on a range of subjobs, the non-running subjobs in that range are run.

11.17 The qmgr Command

The **`qmgr`** command is the Administrator interface to PBS, and is discussed in detail earlier in this book, in the section entitled "The qmgr Command" on page 71.

11.18 The qterm Command

The **`qterm`** command is used to shut down PBS, and is discussed in detail earlier in this book, in section 10.3.5 "Stopping PBS" on page 218.

11.19 The pbs_wish Command

The **`pbs_wish`** command is a version of TK Window Shell linked with a wrapped versions of the PBS Professional external API library. For usage see the `pbs_tclapi(3B)` manual page, and the **PBS Professional External Reference Specification.**

11.20 The qalter Command and Job Comments

Users tend to want to know what is happening to their job. PBS provides a special job attribute, `comment`, which is available to the operator, manager, or the Scheduler program. This attribute can be set to a string to pass information to the job owner. It might be used to display information about why the job is not being run or why a hold was placed on the job. Users are able to see this attribute, when set, by using the `-f and -s` options of the `qstat` command. (For details see “Displaying Job Comments” in the **PBS Professional User’s Guide**.) Operators and managers may use the `-W` option of the `qalter` command, for example

```
qalter -W comment="some text" job_id
```

The qalter command can be used on job array objects, but not on subjobs or ranges of subjobs. Note also that when used on a job array, the job ID must be enclosed in double quotes. See “qalter: Altering a Job Array” on page 148 of the **PBS Professional User’s Guide**.

11.21 The pbs-report Command

The **`pbs-report`** command allows the PBS Administrator to generate a report of job statistics from the PBS accounting logfiles. Options are provided to filter the data reported based on start and end times for the report, as well as indicating specific data that should be reported. The available options are shown below, followed by sample output of the `pbs-report` command.

Important: The `pbs-report` command is not available on Windows.

Before first using `pbs-report`, the Administrator is advised to tune the **`pbs-report`** configuration to match the local site. This can be done by editing the file `PBS_EXEC/lib/pm/PBS.pm`.

Important: If job arrays are being used, the `pbs-report` command will produce errors including some about uninitialized variables. It will report on the job array object as well as on each subjob.

11.21.1 pbs-report Options

`--age -a seconds[ :offset]`

Report age in seconds. If an offset is specified, the age range is taken from that offset backward in time, otherwise a zero offset is assumed. The time span is from (now - age - offset) to (now - offset). This option silently supersedes `--begin`, `--end`, and `--range`.

`--account account`

Limit results to those jobs with the specified account string. Multiple values may be concatenated with colons or specified with multiple instances of `--account`.

`--begin -b yyyymmdd[ :hhmm[ ss]]`

Report begin date and optional time (default: most recent log data).

`--count -c`

Display a numeric count of matching jobs. Currently only valid with `--cpumax` for use in monitoring rapidly-exiting jobs.

`--cpumax seconds`

Filter out any jobs which have more than the specified number of CPU seconds.

`--cpumin seconds`

Filter out any jobs which have less than the specified number of CPU seconds.

`--dept -d department`

Limit results to those jobs whose owners are in the indicated department (default: any). This option only works in conjunction with an LDAP server which supplies department codes. See also the `--group` option. Multiple values may be concatenated with colons or specified with multiple instances of

`--dept`.

`--end -e yyyymmdd[ :hhmm[ ss]]`

Report end date and optional time (default: most recent log data).

`--exit -x integer`

Limit results to jobs with the specified exit status (default: any).

`--group -g group`

Limit results to the specified group name. Multiple values may be concatenated with colons or specified with multiple instances of `--group`.

`--help -h`

Prints a brief help message and exits.

`--host -m execution host`

Limit results to the specified execution host. Multiple values may be concatenated with colons or specified with multiple instances of `--host`.

`--inclusive key`

Limit results to jobs which had *both* start and end times in the range.

`--index -i key`

Field on which to index the summary report (default: user). Valid values include: date, dept, host, package, queue, user.

`--man`

Prints the manual page and exits.

`--negate -n option name`

Logically negate the selected options; print all records *except* those that match the values for the selected criteria (default: unset; valid values: account, dept, exit, group, host, package, queue, user). Defaults cannot be negated; only options explicitly specified are negated. Multiple values may be concatenated with colons or specified with multiple instances of `--negate`.

`--package -p package`

Limit results to the specified software package. Multiple values may be concatenated with colons or specified with multiple instances of `--package`. Valid values are can be seen by running a report with the `--index package` option. This option keys on custom resources requested at job submission time. Sites not using such custom resources will have all jobs reported under the catch-all *None* package with this option.

`--point yyyymmdd[ :hhmm[ ss]]`

Print a report of all jobs which were actively running at the point in time specified. This option cannot be used with any other date or age option.

`--queue -q queue`

Limit results to the specified queue. Multiple values may be concatenated with colons or specified with multiple instances of `--queue`. Note that if specific queues are defined via the `@QUEUES` line in `PBS.pm`, then only those queues will be displayed. Leaving that parameter blank allows all queues to be displayed.

`--range -r date range`

Provides a shorthand notation for current date ranges (default: all). Valid values are today, week, month, quarter, and year. This option silently supersedes `--begin` and `--end`, and is superseded by `--age`.

`--reslist`

Include resource requests for all matching jobs. This option is mutually exclusive with `--verbose`.

`--sched -t`

Generate a brief statistical analysis of Scheduler cycle times. No other data on jobs is reported.

`--sort -s field`

Field by which to sort reports (default: user). Valid values are cpu, date, dept, host, jobs, package, queue, suspend (aka muda), wait, and wall.

`--time option`

Used to indicate how time should be accounted. The default of `full` is to count the entire job's CPU and wall time in the report if the job ended during the report's date range. Optionally the `partial` option is used to cause only CPU and wall time during the report's date range to be counted.

`--user -u username`

Limit results to the specified user name. Multiple values may be concatenated with colons or specified with multiple instances of `--user`.

`--verbose -v`

Include attributes for all matching individual jobs (default: summary only).

`--vsort field`

Field by which to sort the verbose output section reports (default: jobid). Valid values are cpu, date, exit, host, jobid, job-name, mem, name, package, queue, scratch, suspend, user, vmem, wall, wait. If neither `--verbose` nor `--reslist` is specified, `--vsort` is silently ignored. The scratch sort option is available only for resource reports (`--reslist`).

`--waitmax seconds`

Filter out any jobs which have more than the specified wait time in seconds.

`--waitmin seconds`

Filter out any jobs which have less than the specified wait time in seconds.

`--wallmax seconds`

Filter out any jobs which have more than the specified wall time in seconds.

`--wallmin seconds`

Filter out any jobs which have less than the specified wall time in seconds.

`--wall -w`

Use the walltime resource attribute rather than wall time calculated by subtracting the job start time from end time. The walltime resource attribute does *not* accumulate when a job is suspended for any reason, and thus may not accurately reflect the local interpretation of wall time.

Several options allow for filtering of which jobs to include. These options are as follows.

`--begin, --end, --range, --age, --point`

Each of these options allows the user to filter jobs by some range of dates or times. `--begin` and `--end` work from hard date limits. Omitting either will cause the report to contain all data to either the beginning or the end of the accounting data. Unbounded date reports may take several minutes to run, depending on the volume of work logged. `--range` is a shorthand way of selecting a prior date range and will supersede `--begin` and `--end`. `--age` allows the user to select an arbitrary period going back a specified number of seconds from the time the report is run. `--age` will silently supersede all other date options. `--point` displays all jobs which were running at the specified point in time, and is incompatible with the other options. `--point` will produce an error if specified with any other date-related option.

`--cpumax, --cpumin, --wallmax, --wallmin`
`--waitmax, --waitmin,`

Each of these six options sets a filter which bounds the jobs on one of their three time attributes (CPU time, queue wait time, or wall time). A maximum value will cause any jobs with more than the specified amount to be ignored. A minimum value will cause any jobs with less than the specified amount to be ignored. All six options may be combined, though doing so will often restrict the filter such that no jobs can meet the requested criteria. Combine time filters for different time with caution.

`--dept, --group, --user`

Each of these user-based filters allow the user to filter jobs based on who submitted them. `--dept` allows for integration with an LDAP server and will generate reports based on department codes as queried from that server. If no LDAP server is available, department-based filtering and sorting will not function. `--group` allows for filtering of jobs by primary group ownership of the submitting user, as defined by the operating system on which the PBS server runs. `--user` allows for explicit naming of users to be included. It is possible to specify a list of values for these filters, by providing a single colon-concatenated argument or using the option multiple times, each with a single value.

`--account`

This option allows the user to filter jobs based on an arbitrary, user-specified job account string. The content and format of these strings is site-defined and unrestricted; it may be used by a custom job front-end which enforces permissible account strings, which are passed to `qsub` with qsub's -A option.

`--host, --exit, --package, --queue`

Each of these job-based filters allow the user to filter jobs based on some property of the job itself. `--host` allows for filtering of jobs based on the host on which the job was executed. `--exit` allows for filtering of jobs based on the job exit code. `--package` allows for filtering of jobs based on the software package used in the job. This option will only function when a package-specific custom resource is defined for the PBS server and requested by the jobs as they are submitted. `--queue` allows for filtering of jobs based on the queue in which the job finally executed. With the exception of `--exit`, it is possible to specify a list of values for these filters, by providing a single colon-concatenated argument or using the option multiple times, each with a single value.

`--negate`

The `--negate` option bears special mentioning. It allows for logical negation of one or more specified filters. Only the account, dept, exit, group, host, package, queue, and user filters may be negated. If a user is specified with `--user`, and the '`--negate user`' option is used, only jobs *not* belonging to that user will be included in the report. Multiple report filters may be negated by providing a single colon-concatenated argument or using `--negate` multiple times, each with a single value.

Several report types can be generated, each indexed and sorted according to the user's needs.

`--verbose`

This option generates a wide tabular output with detail for every job matching the filtering criteria. It can be used to generate output for import to a spreadsheet which can manipulate the data beyond what `pbs_report` currently provides. Verbose reports may be sorted on any field using the `--vsort` option. The default is to produce a summary report only.

`--reslist`

This option generates a tabular output with detail on resources requested (*not* resources used) for every job matching the filtering criteria. Resource list reports may be sorted on any field using the `--vsort` option. The default is to produce a summary report only.

`--inclusive`

Normal convention is to credit a job's entire run to the time at which it ends. So all date selections are bounds around the end time. This option allows a user to require that the job's start time also falls within the date range.

`--index`

This option allows the user to select a field on which data in the summary should be grouped. The fields listed in the option description are mutually exclusive. Only one can be chosen, and will represent the left-most column of the summary report output. One value may be selected as an index while another is selected for sorting. However, since index values are mutually exclusive, the only sort options which may be used (other than the index itself) are account, cpu, jobs, suspend, wait, and wall. If no sort order is selected, the index is used as the sort key for the summary.

`--sort`

This option allows the user to specify a field on which to sort the summary report. It operates independently of the sort field for verbose reports (see `--vsort`). See the description for `--index` for notes on how the two options interact.

`--vsort`

This option allows the user to specify a field on which to sort the verbose report. It operates independently of the sort field for summary reports (see `--sort`).

`--time`

This option allows the user to modify how time associated with a job is accounted. With *full*, all time is accounted for the job, and credited at the point when the job ended. For a job which ended a few seconds after the report range begins, this can cause significant overlap, which may boost results. During a sufficiently large time frame, this overlap effect is negligible and may be ignored. This value for `--time` should be used when generating monthly usage reports. With *partial*, any CPU or wall time accumulated prior to the beginning of the report is ignored. *partial* is intended to allow for more accurate calculation of overall cluster efficiency during short time spans during which a significant 'overlap' effect can skew results.

11.21.2 pbs-report Examples

This section explains several complex report queries to serve as examples for further experimentation. Note that some of options to `pbs-report` produce summary information of the resources requested by jobs (such as mem, vmem, ncpus, etc.). These resources are explained in Chapter 4 of the **PBS Professional User's Guide**.

Consider the following question: “This month, how much resources did every job which waited more than 10 minutes request?”

```
    pbs-report --range month --waitmin 600 --reslist
```

This information might be valuable to determine if some simple resource additions (e.g. more memory or more disk) might increase overall throughput of the cluster. At the bottom of the summary statistics, prior to the job set summary, is a statistical breakdown of the values in each column. For example:

```
              # of       Total       Total             Average
Date          jobs    CPU Time   Wall Time  Efcy.    Wait Time
----------  -----  ----------  ----------  -----  -----------
TOTAL         1900    10482613    17636290  0.594         1270
... individual rows indexed by date ...
Minimum          4        4715       13276  0.054          221
Maximum        162     1399894     2370006  1.782        49284
Mean            76      419304      705451  0.645         2943
Deviation       41      369271      616196  0.408         9606
Median          80      242685      436724  0.556          465
```

This summary should be read in column format. While the minimum number of jobs run in one day was 4 and the maximum 162, these values do ***not*** correlate to the 4715 and 1399894 CPU seconds listed as minimums and maximums.

In the Job Set Summary section, the values should be read in rows, as shown here:

```
                                                   Standard
              Minimum      Maximum         Mean   Deviation       Median
           ----------   ----------   ----------  ----------   ----------
CPU time            0        18730          343         812            0
Wall time           0       208190         8496       19711           93
Wait time           0       266822         4129        9018            3
```

These values represent aggregate statistical analysis for the entire set of jobs included in the report. The values in the prior summary represent values over the set of totals based on the summary index (e.g. Maximum and Minimum are the maximum and minimum totals for a given day/user/department, rather than an individual job. The job set summary represents an analysis of all individual jobs.

11.21.3 pbs-report Cluster Monitoring

The `pbs-report` options `--count` and `--cpumax` are intended to allow an Administrator to periodically run this report to monitor for jobs which are exiting rapidly, representing a potential global error condition causing all jobs to fail. It is most useful in conjunction with --age, which allows a report to span an arbitrary number of seconds backward in time from the current moment. A typical set of options would be “`--count --cpumax 30 --age 21600`", which would show a total number of jobs which consumed less than 30 seconds of CPU time within the last six hours.

11.22 The xpbs Command (GUI) Admin Features

PBS currently provides two Graphical User Interfaces (GUIs): `xpbs` (intended primarily for users) and `xpbsmon` (intended for PBS operators and managers). Both are built using the Tool Control Language Toolkit (TCL/tk). The first section below discusses the user GUI, `xpbs`. The following section discusses `xpbsmon`.

11.22.1 xpbs GUI Configuration

xpbs provides a user-friendly point-and-click interface to the PBS commands. To run `xpbs` as a regular, non-privileged user, type:

```
xpbs
```

To run `xpbs` with the additional purpose of terminating PBS Servers, stopping and starting queues, running/rerunning jobs (as well as then run:

```
xpbs -admin
```

Important: Table 7 in the **PBS Professional User's Guide** lists all functionality of `xpbs`, and identifies which are available only via the `-admin` option.

Running `xpbs` will initialize the X resource database in order from the following sources:

1. The RESOURCE_MANAGER property on the root window (updated via `xrdb`) with settings usually defined in the `.Xdefaults` file

2. Preference settings defined by the system Administrator in the global `xpbsrc` file

3. User's `.xpbsrc` file-- this file defines various X resources like fonts, colors, list of PBS hosts to query, criteria for listing queues and jobs, and various view states.

The system Administrator can specify a global resources file to be read by the GUI if a personal `.xpbsrc` file is missing: `PBS_EXEC/lib/xpbs/xpbsrc`. Keep in mind that within an Xresources file (Tk only), later entries take precedence. For example, suppose in your `.xpbsrc` file, the following entries appear in order:

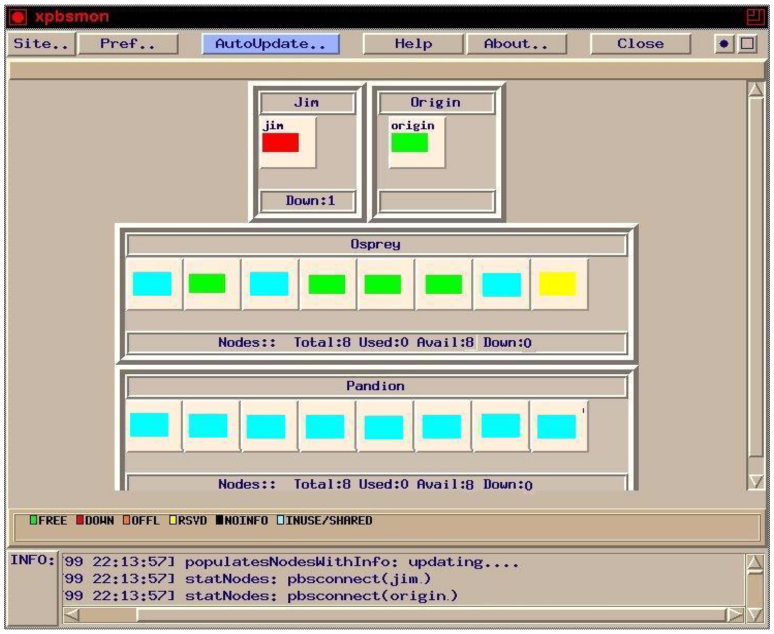
```
xpbsrc*backgroundColor: blue
*backgroundColor: green
```

The later entry "green" will take precedence even though the first one is more precise and longer matching. The things that can be set in the personal preferences file are fonts, colors, and favorite Server host(s) to query.

`xpbs` usage, command correlation, and further customization information is provided in the **PBS Professional User’s Guide**, Chapter 5, “Using the xpbs GUI”.

11.23 The xpbsmon GUI Command

xpbsmon is the node monitoring GUI for PBS. It is used for graphically displaying information about execution hosts in a PBS environment. Its view of a PBS environment consists of a list of sites where each site runs one or more Servers, and each Server runs jobs on one or more execution hosts (nodes).


xpbsmon
Site..
Pref..
AutoUpdate..
Help
About..
Close
Jim
jim
Down:1
Origin
origin
Osprey
Nodes:: Total:8 Used:0 Avail:8 Down:0
Pandion
Nodes:: Total:8 Used:0 Avail:8 Down:0
🟩FREE 🟥DOWN 🟧OFFL 🟨RSVD ■NOINFO 🟦INUSE/SHARED
INFO:

```
99 22:13:57] populatesNodesWithInfo: updating....
99 22:13:57] statNodes: pbsconnect(jim.)
99 22:13:57] statNodes: pbsconnect(origin.)
```

The system Administrator needs to define the site’s information in a global X resources file, *PBS_EXEC/lib/*`xpbsmon/xpbsmonrc` which is read by the GUI if a personal `.xpbsmonrc` file is missing. A default `xpbsmonrc` file usually would have been created already during installation, defining (under *sitesInfo resource) a default site name, list of Servers that run on a site, set of nodes (or execution hosts) where jobs on a particular Server run, and the list of queries that are communicated to each node's `pbs_mom`. If node queries have been specified, the host where `xpbsmon` is running must have been given explicit permission by the `pbs_mom` to post queries to it. This is done by including a `$restricted` entry in the MOM's config file. It is not recommended to manually update the *sitesInfo value in the `xpbsmonrc` file as its syntax is quite cumbersome. The recommended procedure is to bring up `xpbsmon`, click on "Pref.." button, manipulate the widgets in the Sites, Server, and Query Table dialog boxes, then click "Close" button and save the settings to a `.xpbsmonrc` file. Then copy this file over to the *`PBS_EXEC`*`/lib/xpbsmon/` directory.

11.24 The pbskill Command

Under Microsoft Windows XP and Windows 2000, PBS includes the **`pbskill`** utility to terminate any job related tasks or processes. DOS/Windows prompt usage for the `pbskill` utility is:

```
pbskill processID1 [[ processID2] [ processID3]  ... ]
```

Note that Under Windows, if the pbskill command is used to terminate the MOM service, it may leave job processes running, which if present, will prevent a restart of MOM (a "network is busy" message will be reported). This can be resolved by manually killing the errant job processes via the Windows task manager.

Chapter 12

Example Configurations

Up to this point in this manual, we have seen many examples of how to configure the individual PBS components, set limits, and otherwise tune a PBS installation. Those examples were used to illustrate specific points or configuration options. This chapter pulls these various examples together into configuration-specific scenarios which will hopefully clarify any remaining configuration questions. Several configuration models are discussed, followed by several complex examples of specific features.

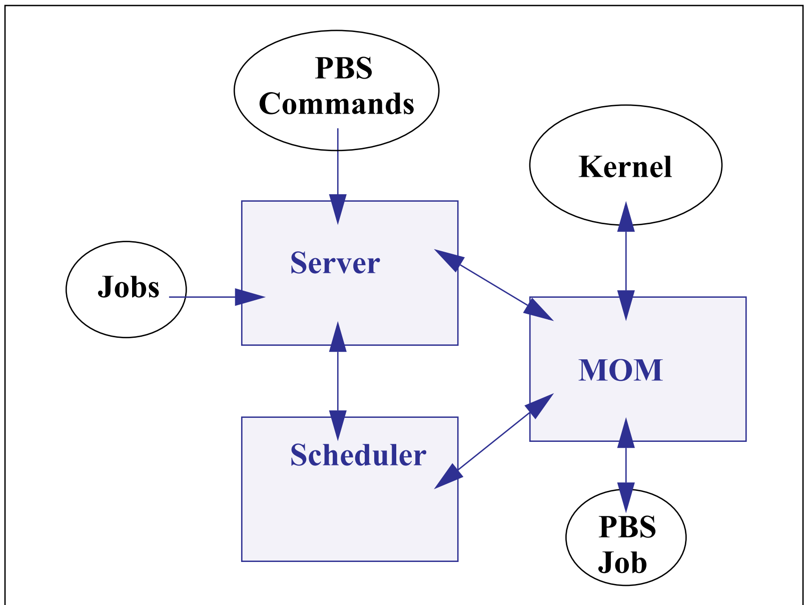
Single Node System
Single Node System with Separate PBS Server
Multi-node Cluster
Complex Multi-level Route Queues (including group ACLs)
Multiple User ACLs

For each of these possible configuration models, the following information is provided:

General description for the configuration model
Type of system for which the model is well suited
Contents of Server nodes file
Any required Server configuration
Any required MOM configuration
Any required Scheduler configuration

12.1 Single Node System

Running PBS on a single node/host as a standalone system is the least complex configuration. This model is most applicable to sites who have a single large Server system, a single SMP system (e.g. an SGI Origin server), or even a vector supercomputer. In this model, all three PBS components run on the same host, which is the same host on which jobs will be executed, as shown in the figure below.



All components on a single host.

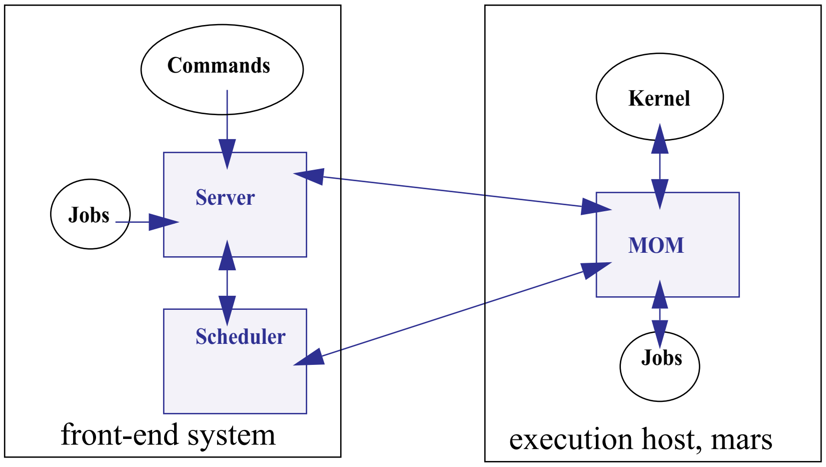
For this example, let’s assume we have a 32-CPU server machine named “mars”. We want users to log into mars and jobs will be run via PBS on mars.

In this configuration, the server’s default `nodes` file (which should contain the name of the host on which the Server was installed) is sufficient. Our example `nodes` file would contain only one entry: `mars`

The default MOM and Scheduler `config` files, as well as the default queue/Server limits are also sufficient in order to run jobs. No changes are required from the default configuration, however, you may wish to customize PBS to your site.

12.2 Separate Server and Execution Host

A variation on the model presented above would be to provide a "front-end" system that ran the PBS Server and Scheduler, and from which users submitted their jobs. Only the MOM would run on our execution server, mars. This model is recommended when the user load would otherwise interfere with the computational load on the Server.



In this case, the PBS `server_priv/nodes` file would contain the name of our execution server mars, but this may not be what was written to the file during installation, depending on which options were selected. It is possible the hostname of the machine on which the Server was installed was added to the file, in which case you would need to either manually edit the `nodes` file, or use `qmgr(1B)` to manipulate the contents to contain one node: `mars`. If the default scheduling policy, based on available CPUs and memory, meets your requirements, then no changes are required in either the MOM or Scheduler configuration files.

However, if you wish the execution node (mars) to be scheduled based on load average, the following changes are needed. Edit MOM's `mom_priv/config` file so that it contains the target and maximum load averages, e.g.:

```
$ideal_load 30
$max_load 32
```

In the Scheduler `sched_priv/config` file, the following options would need to be set:

```
load_balancing: true all
```

12.3 Multiple Execution Hosts

The multi-node cluster model is a very common configuration for PBS. In this model, there is typically a front-end system as we saw in the previous example, with a number of back-end compute nodes. The PBS Server and Scheduler are typically run on the front-end system, and a MOM is run on each of the execution nodes, as shown in the diagram to the right.

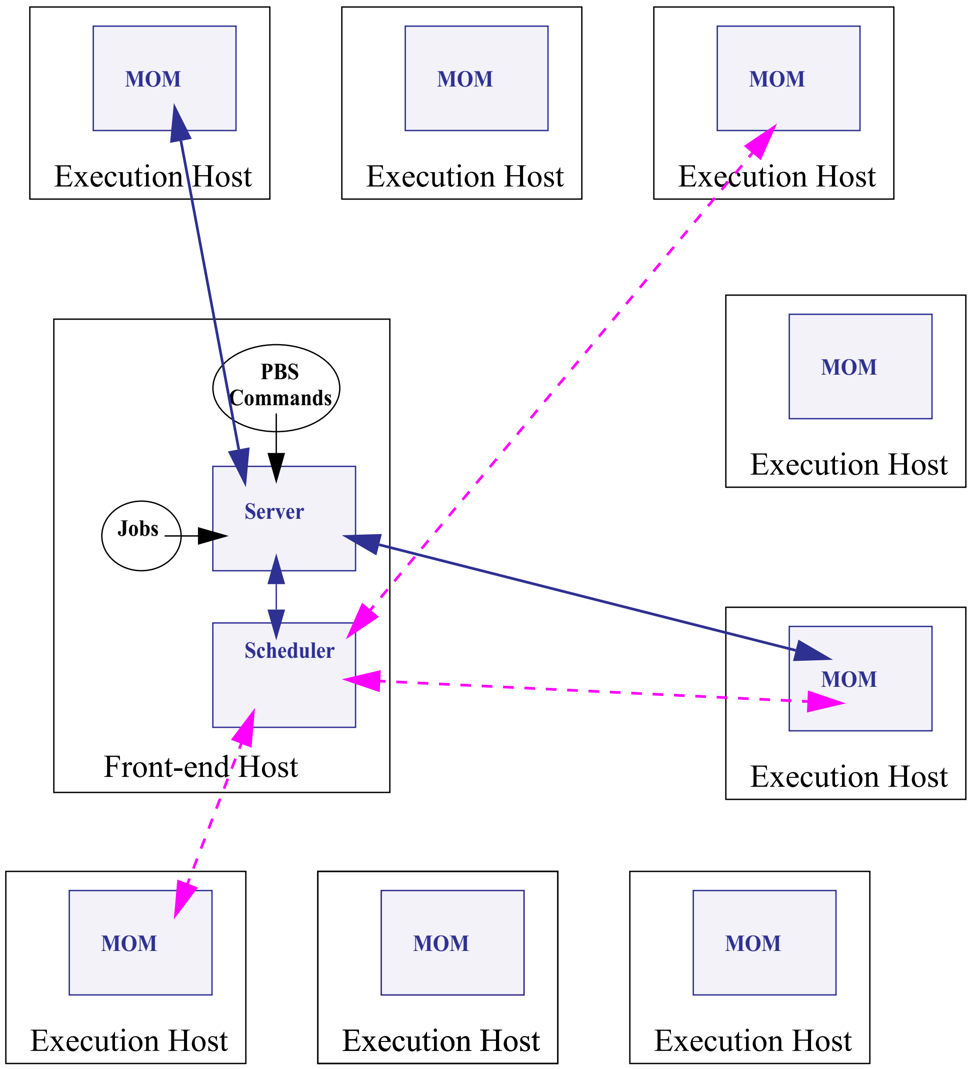
In this model, the server's `nodes` file will need to contain the list of all the nodes in the cluster.

The MOM `config` file on each node will need two static resources added, to specify the target load for each node. If we assume each of the nodes in our "planets" cluster is a 32-processor system, then the following example shows what might be desirable ideal and maximum load values to add to the MOM `config` files:

```
$ideal_load 30
$max_load 32
```

Furthermore, suppose we want the Scheduler to load balance the workload across the available nodes, making sure not to run two job in a row on the same node (round robin node scheduling). We accomplish this by editing the Scheduler configuration file and enabling load balancing:

```
load_balancing: true all
smp_cluster_dist: round_robin
```



This diagram illustrates a multi-node cluster configuration wherein the Scheduler and Server communicate with the MOMs on the execution nodes. Jobs are submitted to the Server, scheduled for execution by the Scheduler, and then transferred to a MOM when it's time to be run. MOM periodically sends status information back to the Server, and answers resource requests from the Scheduler.

12.4 Complex Multi-level Route Queues

There are times when a site may wish to create a series of route queues in order to filter jobs, based on specific resources, or possibly to different destinations. For this example, consider a site that has two large Server systems, and a Linux cluster. The Administrator wants to configure route queues such that everyone submits jobs to a single queue, but the jobs get routed based on (1) requested architecture and (2) individual groupIDs. In other words, users request the architecture they want, and PBS finds the right queue for them. Only groups "math", "chemistry", and "physics" are permitted to use either server systems; while anyone can use the cluster. Lastly, the jobs coming into the cluster should be divided into three separate queues for long, short, and normal jobs. But the "long" queue was created for the astronomy department, so only members of that group should be permitted into that queue. Given these requirements, let's look at how we would set up such a collection of route queues. (Note that this is only one way to accomplish this task. There are various other ways too.)

First we create a queue to which everyone will submit their jobs. Let's call it "submit". It will need to be a route queue with three destinations, as shown:

```
qmgr
Qmgr: create queue submit
Qmgr: set queue submit queue_type = Route
Qmgr: set queue submit route_destinations = server_1
Qmgr: set queue submit route_destinations += server_2
Qmgr: set queue submit route_destinations += cluster
Qmgr: set queue submit enabled = True
Qmgr: set queue submit started = True
```

Now we need to create the destination queues. (Notice in the above example, we have already decided what to call the three destinations: `server_1`, `server_2`, `cluster`.) First we create the `server_1` queue, complete with a group ACL, and a specific architecture limit.

```
Qmgr: create queue server_1
Qmgr: set queue server_1 queue_type = Execution
Qmgr: set queue server_1 from_route_only = True
Qmgr: set queue server_1 resources_max.arch = irix6
Qmgr: set queue server_1 resources_min.arch = irix6
Qmgr: set queue server_1 acl_group_enable = True
Qmgr: set queue server_1 acl_groups = math
Qmgr: set queue server_1 acl_groups += chemistry
Qmgr: set queue server_1 acl_groups += physics
Qmgr: set queue server_1 enabled = True
Qmgr: set queue server_1 started = True
```

Next we create the queues for `server_2` and `cluster`. Note that the `server_2` queue is very similar to the `server_1` queue, only the architecture differs. Also notice that the `cluster` queue is another route queue, with multiple destinations.

```
Qmgr: create queue server_2
Qmgr: set queue server_2 queue_type = Execution
Qmgr: set queue server_2 from_route_only = True
Qmgr: set queue server_2 resources_max.arch = sv2
Qmgr: set queue server_2 resources_min.arch = sv2
Qmgr: set queue server_2 acl_group_enable = True
Qmgr: set queue server_2 acl_groups = math
Qmgr: set queue server_2 acl_groups += chemistry
Qmgr: set queue server_2 acl_groups += physics
Qmgr: set queue server_2 enabled = True
Qmgr: set queue server_2 started = True
Qmgr: create queue cluster
Qmgr: set queue cluster queue_type = Route
Qmgr: set queue cluster from_route_only = True
Qmgr: set queue cluster resources_max.arch = linux
Qmgr: set queue cluster resources_min.arch = linux
Qmgr: set queue cluster route_destinations = long
Qmgr: set queue cluster route_destinations += short
Qmgr: set queue cluster route_destinations += medium
Qmgr: set queue cluster enabled = True
Qmgr: set queue cluster started = True
```

In the cluster queue above, you will notice the particular order of the three destination queues (`long`, `short`, `medium`). PBS will attempt to route a job into the destination queues in the order specified. Thus, we want PBS to first try the `long` queue (which will have an ACL on it), then the `short` queue (with its short time limits). Thus any jobs that had not been routed into any other queues (server or cluster) will end up in the `medium` cluster queue. Now to create the remaining queues.

```
Qmgr: create queue long
Qmgr: set queue long queue_type = Execution
Qmgr: set queue long from_route_only = True
Qmgr: set queue long resources_max.cput = 20:00:00
Qmgr: set queue long resources_max.walltime = 20:00:00
Qmgr: set queue long resources_min.cput = 02:00:00
Qmgr: set queue long resources_min.walltime = 03:00:00
Qmgr: set queue long acl_group_enable = True
Qmgr: set queue long acl_groups = astrology
Qmgr: set queue long enabled = True
Qmgr: set queue long started = True
```

```
Qmgr: create queue short
Qmgr: set queue short queue_type = Execution
Qmgr: set queue short from_route_only = True
Qmgr: set queue short resources_max.cput = 01:00:00
Qmgr: set queue short resources_max.walltime = 01:00:00
Qmgr: set queue short enabled = True
Qmgr: set queue short started = True
Qmgr: create queue medium
Qmgr: set queue medium queue_type = Execution
Qmgr: set queue medium from_route_only = True
Qmgr: set queue medium enabled = True
Qmgr: set queue medium started = True

Qmgr: set server default_queue = submit
```

Notice that the `long` and `short` queues have time limits specified. This will ensure that jobs of certain sizes will enter (or be prevented from entering) these queues. The last queue, `medium`, has no limits, thus it will be able to accept any job that is not routed into any other queue.

Lastly, note the last line in the example above, which specified that the default queue is the new `submit` queue. This way users will simply submit their jobs with the resource and architecture requests, without specifying a queue, and PBS will route the job into the correct location. For example, if a user submitted a job with the following syntax, the job would be routed into the `server_2` queue:

```
qsub -l select=arch=sv2:ncpus=4 testjob
```

12.5 External Software License Management

PBS Professional can be configured to schedule jobs based on externally-controlled licensed software (such as applications licensed via FlexLM). A detailed example is provided in section 9.7.3 "Server-level External Licenses Example" on page 201.

12.6 Multiple User ACL Example

A site may have a need to restrict individual users to particular queues. In the previous example we set up queues with group-based ACLs, in this example we show user-based ACLs. Say a site has two different groups of users, and wants to limit them to two separate queues (perhaps with different resource limits). The following example illustrates this.

```
Qmgr: create queue structure
Qmgr: set queue structure queue_type = Execution
Qmgr: set queue structure acl_user_enable = True
Qmgr: set queue structure acl_users = curly
Qmgr: set queue structure acl_users += jerry
Qmgr: set queue structure acl_users += larry
Qmgr: set queue structure acl_users += moe
Qmgr: set queue structure acl_users += tom
Qmgr: set queue structure resources_max.nodes = 48
Qmgr: set queue structure enabled = True
Qmgr: set queue structure started = True
Qmgr:
Qmgr: create queue engine
Qmgr: set queue engine queue_type = Execution
Qmgr: set queue engine acl_user_enable = True
Qmgr: set queue engine acl_users = bill
Qmgr: set queue engine acl_users += bobby
Qmgr: set queue engine acl_users += chris
Qmgr: set queue engine acl_users += jim
Qmgr: set queue engine acl_users += mike
Qmgr: set queue engine acl_users += rob
Qmgr: set queue engine acl_users += scott
Qmgr: set queue engine resources_max.nodes = 12
Qmgr: set queue engine resources_max.walltime=04:00:00
Qmgr: set queue engine enabled = True
Qmgr: set queue engine started = True
Qmgr:
```

Chapter 13
Problem Solving

The following is a list of common problems and recommended solutions. Additional information is always available online at the PBS website, www.domain.com. The last section in this chapter gives important information on how to get additional assistance from the PBS Support staff.

13.1 Directory Permission Problems

If for some reason the access permissions on the PBS file tree are changed from their default settings, a component of the PBS system may detect this as a security violation, and refuse to execute. If this is the case, an error message to this effect will be written to the corresponding log file. You can run the `pbs_probe` command to check (and optionally correct) any directory permission (or ownership) problems. For details on usage of the `pbs_probe` command see section 11.5 “The pbs_probe Command” on page 260.

13.2 Job Exit Codes

The exit value of a job may fail in one of three ranges: X < 0, 0 >=X < 128, X >=128.

X < 0:
This is a PBS special return value indicating that the job could not be executed. These

negative values are listed in the table below.

0 >= X < 128 (or 256):
This is the exit value of the top process in the job, typically the shell.

X >= 128 (or 256 depending on the system)
This means the job was killec with a signal. The signal is given by X modulo 128 (or 256). For example an exit value of 137 means the job's top process was killed with signal 9 (137 % 128 = 9).

	Name	Description
0	`JOB_EXEC_OK`	job exec successful
-1	`JOB_EXEC_FAIL1`	Job exec failed, before files, no retry
-2	`JOB_EXEC_FAIL2`	Job exec failed, after files, no retry
-3	`JOB_EXEC_RETRY`	Job execution failed, do retry
-4	`JOB_EXEC_INITABT`	Job aborted on MOM initialization
-5	`JOB_EXEC_INITRST`	Job aborted on MOM init, chkpt, no migrate
-6	`JOB_EXEC_INITRMG`	Job aborted on MOM init, chkpt, ok migrate
-7	`JOB_EXEC_BADRESRT`	Job restart failed
-8	`JOB_EXEC_GLOBUS_INIT_RETRY`	Init. globus job failed. do retry
-9	`JOB_EXEC_GLOBUS_INIT_FAIL`	Init. globus job failed. no retry
-10	`JOB_EXEC_FAILUID`	invalid uid/gid for job
-11	`JOB_EXEC_RERUN`	Job rerun
-12	`JOB_EXEC_CHKP`	Job was checkpointed and killed
-13	`JOB_EXEC_FAIL_PASSWORD`	Job failed due to a bad password

13.3 Common Errors

13.3.1 Clients Unable to Contact Server

If a client command (such as `qstat` or `qmgr`) is unable to connect to a Server there are several possibilities to check. If the error return is `15034`, "`No server to connect to`", check (1) that there is indeed a Server running and (2) that the default Server information is set correctly. The client commands will attempt to connect to the Server specified on the command line if given, or if not given, the Server specified by **`SERVER_NAME`** in `pbs.conf`.

If the error return is `15007`, "`No permission`", check for (2) as above. Also check that the executable `pbs_iff` is located in the search path for the client and that it is setuid root. Additionally, try running `pbs_iff` by typing:

```
pbs_iff -t server_host 15001
```

Where *`server_host`* is the name of the host on which the Server is running and `15001` is the port to which the Server is listening (if started with a different port number, use that number instead of `15001`). Check for an error message and/or a non-zero exit status. If `pbs_iff` exits with no error and a non-zero status, either the Server is not running or was installed with a different encryption system than was `pbs_iff`.

13.3.2 Nodes Down

The PBS Server determines the state of nodes (`up` or `down`), by communicating with MOM on the node. The state of nodes may be listed by two commands: `qmgr` and `pbsnodes`.

```
qmgr
Qmgr: list node @active
pbsnodes -a
Node jupiter
        state = down, state-unknown
```

A node in PBS may be marked "`down`" in one of two substates. For example, the state above of node "jupiter" shows that the Server has not had contact with MOM since the Server came up. Check to see if a MOM is running on the node. If there is a MOM and if the MOM was just started, the Server may have attempted to poll her before she was up. The Server should see her during the next polling cycle in 10 minutes. If the node is still marked "`down, state-unknown`" after 10+ minutes, either the node name specified in the Server's node file does not map to the real network hostname or there is a network problem between the Server's host and the node.

If the node is listed as

```
pbsnodes -a
Node jupiter
        state = down
```

then the Server has been able to ping MOM on the node in the past, but she has not responded recently. The Server will send a "ping" PBS message to every free node each ping cycle, 10 minutes. If a node does not acknowledge the ping before the next cycle, the Server will mark the node down.

13.3.3 Requeueing a Job "Stuck" on a Down Node

PBS Professional will detect if a node fails when a job is running on it, and will automatically requeue and schedule the job to run elsewhere. If the user marked the job as "not rerunnable" (i.e. via the `qsub -r n` option), the then job will be deleted rather than requeued. If the affected node is node 0 (Mother Superior), the requeue will occur quickly. If it is another node in the set assigned to the job, it could take a few minutes before PBS takes action to requeue or delete the job. However, if the auto-requeue feature is not enabled (see "node_fail_requeue" on page 82), or if you wish to act immediately, you can manually force the requeueing and/or rerunning of the job.

If you wish to have PBS simply remove the job from the system, use the "`-Wforce`" option to `qdel`:

```
qdel -Wforce jobID
```

If instead you want PBS to requeue the job, and have it immediately eligible to run again, use the "`-Wforce`" option to `qrerun`:

```
qrerun -Wforce jobID
```

13.3.4 File Stage-in Failure

When stage-in fails, the job is placed in a 30-minute wait to allow the user time to fix the problem. Typically this is a missing file or a network outage. Email is sent to the job owner when the problem is detected. Once the problem has been resolved, the job owner or the Operator may remove the wait by resetting the time after which the job is eligible to be run via the `-a` option to `qalter`.

13.3.5 Non Delivery of Output

If the output of a job cannot be delivered to the user, it is saved in a special directory: *PBS_HOME*/`undelivered` and mail is sent to the user. The typical causes of non-delivery are:

1. The destination host is not trusted and the user does not have a `.rhosts` file.
2. An improper path was specified.
3. A directory in the specified destination path is not writable.
4. The user's `.cshrc` on the destination host generates output when executed.
5. The path specified by **`PBS_SCP`** in `pbs.conf` is incorrect.
6. The *PBS_HOME*/`spool` directory on the execution host does not have the correct permissions. This directory must have mode 1777 `drwxrwxrwxt` (on UNIX) or "Full Control" for "Everyone" (on Windows).

See also the "Delivery of Output Files" section of the **PBS Professional User's Guide**.

13.3.6 Job Cannot be Executed

If a user receives a mail message containing a job id and the line "`Job cannot be executed`", the job was aborted by MOM when she tried to place it into execution. The complete reason can be found in one of two places, MOM's log file or the standard error file of the user's job. If the second line of the message is "`See Administrator for help`", then MOM aborted the job before the job's files were set up. The reason will be noted in MOM's log. Typical reasons are a bad user/group account, checkpoint/restart file (Cray or SGI), or a system error. If the second line of the message is "`See job standard error file`", then MOM had created the job's file and additional messages were written to standard error. This is typically the result of a bad resource request.

13.3.7 Running Jobs with No Active Processes

On very rare occasions, PBS may be in a situation where a job is in the Running state but has no active processes. This should never happen as the death of the job's shell should trigger MOM to notify the Server that the job exited and end-of-job processing should begin. If this situation is noted, PBS offers a way out. Use the `qsig` command to send `SIGNULL`, signal 0, to the job. (Usage of the `qsig` command is provided in the **PBS Professional User's Guide**.) If MOM finds there are no processes then she will force the job into the exiting state.

13.3.8 Job Held Due to Invalid Password

If a job fails to run due to an invalid password, then the job will be put on hold (hold type "p"), its comment field updated as to why it failed, and an email sent to user for remedy action. See also the `qhold` and `qrls` commands in the **PBS Professional User's Guide**.

13.4 Common Errors on Windows

This section discusses errors often encountered under Windows.

13.4.1 Windows: qstat errors

If the `qstat` command produces an error such as:

```
illegally formed job identifier.
```

This means that the DNS lookup is not working properly, or reverse lookup is failing. Use the following command to verify DNS reverse lookup is working

```
pbs_hostn -v hostname
```

If however, `qstat` reports "No Permission", then check `pbs.conf`, and look for the entry "PBS_EXEC". `qstat` (in fact all the PBS commands) will execute the command "*PBS_EXEC*\ `sbin\pbs_iff`" to do its authentication. Ensure that the path specified in `pbs.conf` is correct.

13.4.2 Windows: qsub errors

If, when attempting to submit a job to a remote server, qsub reports:

```
BAD uid for job execution
```

Then you need to add an entry in the remote system's `.rhosts` or `hosts.equiv` pointing to your Windows 2000 machine. Be sure to put in all hostnames that resolve to your machine. See also section 10.7.5 "User Authorization" on page 227.

If remote account maps to an Administrator-type account, then you need to set up a `.rhosts` entry, and the remote server must carry the account on its `acl_roots` list.

13.4.3 Windows: Server Reports Error 10035

If Server is not able to contact the Scheduler running on the same local host, it may print to its log file the error message,

```
10035 (Resources Temporarily Unavailable)
```

This is often caused by the local hostname resolving to a bad IP address. Perhaps, in `%WINDIR%\system32\drivers\etc\hosts`, localhost and *hostname* were mapped to 127.0.0.1.

13.4.4 Windows: Server Reports Error 10054

If the Server reports error 10054 `rp_request()`, this indicates that another process, probably `pbs_sched`, `pbs_mom`, or `pbs_send_job` is hung up causing the Server to report bad connections. If you desire to kill these services, then use Task Manager to find the Service's process id, and then issue the command:

```
pbskill process-id
```

13.4.5 Windows: PBS Permission Errors

If the Server, MOM, or Scheduler fails to start up because of permission problems on some of its configuration files like `pbs_environment`, `server_priv/nodes`, `mom_priv/config`, then correct the permission by running:

```
pbs_mkdirs server
pbs_mkdirs mom
pbs_mkdirs sched
```

13.4.6 Windows: Errors When Not Using Drive C:

If PBS is installed on a hard drive other than `C:`, it may not be able to locate the `pbs.conf` global configuration file. If this is the case, PBS will report the following message:

```
E:\Program Files\PBS Pro\exec\bin>qstat -
pbsconf error: pbs conf variables not found:
PBS_HOME PBS_EXEC
No such file or directory
qstat: cannot connect to server UNKNOWN (errno=0)
```

To correct this problem, set PBS_CONF_FILE to point pbs.conf to the right path. Normally, during PBS Windows installation, this would be set in system autoexec.bat which will be read after the Windows system has been restarted. Thus, after PBS Windows installation completes, be sure to reboot the Windows system in order for this variable to be read correctly.

13.4.7 Windows: Node Comment “ping: no stream”

If a node shows a “down” status in xpbsmon or “pbsnodes -a” and contains a node comment with the text “ping: no stream” and “write err”, then attempt to restart the Server as follows to clear the error:

```
net stop pbs_server
net start pbs_server
```

13.4.8 Windows: Services Debugging Enabled

The PBS services, pbs_server, pbs_mom, pbs_sched, and pbs_rshd are compiled with debugging information enabled. Therefore you can use a debugging tool (such as Dr. Watson) to capture a crash dump log which will aid the developers in troubleshooting the problem. To configure and run Dr. Watson, execute drwtsn32 on the Windows command line, set its “Log Path” appropriately and click on the button that enables a popup window when Dr. Watson encounters an error. Then run a test that will cause one of the PBS services to crash and email to PBS support the generated output in Log_Path. Other debugging tools may be used as well.

13.5 Getting Help

If the material in the PBS manuals is unable to help you solve a particular problem, you may need to contact the PBS Support Team for assistance. First, be sure to check the Customer Login area of the PBS Professional website, which has a number of ways to assist you in resolving problems with PBS, such as the Tips & Advice page.

The PBS Professional support team can also be reached directly via email and phone (contact information on the inside front cover of this manual).

Important: When contacting PBS Professional Support, please provide as much of the following information as possible:

PBS SiteID

Output of the following commands:

```
qstat -Bf
qstat -Qf
pbsnodes -a
```

If the question pertains to a certain type of job, include:

```
qstat -f job_id
```

If the question is about scheduling, also send your:

`(PBS_HOME)/sched_priv/sched_config` file.

To expand, renew, or change your PBS support contract, contact our Sales Department. (See contact information on the inside front cover of this manual.)

Appendix A: Error Codes

The following table lists all the PBS error codes, their textual names, and a description of each.

Error Name	Error Code	Description
PBSE_NONE	0	No error
PBSE_UNKJOBID	15001	Unknown Job Identifier
PBSE_NOATTR	15002	Undefined Attribute
PBSE_ATTRRO	15003	Attempt to set READ ONLY attribute
PBSE_IVALREQ	15004	Invalid request
PBSE_UNKREQ	15005	Unknown batch request
PBSE_TOOMANY	15006	Too many submit retries
PBSE_PERM	15007	No permission
PBSE_BADHOST	15008	Access from host not allowed
PBSE_JOBEXIST	15009	Job already exists
PBSE_SYSTEM	15010	System error occurred

Error Name	Error Code	Description
PBSE_INTERNAL	15011	Internal Server error occurred
PBSE_REGROUTE	15012	Parent job of dependent in route queue
PBSE_UNKSIG	15013	Unknown signal name
PBSE_BADATVAL	15014	Bad attribute value
PBSE_MODATRRUN	15015	Cannot modify attrib in run state
PBSE_BADSTATE	15016	Request invalid for job state
PBSE_UNKQUE	15018	Unknown queue name
PBSE_BADCRED	15019	Invalid Credential in request
PBSE_EXPIRED	15020	Expired Credential in request
PBSE_QUNOENB	15021	Queue not enabled
PBSE_QACESS	15022	No access permission for queue
PBSE_BADUSER	15023	Missing userID, username, or GID.
PBSE_HOPCOUNT	15024	Max hop count exceeded
PBSE_QUEEXIST	15025	Queue already exists
PBSE_ATTRTYPE	15026	Incompatible queue attribute type
PBSE_OBJBUSY	15027	Object Busy
PBSE_QUENBIG	15028	Queue name too long
PBSE_NOSUP	15029	Feature/function not supported
PBSE_QUENOEN	15030	Cannot enable queue, needs add def
PBSE_PROTOCOL	15031	Protocol (ASN.1) error
PBSE_BADATLST	15032	Bad attribute list structure
PBSE_NOCONNECTS	15033	No free connections
PBSE_NOSERVER	15034	No Server to connect to
PBSE_UNKRESC	15035	Unknown resource

Error Name	Error Code	Description
PBSE_EXCQRESC	15036	Job exceeds Queue resource limits
PBSE_QUENODFLT	15037	No Default Queue Defined
PBSE_NORERUN	15038	Job Not Rerunnable
PBSE_ROUTEREJ	15039	Route rejected by all destinations
PBSE_ROUTEEXPD	15040	Time in Route Queue Expired
PBSE_MOMREJECT	15041	Request to MOM failed
PBSE_BADSCRIPT	15042	(qsub) Cannot access script file
PBSE_STAGEIN	15043	Stage In of files failed
PBSE_RESCUNAV	15044	Resources temporarily unavailable
PBSE_BADGRP	15045	Bad Group specified
PBSE_MAXQUED	15046	Max number of jobs in queue
PBSE_CKPBSY	15047	Checkpoint Busy, may be retries
PBSE_EXLIMIT	15048	Limit exceeds allowable
PBSE_BADACCT	15049	Bad Account attribute value
PBSE_ALRDYEXIT	15050	Job already in exit state
PBSE_NOCOPYFILE	15051	Job files not copied
PBSE_CLEANEDOUT	15052	Unknown job id after clean init
PBSE_NOSYNCMSTR	15053	No Master in Sync Set
PBSE_BADDEPEND	15054	Invalid dependency
PBSE_DUPLIST	15055	Duplicate entry in List
PBSE_DISPROTO	15056	Bad DIS based Request Protocol
PBSE_EXECTHERE	15057	Cannot execute there
PBSE_SISREJECT	15058	Sister rejected

Error Name	Error Code	Description
PBSE_SISCOMM	15059	Sister could not communicate
PBSE_SVRDOWN	15060	Request rejected -server shutting down
PBSE_CKPSHORT	15061	Not all tasks could checkpoint
PBSE_UNKNODE	15062	Named node is not in the list
PBSE_UNKNODEATR	15063	Node-attribute not recognized
PBSE_NONODES	15064	Server has no node list
PBSE_NODENBIG	15065	Node name is too big
PBSE_NODEEXIST	15066	Node name already exists
PBSE_BADNDATVAL	15067	Bad node-attribute value
PBSE_MUTUALEX	15068	State values are mutually exclusive
PBSE_GMODERR	15069	Error(s) during global mod of nodes
PBSE_NORELYMOM	15070	Could not contact MOM
PBSE_RESV_NO_WALLTIME	15075	Job reserv lacking walltime
PBSE_JOBNOTRESV	15076	Not a reservation job
PBSE_TOOLATE	15077	Too late for job reservation
PBSE_IRESVE	15078	Internal reservation-system error
PBSE_UNKRESVTYPE	15079	Unknown reservation type
PBSE_RESVEXIST	15080	Reservation already exists
PBSE_resvFail	15081	Reservation failed
PBSE_genBatchReq	15082	Batch request generation failed
PBSE_mgrBatchReq	15083	qmgr batch request failed
PBSE_UNKRESVID	15084	Unknown reservation ID
PBSE_delProgress	15085	Delete already in progress
PBSE_BADTSPEC	15086	Bad time specification(s)

Error Name	Error Code	Description
PBSE_RESVMSG	15087	So reply_text can return a msg
PBSE_NOTRESV	15088	Not a reservation
PBSE_BADNODESPEC	15089	Node(s) specification error
PBSE_LICENSECPU	15090	Licensed CPUs exceeded
PBSE_LICENSEINV	15091	License is invalid
PBSE_RESVAUTH_H	15092	Host not authorized to make AR
PBSE_RESVAUTH_G	15093	Group not authorized to make AR
PBSE_RESVAUTH_U	15094	User not authorized to make AR
PBSE_R_UID	15095	Bad effective UID for reservation
PBSE_R_GID	15096	Bad effective GID for reservation
PBSE_IBMSPSWITCH	15097	IBM SP Switch error
PBSE_LICENSEUNAV	15098	Floating License unavailable
	15099	UNUSED
PBSE_RESCNOTSTR	15100	Resource is not of type string
PBSE_SSIGNON_UNSET_REJECT	15101	rejected if SVR_ssignon_enable not set
PBSE_SSIGNON_SET_REJECT	15102	rejected if SVR_ssignon_enable set
PBSE_SSIGNON_BAD_TRANSITION1	15103	bad attempt: true to false
PBSE_SSIGNON_BAD_TRANSITION2	15104	bad attempt: false to true
PBSE_SSIGNON_NOCONNECT_DEST	15105	couldn't connect to dest. host during a user migration request
PBSE_SSIGNON_NO_PASSWORD	15106	no per-user/per-server password
Resource monitor specific error codes		
PBSE_RMUNKNOWN	15201	Resource unknown

Error Name	Error Code	Description
PBSE_RMBADPARAM	15202	Parameter could not be used
PBSE_RMNOPARAM	15203	A needed parameter did not exist
PBSE_RMEXIST	15204	Something specified didn't exist
PBSE_RMSYSTEM	15205	A system error occurred
PBSE_RMPART	15206	Only part of reservation made
RM_ERR_UNKNOWN	PBSE_RMUNKNOWN	
RM_ERR_BADPARAM	PBSE_RMBADPARAM	
RM_ERR_NOPARAM	PBSE_RMNOPARAM	
RM_ERR_EXIST	PBSE_RMEXIST	
RM_ERR_SYSTEM	PBSE_RMSYSTEM	

Appendix B: Request Codes

When reading the PBS event logfiles, you may see messages of the form "Type 19 request received from PBS_Server...". These "type codes" correspond to different PBS batch requests. The following table lists all the PBS type codes and the corresponding request of each.

0	`PBS_BATCH_Connect`
1	`PBS_BATCH_QueueJob`
2	`UNUSED`
3	`PBS_BATCH_jobscript`
4	`PBS_BATCH_RdytoCommit`
5	`PBS_BATCH_Commit`
6	`PBS_BATCH_DeleteJob`
7	`PBS_BATCH_HoldJob`
8	`PBS_BATCH_LocateJob`
9	`PBS_BATCH_Manager`
10	`PBS_BATCH_MessJob`
11	`PBS_BATCH_ModifyJob`

12	`PBS_BATCH_MoveJob`
13	`PBS_BATCH_ReleaseJob`
14	`PBS_BATCH_Rerun`
15	`PBS_BATCH_RunJob`
16	`PBS_BATCH_SelectJobs`
17	`PBS_BATCH_Shutdown`
18	`PBS_BATCH_SignalJob`
19	`PBS_BATCH_StatusJob`
20	`PBS_BATCH_StatusQue`
21	`PBS_BATCH_StatusSvr`
22	`PBS_BATCH_TrackJob`
23	`PBS_BATCH_AsyrunJob`
24	`PBS_BATCH_Rescq`
25	`PBS_BATCH_ReserveResc`
26	`PBS_BATCH_ReleaseResc`
27	`PBS_BATCH_FailOver`
48	`PBS_BATCH_StageIn`
49	`PBS_BATCH_AuthenUser`
50	`PBS_BATCH_OrderJob`
51	`PBS_BATCH_SelStat`
52	`PBS_BATCH_RegistDep`
54	`PBS_BATCH_CopyFiles`
55	`PBS_BATCH_DelFiles`
56	`PBS_BATCH_JobObit`
57	`PBS_BATCH_MvJobFile`
58	`PBS_BATCH_StatusNode`

59	PBS_BATCH_Disconnect
60	UNUSED
61	UNUSED
62	PBS_BATCH_JobCred
63	PBS_BATCH_CopyFiles_Cred
64	PBS_BATCH_DelFiles_Cred
65	PBS_BATCH_GSS_Context
66	UNUSED
67	UNUSED
68	UNUSED
69	UNUSED
70	PBS_BATCH_SubmitResv
71	PBS_BATCH_StatusResv
72	PBS_BATCH_DeleteResv
73	PBS_BATCH_UserCred
74	PBS_BATCH_UserMigrate

Appendix C: File Listing

The following table lists all the PBS files and directories; owner and permissions are specific to UNIX systems.

Directory / File	Owner	Permission	Average Size
PBS_HOME	root	drwxr-xr-x	4096
PBS_HOME/pbs_environment	root	-rw-r--r--	0
PBS_HOME/server_logs	root	drwxr-xr-x	4096
PBS_HOME/spool	root	drwxrwxrwt	4096
PBS_HOME/server_priv	root	drwxr-x---	4096
PBS_HOME/server_priv/accounting	root	drwxr-xr-x	4096
PBS_HOME/server_priv/acl_groups	root	drwxr-x---	4096
PBS_HOME/server_priv/acl_hosts	root	drwxr-x---	4096
PBS_HOME/server_priv/acl_svr	root	drwxr-x---	4096
PBS_HOME/server_priv/acl_svr/managers	root	-rw-------	13
PBS_HOME/server_priv/acl_users	root	drwxr-x---	4096

Directory / File	Owner	Permission	Average Size
PBS_HOME/server_priv/jobs	root	drwxr-x---	4096
PBS_HOME/server_priv/queues	root	drwxr-x---	4096
PBS_HOME/server_priv/queues/workq	root	-rw-------	303
PBS_HOME/server_priv/queues/newqueue	root	-rw-------	303
PBS_HOME/server_priv/resvs	root	drwxr-x---	4096
PBS_HOME/server_priv/nodes	root	-rw-r--r--	59
PBS_HOME/server_priv/server.lock	root	-rw-------	4
PBS_HOME/server_priv/tracking	root	-rw-------	0
PBS_HOME/server_priv/serverdb	root	-rw-------	876
PBS_HOME/server_priv/license_file	root	-rw-r--r--	34
PBS_HOME/aux	root	drwxr-xr-x	4096
PBS_HOME/checkpoint	root	drwx------	4096
PBS_HOME/mom_logs	root	drwxr-xr-x	4096
PBS_HOME/mom_priv	root	drwxr-x--x	4096
PBS_HOME/mom_priv/jobs	root	drwxr-x--x	4096
PBS_HOME/mom_priv/config	root	-rw-r--r--	18
PBS_HOME/mom_priv/mom.lock	root	-rw-r--r--	4
PBS_HOME/undelivered	root	drwxrwxrwt	4096
PBS_HOME/sched_logs	root	drwxr-xr-x	4096
PBS_HOME/sched_priv	root	drwxr-x---	4096
PBS_HOME/sched_priv/dedicated_time	root	-rw-r--r--	557
PBS_HOME/sched_priv/holidays	root	-rw-r--r--	1228
PBS_HOME/sched_priv/sched_config	root	-rw-r--r--	6370
PBS_HOME/sched_priv/resource_group	root	-rw-r--r--	0

Directory / File	**Owner**	**Permission**	**Average Size**
PBS_HOME/sched_priv/sched.lock	root	-rw-r--r--	4
PBS_HOME/sched_priv/sched_out	root	-rw-r--r--	0
PBS_EXEC/	root	drwxr-xr-x	4096
PBS_EXEC/bin	root	drwxr-xr-x	4096
PBS_EXEC/bin/nqs2pbs	root	-rwxr-xr-x	16062
PBS_EXEC/bin/pbs_hostid	root	-rwxr-xr-x	35604
PBS_EXEC/bin/pbs_hostn	root	-rwxr-xr-x	35493
PBS_EXEC/bin/pbs_rdel	root	-rwxr-xr-x	151973
PBS_EXEC/bin/pbs_rstat	root	-rwxr-xr-x	156884
PBS_EXEC/bin/pbs_rsub	root	-rwxr-xr-x	167446
PBS_EXEC/bin/pbs_tclsh	root	-rwxr-xr-x	857552
PBS_EXEC/bin/pbs_wish	root	-rwxr-xr-x	1592236
PBS_EXEC/bin/pbsdsh	root	-rwxr-xr-x	111837
PBS_EXEC/bin/pbsnodes	root	-rwxr-xr-x	153004
PBS_EXEC/bin/printjob	root	-rwxr-xr-x	42667
PBS_EXEC/bin/qalter	root	-rwxr-xr-x	210723
PBS_EXEC/bin/qdel	root	-rwxr-xr-x	164949
PBS_EXEC/bin/qdisable	root	-rwxr-xr-x	139559
PBS_EXEC/bin/qenable	root	-rwxr-xr-x	139558
PBS_EXEC/bin/qhold	root	-rwxr-xr-x	165368
PBS_EXEC/bin/qmgr	root	-rwxr-xr-x	202526
PBS_EXEC/bin/qmove	root	-rwxr-xr-x	160932
PBS_EXEC/bin/qmsg	root	-rwxr-xr-x	160408

Directory / File	Owner	Permission	Average Size
PBS_EXEC/bin/qorder	root	-rwxr-xr-x	146393
PBS_EXEC/bin/qrerun	root	-rwxr-xr-x	157228
PBS_EXEC/bin/qrls	root	-rwxr-xr-x	165361
PBS_EXEC/bin/qrun	root	-rwxr-xr-x	160978
PBS_EXEC/bin/qselect	root	-rwxr-xr-x	163266
PBS_EXEC/bin/qsig	root	-rwxr-xr-x	160083
PBS_EXEC/bin/qstart	root	-rwxr-xr-x	139589
PBS_EXEC/bin/qstat	root	-rwxr-xr-x	207532
PBS_EXEC/bin/qstop	root	-rwxr-xr-x	139584
PBS_EXEC/bin/qsub	root	-rwxr-xr-x	275460
PBS_EXEC/bin/qterm	root	-rwxr-xr-x	132188
PBS_EXEC/bin/tracejob	root	-rwxr-xr-x	64730
PBS_EXEC/bin/xpbs	root	-rwxr-xr-x	817
PBS_EXEC/bin/xpbsmon	root	-rwxr-xr-x	817
PBS_EXEC/etc	root	drwxr-xr-x	4096
PBS_EXEC/etc/pbs_dedicated	root	-rw-r--r--	557
PBS_EXEC/etc/pbs_holidays	root	-rw-r--r--	1173
PBS_EXEC/etc/pbs_init.d	root	-rwx------	5382
PBS_EXEC/etc/pbs_postinstall	root	-rwx------	10059
PBS_EXEC/etc/pbs_resource_group	root	-rw-r--r--	657
PBS_EXEC/etc/pbs_sched_config	root	-rw-r--r--	9791
PBS_EXEC/etc/pbs_setlicense	root	-rwx------	2118
PBS_EXEC/include	root	drwxr-xr-x	4096
PBS_EXEC/include/pbs_error.h	root	-r--r--r--	7543

Directory / File	**Owner**	**Permission**	**Average Size**
PBS_EXEC/include/pbs_ifl.h	root	-r--r--r--	17424
PBS_EXEC/include/rm.h	root	-r--r--r--	740
PBS_EXEC/include/tm.h	root	-r--r--r--	2518
PBS_EXEC/include/tm_.h	root	-r--r--r--	2236
PBS_EXEC/lib	root	drwxr-xr-x	4096
PBS_EXEC/lib/libattr.a	root	-rw-r--r--	390274
PBS_EXEC/lib/libcmds.a	root	-rw-r--r--	328234
PBS_EXEC/lib/liblog.a	root	-rw-r--r--	101230
PBS_EXEC/lib/libnet.a	root	-rw-r--r--	145968
PBS_EXEC/lib/libpbs.a	root	-rw-r--r--	1815486
PBS_EXEC/lib/libsite.a	root	-rw-r--r--	132906
PBS_EXEC/lib/pbs_sched.a	root	-rw-r--r--	822026
PBS_EXEC/lib/pm	root	drwxr--r--	4096
PBS_EXEC/lib/pm/PBS.pm	root	-rw-r--r--	3908
PBS_EXEC/lib/xpbs	root	drwxr-xr-x	4096
PBS_EXEC/lib/xpbs/pbs_acctname.tk	root	-rw-r--r--	3484
PBS_EXEC/lib/xpbs/pbs_after_depend.tk	root	-rw-r--r--	8637
PBS_EXEC/lib/xpbs/pbs_auto_upd.tk	root	-rw-r--r--	3384
PBS_EXEC/lib/xpbs/pbs_before_depend.tk	root	-rw-r--r--	8034
PBS_EXEC/lib/xpbs/pbs_bin	root	drwxr-xr-x	4096
PBS_EXEC/lib/xpbs/pbs_bin/xpbs_datadump	root	-rwxr-xr-x	190477
PBS_EXEC/lib/xpbs/pbs_bin/xpbs_scriptload	root	-rwxr-xr-x	173176
PBS_EXEC/lib/xpbs/pbs_bindings.tk	root	-rw-r--r--	26029

Directory / File	Owner	Permission	Average Size
PBS_EXEC/lib/xpbs/pbs_bitmaps	root	drwxr-xr-x	4096
PBS_EXEC/lib/xpbs/pbs_bitmaps/Downarrow.bmp	root	-rw-r--r--	299
PBS_EXEC/lib/xpbs/pbs_bitmaps/Uparrow.bmp	root	-rw-r--r--	293
PBS_EXEC/lib/xpbs/pbs_bitmaps/ curve_down_arrow.bmp	root	-rw-r--r--	320
PBS_EXEC/lib/xpbs/pbs_bitmaps/ curve_up_arrow.bmp	root	-rw-r--r--	314
PBS_EXEC/lib/xpbs/pbs_bitmaps/cyclist-only.xbm	root	-rw-r--r--	2485
PBS_EXEC/lib/xpbs/pbs_bitmaps/hourglass.bmp	root	-rw-r--r--	557
PBS_EXEC/lib/xpbs/pbs_bitmaps/iconize.bmp	root	-rw-r--r--	287
PBS_EXEC/lib/xpbs/pbs_bitmaps/logo.bmp	root	-rw-r--r--	67243
PBS_EXEC/lib/xpbs/pbs_bitmaps/maximize.bmp	root	-rw-r--r--	287
PBS_EXEC/lib/xpbs/pbs_bitmaps/ sm_down_arrow.bmp	root	-rw-r--r--	311
PBS_EXEC/lib/xpbs/pbs_bitmaps/ sm_up_arrow.bmp	root	-rw-r--r--	305
PBS_EXEC/lib/xpbs/pbs_box.tk	root	-rw-r--r--	25912
PBS_EXEC/lib/xpbs/pbs_button.tk	root	-rw-r--r--	18795
PBS_EXEC/lib/xpbs/pbs_checkpoint.tk	root	-rw-r--r--	6892
PBS_EXEC/lib/xpbs/pbs_common.tk	root	-rw-r--r--	25940
PBS_EXEC/lib/xpbs/pbs_concur.tk	root	-rw-r--r--	8445
PBS_EXEC/lib/xpbs/pbs_datetime.tk	root	-rw-r--r--	4533
PBS_EXEC/lib/xpbs/pbs_email_list.tk	root	-rw-r--r--	3094
PBS_EXEC/lib/xpbs/pbs_entry.tk	root	-rw-r--r--	12389
PBS_EXEC/lib/xpbs/pbs_fileselect.tk	root	-rw-r--r--	7975
PBS_EXEC/lib/xpbs/pbs_help	root	drwxr-xr-x	4096

Directory / File	**Owner**	**Permission**	**Average Size**
PBS_EXEC/lib/xpbs/pbs_help/after_depend.hlp	root	-rw-r--r--	1746
PBS_EXEC/lib/xpbs/pbs_help/auto_update.hlp	root	-rw-r--r--	776
PBS_EXEC/lib/xpbs/pbs_help/before_depend.hlp	root	-rw-r--r--	1413
PBS_EXEC/lib/xpbs/pbs_help/concur.hlp	root	-rw-r--r--	1383
PBS_EXEC/lib/xpbs/pbs_help/datetime.hlp	root	-rw-r--r--	698
PBS_EXEC/lib/xpbs/pbs_help/delete.hlp	root	-rw-r--r--	632
PBS_EXEC/lib/xpbs/pbs_help/email.hlp	root	-rw-r--r--	986
PBS_EXEC/lib/xpbs/pbs_help/fileselect.hlp	root	-rw-r--r--	1655
PBS_EXEC/lib/xpbs/pbs_help/hold.hlp	root	-rw-r--r--	538
PBS_EXEC/lib/xpbs/pbs_help/main.hlp	root	-rw-r--r--	15220
PBS_EXEC/lib/xpbs/pbs_help/message.hlp	root	-rw-r--r--	677
PBS_EXEC/lib/xpbs/pbs_help/misc.hlp	root	-rw-r--r--	4194
PBS_EXEC/lib/xpbs/pbs_help/modify.hlp	root	-rw-r--r--	6034
PBS_EXEC/lib/xpbs/pbs_help/move.hlp	root	-rw-r--r--	705
PBS_EXEC/lib/xpbs/pbs_help/notes.hlp	root	-rw-r--r--	3724
PBS_EXEC/lib/xpbs/pbs_help/preferences.hlp	root	-rw-r--r--	1645
PBS_EXEC/lib/xpbs/pbs_help/release.hlp	root	-rw-r--r--	573
PBS_EXEC/lib/xpbs/pbs_help/select.acctname.hlp	root	-rw-r--r--	609
PBS_EXEC/lib/xpbs/pbs_help/select.checkpoint.hlp	root	-rw-r--r--	1133
PBS_EXEC/lib/xpbs/pbs_help/select.hold.hlp	root	-rw-r--r--	544
PBS_EXEC/lib/xpbs/pbs_help/select.jobname.hlp	root	-rw-r--r--	600
PBS_EXEC/lib/xpbs/pbs_help/select.owners.hlp	root	-rw-r--r--	1197
PBS_EXEC/lib/xpbs/pbs_help/select.priority.hlp	root	-rw-r--r--	748

Directory / File	Owner	Permission	Average Size
PBS_EXEC/lib/xpbs/pbs_help/select.qtime.hlp	root	-rw-r--r--	966
PBS_EXEC/lib/xpbs/pbs_help/select.rerun.hlp	root	-rw-r--r--	541
PBS_EXEC/lib/xpbs/pbs_help/select.resources.hlp	root	-rw-r--r--	1490
PBS_EXEC/lib/xpbs/pbs_help/select.states.hlp	root	-rw-r--r--	562
PBS_EXEC/lib/xpbs/pbs_help/signal.hlp	root	-rw-r--r--	675
PBS_EXEC/lib/xpbs/pbs_help/staging.hlp	root	-rw-r--r--	3702
PBS_EXEC/lib/xpbs/pbs_help/submit.hlp	root	-rw-r--r--	9721
PBS_EXEC/lib/xpbs/pbs_help/terminate.hlp	root	-rw-r--r--	635
PBS_EXEC/lib/xpbs/pbs_help/trackjob.hlp	root	-rw-r--r--	2978
PBS_EXEC/lib/xpbs/pbs_hold.tk	root	-rw-r--r--	3539
PBS_EXEC/lib/xpbs/pbs_jobname.tk	root	-rw-r--r--	3375
PBS_EXEC/lib/xpbs/pbs_listbox.tk	root	-rw-r--r--	10544
PBS_EXEC/lib/xpbs/pbs_main.tk	root	-rw-r--r--	24147
PBS_EXEC/lib/xpbs/pbs_misc.tk	root	-rw-r--r--	14526
PBS_EXEC/lib/xpbs/pbs_owners.tk	root	-rw-r--r--	4509
PBS_EXEC/lib/xpbs/pbs_pbs.tcl	root	-rw-r--r--	52524
PBS_EXEC/lib/xpbs/pbs_pref.tk	root	-rw-r--r--	3445
PBS_EXEC/lib/xpbs/pbs_preferences.tcl	root	-rw-r--r--	4323
PBS_EXEC/lib/xpbs/pbs_prefsave.tk	root	-rw-r--r--	1378
PBS_EXEC/lib/xpbs/pbs_priority.tk	root	-rw-r--r--	4434
PBS_EXEC/lib/xpbs/pbs_qalter.tk	root	-rw-r--r--	35003
PBS_EXEC/lib/xpbs/pbs_qdel.tk	root	-rw-r--r--	3175
PBS_EXEC/lib/xpbs/pbs_qhold.tk	root	-rw-r--r--	3676
PBS_EXEC/lib/xpbs/pbs_qmove.tk	root	-rw-r--r--	3326

Directory / File	**Owner**	**Permission**	**Average Size**
PBS_EXEC/lib/xpbs/pbs_qmsg.tk	root	-rw-r--r--	4032
PBS_EXEC/lib/xpbs/pbs_qrls.tk	root	-rw-r--r--	3674
PBS_EXEC/lib/xpbs/pbs_qsig.tk	root	-rw-r--r--	5171
PBS_EXEC/lib/xpbs/pbs_qsub.tk	root	-rw-r--r--	37466
PBS_EXEC/lib/xpbs/pbs_qterm.tk	root	-rw-r--r--	3204
PBS_EXEC/lib/xpbs/pbs_qtime.tk	root	-rw-r--r--	5790
PBS_EXEC/lib/xpbs/pbs_rerun.tk	root	-rw-r--r--	2802
PBS_EXEC/lib/xpbs/pbs_res.tk	root	-rw-r--r--	4807
PBS_EXEC/lib/xpbs/pbs_spinbox.tk	root	-rw-r--r--	7144
PBS_EXEC/lib/xpbs/pbs_staging.tk	root	-rw-r--r--	12183
PBS_EXEC/lib/xpbs/pbs_state.tk	root	-rw-r--r--	3657
PBS_EXEC/lib/xpbs/pbs_text.tk	root	-rw-r--r--	2738
PBS_EXEC/lib/xpbs/pbs_trackjob.tk	root	-rw-r--r--	13605
PBS_EXEC/lib/xpbs/pbs_wmgr.tk	root	-rw-r--r--	1428
PBS_EXEC/lib/xpbs/tclIndex	root	-rw-r--r--	19621
PBS_EXEC/lib/xpbs/xpbs.src.tk	root	-rwxr-xr-x	9666
PBS_EXEC/lib/xpbs/xpbsrc	root	-rw-r--r--	2986
PBS_EXEC/lib/xpbsmon	root	drwxr-xr-x	4096
PBS_EXEC/lib/xpbsmon/pbs_auto_upd.tk	root	-rw-r--r--	3281
PBS_EXEC/lib/xpbsmon/pbs_bindings.tk	root	-rw-r--r--	9288
PBS_EXEC/lib/xpbsmon/pbs_bitmaps	root	drwxr-xr-x	4096
PBS_EXEC/lib/xpbsmon/pbs_bitmaps/cyclist-only.xbm	root	-rw-r--r--	2485

Directory / File	Owner	Permission	Average Size
PBS_EXEC/lib/xpbsmon/pbs_bitmaps/hour-glass.bmp	root	-rw-r--r--	557
PBS_EXEC/lib/xpbsmon/pbs_bitmaps/iconize.bmp	root	-rw-r--r--	287
PBS_EXEC/lib/xpbsmon/pbs_bitmaps/logo.bmp	root	-rw-r--r--	67243
PBS_EXEC/lib/xpbsmon/pbs_bitmaps/maxi-mize.bmp	root	-rw-r--r--	287
PBS_EXEC/lib/xpbsmon/pbs_box.tk	root	-rw-r--r--	15607
PBS_EXEC/lib/xpbsmon/pbs_button.tk	root	-rw-r--r--	7543
PBS_EXEC/lib/xpbsmon/pbs_cluster.tk	root	-rw-r--r--	44406
PBS_EXEC/lib/xpbsmon/pbs_color.tk	root	-rw-r--r--	5634
PBS_EXEC/lib/xpbsmon/pbs_common.tk	root	-rw-r--r--	5716
PBS_EXEC/lib/xpbsmon/pbs_dialog.tk	root	-rw-r--r--	8398
PBS_EXEC/lib/xpbsmon/pbs_entry.tk	root	-rw-r--r--	10697
PBS_EXEC/lib/xpbsmon/pbs_expr.tk	root	-rw-r--r--	6163
PBS_EXEC/lib/xpbsmon/pbs_help	root	drwxr-xr-x	4096
PBS_EXEC/lib/xpbsmon/pbs_help/auto_update.hlp	root	-rw-r--r--	624
PBS_EXEC/lib/xpbsmon/pbs_help/main.hlp	root	-rw-r--r--	15718
PBS_EXEC/lib/xpbsmon/pbs_help/notes.hlp	root	-rw-r--r--	296
PBS_EXEC/lib/xpbsmon/pbs_help/pref.hlp	root	-rw-r--r--	1712
PBS_EXEC/lib/xpbsmon/pbs_help/prefQuery.hlp	root	-rw-r--r--	4621
PBS_EXEC/lib/xpbsmon/pbs_help/prefServer.hlp	root	-rw-r--r--	1409
PBS_EXEC/lib/xpbsmon/pbs_listbox.tk	root	-rw-r--r--	10640
PBS_EXEC/lib/xpbsmon/pbs_main.tk	root	-rw-r--r--	6760
PBS_EXEC/lib/xpbsmon/pbs_node.tk	root	-rw-r--r--	60640
PBS_EXEC/lib/xpbsmon/pbs_pbs.tk	root	-rw-r--r--	7090

Directory / File	Owner	Permission	Average Size
PBS_EXEC/lib/xpbsmon/pbs_pref.tk	root	-rw-r--r--	22117
PBS_EXEC/lib/xpbsmon/pbs_preferences.tcl	root	-rw-r--r--	10212
PBS_EXEC/lib/xpbsmon/pbs_prefsave.tk	root	-rw-r--r--	1482
PBS_EXEC/lib/xpbsmon/pbs_spinbox.tk	root	-rw-r--r--	7162
PBS_EXEC/lib/xpbsmon/pbs_system.tk	root	-rw-r--r--	47760
PBS_EXEC/lib/xpbsmon/pbs_wmgr.tk	root	-rw-r--r--	1140
PBS_EXEC/lib/xpbsmon/tclIndex	root	-rw-r--r--	30510
PBS_EXEC/lib/xpbsmon/xpbsmon.src.tk	root	-rwxr-xr-x	13999
PBS_EXEC/lib/xpbsmon/xpbsmonrc	root	-rw-r--r--	3166
PBS_EXEC/man	root	drwxr-xr-x	4096
PBS_EXEC/man/man1	root	drwxr-xr-x	4096
PBS_EXEC/man/man1/nqs2pbs.1B	root	-rw-r--r--	3276
PBS_EXEC/man/man1/pbs.1B	root	-rw-r--r--	5376
PBS_EXEC/man/man1/pbs_rdel.1B	root	-rw-r--r--	2342
PBS_EXEC/man/man1/pbs_rstat.1B	root	-rw-r--r--	2682
PBS_EXEC/man/man1/pbs_rsub.1B	root	-rw-r--r--	9143
PBS_EXEC/man/man1/pbsdsh.1B	root	-rw-r--r--	2978
PBS_EXEC/man/man1/qalter.1B	root	-rw-r--r--	21569
PBS_EXEC/man/man1/qdel.1B	root	-rw-r--r--	3363
PBS_EXEC/man/man1/qhold.1B	root	-rw-r--r--	4323
PBS_EXEC/man/man1/qmove.1B	root	-rw-r--r--	3343
PBS_EXEC/man/man1/qmsg.1B	root	-rw-r--r--	3244
PBS_EXEC/man/man1/qorder.1B	root	-rw-r--r--	3028

Directory / File	Owner	Permission	Average Size
PBS_EXEC/man/man1/qrerun.1B	root	-rw-r--r--	2965
PBS_EXEC/man/man1/qrls.1B	root	-rw-r--r--	3927
PBS_EXEC/man/man1/qselect.1B	root	-rw-r--r--	12690
PBS_EXEC/man/man1/qsig.1B	root	-rw-r--r--	3817
PBS_EXEC/man/man1/qstat.1B	root	-rw-r--r--	15274
PBS_EXEC/man/man1/qsub.1B	root	-rw-r--r--	36435
PBS_EXEC/man/man1/xpbs.1B	root	-rw-r--r--	26956
PBS_EXEC/man/man1/xpbsmon.1B	root	-rw-r--r--	26365
PBS_EXEC/man/man3	root	drwxr-xr-x	4096
PBS_EXEC/man/man3/pbs_alterjob.3B	root	-rw-r--r--	5475
PBS_EXEC/man/man3/pbs_connect.3B	root	-rw-r--r--	3493
PBS_EXEC/man/man3/pbs_default.3B	root	-rw-r--r--	2150
PBS_EXEC/man/man3/pbs_deljob.3B	root	-rw-r--r--	3081
PBS_EXEC/man/man3/pbs_disconnect.3B	root	-rw-r--r--	1985
PBS_EXEC/man/man3/pbs_geterrmsg.3B	root	-rw-r--r--	2473
PBS_EXEC/man/man3/pbs_holdjob.3B	root	-rw-r--r--	3006
PBS_EXEC/man/man3/pbs_manager.3B	root	-rw-r--r--	4337
PBS_EXEC/man/man3/pbs_movejob.3B	root	-rw-r--r--	3220
PBS_EXEC/man/man3/pbs_msgjob.3B	root	-rw-r--r--	2912
PBS_EXEC/man/man3/pbs_orderjob.3B	root	-rw-r--r--	2526
PBS_EXEC/man/man3/pbs_rerunjob.3B	root	-rw-r--r--	2531
PBS_EXEC/man/man3/pbs_rescquery.3B	root	-rw-r--r--	5804
PBS_EXEC/man/man3/pbs_rescreserve.3B	root	-rw-r--r--	4125
PBS_EXEC/man/man3/pbs_rlsjob.3B	root	-rw-r--r--	3043

Directory / File	**Owner**	**Permission**	**Average Size**
PBS_EXEC/man/man3/pbs_runjob.3B	root	-rw-r--r--	3484
PBS_EXEC/man/man3/pbs_selectjob.3B	root	-rw-r--r--	7717
PBS_EXEC/man/man3/pbs_sigjob.3B	root	-rw-r--r--	3108
PBS_EXEC/man/man3/pbs_stagein.3B	root	-rw-r--r--	3198
PBS_EXEC/man/man3/pbs_statjob.3B	root	-rw-r--r--	4618
PBS_EXEC/man/man3/pbs_statnode.3B	root	-rw-r--r--	3925
PBS_EXEC/man/man3/pbs_statque.3B	root	-rw-r--r--	4009
PBS_EXEC/man/man3/pbs_statserver.3B	root	-rw-r--r--	3674
PBS_EXEC/man/man3/pbs_submit.3B	root	-rw-r--r--	6320
PBS_EXEC/man/man3/pbs_submitresv.3B	root	-rw-r--r--	3878
PBS_EXEC/man/man3/pbs_terminate.3B	root	-rw-r--r--	3322
PBS_EXEC/man/man3/rpp.3B	root	-rw-r--r--	6476
PBS_EXEC/man/man3/tm.3B	root	-rw-r--r--	11062
PBS_EXEC/man/man7	root	drwxr-xr-x	4096
PBS_EXEC/man/man7/pbs_job_attributes.7B	root	-rw-r--r--	15920
PBS_EXEC/man/man7/pbs_node_attributes.7B	root	-rw-r--r--	7973
PBS_EXEC/man/man7/pbs_queue_attributes.7B	root	-rw-r--r--	11062
PBS_EXEC/man/man7/pbs_resources_linux.7B	root	-rw-r--r--	8452
PBS_EXEC/man/man7/pbs_resv_attributes.7B	root	-rw-r--r--	11662
PBS_EXEC/man/man7/pbs_server_attributes.7B	root	-rw-r--r--	14327
PBS_EXEC/man/man8	root	drwxr-xr-x	4096
PBS_EXEC/man/man8/pbs_idled.8B	root	-rw-r--r--	2628
PBS_EXEC/man/man8/pbs_mom.8B	root	-rw-r--r--	23496

Directory / File	Owner	Permission	Average Size
PBS_EXEC/man/man8/pbs_mom_globus.8B	root	-rw-r--r--	11054
PBS_EXEC/man/man8/pbs_sched_cc.8B	root	-rw-r--r--	6731
PBS_EXEC/man/man8/pbs_server.8B	root	-rw-r--r--	7914
PBS_EXEC/man/man8/pbsfs.8B	root	-rw-r--r--	3703
PBS_EXEC/man/man8/pbsnodes.8B	root	-rw-r--r--	3441
PBS_EXEC/man/man8/qdisable.8B	root	-rw-r--r--	3104
PBS_EXEC/man/man8/qenable.8B	root	-rw-r--r--	2937
PBS_EXEC/man/man8/qmgr.8B	root	-rw-r--r--	7282
PBS_EXEC/man/man8/qrun.8B	root	-rw-r--r--	2850
PBS_EXEC/man/man8/qstart.8B	root	-rw-r--r--	2966
PBS_EXEC/man/man8/qstop.8B	root	-rw-r--r--	2963
PBS_EXEC/man/man8/qterm.8B	root	-rw-r--r--	4839
PBS_EXEC/sbin	root	drwxr-xr-x	4096
PBS_EXEC/sbin/pbs-report	root	-rwxr-xr-x	68296
PBS_EXEC/sbin/pbs_demux	root	-rwxr-xr-x	38688
PBS_EXEC/sbin/pbs_idled	root	-rwxr-xr-x	99373
PBS_EXEC/sbin/pbs_iff	root	-rwsr-xr-x	133142
PBS_EXEC/sbin/pbs_mom	root	-rwx------	839326
PBS_EXEC/sbin/(pbs_mom.cpuset or pbs_mom.cpuset4)	root	-rwx------	0
PBS_EXEC/sbin/pbs_mom.standard	root	-rwx------	0
PBS_EXEC/sbin/pbs_rcp	root	-rwsr-xr-x	75274
PBS_EXEC/sbin/pbs_sched	root	-rwx------	705478
PBS_EXEC/sbin/pbs_server	root	-rwx------	1133650
PBS_EXEC/sbin/pbsfs	root	-rwxr-xr-x	663707

Directory / File	**Owner**	**Permission**	**Average Size**
PBS_EXEC/tcltk	root	drwxr-xr-x	4096
PBS_EXEC/tcltk/bin	root	drwxr-xr-x	4096
PBS_EXEC/tcltk/bin/tclsh8.3	root	-rw-r--r--	552763
PBS_EXEC/tcltk/bin/wish8.3	root	-rw-r--r--	1262257
PBS_EXEC/tcltk/include	root	drwxr-xr-x	4096
PBS_EXEC/tcltk/include/tcl.h	root	-rw-r--r--	57222
PBS_EXEC/tcltk/include/tclDecls.h	root	-rw-r--r--	123947
PBS_EXEC/tcltk/include/tk.h	root	-rw-r--r--	47420
PBS_EXEC/tcltk/include/tkDecls.h	root	-rw-r--r--	80181
PBS_EXEC/tcltk/lib	root	drwxr-xr-x	4096
PBS_EXEC/tcltk/lib/libtcl8.3.a	root	-rw-r--r--	777558
PBS_EXEC/tcltk/lib/libtclstub8.3.a	root	-rw-r--r--	1832
PBS_EXEC/tcltk/lib/libtk8.3.a	root	-rw-r--r--	1021024
PBS_EXEC/tcltk/lib/libtkstub8.3.a	root	-rw-r--r--	3302
PBS_EXEC/tcltk/lib/tcl8.3	root	drwxr-xr-x	4096
PBS_EXEC/tcltk/lib/tclConfig.sh	root	-rw-r--r--	7076
PBS_EXEC/tcltk/lib/tk8.3	root	drwxr-xr-x	4096
PBS_EXEC/tcltk/lib/tkConfig.sh	root	-rw-r--r--	3822
PBS_EXEC/tcltk/license.terms	root	-rw-r--r--	2233

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