SOFTWARE USER'S GUIDE FOR THE RAD6000 PROCESSOR

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DOCUMENT REVISION HISTORY

Date	Comments
February 17, 1997	First official release.
May 8, 1997	Updated Section 8 with additional information about the Progressive Systems Morning Star product.
July 16, 1997	Added 1553, LIO, AMBI, and SUROM sections for GPS IIF configuration.
August 6, 1998	Added references for VxWorks 5.3 (Tornado) usage

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1 About This Document

This User's Guide describes the system software available for Lockheed Martin's radiation-hardened RAD6000–based processor boards (collectively known as PSA–32), and the software development tools available to write application–level software for those boards. The system software includes Wind River Systems' VxWorks operating system as well as one or more Board Support Packages (BSP), including start–up code, device drivers, and other customizations, targeted for a particular board. The software development system is the AdaMULTI toolset from Green Hills Software.

This document is **not** intended to replace existing manuals describing VxWorks, AdaMULTI, and the POWER processor architecture. Rather, this document can be viewed as a bridge between these documents. It will concentrate on the features of the RAD6000 processor and discuss how an application programmer can take advantage of those features using the available system software and software development tools.

1.1 Who Should Use This Document

This document is intended for programmers who need to develop software for a RAD6000 processor. It is assumed that the reader is familiar with the concepts behind developing real–time embedded software for operating systems such as VxWorks. It is further assumed that the reader is familiar with using UNIX–like operating systems, since the software development tools are hosted on this environment.

1.2 About The RAD6000

PSA–32 is the name given to Lockheed Martin's line of 32–bit space processor subassemblies. These boards are based on Lockheed Martin's RAD6000 32–bit processor. The RAD6000 is a radiation hardened version of IBM's RISC Single–Chip (RSC) processor that was the precursor to the PowerPC line of processors. Lockheed Martin provides several variations of the RAD6000 utilizing different busses and I/O devices to meet the needs of a varied customer base.

1.3 VxWorks Version Differences

This manual was originally written in support of VxWorks version 5.1 and 5.2 and Green Hills tools version 1.8.7. VxWorks version 5.3 (Tornado) and Green Hills version 1.8.8 have since been released. Some of the differences between these versions are worth noting. For instance, SLIP has been replaced with raw serial as the communications backend. In addition, the Tornado directory structure has changed. Where possible this manual has been updated to reflect these version differences. However, should questions arise please refer to the appropriate documentation or Lockheed Martin personnel to fully understand the differences.

1.4 How This Document Is Organized

This document is organized into the following sections:

Section 1. About This Document	Introductory information and overview.
Section 2. An Overview of the Software Development Environment	Describes all of the pieces of software that comprise the software development and run–time environments and how they all fit together.

Section 3. AdaMULTI on Your Host	Installing and using AdaMULTI.
Section 4. VxWorks on Your Host	Installing and using VxWorks.
Section 5. RAD6000 Board Support Packages	Installing and using a board support package (BSP).
Section 6. Pulling It All Together - How to Build for Your Target	How to customize the system software and build it with an application.
Section 7. Communicating over a Serial Port	Connecting and using the RAD6000's serial port to load and debug programs.
Section 8. Using SLIP to Connect a RAD6000 to a Network	Configuring and using SLIP to load and debug programs.
Section 9.4. Error! Not a valid result for table.	Describes features specific to the RAD6000 processor, such as interrupts, I/O, and the real–time clock; and how to use them.
Section 11. Debugging with RISCWatch	Using RISCWatch to perform processor–level debugging.
Appendices	Appendicies are added for board-specific I/O devices (e.g., 1553, QHSS, Plasma)

1.5 Conventions

This document uses the following conventions to differentiate certain elements:

TERM	**EXAMPLE**
Files, paths	"/usr/vw/config/rscvme/Makefile"
Books	*PowerPC VxWorks Development Guide*
Commands, function names	**`tar xv`**
Examples, display output	`CONFIG_ALL = ../all/`
Variables	*`Filename`*
Keyboard key	<RETURN>

1.6 Referenced Documents

The following documents will prove useful to programmers developing software for a RAD6000.

DOCUMENT	**DOCUMENT DESCRIPTION**
POWER Processor Architecture	Reference manual describing the processor architecture of IBM's POWER family, including the RAD6000.
Wind River Products Installation Guide (UNIX Version)	Installation instructions for VxWorks on UNIX platforms.
VxWorks Release Notes	Version information on VxWorks.
VxWorks RAD6000 Release Notes	Version information on VxWorks for RAD6000 targets.

DOCUMENT	DOCUMENT DESCRIPTION
VxWorks Programmer's Guide	Overview and user's guide for VxWorks.
VxWorks Reference Manual	Detailed reference manual of VxWorks system calls and libraries.
Green Hills Installation Guide for UNIX	Installation instructions for Green Hills AdaMULTI toolset.
MULTI Software Development Environment User's Guide	Overview and tutorial of Green Hills AdaMULTI toolset.
MULTI Ada Language User's Guide and Reference Manual	Reference manual for the Ada compiler available for AdaMULTI.
MULTI C Language User's Guide	Reference manual for the C compiler available for AdaMULTI.
MULTI PowerPC VxWorks Development Guide	Reference manual describing developing software for VxWorks on the POWER architecture using Green Hills AdaMULTI.
Morning Star PPP User Guide	User's guide and reference manual for Progressive System's Morning Star PPP software.
RISCWatch User's Manual	User's guide and reference manual for IBM's RISCWatch tool.

2 An Overview of the Software Development Environment

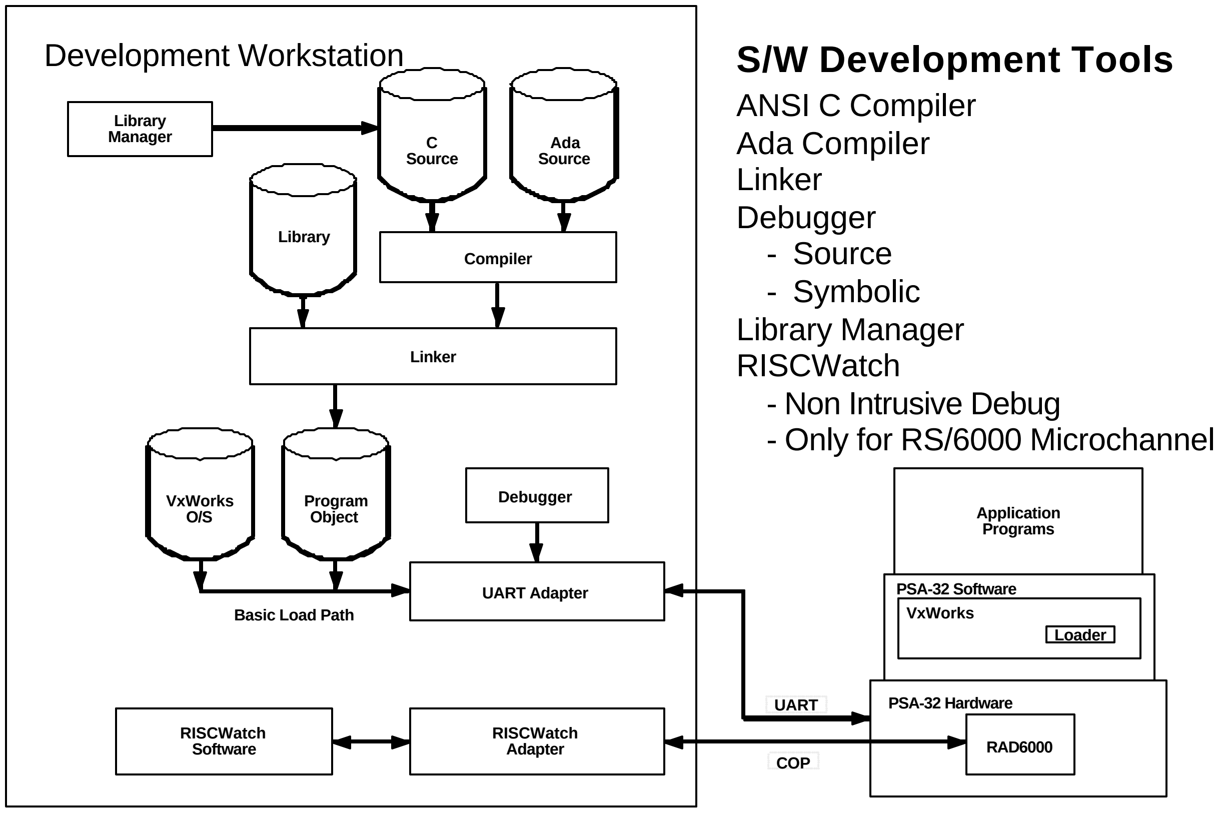


Figure 1 RAD6000 Software Development Environment

The PSA–32 single board computer is a RAD6000–based processor board. The RAD6000 is an IBM RISC Single–Chip (RSC) manufactured to be radiation–hardened. To support embedded software development for a RAD6000, the following products are commercially available: VxWorks by Wind River Systems, Inc. and AdaMULTI by Green Hills Software, Inc.

VxWorks is a user-configurable real-time operating system that supports preemptive priority multitasking, intertask communications, timers, and TCP/IP networking. VxWorks also includes a comprehensive development platform for real–time applications.

AdaMULTI is an integrated development environment including an editor, compilers (Ada, C, Assembler, and others are available), version control system, builder, and debugger. Please note that, despite the name, AdaMULTI is **not** an Ada–only product. Developers may use the AdaMULTI product to develop C language code that contains none of the Ada library code if desired.

These products combine to form an environment providing system services to application programs on the RAD6000 target processor and a productive development interface on a host workstation running a UNIX–like operating system. Several host systems are supported, including IBM RISC System/6000s running AIX and Suns running Solaris. Consult with your Wind River, Green Hills, or Lockheed Martin representative to inquire about currently supported hosts.

3 AdaMULTI on Your Host

AdaMULTI from Green Hills Software, Inc. provides a complete software development environment that fully supports embedded real–time systems. It is available for a variety of host and target platforms and includes an editor, compilers for a variety of languages, source level debugger, profiler, source code and version controllers, and a multi–language program builder that are fully integrated in a window–based system. Note that, despite the name, AdaMULTI may be used for developing either Ada or C language applications.

The AdaMULTI product is shipped as a tape or CD containing the software and the following set of manuals:

Installation Guide
MULTI Software Development Environment User's Guide
Ada Language User's Guide and Reference Manual
C Language User's Guide
C++ Language User's Guide
Embedded PowerPC Development Guide

If you are interested in getting an overview of the tools provided with AdaMULTI, the best place to start is the *MULTI Software Development Environment User's Guide*. However, as it is written as a tutorial to using the toolset, it may be best to wait until the product has been installed before getting into it in too much detail.

The installation instructions are, obviously, in the *Installation Guide*. This manual contains installation instructions for several different types of setups. The one you are interested in is "Installation for VxWorks Products". We'll talk about this more in *Section 3.1 Installing AdaMULTI.*

The *Embedded PowerPC Development Guide* has a lot of good information for programmers developing embedded software for VxWorks running on a PowerPC platform which applies to the RAD6000. The two language guides provide information on Green Hills' implementation of C and Ada.

The remainder of this section is an overview of the information found in these documents as they pertain to developing software for VxWorks on a RAD6000. However, the intent is not to replace those documents and, in the case of conflicts, the Green Hills' documentation is probably correct.

3.1 Installing AdaMULTI

As mentioned above, the *Installation Guide* that ships with AdaMULTI contains a chapter called *Installation for VxWorks Products* that provides very detailed instructions. This section tailors those instructions for installation on both AIX and Solaris hosts. Other minor changes may be necessary for other hosts and/or for your environment. Of course, Green Hills may change the installation method for future releases. We recommend that you compare the information in this section with the information provided with AdaMULTI to determine what needs to be done to install the product in your environment.

Note that if you are going to be using the floating license manager, make sure to perform these instructions while logged on to the host which is to run the license manager daemon. Also, the user performing the installation must have write access to the directory under which the program is to be installed. However, it is best if the software is **not** installed by the root user, since this may require significant changes to the file permissions after the installation has completed in order for other users to access the software.

1. The first step is to create a directory for the AdaMULTI product which is accessible by everyone on the development team. The AdaMULTI documentation suggests creating that directory under the "/usr" directory. Here at Lockheed Martin Manassas, we use a directory named "/proj". If you are unsure where to create the AdaMULTI directory, discuss it with your system administrator. We definitely recommend that the software **not** be installed in a subdirectory of a user's home directory.

   Once you've decided where to install the software, you need to decide on the name for the directory. We recommend "green" as that is what the AdaMULTI documentation uses. This is done with the following commands:

   ```
   cd /usr
   mkdir green
   cd green
   ```

2. Once a shared AdaMULTI directory has been created, the product tape or CD can be installed into it. This is done using the `tar` command. Usually the tape drive attached to your workstation has been designated the default device for tar. If this is the case, you need only enter the following, **after** inserting the AdaMULTI product tape into the tape drive:

   ```
   tar xv
   ```

   If, however, the tape drive you wish to use is not the default device, you will need to enter the device name as part of the tar command. For example, if the tape drive you wish to use is installed as "/dev/rmt1", use this command instead:

   ```
   tar xvf /dev/rmt1
   ```

   If you are unsure which of the above to use, try the first one first. If this doesn't work and you don't know the device name for your tape drive, contact your local system administrator for assistance.

3. After loading the contents of the tape, you will need to run the AdaMULTI install script. Please read the installation instructions in the AdaMULTI documentation closely at this point, as there are a number of possible scenarios for exactly how to continue. For example, you may have to run the `update` program before running the install script. If so, you will have to contact Green Hills at the phone number or address listed in the *Installation Guide* and provide them with some information about your system in order to get a software key needed to use AdaMULTI on your system. If you are unsure how to continue at this point, please contact Green Hills for more information.

   For the purposes of this document, we'll describe how to continue once you reach the point of running the install script. If you have problems performing this step, contact Green Hills as mentioned before. To run the install script, merely enter:

   ```
   install.sh
   ```

   The install script will ask you for the name of the directory in which the product is to be installed:

   ```
   Enter an absolute pathname for the current directory or press return to use
   /usr/green:
   ```

Assuming the default ("/usr/green") is correct, you should merely press `<RETURN>`. However, if you chose to install the software in another directory, enter that directory name and press `<RETURN>`.

You will next be shown a list of product executables that have been placed in the installation directory. After this you will be asked whether you wish the executables to be copied to "/usr/bin":

```
Press <return> to copy files to /usr/bin, or ’n’ to skip:
```

Copying the files to "/usr/bin" has the advantage that user's will be able to access them without having to change their PATH. However, it has the disadvantage of polluting the directory, which makes it more difficult to uninstall the product if this becomes necessary. At Lockheed Martin, we recommend entering 'n' at this prompt so that the files are not copied.

The installation of AdaMULTI is now complete. If you have trouble, please call Green Hills.

3.2 AdaMULTI and Your Environment

You now need to make the AdaMULTI tools available by setting some environment variables. For simplicities sake, these can be placed in a shell script to which all of the software developers have access, and that shell script can be called from each user's ".profile", ".kshrc", or ".cshrc" file.

If you are using the Korn Shell (ksh), use the following commands:

```
export ADABASE=/usr/green/vxrsc
export PATH=$PATH:/usr/green:/usr/green/adabin
```

If you are using the C Shell (csh), use the following commands:

```
setenv ADABASE /usr/green/vxrsc
setenv PATH ${PATH}:/usr/green:/usr/green/adabin
```

Note that if these commands are entered directly at the shell, instead of being run from the ".cshrc" file, you may also need to use the following command:

```
rehash
```

If you are using a shell other than ksh or csh, refer to the documentation for your shell to determine the proper syntax for setting these environment variables.

The above examples assume that AdaMULTI was installed in the "/usr/green" directory, as in the examples in Section 3.1. If a different directory was used, use the correct name.

3.3 Using AdaMULTI

The AdaMULTI toolset may be used either from the Builder, which provides a GUI, or from the UNIX command line. If you have never used MULTI before, we highly recommend you try the tutorial contained in the *MULTI Software Development Environment User's Guide*.

3.3.1 Compiling C Programs

The C compiler can be invoked from the command line with the following command:

```
ccppc -cpu=rsc -nosda -nostdinc -ansi filename  (GHS version 1.8.7)

ccvxppc -cpu=rsc -nosda -nostdinc -ansi filename (GHS version 1.8.8)
```

In addition, programs that need to use floating point zero-divide checking should add the following flag:

```
-check=zerodivide
```

Refer to the Green Hills documentation for a complete description of the available flags.

3.3.2 Compiling and Linking Ada Programs with GHS Version 1.8.7

Before compiling your first Ada program for a given project, you must create an Ada library for that project. This is done with the following command, which will create the Ada library in the current directory:

```
newlib
```

After the Ada library has been created, you can compile an Ada file using the following command:

```
ada filename
```

The compiler will place the compiled code in the Ada library. When you are ready to build an executable program using an Ada main procedure, you can use the following command:

```
bamp proc
```

where *proc* is the name of the Ada main procedure. Refer to the Green Hills documentation for more information on all of these commands.

3.3.3 Compiling and Linking Ada Programs with GHS Version 1.8.8

The VxWorks cross compiler for GHS version 1.8.8 and Ada95 is **acvxppc**, the **newlib** command is not needed for version 1.8.8.

```
acvxppc –cpu=rsc filename
```

The Ada linker is called **alxvxppc**.

```
alxvppc proc
```

where *proc* is the name of the Ada main procedure. Refer to the Green Hills documentation for more information on all of these commands.

3.3.4 Assembling RAD6000 Assembly Programs

Assembler modules are pre-processed and then compiled using the following commands:

3.3.4.1 GHS Version 1.8.7

```
cpp filename > tmp.s

ccppc –o filename.o tmp.s
```

3.3.4.2 GHS Version 1.8.8

```
cppppc filename > tmp.s for (GHS version 1.8.8)

ccvxppc –o filename.o tmp.s
```

Refer to the Green Hills documentation for more information on the options available for these commands.

4 VxWorks on Your Host

VxWorks is a popular, mature real–time operating system available from Wind River Systems, Inc. It is available for a variety of target platforms, including the RAD6000. Although the VxWorks product comes with a few tools to help programmers build their target application, it is, strictly speaking, not a tool itself but an operating system.

The VxWorks product comes with one or two tapes or CD containing the software and the following set of manuals:

Wind River Products Installation Guide
VxWorks Programmer's Guide
VxWorks Reference Manual
VxWorks Release Notes
*Tornado User's Guide**
*Tornado API Guide**
*Tornado Release Notes**
** - forVxWorks version 5.3 or later*

You may also receive manuals relating to the GNU toolkit. Lockheed Martin does not support GNU for the RAD6000, so these manuals are not necessary.

If the software is delivered on only one tape, it should contain just the operating system and host tools. If two tapes are delivered, one should contain the operating system and host tools, and the other should contain the BSP for the VME–based RAD6000. Note that other BSPs, such as the ASCM Module Bus, are available from Lockheed Martin and not from Wind River Systems. If you are using one of these BSPs, you do not need to install the VME–based BSP. See *Section 5 RAD6000 Board Support Packages* for information on installing Lockheed Martin–provided Board Support Packages.

The *VxWorks Programmer's Guide* is an excellent document for getting started. It contains an overview of the VxWorks product and a very detailed chapter on installation. It is highly recommended that you read that now, especially if you are unfamiliar with VxWorks and / or real–time operating systems in general.

The *VxWorks Reference Manual* contains descriptions of all of the VxWorks libraries and system calls. It is invaluable during application program development, but not of interest now.

The *Tornado User's Guide* is the central documentation for the Tornado development environment. It includes a global overview of Tornado, instructions on how to configure your environment and set up communications with a target system, a chapter on each of the interactive Tornado tools and appendices on the use of Tcl, the Tool Command Language and Tornado directories and files.

The *Tornado API Guide* is a detailed reference fro developers who wish to extend the Tornado development environment. It discusses the Tornado architecture from the perspective of software APIs and protocols, and describes how to extend and modify the Tornado tools and how to integrate them with your own software.

Much of the remaining information in this section has been culled from the *Wind River Products Installation Guide* and the VxWorks *Programmer's Guide*, but the intent is not to replace that document. Rather, this section concentrates on those sections that are most applicable to using VxWorks for the RAD6000.

However, the documentation that ships with VxWorks should be considered the most up–to–date and, in the case of conflicts, is probably correct.

4.1 Installing VxWorks[1]

This section provides an overview of the installation process tailored for the version of VxWorks targeted for the RAD6000 and hosted on either an IBM RISC System/6000 AIX or Sun Solaris workstation. The instructions may be slightly different for other hosts, and, of course, Wind River Systems may change the method used to install VxWorks in future releases. We recommend that you compare the information in this section with the information provided with VxWorks to determine what needs to be done to install VxWorks in your environment.

1. The first step is to create a directory for the VxWorks product that is accessible by everyone on the development team. Here at Lockheed Martin Manassas we have a high–level directory named "/proj" that is accessible from all workstations on our internal network. If you have a similar setup that would be an ideal place to create the VxWorks directory. If not, you should talk to your system administrator about where the software should be installed. We definitely recommend that the software **not** be installed in a subdirectory of a user's home directory.

   Once you've decided where to install the software, you need to decide on the name for the directory. The VxWorks Programmer's Guide recommends using the name "vw". Here at Lockheed Martin, we use the name "vxworks". It doesn't matter much, so long as the name is unique. In this section, we will use the VxWorks naming convention to keep things simple.

   Now that you've decided where to install the software and what to call the directory, you can actually create it. This is done with the following commands:

   ```
   cd /usr
   mkdir vw
   cd vw
   ```

2. Once a shared VxWorks directory has been created, the product tape can be installed into it. This is done using the **tar** command. Usually the tape drive attached to your workstation has been designated the default device for tar. If this is the case, you need only enter the following, **after** inserting the VxWorks product tape (not the tape containing the Board Support Package) into the tape drive:

   ```
   tar xv
   ```

   If, however, the tape drive you wish to use is not the default device, you will need to enter the device name as part of the tar command. For example, if the tape drive you wish to use is installed as "/dev/rmt1", use this command instead:

   ```
   tar xvf /dev/rmt1
   ```

   If you are unsure which of the above to use, try the first one first. If this doesn't work and you don't know the device name for your tape drive, contact your local system administrator for assistance.

[1] This is a tailored installation process for VxWorks versions 5.2 and earlier. If you are installing version 5.3 and later, please refer to the Wind River Products Installation Guide for Tornado.

3. If there is a separate tape for the RAD6000 Board Support Package, it should be installed after the VxWorks product tape. Insert the BSP tape into the tape drive now (while still in the "/usr/vw" directory) and enter the following command:

   ```
   bin/host/installOption
   ```

   where *host* is **rs6000** if you are installing on an IBM RISC/System 6000 workstation, or **solaris** if you are installing on a Sun Solaris workstation.

   Note that if the tape drive is not the default drive you must tell the program which device to use. For example, if the tape drive is "/dev/rmt1", use this command instead:

   ```
   bin/host/installOption -f /dev/rmt1
   ```

4. The final step of the installation process is to create a symbolic link to allow the Green Hills compilers access to the VxWorks header files. This is done with the following commands:

   ```
   cd /usr/green/vxworks
   ln -s /usr/vw/h usrinc
   ```

   Obviously if the directory names you used when installing the products differ from the above, you must use the correct names.

That's all there is to the installation of VxWorks and the RAD6000 Board Support Package.

4.2 VxWorks Directory Structure

After installing VxWorks on your host, you will have available the libraries and header files documented in the *VxWorks Reference Manual*, as well as some tools used to build VxWorks and your application programs. The directory structure is as follows:

./bin	Contains one or more subdirectories, each of which contains the executable VxWorks software development tools for a particular host. For example, if you have VxWorks hosted on an IBM RISC System/6000, there should be a directory named "./bin/rs6000".
./config/all	Contains target–independent system configuration modules for VxWorks.
./config/rscvme	Contains VxWorks system configuration modules used solely for the VME–based RAD6000.
./h	Contains the VxWorks header files.
./lib	Contains the VxWorks machine–independent object libraries.
./man	Contains VxWorks documentation in UNIX man page format.
./src	Contains VxWorks source files. Any source files that are expected to be modified by the application software developer, such as configuration files and device drivers are always shipped. Other source files will be here only if a source license was purchased from Wind River Systems, Inc.

For more information on these directories and their contents, refer to the *VxWorks Programmer's Guide*.

4.3 VxWorks and Your Environment

You will need to set up several environment variables in order to build VxWorks images and develop application software for VxWorks. For simplicities sake, these can be placed in a shell script to which all of the software developers have access, and that shell script can be called from each user's ". profile", ".kshrc", or ".cshrc" file.

If you are using the Korn Shell (ksh), use the following commands for **VxWorks versions 5.2 and earlier**:

```
export VX_VW_BASE=VxWorks-base-directory
export VX_HSP_BASE=$VX_VW_BASE
export VX_BSP_BASE=$VX_VW_BASE
export VX_HOST_TYPE=host
export PATH=$PATH:$VX_VW_BASE/bin/$VX_HOST_TYPE
export MANPATH=$MANPATH:$VX_VW_BASE/man
```

In the above example, `VxWorks-base-directory` should be the name of the directory created to hold VxWorks during the installation process, e.g. "/usr/vw". `host` should be the name used to identify your host workstation: `rs6000` if your software is hosted on an IBM RISC/System 6000 AIX workstation, or `solaris` if your software is hosted on a Sun Solaris workstation. If you are unsure of what `host` should be, refer to the *VxWorks Programmer's Guide* that lists all the valid values.

If you are using the Korn Shell (ksh), use the following commands for **VxWorks versions 5.3 and later**:

```
export WIND_BASE=installation directory for Tornado (e.g. "/usr/torn")
export WIND_HOST_TYPE=name of host type (e.g. "sun4-solaris2")
export WIND_REGISTRY=name of host where regsitry is running
export PATH=$PATH:$WIND_BASE/host/$WIND_HOST_TYPE/bin
export LM_LICENSE_FILE= path to license-key repository file (e.g.
"/usr/torn/.wind/license)
export MANPATH=$MANPATH:$WIND_BASE/host/man:$WIND_BASE/target/man
```

If you are using the C Shell (csh), use the following commands for **VxWorks versions 5.2 and earlier:**

```
setenv VX_VW_BASE VxWorks-base-directory
setenv VX_HSP_BASE ${VX_VW_BASE}
setenv VX_BSP_BASE ${VX_VW_BASE}
setenv VX_HOST_TYPE host
setenv PATH ${PATH}:${VX_VW_BASE}/bin/${VX_HOST_TYPE}
setenv MANPATH ${MANPATH}:${VX_VW_BASE}/man
```

If you are using the Korn Shell (ksh), use the following commands for **VxWorks versions 5.3 and later**:

```
setenv WIND_BASE installation directory for Tornado (e.g. "/usr/torn")
setenv WIND_HOST_TYPE name of host type (e.g. "sun4-solaris2")
setenv WIND_REGISTRY name of host where registry is running
setenv PATH $PATH:$WIND_BASE/host/$WIND_HOST_TYPE/bin
setenv LM_LICENSE_FILE  path to license-key repository file (e.g.
"/usr/torn/.wind/license)
setenv MANPATH $MANPATH:$WIND_BASE/host/man:$WIND_BASE/target/man
```

Note that if these commands are entered directly at the shell, instead of being run from the .cshrc file, you may also need to use the following command:

```
rehash
```

If you are using a shell other than ksh or csh, refer to the documentation for your shell to determine the proper syntax for setting these environment variables.

After finishing the installation process and setting up the environment variables, you are now ready to begin developing software for use with VxWorks.

4.4 Setting up the Tornado Registry

Before anyone at your site can use Tornado, someone must set up the *Tornado Registry*, a daemon that keeps track of all available targets by name. Only one registry is required on your network, and it can run on any networked host. The registry daemon must always run; otherwise Tornado tools cannot locate targets. Thus, it is best to add commands to start up the daemon in a system start-up file.

To start the daemon from a command line, execute **wtxregd** in the background. For example, on a Sun host running Solaris OS:

% /usr/torn/host/sun4-solaris2/bin/wtxregd –V > /tmp/wtxregd.log &

The Tornado tools locate the registry daemon through the environment variable **WIND_REGISTRY**. If this variable is not set at all, the tools will look for the registry daemon on the local host.

5 RAD6000 Board Support Packages

A Board Support Package (BSP) contains system configuration modules and services that tailor VxWorks for a particular board. It includes start–up routines, interrupt handlers, device drivers, and other machine–dependent modules.

Wind River Systems, Inc. provides the BSP for Lockheed Martin's RSCVME board with VxWorks. The RSCVME is a RAD6000 with a VMEbus interface. BSPs for other variations of the RAD6000 family, such as the ASCM Module Bus, are available from Lockheed Martin.

If you are using a RSCVME, your BSP should already have been installed when you installed VxWorks and you can ignore this section. See *Section 4 VxWorks on Your Host* for more information.

This section will discuss how to install and set up BSPs received from Lockheed Martin.

5.1 Installing a Board Support Package

Lockheed Martin always ships formal deliveries of a Board Support Package on magnetic media. However, under some circumstances an informal delivery of a BSP may be made if acceptable to both Lockheed Martin and the receiving customer. Informal deliveries may be made via electronic mail or file transfer protocol (ftp) if the receiving customer has access to the Internet and is willing to accept delivery in this fashion.

You will need to perform these steps on a machine that has access to the directory in which you installed VxWorks. The installation script used to install the BSP will use the environment variables defined during the installation of VxWorks to determine where to install the software. So you must have these variables defined before proceeding.

5.1.1 Preparing to Install a BSP from Diskette or Tape

The first step is to load the installation script on your machine. The installation script, along with a file containing the BSP, is delivered in tar format. They should be placed in either a user directory or a temp directory. They should **not** be placed in the VxWorks installation directory.

1. Change to the directory where you want to place the installation script and then load the tape or diskette in the appropriate drive. After this has been done, you can use the following command to unload the tape (assuming the device being used is the default device):

   ```
   tar xv
   ```

   If the device being used is not the default device, you will need to enter the device name as part of the tar command. For example, if the tape drive you wish to use is installed as "/dev/rmt1", use this command instead:

   ```
   tar xvf /dev/rmt1
   ```

   If you are unsure which of the above to use, try the first one first. If this doesn't work and you don't know the device name for your tape drive, contact your local system administrator for assistance.

Now skip to *Section* ***Error! Reference source not found. Error! Reference source not found.***, to finish the installation.

5.1.2 Preparing to Install a BSP from an Internet Delivery

Internet deliveries are made via e–mail or anonymous ftp from an Internet–connected Lockheed Martin site. An e–mail delivery will arrive in the form of a uuencoded, compressed, tar file. An ftp delivery will arrive in the form of a compressed tar file. The file name and IP address of the ftp site will be provided by your Lockheed Martin representative when a delivery is available.

Once you have received the file, the first step in the installation process is to load the installation script on your machine. Place the delivered file in either a user directory or a temp directory. It should **not** be placed in the VxWorks installation directory.

1. If you received the BSP by anonymous ftp, skip this step. It applies only to e–mail deliveries.

   Name the received file "bsp.uue" and then use the following command to decode it:

   `uudecode bsp.uue`

   This will create a file called "bsp.i.*date*.tar.Z", where *date* is the date the BSP was built.

2. From the directory containing the file "bsp.i.*date*.tar.Z", enter the following:

   uncompress bsp.i.*date*.tar.Z

   This will create a file called "bsp.i.*date*.tar".

3. Now use the following commands to install the BSP to a shared directory:

   tar –xvf bsp.i.*date*.tar

Your BSP is now installed under the "config/*xxxxxx*" directory of your VxWorks installation directory, where '*xxxxxx*' is your project name. If you have problems, please contact your Lockheed Martin representative.

6 Pulling It All Together - How to Build for Your Target

The VxWorks operating system allows application programs to be either linked with VxWorks or linked as separate load modules. By taking advantage of VxWorks capabilities such as networking and the interactive shell, separately linked application programs can be loaded dynamically on a target board by VxWorks. Since this feature is invaluable during development and debug, we recommend that during these stages application programs should **not** be linked with VxWorks. Eventually, however, you will probably want to link them together to create a stand–alone, bootable application.

The *VxWorks Programmer's Guide* contains a chapter called "Configuration" which discusses building VxWorks both separate from, and linked with, an application program. This section will look at some of the issues raised in that chapter as they relate to building for a RAD6000 board.

6.1 Creating a Build Directory

The first thing you should consider doing is creating a build directory that is separate from the VxWorks installation directory. This is especially useful if multiple projects will be sharing one VxWorks installation or if a single project wants to test various VxWorks configurations. Another reason to create a build directory is to keep the original VxWorks installation intact in case problems due to configuration changes develop.

If you decide to create a build directory, you will need to decide where to place it. If the build directory will be used by several developers, it should be placed in a common location where all can access it. If it will only be used by one developer, that user's home directory is good. Keep in mind that you want it in a place where everyone who needs it has access to it, but that you don't want a situation where a developer inadvertently causes problems for others due to configuration changes.

Once you have decided where to place it, change to that directory and copy everything under $WIND($VX_VW)_BASE/target/config. A simple way to do this is:

```
cp -r $WIND($VX_VW)_BASE/config .
```

Now change to the BSP directory under the "config" directory (probably "rscvme" or "psa32") and use your favorite editor to edit the file "Makefile(.RSCgreen)". Change the line that sets the CONFIG_ALL variable to the following:

```
CONFIG_ALL = ../all/
```

Once that has been done, you need to verify that the file "Makefile" has the correct definitions for the target CPU and the development toolset. Edit the file using your favorite editor and ensure the following variables exist and are set to the proper values:

```
CPU  = RSC
TOOL = green
```

6.2 Including Only the Capabilities You Need

You should consult the *VxWorks Programmer's Guide* for a discussion of VxWorks components and their uses. This section will highlight some common configurations already tried on the RAD6000.

One of the first big decisions you need to make is whether to include networking and/or the interactive shell. The networking component, in conjunction with SLIP (Serial Line/Interface Protocol) or an Ethernet driver, allows the target RAD6000 to be connected to a local area network (LAN). This permits the target board to be used remotely and also allows applications to be downloaded dynamically. If networking is not included, application programs must be linked with VxWorks before downloading.

The interactive shell provides a command line for interacting with VxWorks. This also aids in dynamically downloading programs and fixes, and provides many interactive debugging features.

Other components you should consider using during program development include symbolic debug information and the remote debugger, both of which are necessary to take advantage of AdaMULTI's source level remote debugger.

Lockheed Martin highly recommends using both networking and the interactive shell during program development, assuming your RAD6000 has enough memory to include these components. VxWorks image sizes built to date have varied from an 800 KB image which included a SLIP network connection, interactive shell, remote debugger, symbolic debug information, Ada Runtime Environment, and the VxWorks kernel; to a 250 KB image which included only the Ada Runtime Environment and the VxWorks kernel. See **Table 1** for the approximate sizes of various VxWorks components.

Component	**Approximate Size (KB)**
VxWorks Kernel	100
Ada Runtime Environment	150
SLIP	135
Interactive Shell	145
Symbolic Debug Information	50
Remote Debugger	200

Table 1 Memory Requirements of VxWorks Components

6.2.1 Including and Excluding VxWorks Components

Now that you've given some thought to which components you want to use, and which you don't, we will look at how to configure your VxWorks build. In the "all" subdirectory of your build directory, there is a file named "configAll.h". This file determines which components will be included when VxWorks is built. Note that the Ada Runtime Environment, since it is actually part of the Green Hills Ada Compiler rather than a VxWorks component, is not handled in "configAll.h". See Section 6.2.2 for information on linking the Ada Runtime Environment with VxWorks.

An outline of "configAll.h" is shown in **Figure 2**. The only two sections that matter here are under the banners "INCLUDED SOFTWARE FACILITIES" and "EXCLUDED SOFTWARE FACILITIES". Under each of these sections is a collection of macro definitions that determine which components are included and which are excluded. The macro names are somewhat descriptive and each contains a short comment. You can configure your VxWorks build by simply moving the macro definitions between the two sections.

```
/* configAll.h - default configuration header */

/* Copyright 1984-1993 Wind River Systems, Inc. */

/*
modification history
--------------------

          List of File Modifications

*/

/*
DESCRIPTION
This header contains the parameters that define the default
configuration for VxWorks.
*/

#ifndef INCconfigAllh
#define INCconfigAllh

          Include Header Files

/************************************************************************/
/*                                                                      */
/*                   INCLUDED SOFTWARE FACILITIES                       */
/*                                                                      */
/************************************************************************/

          Defines of Components to Include
          This section should be customized for your build.

/* CPU-SPECIFIC INCLUDED SOFTWARE FACILITIES */

          There should be no need to change this section.


/************************************************************************/
/*                                                                      */
/*                   EXCLUDED SOFTWARE FACILITIES                       */
/*                                                                      */
/************************************************************************/
#if FALSE

          Defines of Components to Exclude
          This section should be customized for your build.

#endif  /* FALSE */

/************************************************************************/
```

```
/*                                                                      */
/*                 KERNEL SOFTWARE CONFIGURATION                        */
/*                                                                      */
/************************************************************************/

          Nothing below this point should be configured.

#endif  /* INCconfigAllh */
```

Figure 2 Outline of file “configAll.h”

6.2.2 The Ada Runtime Environment

Ada programs require the use of an Ada Runtime Environment. AdaMULTI allows software developers to choose one of two methods for providing the services of the Ada Runtime Environment to their application programs. The first method is to link those services that are used by a given Ada program directly with that program. The second method is to link the Ada Runtime Environment with the VxWorks operating system so that each Ada program need not contain its own copy of these services.

There is a tradeoff in deciding which of these methods is best for you. Linking the services with your application programs saves memory space if your system comprises only one or a few Ada programs each using only a few of the Ada Runtime Environment services. However, if there are many Ada programs or just a few Ada programs each requiring many runtime services, linking the Ada Runtime Environment with VxWorks will reduce memory requirements. You will need to decide for yourself which is the best option and then perform the instructions in one of the next two sections.

6.2.2.1 Linking the Ada Runtime Environment with VxWorks

To build the Ada Runtime Environment into VxWorks, you need to add the Green Hills Ada libraries to the list of object files to be linked with VxWorks. To do this, use your favorite editor to edit the file “Makefile.RSCgreen” in your build directory. Find the lines that set the LIBS variable and add the following five lines:

```
$(ADABASE)/adalib/libs.o        \
$(ADABASE)/adalib/lowrt_wr.a    \
$(ADABASE)/adalib/lowtask_wr.a  \
$(ADABASE)/adalib/predef_wr.a   \
$(ADABASE)/adalib/util_wr.a
```

Make sure that all lines except for the last one end with a line continuation character (” \ ”). Once you have done this, save the file and exit the editor.

Now go to the Ada library under the ADABASE directory and copy the following files:

```
cd $ADABASE/adalib
cp lowrt_blank.a lowrt.a
cp lowtask_blank.a lowtask.a
cp predef_blank.a predef.a
cp util_blank.a util.a
```

Finally, edit the file named "ada" using your favorite editor. Search the file for two lines that look something like this:

```
#.o.:$wrld $ldflags -sde -o $final.o -r $(lib)btmain.o $objects
$linkobjects $tasklib $adaar $endargs

.o.:$wrld $ldflags -sde -o $final.o -r -e tmain $(lib)btmain.o
$(lib)amain.o $(lib)bamain.o $objects $linkobjects
```

If there is a comment character ("#") in front of the first line and not in front of the second line (as shown above), you don't need to modify the file. If not, comment out the first of the two lines and make sure the other is not commented out.

Once all of this is done, you can rebuild VxWorks and it will contain the Ada Runtime Environment.

6.2.2.2 Linking the Ada Runtime Environment with Your Application Programs

To build the required services of the Ada Runtime Environment into each Ada application program, you need to edit the file "Makefile.RSCgreen" in your build directory using your favorite editor. Find the lines that set the LIBS variable and remove the following five lines, if they exist:

```
$(ADABASE)/adalib/libs.o        \
$(ADABASE)/adalib/lowrt_wr.a    \
$(ADABASE)/adalib/lowtask_wr.a  \
$(ADABASE)/adalib/predef_wr.a   \
$(ADABASE)/adalib/util_wr.a
```

Those lines can be physically deleted, or just commented out by placing a "#" at the beginning of each line. Make sure, however, that the last non–comment line of the statement does **not** end with a line continuation character (" \ ").

Now go to the Ada library under the ADABASE directory and copy the following files:

```
cd $ADABASE/adalib
cp lowrt_wr.a lowrt.a
cp lowtask_wr.a lowtask.a
cp predef_wr.a predef.a
cp util_wr.a util.a
```

Finally, edit the file named "ada" using your favorite editor. Search the file for two lines that look something like this:

```
.o.:$wrld $ldflags -sde -o $final.o -r $(lib)btmain.o $objects $linkobjects
$tasklib $adaar $endargs

#.o.:$wrld $ldflags -sde -o $final.o -r -e tmain $(lib)btmain.o
$(lib)amain.o $(lib)bamain.o $objects $linkobjects
```

If there is a comment character ("#") in front of the second line and not in front of the first line (as shown above), you don't need to modify the file. If not, comment out the latter of the two lines and make sure the other is not commented out.

Once all of this is done, you can rebuild VxWorks so that it does not contain the Ada Runtime Environment. After this, whenever you build your application programs, they will include those runtime services that they need.

6.3 Linking Your Application Program with VxWorks

If you are building VxWorks without the networking facilities, you will need to link your application program with VxWorks — otherwise you will have no way of loading the program onto the target board once VxWorks is loaded. Also, eventually you will probably want to link your application with VxWorks whether or not you plan on using the networking facilities in your operational system.

Two steps are required to do this. First, you need to edit the file “Makefile.RSCgreen” in the BSP subdirectory of your build directory to add the names of the object file(s) that comprise your program. Second, you need to create a dummy reference to the first function of your program to gain control. This is necessary because the linker will remove object files that contain only unreferenced symbols.

As an example, let’s assume you have a C language function named “user_proc” contained in a source file named “user.c” that you want to link with the VxWorks image. Compiling this source file will create an object file named “user.o” which needs to be added to the makefile, ”Makefile.RSCgreen”, in your build directory. To do this, use your favorite editor to edit that file and set the MACH_LIBS variable as follows:

```
MACH_LIBS = user.o
```

Next edit the file “userLink.c” and add the following lines:

```
/* User functions */
void User_Fns (void) {
  user_proc();
}
```

This last reference creates the dummy reference to your function, as mentioned above. Although the function, “User_Fns”, is never called by another function, because it is in an object file that will be linked when VxWorks is built, it fools the linker into thinking that your function, “user_proc”, is being called. Therefore the linker will include your object file as desired.

As another example, let’s add an Ada language procedure named “ada_main” contained in a source file named “user.ada” to the VxWorks image. Again, use your favorite editor to edit “Makefile.RSCgreen” and set the MACH_LIBS variable as follows:

```
MACH_LIBS = user.o
```

Then edit the file “userLink.c” and add the following lines:

```
/* User functions */
void User_Fns (void) {
  ada_main();
}
```

Once your program is linked with VxWorks, they can be invoked from the shell command line. For more information, see the *VxWorks Programmer’s Guide*.

6.4 Configuring Communications Options for Pre-Tornado (VxWorks Version 5.2 and Earlier)

Now, let's discuss the options for communicating with your target board. Lockheed Martin provides some preset VxWorks configurations: one for an interactive shell via the UART, one for SLIP connection via the UART, and one for TCP/IP over an ethernet device. To use the shell, go to the "all" directory under your build directory and copy "configAll.shell" to "configAll.h":

```
cp configAll.shell configAll.h
```

You must then rebuild VxWorks. The shell will become active when VxWorks is started on the target computer. The local debugger and symbol information will still be available. When building without network capability you must link user programs with VxWorks.

To use a SLIP connection requires more setup than the shell. First get the proper "configAll.h" by copying "configAll.slip":

```
cp configAll.slip configAll.h
```

Next, edit the file "config.h" to inform VxWorks of the IP address and name of the target computer and the host computer.

```
#define DEFAULT_BOOT_LINE \
   "sl(0,0)HOST:SYMBOLFILE h=HOSTADDR e=TARGETADDR u=USER tn=TARGET"
```

Where ***HOST*** is the IP name of the host computer, ***SYMBOLFILE*** is the name of the symbol file to use when loading via network (e.g., "/u/***USER***/vxWorks.sym" — but this parameter is unused on the RAD6000), ***HOSTADDR*** is the dotted decimal IP address of the host computer (e.g., 90.0.0.1), ***TARGETADDR*** is the dotted decimal IP address of the target computer (e.g., 90.0.0.2), ***USER*** is a username accessible on the host computer, and ***TARGET*** is the IP name of the target computer.

The DEFAULT_BOOT_LINE must match the configuration found on the host machine. In particular, the host and target computers must agree on the IP names and addresses. The host may have a different IP address for the SLIP connection than it does for its normal network connection (maybe Ethernet), but whatever name and address it believes itself to be on the SLIP port, the target must be informed. See Section 8 for more information on configuring SLIP on the host workstation.

In addition to setting the communications configuration in DEFAULT_BOOT_LINE, you will probably also want to configure VxWorks to initialize the network connection during startup. To do this, edit the file "usrConfig.c" and define the variable INCLUDE_NET_INIT immediately prior to the line testing for its existence:

```
#define INCLUDE_NET_INIT
#ifdef  INCLUDE_NET_INIT
```

Those who have a VME–based RAD6000 target computer have an additional option, VME–based Ethernet. The setup for the Ethernet is very similar to the SLIP setup. For this option, use the "configAll.enp" file:

```
cp configAll.enp configAll.h
```

In addition, the DEFAULT_BOOT_LINE must be set for Ethernet in the file "config.h":

```
#define DEFAULT_BOOT_LINE \
   "enp(0,0)HOST:SYMBOLFILE h=HOSTADDR e=TARGETADDR u=USER tn=TARGET"
```

Where ***HOST*** is the IP name of the host computer, ***SYMBOLFILE*** is the name of the symbol file to use when loading via network (e.g., "/u/***USER***/vxWorks.sym" — but this parameter is unused on the RAD6000), ***HOSTADDR*** is the dotted decimal IP address of the host computer (e.g., 90.0.0.1), *TARGETADDR* is the dotted decimal IP address of the target computer (e.g., 90.0.0.2), *USER* is a username accessible on the host computer, and ***TARGET*** is the IP name of the target computer.

The only ethernet card supported by VxWorks on a RAD6000 is the Rockwell ENP–10L VME Ethernet board. Non–VME–based RAD6000s do not support ethernet.mjf update this for RAMix

6.5 Configuring Communications Options for Tornado (VxWorks Versions 5.3 and Later)

Tornado offers the same communication options as previous versions but with some enhancements. With Tornado, you choose the backend your target server will use to communicate to the VxWorks target. All of the standard backends connect to the target through the Wind Debugger (WDB) target agent. Let's look at two backends - network and serial-line.

6.5.1 Network Connections

A network connection is the easiest and is typically the board's fastest physical communication channel. The network is the default communication path, as specified in the following line from **configAll.h**:

```
  #define WDB_COMM__TYPE      WDB_COMM_NETWORK         /* vxWorks network */
```

The target server can then connect to the target agent using the default *wdbrpc* backend.

To use the network one of the following defines needs to be included in **config.h** in your BSP directory:

```
#define INCLUDE_ENP                /*   Osicom VME Ethernet adapter */
#define INCLUDE_PMC661             /*  RAMix PMC Ethernet adapter  */
#define INCLUDE_LAN_PCMCIA    /*   RAMix VME Ethernet adapter */
```

You will also need to update the DEFAULT_BOOT_LINE in **config.h** with the appropriate host and target addresses and target name.
Once these changes have been made and the driver has been added to **Makefile** you are ready to build a network vxWorks image. Refer to section 6.7 below for details.

6.5.2 Serial-Line Connections

One option for serial-line communication is using the *wdbrpc* back end over a serial line SLIP connection. This is discussed in section 8 below. Using IP networking has some advantages in that it provides routing and all the standard network services. Conversely, using a raw serial connection also has some advantages over an IP serial connection. System mode debugging for ISRs (see section 7.5 in the Tornado User's Guide) works when the target agent is configured for a raw serial connection, but not when it is configured for a networked serial connection. In addition, the raw serial connection allows you to scale down the VxWorks image for memory-constrained applications that do not require networking: you can remove the VxWorks network support from the image.

To configure your target for a raw serial connection the following lines need to be in **config.h** in your BSP directory:

```
/* Override the following defs for debugging via serial */
#undef  CONSOLE_TTY
#define CONSOLE_TTY NONE
#undef  WDB_TTY_DEV_NAME
#define WDB_TTY_DEV_NAME "tyCo/0"
#undef  WDB_COMM_TYPE
#define WDB_COMM_TYPE    WDB_COMM_SERIAL
#undef  WDB_MODE
#define WDB_MODE         WDB_MODE_DUAL
#undef  WDB_TTY_CHANNEL
#define WDB_TTY_CHANNEL  0
#undef  WDB_TTY_BAUD
#define WDB_TTY_BAUD     9600 or 38400  /* set to the specific baud rate of
the serial port */
#endif
```

These will override any defines in **configAll.h**. Once these changes have been made you are ready to build a raw serial vxWorks image. Refer to section 6.7 below for details.

6.6 Configuring Memory

The default VxWorks configuration delivered by Wind River is for a RAD6000 with 128 MB of local memory. Most RAD6000 boards have between 2 and 8 MB of RAM, so some changes will have to be made. Before you can configure your memory, however, you must understand what features are configurable and what restrictions are placed on the configuration.

There are four tables defined by the RAD6000 architecture that must reside in lower memory. These are the Interrupt Vector Table, the Hash Allocation Table (HAT), the Page Frame Table (PFT), and the Translation Control Word Table (TCW). In addition, some areas of lower memory are reserved for use by VxWorks. Finally, you may also want to reserve some space in lower memory for use by your application program.

Let’s start by looking at the default VxWorks configuration and what a memory map based on that configuration looks like. In the memory map shown in **Table 2**, all address ranges marked “unused” may be used by the application program. However it is best to check with Lockheed Martin as to availability as some device drivers also use these areas for buffer space. All other address ranges, however, are strictly reserved and must not be modified directly by the application.

Starting Address	**Ending Address**	
0x00000000	0x000000FF	**Reserved**
0x00000100	0x00001FFF	**Interrupt Vector Table**
0x00002000	0x000026FF	Unused
0x00002700	0x00002FFF	**Reserved**
0x00003000	0x0001FFFF	Unused
0x00008000	0x0000FFFF	**Hash Allocation Table (HAT)**
0x00010000	0x0001FFFF	**Page Frame Table (PFT)**

Starting Address	Ending Address	
0x00020000	0x0002FFFF	**Translation Control Word Table (TCW)**
0x00050000	0x003FFFFF	**VxWorks & Application**

Table 2 Typical RAD6000 Memory Map (4 MB Memory)

The Interrupt Vector Table and those address ranges marked "Reserved" must reside at the addresses shown in **Table 2** and are therefore not configurable.

The HAT and the PFT are used by the memory management subsystem. The size of these tables depends on the amount of local memory on your RAD6000 board and is therefore also not configurable. The starting address of each of these tables, however, is configurable within certain limitations.

The TCW is used for DMA operations to map bus addresses to local addresses. Both the size and starting address of the TCW are configurable. And, if you are not using DMA operations, you can set TCW_SIZE to 0 (zero) so that no space is reserved for a TCW at all.

6.6.1 Configuring the Hash Allocation Table (HAT)

The starting address for the HAT is defined by setting the HAT_ADRS variable in "config.h". It must start on a 32K boundary and its starting address must be greater than or equal to its size. Thus the starting address for a 128K HAT must be equal to any 32K boundary at address 0x20000 or above.

The size of the HAT is dependent on the size of local memory and is therefore not user configurable. To determine its size, take the size of local memory in bytes and divide it by 1024. However, the minimum HAT size is 32K.

6.6.2 Configuring the Page Frame Table (PFT)

The starting address for the PFT is defined by setting the PFT_ADRS variable in "config.h". It must start on a 64K boundary and its starting address must be greater than or equal to its size. Thus the starting address for a 512K PFT must be equal to any 32K boundary at address 0x80000 or above.

The size of the PFT is dependent on the size of local memory and is therefore not user configurable. To determine its size, take the size of local memory in bytes and divide it by 256. The minimum PFT size is 64K.

6.6.3 Configuring the Translation Control Word Table (TCW)

The TCW is used for mapping local addresses to bus addresses for DMA operations. Each entry in the table is 4 bytes long and maps an entire 4K page of addresses. To determine how large the TCW table should be, first determine the largest I/O bus address that will need to be mapped for DMA. Dividing that address by 4096 will give you the number of pages of address space that need to be mapped, and, therefore, the number of TCW entries that will be required. Multiplying the number of TCW entries by 4 gives you the size of the TCW table in bytes. This formula, of course, can be simplified to dividing the largest I/O bus address to be mapped by 1024.

Table Size (in bytes)	**TCW_SIZE Value**
32 K	0x00008000
64 K	0x00010000
128 K	0x00020000
256 K	0x00040000
512 K	0x00080000
1 M	0x00100000
2 M	0x00200000
4 M	0x00400000

Table 3 Supported TCW Sizes

That should be all there is to determining the size of the TCW. However, the RAD6000 architecture only supports certain sizes. Therefore, once you have determined the size you need for the amount of address space you intend to map, you must round it up to one of the sizes shown in **Table 3**. That table also provides the value to be assigned to the variable TCW_SIZE in "config.h" in order to configure the TCW.

Once you have determined its size, you can easily determine its starting address, which must be on a boundary equal to its size. Thus, a 128K TCW may be located at any address divisible by 128K. The address is defined by setting the TCW_ADRS variable in "config.h".

For more information on the TCW table and how it is used, please refer to *Section 10.2.3.1 TCW Table Management*.

6.6.4 Locating VxWorks and Application Programs

Once you have determined the starting addresses and sizes for all of the system tables, you can define where VxWorks and your application code and data should reside. This is done using two variables in "config.h": RAM_LOW_ADRS and LOCAL_MEM_SIZE. RAM_LOW_ADRS defines where VxWorks is to be loaded and LOCAL_MEM_SIZE defines the maximum amount of local memory on your board. VxWorks expects to be able to use all of the memory between RAM_LOW_ADRS and the top of memory (LOCAL_MEM_SIZE).

Note that these variables also exist in "Makefile" and the values set in that file must match the values set in "config.h". Refer to the VxWorks documentation for more information on these variables.

6.6.5 Summary

Table 4 provides a summary of the variables defined in "config.h" that are used to configure memory.

Variable	**Description**	**Legal Values**
HAT_ADRS	Starting address of Hash Allocation Table.	• Must be on a 32K boundary. • Must be greater than or equal to the size of the

Variable	Description	Legal Values
		HAT (LOCAL_MEM_SIZE / 1024).
PFT_ADRS	Starting address of Page Frame Table.	• Must be on a 64K boundary. • Must be greater than or equal to the size of the PFT (LOCAL_MEM_SIZE / 256).
TCW_SIZE	Size of Translation Control Word Table in bytes.	• Determine the largest I/O bus address to be mapped for DMA and divide it by 1024. • Refer to **Table 3** and find the smallest value greater than or equal to the above result.
TCW_ADRS	Starting address of Translation Control Word Table.	• Must reside on a boundary equal to its size.
RAM_LOW_ADRS	Starting address of VxWorks and application code and data.	• Must not conflict with system tables. • Variable must be set to the same value in both “config.h” and “Makefile”.
LOCAL_MEM_SIZE	Amount of local memory in bytes.	• Must be equal to the amount of local memory in bytes. • Variable must be set to the same value in both “config.h” and “Makefile”.

Table 4 Memory Configuration Variables

6.7 Building VxWorks

Now the decisions are behind you for a while and you can build VxWorks for your computer. From the BSP directory in your build directory, enter the following command:

```
make vxWorks.st (for VxWorks pre-Tornado versions)

     or

make vxWorks  (for VxWorks Tornado versions )
```

Messages indicating ”no rules defined to build ...” usually mean that the environment variables are not set (see Sections 2 and 3) or that an object file is referenced in “Makefile.RSCgreen” which has no source file associated with it (check your additional objects defined in MACH_EXTRA or EXTRA_LIB).

If the build completes successfully, you will now have a new vxWorks[.st] file that contains the VxWorks kernel configured for your board. In order to load it to your target you will have to convert it to a binary image. If you are using the AdaMULTI toolset, this is done as follows:

```
elfToBin < vxWorks[.st] > vxWorks[.st].bin
```

If you are using IBM’s AIX XLC compiler, use the following command instead:

```
xcoffToBin < vxWorks[.st] > vxWorks[.st].bin
```

The file vxWorks[.st].bin can now be loaded on your target.

7 Communicating over a Serial Port

Some RAD6000 boards use a RS–232 UART and have a standard 9–pin D–shell female connector. Others, however, use an RS–422 UART with differential signals that can travel greater distances than the RS–232 signals. In these cases, the UART signals are usually connected to the backplane. Also, custom configurations different than either of these options may be available.

This section discusses how to connect, configure, and use the serial device on your RAD6000, whichever variety of UART happens to be on it.

This section also discusses the use of **sendbin**, a Lockheed Martin–provided tool that allows you to download a VxWorks binary image to the target via the serial port.

7.1 Connecting a Serial Cable

As mentioned above, most RAD6000 boards use an RS–232 UART and have a standard 9–pin D–shell female connector on the front panel of the board. Since most workstations have a 25–pin male serial connector, an adapter is necessary to connect the serial ports. Also a null modem is required to interchange transmit and receive signals. **Figure 3** shows this set–up in graphical format.

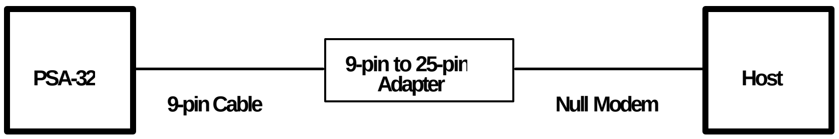


Figure 3 Typical Serial Connection with an RS-232 UART

Since RAD6000 boards with a RS–422 UART usually have UART signals connected to the backplane, they will require a custom adapter. Again, a null modem is also required. **Figure 4** shows this set–up in graphical format.

Lockheed Martin will usually provide the custom serial adapter when Lockheed Martin is also providing the backpanel (depending, of course, on the terms of the contract). However, for customers who buy only a RAD6000 board and make their own backpanel, Lockheed Martin will provide the specs necessary to create the custom serial adapter.

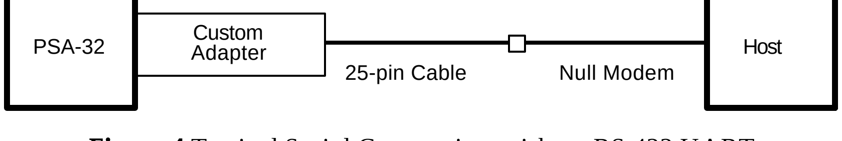


Figure 4 Typical Serial Connection with an RS-422 UART

7.2 Configuring the Serial Port and a Terminal Emulator

Once the UART is connected, the serial ports on the host and target computers must be configured to match baud rates, parity bits, stop bits, and data bits. VxWorks and **sendbin** both set the target UART to 8 data bits, 1 stop bit, and no parity. The baud rate used by RAD6000s vary based on the specific model. To summarize, configure your host UART with:

- 8 Data Bits
- 1 Stop Bit
- No Parity
- Baud Rate varies.

Basic communication to the target is accomplished via a terminal emulator such as tip or Kermit. Refer to the documentation that comes with your terminal emulator to determine how to configure it.

7.3 Using sendbin to Download Target Software

Lockheed Martin provides boot software for RAD6000 breadboards to be used during application program development. This boot software initializes the RAD6000's memory and then accepts a load image from an outside source. Since the one interface common to all RAD6000s and all host computers is the serial port, the boot software uses that interface as a load path.

Binary load images are sent from the host to the target RAD6000 over the serial interface by a program called **sendbin**. **sendbin** is a C program which uses standard system calls to interact with the serial port so that it may be recompiled for any host running a UNIX–like operating system. Source code for **sendbin** is provided to the user for this reason. **sendbin** has been compiled for AIX and Solaris platforms.

To compile **sendbin** for your host:

```
cc -o sendbin sendbin.c
```

sendbin does not configure the serial port that is being used for the download. It takes the values defined in the operating system or the configuration defined by a terminal emulator such as tip or Kermit. See Section 7.2 for more information.

Whether or not a terminal emulator is used to configure the host's serial port, one should be used during the boot process. Lockheed Martin's boot software will notify the user that it is ready to receive a load image by sending characters over the serial port. Once these characters are received, the user can start **sendbin**.

To use **sendbin**, type the following command:

```
sendbin vxWorks[.st].bin load_address entry size tty
```

Where:

load_address is the address where VxWorks is to be loaded specified as a hexadecimal value

entry is the address of the program's entry point specified as a hexadecimal value

size is the size of the program in bytes specified as a decimal value `tty` is an optional parameter specifying which serial port to use for AIX use /dev/tty format for Sun use /dev/cua format.

The `load_address` and `entry` parameters must both be equal to the value of the RAM_LOW_ADRS variable in "config.h". The value of the `size` parameter can be easily determined by using the UNIX **`ls -l`** command to determine the size of "vxWorks[.st].bin". They `tty` parameter is only necessary if you are not using the default serial port on your host workstation.

As an example, let's say you want to load "vxWorks[.st].bin" using the "/dev/tty2" serial port. You first need to look in "config.h" for the RAM_LOW_ADRS variable to find where the program is to be loaded. Let's say it is equal to 0x140000. Next, you will need to determine the size of the "vxWorks[.st].bin" file. For our example, we'll assume it's equal to 638,040 bytes. The following command is used to load:

```
sendbin vxWorks[.st].bin 140000 140000 638040 /dev/tty2
```

7.4 Summary

Using the serial port to load VxWorks can be summarized as follows:

- Connect host and target serial ports as described in Section 7.1.
- Start terminal emulator with serial port parameters set as described in Section 7.2.
- Reset target computer.
- Wait for prompt from boot software.
- When prompted, use **sendbin** to transfer binary load image to target as described in Section 7.3.
- When transfer is complete, **sendbin** indicates "Finished sending file".
- The boot software will then indicate "Jumping to program" and will transfer execution to the downloaded program.
- If the VxWorks image does not use SLIP, you will see the VxWorks banner and prompt arrow.
- If the VxWorks image does use SLIP, you will see "nonsense characters" appearing in small groups periodically. This is VxWorks trying to contact the other end of the point to point SLIP connection. See *Section 8 Using SLIP to Connect a RAD6000 to a Network*, for more information.

7.5 Avoiding Common Pitfalls

Symptom	**Problem**	**Solution**
Unable to open serial port with the terminal emulator.	Device is in use by another task.	Terminate other task. Can not have Serial Port and SLIP active at the same time.
	Terminal Emulator is not properly configured.	Ensure terminal emulator is installed properly. (missing files or permissions ?)
	Mismatch of serial port parameters.	Ensure terminal emulator parameters match the serial port parameters specified by the host operating system.
Prompt does not appear after reset.	RISCWatch holding RAD6000.	From RISCWatch, enter **`ocs on`**.
	Serial ports not connected or	Properly connect serial ports.

Symptom	**Problem**	**Solution**
	no null modem is attached.	
	Mismatch of serial port parameters.	Ensure terminal emulator is using the correct parameters.
No “Jumping to program” message after **sendbin**, or program crashes after “Jumping to program” message.	Extraneous characters sent to target during load.	Do **not** touch keyboard while terminal emulator is in the active window and **sendbin** is executing.
		Check tty parameters to ensure that `<CR>` is not inserted before `<LF>` on outgoing characters.
	Bad binary load image.	Download “sendTst.bin” to verify download procedure.
No characters appear after apparently successful download.	VxWorks using different baud rate than boot software.	Change baud rate of terminal emulator after completion of download.
	Incorrect SLIP IP address.	Modify “config.h” to include proper SLIP IP address for target and host.

Table 5 Common Serial Communications Problems

8 Using SLIP to Connect a RAD6000 to a Network

Serial Link Interface Protocol, or SLIP, is a layer of software that sits between the TCP / IP protocol stack and a serial device driver. It allows the TCP / IP protocol to be used on a serial link, thus allowing a computer with only a serial device (such as a RAD6000) to be placed on a network.

SLIP is provided as part of the AIX operating system that comes with IBM's RISC System / 6000 workstations. However, UNIX–like operating systems for other platforms, such as Solaris on Sun workstations, do not necessarily come bundled with SLIP. Products available provide SLIP for these platforms. See Section 8.6 for a list of some of these products and what is known about using them.

This section will concentrate on configuring and using SLIP with AIX. Lockheed Martin has little experience using SLIP products on other platforms, although some of our customers have used them successfully. Hopefully even if you are using a platform other than AIX, you will be able to get an idea of the general process from this section. Details, however, will have to come from the providers of the SLIP product you are using.

8.1 Configuring SLIP for AIX

On the RAD6000 target board, the SLIP configuration is built into VxWorks. Only rebuilding the operating system may change it. Refer to Section 6 to learn how to do this. Note that several of the SLIP parameters built into VxWorks must match the SLIP parameters on your host workstation. This will be discussed in more detail below.

For some of these steps, you will need to have root access. If you do not have root access to the workstation you are using as a host, you will have to get your system administrator to perform these steps.

8.1.1 Attaching SLIP to the TCP/IP Protocol Stack

The first thing you have to do is create and configure a network interface and attach it to an existing serial device. This requires root access. After logging into your host workstation as root, do the following steps:

1. Use the following command to create and configure a network interface:

   ```
   mkdev -c if -s SL -t sl -w slSN -a netaddr=HOSTADDR -a dest=TARGETADDR \
   -a state=up -a ttyport=ttyTN -a baudrate=BAUD
   ```

   Where *SN* is a number from 0 to 9 identifying your new network interface, *HOSTADDR* is your host's IP dotted decimal address, *TARGETADDR* is your target's IP dotted decimal address, *SN* is a number from 0 to 9 identifying the serial device to be used, and *BAUD* is the baud rate (e.g., 9600).

   TN must correspond to an existing tty device on your workstation. Most AIX workstations have two serial ports named tty0 and tty1. Use the name corresponding to the serial port you plan to use for SLIP.

   The value used for *SN* is up to you, but it must not be an existing serial link network interface. We recommend that you always use the same value for *SN* that you use for *TN*. This way you should never have a naming conflict.

HOSTADDR, *TARGETADDR*, and *BAUD* must match the values given in the DEFAULT_BOOT_LINE variable when you build VxWorks. See Section 6. for more information.

For example, to create a serial link network device named “sl1” to be attached to the serial port “tty1” with a host TCP/IP address of 90.0.0.1 and a target TCP/IP address of 90.0.0.2 at 9600 baud, use the following command:

```
mkdev -c if -s SL -t sl -w sl1 -a netaddr=90.0.0.1 -a dest=90.0.0.2 \
-a state=up -a ttyport=tty1 -a baudrate=9600
```

If you receive an error from this command, then it is most likely because:

a. You are not logged in as root. Log in as root and try again.

b. The value chosen for *SN* corresponds to an existing network interface. Use a different value.

c. The value chosen for *TN* does not correspond to an existing serial device. Use a different value.

2. Once you have successfully created a network interface, you must attach it to the chosen serial port. Do this using the following command:

```
slattach ttyTN
```

Where *TN* is the same value given to *TN* in step 1. Using the same values as in the example above, you would enter:

```
slattach tty1
```

Note that sometimes when the target computer is reset or turned off, the host computer’s serial link connection will go down. If this happens, simply use the “slattach” command again to reconnect it.

8.1.2 Verifying or Modifying a SLIP Configuration

Once the SLIP connection is created, the “ifconfig” command can be used to verify or change the IP addresses, network mask, and up/down status. Anyone can use this command to verify the parameters, but you must have root access to modify them.

To verify them, merely enter:

```
ifconfig slSN
```

Where *SN* is the same value used for *SN* when the device was created.

To modify the parameters, first log in as root, and then enter:

```
ifconfig slSN HOSTADDR TARGETADDR NETMASK UPDOWN
```

Where *SN*, again, is the value used for *SN* when the device was created; *HOSTADDR* is the new host IP dotted decimal address; *TARGETADDR* is the new target IP dotted decimal address; *NETMASK* is the TCP/IP network mask (if unsure, use 255.255.255.0); and *UPDOWN* is either “up” if you want the device to be active, or “down” if you want to disable the device.

8.1.3 Detaching and Deleting a SLIP Device

To detach a serial link network device from a serial port, enter:

```
ifconfig slSN detach
```

Where *SN* is the value used for *SN* when the device was created.

To delete a serial link network device, enter:

```
rmdev -l slSN -d
```

Where *SN*, again, is the value used for *SN* when the device was created.

8.2 Creating .rhosts to allow remote operations

In order for you to be able to rlogin from your host into your target for the defined user you must tell the host that the target is allowed to perform remote operations. In the home directory of the ***USER*** defined in the boot line (as listed in Section 6.4) you must create a file called .rhosts. the .rhosts file must contain the name of the *Target* board. A sample .rhosts file:

```
rsc
rsc2
target
```

8.3 Defining an IP Name for the Target

Since you probably don’t want to be referring to the target computer using its dotted decimal IP address all the time, you should give the target an alphanumeric name. To do this, use your favorite editor to edit the host file named “/etc/hosts” to add the following lines:

```
90.0.0.1     host
90.0.0.2     rsc
```

Each line associates a dotted decimal IP address with a name so that the name can be used in place of the IP address. The values given above correspond to the examples in Section 8 above and in Section 6.4. If you used different values when creating the serial link network device and when building VxWorks, you must use those values here. That is, the values set in the DEFAULT_BOOT_LINE variable when VxWorks was built must be the same values used in the “mkdev” command used to create the host serial link network device and the same values used in the file “/etc/hosts”.

Next, you must define the target computer as ”trusted” when accessing the host. To do this, you must edit the file named “.rhosts” in the home directory of the userid specified in the VxWorks DEFAULT_BOOT_LINE variable. For more information on this variable, refer back to Section 6.4. All you have to add to this file is a single line containing only the name of the target computer. Using the same values as in the other examples in this document, merely add the following line:

```
rsc
```

8.4 Using SLIP

Once you have SLIP configured on the host (which you should only have to do once) and have built a version of VxWorks containing SLIP, you are ready to test it. To do this, first download VxWorks to the target board as described in Section 7.3. Note that you will need to use a serial port for a terminal emulator and the **sendbin** program during the download process. If you have SLIP attached to a serial port on your host, you can not also use that serial port for terminal emulation and / or **sendbin**. One possibility is to detach the serial port from SLIP while doing the download as described in Section 8.1.3. However, at Lockheed Martin we have found that this sometimes leads to unreliable downloads and / or SLIP operation and can generally be a hassle. Instead, if your host has more than one serial port, we recommend dedicating one of them to terminal emulation and **sendbin** (we use tty0 or cua / a) and another for SLIP (we use tty1 or cua / b). We then connect the serial cables from both ports to an A–B switch and attach the serial cable from the target to the other end of the switch. This way, when the download has completed, you can merely flip the switch to go from using terminal emulation to SLIP.

When the download has completed and a serial port with SLIP attached is connected from the host to the target, try to ping the target. From the host, enter this command:

```
    ping TARGET
```

Where *TARGET* is the IP address of the target (using the above examples, you would use 90.0.0.1). If this works, try the command again, but this time use the IP name instead of the IP address (e.g., rsc). If either of these did not work, see Section 8.7 for troubleshooting advice.

Once you have ping working, try to login to the target board. To do this, enter the following command from the host:

```
    rlogin TARGET
```

Where TARGET, again, is the IP name or address of the target board. If it worked, you should see the following VxWorks interactive shell prompt:

```
    ->
```

If you don’t see that, refer to Section 8.7 for troubleshooting advice.

Once you have successfully logged in to the interactive shell on the target board, you can be sure that SLIP is working properly.

8.5 Connecting AdaMULTI’s Debugger via SLIP

If you want to use AdaMULTI’s debugger over your SLIP connection, you must connect it within 60 seconds from when you finished downloading VxWorks to the target board. This is due to a timeout in the remote procedure call service in VxWorks. If more than a minute has passed since the download finished and you want to use the AdaMULTI debugger, you must reset the target computer and reload VxWorks.

Once you have loaded VxWorks and have a SLIP connection between the host and the target, you can attach the AdaMULTI debugger. To do this, bring up AdaMULTI if it is not already running by entering the following:

```
adamulti &
```

When the AdaMULTI Builder window appears, type the following in the text field to the right of the button labeled “Remote”:

`vxserv` ***`ipname`*** **`–rsc`**`, where` *`ipname`* `is the IP name of the RAD6000 target board.`

Now click on the “Remote” button. This will bring up the main Debugger window that should contain the source code for the program you are debugging. Refer to the Green Hills documentation for more information on using the AdaMULTI debugger.

8.6 SLIP Products for Sun Workstations

This section is intended to help users of Sun workstations find SLIP products. However, Lockheed Martin has limited experience with them. If you use any of these products, or other Sun workstation SLIP products, we would appreciate hearing about your experiences with them to pass on to help other customers.

For the Solaris operating system there is a product called Morning Star. A trial copy can be retrieved from the World Wide Web at http://www.morningstar.com. With this trial copy, the user gets a temporary license that expires at the end of a trial period. After this, if interested in using the product, the user must obtain a licensed copy. Please refer to their web site for more information.

8.6.1 Morning Star

We have successfully installed the Progressive Systems Morning Star product on a Sun Workstation. Using Morning Star Version 1.4.1 using UNIX(r) System V Release 4.0 and Solaris 2.5.1 we were able to run slip on the A or B serial ports on the Workstation. The rest of this section will explain how we configured our Sun Workstation. The values given below for ***`TARGET`*** and ***`HOST`*** correspond to the variables in the examples in Section 6.4. If anything listed in the following paragraphs is in conflict with what is found in the Morning Star documentation, the Morning Star documentation should be presumed to be correct. Also, please let Lockheed Martin know about the conflict so that we can make the required changes to our documentation.

8.6.1.1 Configuration

Install Morning Star as instructed in the “Morning Star PPP User Guide”. Once Morning Star has been installed and licensed login into your machine as the root user. There are several files that were installed in the /usr/lib/ppp directory and some additional files will need to be created. Fortunately Morning Star has created example files of each of the required files. We strongly urge you to change the mode of these files from owner read/write to owner read to prevent accidental modification. This can be accomplished by the following:

```
cd /usr/lib/ppp
chmod -w *.ex
chmod -w Examples/*
```

8.6.1.1.1 DevicesA and DevicesB

Create a writable file called DevicesA from the Devices.ex file.

```
cp Devices.ex DevicesA
chmod 666 DevicesA
```

Using your favorite editor add the following line to the file (SPEED is the speed of the of the device, 19200, 9600....):

```
Direct cua/a SPEED
```

Create a copy of the DevicesA file called DevicesB with the last line content line modified to use cua/b instead of cua/a.

8.6.1.1.2 Filter

Create a writable file called Filter from the Filter.ex file.

```
cp Filter.ex Filter
chmod 644 Filter
```

Using your favorite editor: uncomment the lines starting with “internet gateway” and ending with “log rejected” by deleting the leading “#” symbol and create a new default line as follows:

```
default bringup !ntp !3/icmp !5/icmp !11/icmp !who !route !60000/udp
       keepup !send !ntp !3/icmp !5/icmp !11/icmp !who !route
```

8.6.1.1.3 SystemA and SystemB

Create a writable file called SystemA from the System.ex file.

```
cp System.ex SystemA
chmod 666 SystemA
```

Using your favorite editor add the following line to the file (*TARGET* is the name of the target board, *SPEED* is the speed of the of the device, 19200, 9600 ....):

```
TARGET Any;5 /dev/cua/a SPEED
```

Create a copy of the SystemA file called SystemB with the last line modified to use cua/b instead of cua/a.

8.6.1.1.4 pppSlipA and pppSlipB

Create a writable file with the “sticky bit” set called pppSlipA from the Examples/S65ppp.ex file. Setting the mode to 7755 by “root” user allows any user to be able to run this script and even though the commands inside of it that work with the serial ports are limited to use by the “root” user. Failure to set the “sticky bit” will cause non root user to get error message indicating insufficient privilege to perform the requested action. The following example shows the commands the root user will use to copy the file and set the “sticky bit”:

```
cp Examples/S65ppp.ex pppSlipA
chmod 7755 DevicesA
```

Using your favorite editor edit DevicesA and change the following lines from:

```
#LOCAL='/usr/ucb/hostname'
#REMOTE="manatee"
```

to:

```
LOCAL="Host"
REMOTE="Target"
cp /usr/lib/ppp/SystemsA /usr/lib/ppp/Systems
cp /usr/lib/ppp/DevicesA /usr/lib/ppp/Devices
```

Create a copy of the pppSlipA called pppSlipB with the new lines using files SystemsB and DevicesB instead of SystemsA and DevicesA. Lockheed Martin recommends that pppSlipA and pppSlipB be moved into directory that is in all the users paths if desired so that user does not have to know where these files exist to use them (i.e. the same place as kermit or **sendbin** are stored).

8.6.1.2 Starting and Stopping SLIP on Morning Star

In order to start the slip connection on serial port b enter the following command:

```
pppSlipB Start
```

The SLIP port will remain active until the Morning Star ppp daemon is terminated. Morning Star User Guide states that the ppp daemon should be terminated with a kill -term command and NOT a kill -9 command because it will leave your serial interfaces in an unknown state (See the pppd section on signals in the Morning Star Users guide for additional information). Thus the recommended way to stop ppp is to use the script by entering:

```
pppSlipB Stop
```

Serial port A works the same way as serial port b. SLIP on serial port A is started an stopped by using "pppSlipA" instead of "pppSlipB".

8.7 Avoiding Common Pitfalls

Symptom	**Problem**	**Solution**
No SLIP characters appear after "Jumping to program" message.	Bad download process.	See Section 7.5.
	VxWorks did not start network automatically.	Check that the file "usrConfig.c" contains the line: `#define INCLUDE_NET_INIT`
SLIP characters appear, but can not ping or rlogin target using either the IP name or IP address.	SLIP is not active on the host.	Start SLIP on host and attach it to serial port connected to target using **`ifconfig`** or **`slattach`**. or **`pppSlipA`** or **`pppSlipB`**
	UART signals in addition to TX and RX must be active to use SLIP.	Verify null modem against UART appendix. Or wire control

Symptom	Problem	Solution
	Note: Which ones?	signals to always active.
	Mismatch between host and target regarding IP names and / or addresses.	Check host files "/ etc / hosts" and "/ etc / routes" against VxWorks variable "DEFAULT_BOOT_LINE" found in "config.h".
Can ping, but can not rlogin.	UART incorrectly connected.	Verify null modem against UART appendix. Or wire control signals to always active.
	Boards with less than 2 MB of RAM can not run interactive shell with network.	Configure more memory, if available. Otherwise use a direct serial connection to access interactive shell, rather than using SLIP.
Can ping or rlogin using IP address, but not using IP name.	IP name is not defined on host.	Place IP address to IP name mapping in host file "/ etc / hosts".
Can rlogin, but can not use VxWorks load command: **`ld < `*`filename`***	Target not trusted by host.	Place target IP name in ".rhosts" file in home directory of user identified by the VxWorks variable "DEFAULT_BOOT_LINE" found in "config.h".
	Insufficient permission to access files on host.	Use **`chmod`** to give access to object files on host.
Can rlogin from host, but attempts to connect with AdaMULTI give "RPC not registered" message.	RPC timed out on target.	Connect AdaMULTI within 60 seconds of completion of download.
Can connect with AdaMULTI, but can not use AdaMULTI "load module" menu option.	Unresolved references in file being loaded.	Load objects being referenced before loading current file.
	Not enough memory.	Configure more memory, if available, or unload unused objects.
	No error messages displayed.	Rlogin to target and retry load module command.
	No error messages displayed in rlogin window, but error message displayed in AdaMULTI window.	No error actually occurred, but AdaMULTI timed out. Use **`moduleShow`** to confirm presence of new object file. Disconnect and reconnect AdaMULTI debugger to get file

Symptom	Problem	Solution
		into debugger.

9 Connecting a Tornado Target Server

To make a VxWorks target ready for use with the Tornado development tools, you must start a target-server daemon for that target on your host. One way to accomplish that is from the Tornado launcher. Once you become more familiar with Tornado and its tools you might want start the server from the Sun command line. For more on that approach, see section 3.6 *Connecting a Tornado Server* in the Tomado User's Guide. For the remainder of this section, we will be concerned with using the launcher method. To start the launcher execute the following command:

launch &

After your host and target are connected properly and you have downloaded a VxWorks binary image to the RAD6K, you can now configure the target server to communicate to the target. Below are two examples configuring the RAD6K target using ethernet and raw serial as the target server backend. Also included is a method for creating a virtual console.

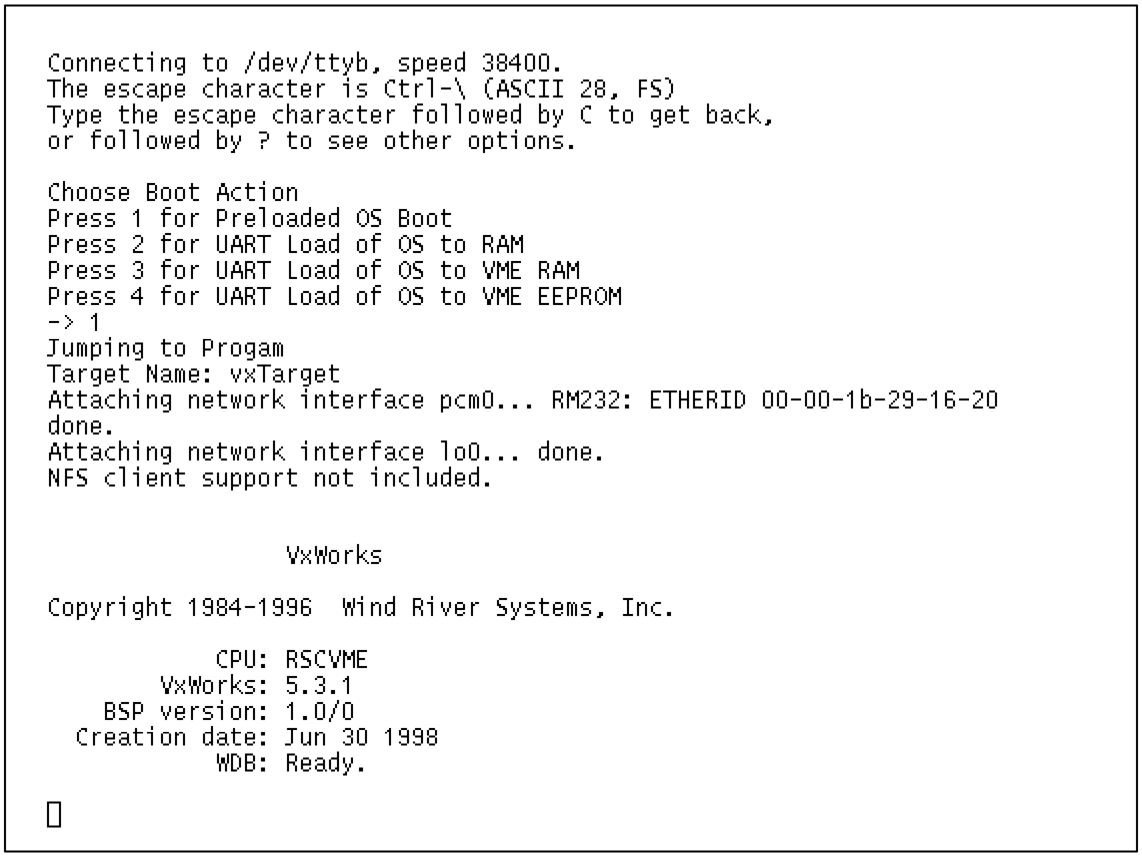
9.1 Creating a Virtual Console

Virtual I/O is a service provided jointly by the target agent and target server. It consists of an arbitrary number of logical devices that convey application input or output through standard C-language calls. On the host, virtual I/O is most easily connected to a dedicated display called the virtual console, under the control of the target server. This method is used in the following two configurations. To automatically redirect the standard I/O to the virtual console a file called *windsh.tcl* in your *$HOME/.wind* directory needs to be created. Tornado looks for this file each time you execute an instance of the Tornado shell. If the file exists, the shell reads and executes its contents as Tcl expressions before beginning to interact. You can use this file to automate any initialization steps you perform repeatedly. The following example shell initialization file assigns standard input and output to the virtual console using channel 0, but only if virtual channel 0 is not yet in use on the target:

```
# Set stdin, stdout, stderr and logging output to /vio/0 iff not already in use
if { [shParse {tstz = open ("/vio/0",2,0)}] != -1 } {
    shParse {vf0 = tstz};
    shParse {ioGlobalStdSet (0,vf0)} ;
    shParse {ioGlobalStdSet (1,vf0)} ;
    shParse {ioGlobalStdSet (2,vf0)} ;
    shParse {logFdAdd (vf0)} ;
    shParse {printf ("Std I/O set here!\n")}
} else {
    shParse {printf ("Std I/O unchanged.\n")}
}
```

9.2 Creating an Ethernet Target Connection

After creating an ethernet network vxWorks image (see 6.5.1Network Connections) the target server will then connect to the target agent using the default *wdbrpc* back end. This interface is the RAD6K's fastest physical communication channel. After downloading the binary vxWorks image to the RAD6K and the target agent has booted it sends the message *WDB READY* to help test the connection. The following figure is typically seen in the serial window.



```
Connecting to /dev/ttyb, speed 38400.
The escape character is Ctrl-\ (ASCII 28, FS)
Type the escape character followed by C to get back,
or followed by ? to see other options.

Choose Boot Action
Press 1 for Preloaded OS Boot
Press 2 for UART Load of OS to RAM
Press 3 for UART Load of OS to VME RAM
Press 4 for UART Load of OS to VME EEPROM
-> 1
Jumping to Progam
Target Name: vxTarget
Attaching network interface pcm0... RM232: ETHERID 00-00-1b-29-16-20
done.
Attaching network interface lo0... done.
NFS client support not included.


                 VxWorks

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            CPU: RSCVME
        VxWorks: 5.3.1
    BSP version: 1.0/0
  Creation date: Jun 30 1998
            WDB: Ready.

▯
```

Figure 5 VME Ethernet serial window example

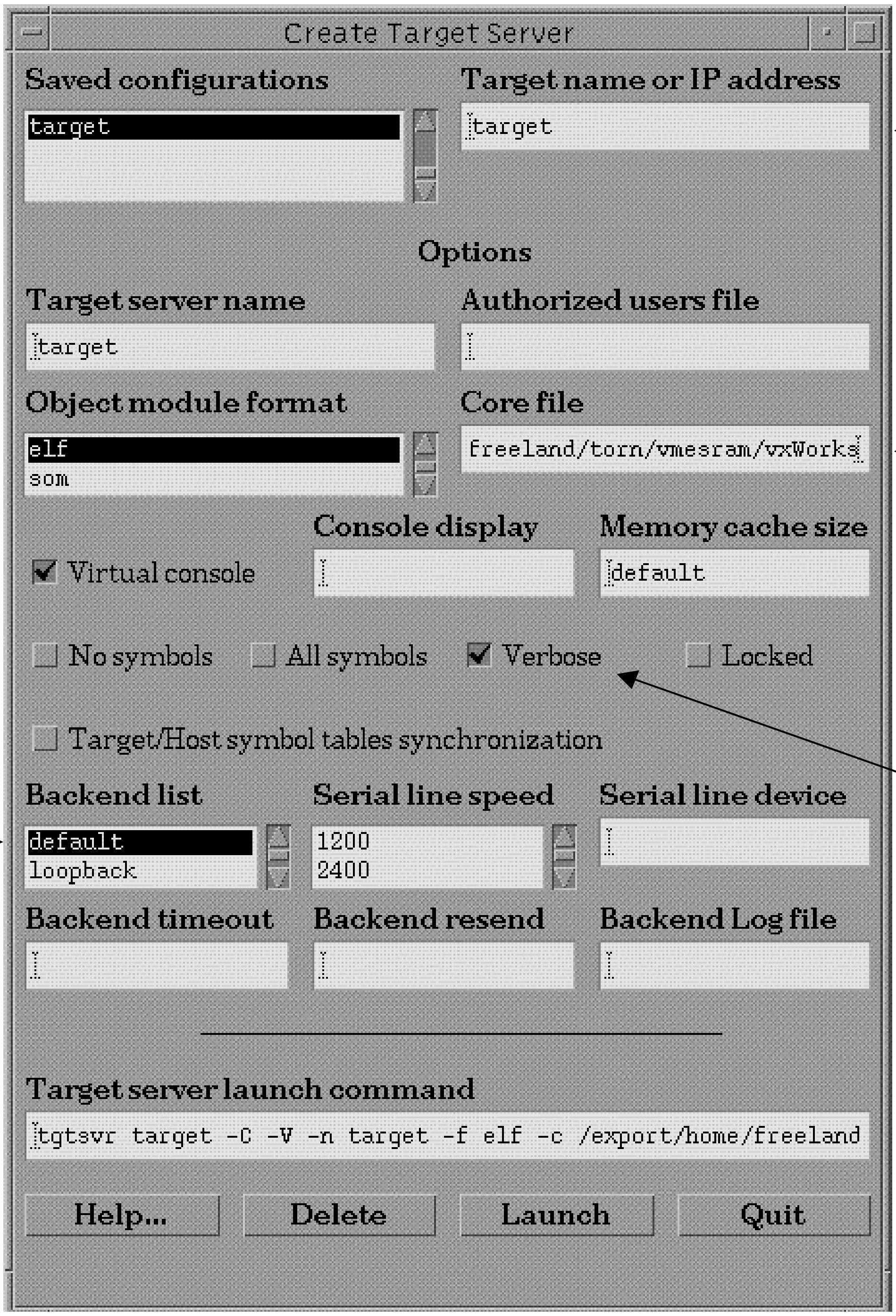
After a successful boot the next step is to configure the target server. This is done by selecting *Create* from the Target options from the Tornado launcher. Below is an example of an ethernet configuration. When this screen is filled out press the *Launch* button to start the target server.

same name as in bootline and /etc/hosts

path to vxWorks image

click for debug

select default for network backend



Saved configurations: target

Target name or IP address: target

Target server name: target

Authorized users file:

Object module format: elf [selected], som

Core file: freeland/torn/vmesram/vxWorks

[✓] Virtual console

Console display:

Memory cache size: default

[ ] No symbols [ ] All symbols [✓] Verbose [ ] Locked

[ ] Target/Host symbol tables synchronization

Backend list: default [selected], loopback

Serial line speed: 1200, 2400

Serial line device:

Backend timeout:

Backend resend:

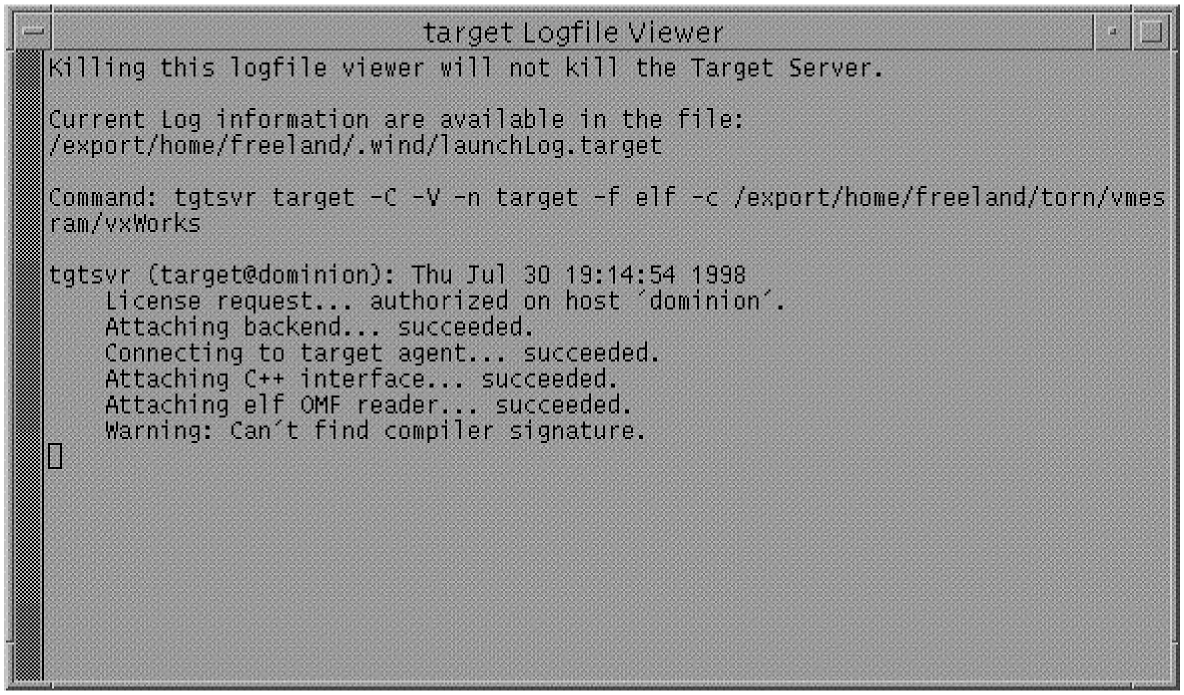
Backend Log file:

Target server launch command:

```
tgtsvr target -C -V -n target -f elf -c /export/home/freeland
```

Figure 6 Create Ethernet Target Example

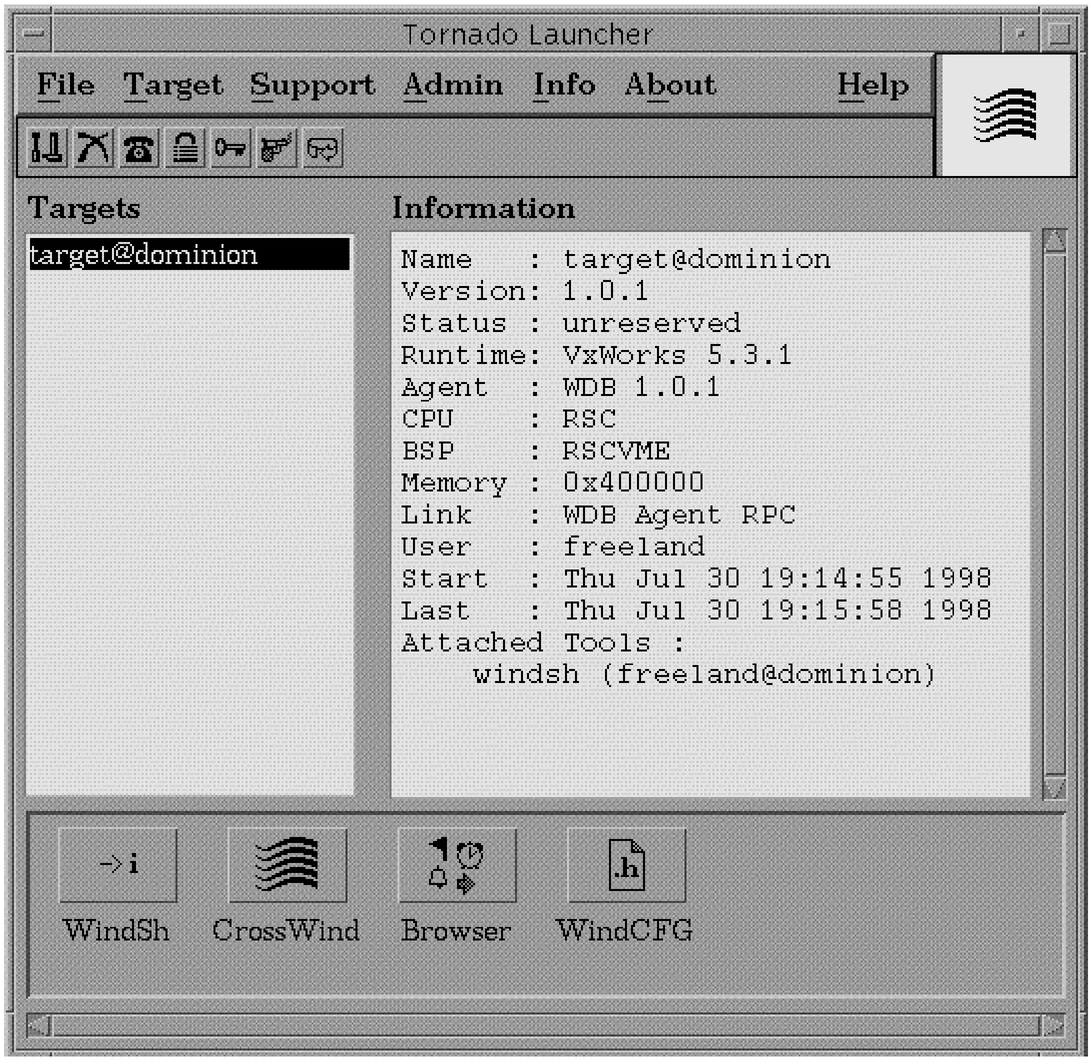
Following a successful start the following messages are displayed in the Logfile Viewer window:



```
Killing this logfile viewer will not kill the Target Server.

Current Log information are available in the file:
/export/home/freeland/.wind/launchLog.target

Command: tgtsvr target -C -V -n target -f elf -c /export/home/freeland/torn/vmes
ram/vxWorks

tgtsvr (target@dominion): Thu Jul 30 19:14:54 1998
    License request... authorized on host ´dominion´.
    Attaching backend... succeeded.
    Connecting to target agent... succeeded.
    Attaching C++ interface... succeeded.
    Attaching elf OMF reader... succeeded.
    Warning: Can´t find compiler signature.
```

Figure 7 Successful Logfile Example

At this point, the target server and agent are connected and the buttons at the bottom of the Tornado Launcher can now be used to select the Tornado tools - Windshell, Browser, or WindConfig.

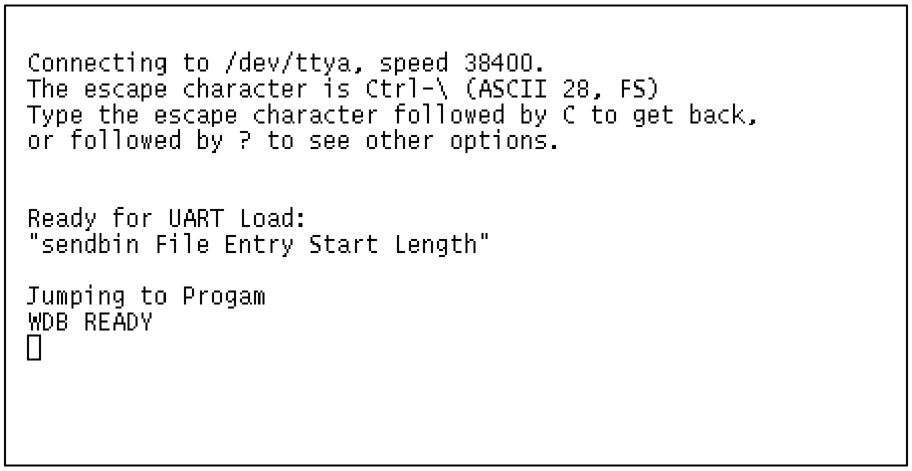


```
Name    : target@dominion
Version: 1.0.1
Status : unreserved
Runtime: VxWorks 5.3.1
Agent  : WDB 1.0.1
CPU    : RSC
BSP    : RSCVME
Memory : 0x400000
Link   : WDB Agent RPC
User   : freeland
Start  : Thu Jul 30 19:14:55 1998
Last   : Thu Jul 30 19:15:58 1998
Attached Tools :
    windsh (freeland@dominion)
```

Figure 8 Launcher Window Example

9.3 Creating a Raw Serial Target Connection

After creating a raw serial image (see 6.5.2 Serial-Line Connections) the target server will then connect to the target agent using the wdbserial backend. This is the most compact image since the VxWorks network code is not needed and allows for system-mode as well as task-mode debugging. After the binary image has been downloaded to RAD6K and booted the target agent sends the *WDB READY* message over the serial line. Below is an example of a serial window after the raw serial image has booted.

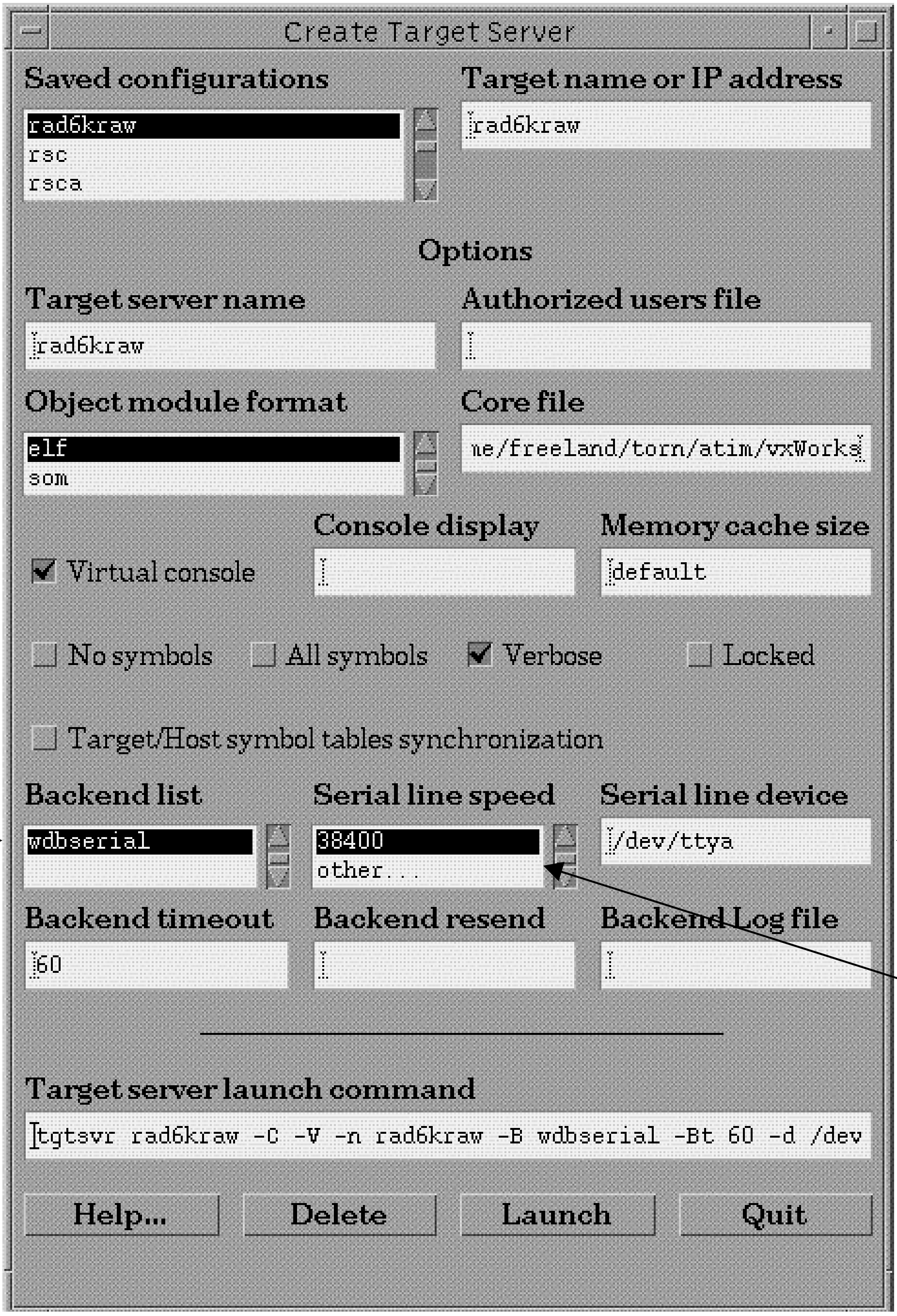


```
Connecting to /dev/ttya, speed 38400.
The escape character is Ctrl-\ (ASCII 28, FS)
Type the escape character followed by C to get back,
or followed by ? to see other options.


Ready for UART Load:
"sendbin File Entry Start Length"

Jumping to Progam
WDB READY
▯
```

Figure 9 TTY Raw Serial Example

Note: At this point, your terminal emulation software must be disconnected so that it does not interfere with the target server and agent communication.

After a successful boot the next step is to configure the target server. This is done by selecting *Create* from the Target options from the Tornado launcher. Below is an example of a raw serial configuration with a baud rate of 38400. When this screen is filled out press the *Launch* button to start the target server.


Create Target Server
Help...
Delete
Launch
Quit
select wdbserial for raw serial
name of serial port
select baud rate of UART and serial port (9600 for VME)

Saved configurations: rad6kraw (selected), rsc, rsca
Target name or IP address: rad6kraw

Options

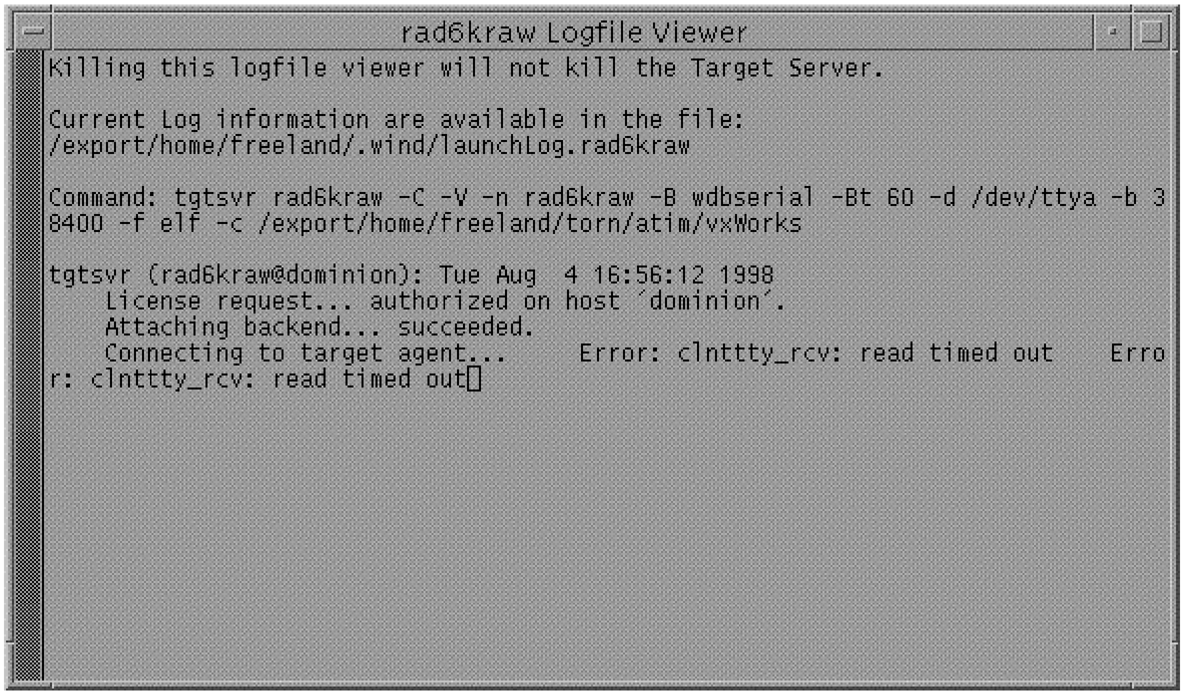
Target server name: rad6kraw
Authorized users file:
Object module format: elf (selected), som
Core file: ne/freeland/torn/atim/vxWorks
✓ Virtual console
Console display:
Memory cache size: default
☐ No symbols ☐ All symbols ✓ Verbose ☐ Locked
☐ Target/Host symbol tables synchronization
Backend list: wdbserial (selected)
Serial line speed: 38400 (selected), other...
Serial line device: /dev/ttya
Backend timeout: 60
Backend resend:
Backend Log file:

Target server launch command

```
tgtsvr rad6kraw -C -V -n rad6kraw -B wdbserial -Bt 60 -d /dev
```

Figure 10 Create Raw Serial Target Example

If you forgot to disconnect your terminal emulation program you might see a message like the following in the Logfile viewer window:



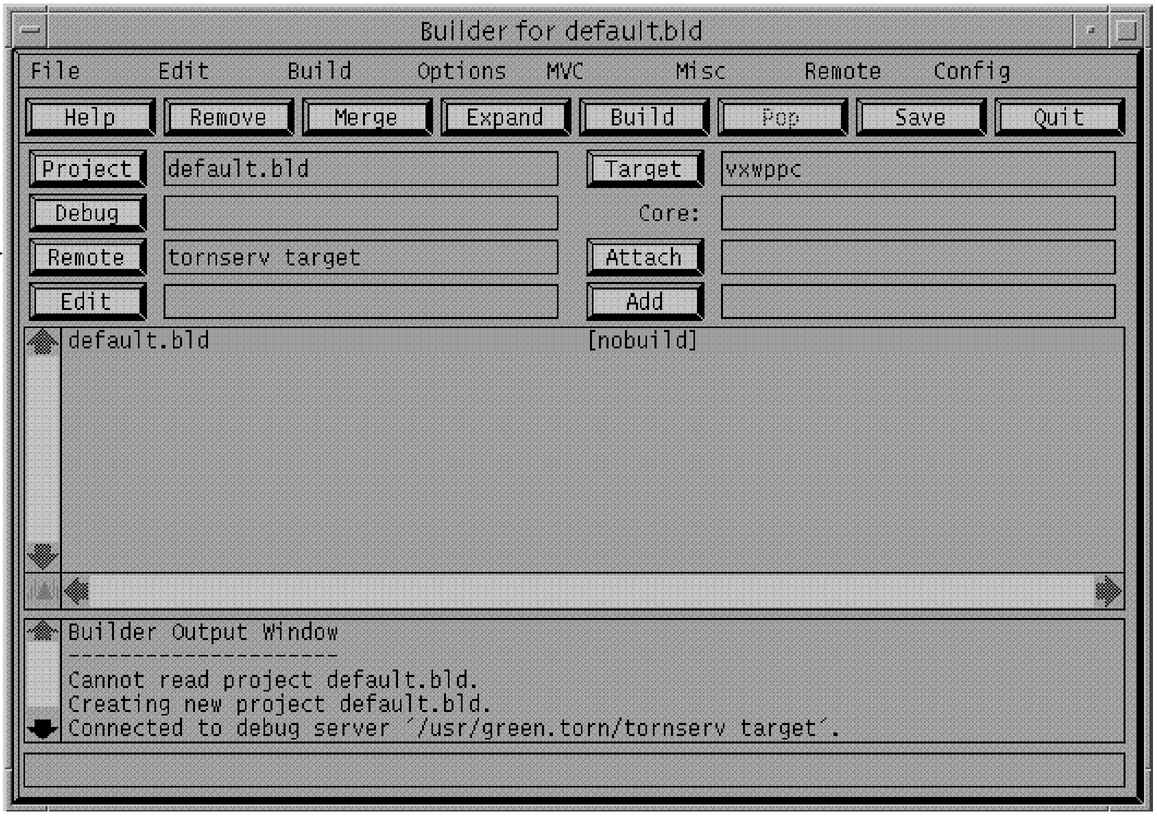
```
Killing this logfile viewer will not kill the Target Server.

Current Log information are available in the file:
/export/home/freeland/.wind/launchLog.rad6kraw

Command: tgtsvr rad6kraw -C -V -n rad6kraw -B wdbserial -Bt 60 -d /dev/ttya -b 3
8400 -f elf -c /export/home/freeland/torn/atim/vxWorks

tgtsvr (rad6kraw@dominion): Tue Aug  4 16:56:12 1998
    License request... authorized on host ´dominion´.
    Attaching backend... succeeded.
    Connecting to target agent...     Error: clnttty_rcv: read timed out    Erro
r: clnttty_rcv: read timed out
```

Figure 11 Logfile Example Showing Bad Serial Connection

Otherwise, you will see a successful set of messages as shown in the **Figure 7** Successful Logfile Example. At this point, the target server and agent are connected and the buttons at the bottom of the Tornado Launcher can now be used to select the Tornado tools - Windshell, Browser, or WindConfig as shown in **Figure 8**.

9.4 Connecting Green Hills Multi to the Target Server

Connect
to
Target
Server


Builder for default.bld
File Edit Build Options MVC Misc Remote Config
Help Remove Merge Expand Build Pop Save Quit
Project
Debug
Remote
Edit
Target
Core:
Attach
Add

```
default.bld
tornserv target
vxwppc
default.bld                                [nobuild]

Builder Output Window
---------------------
Cannot read project default.bld.
Creating new project default.bld.
Connected to debug server ´/usr/green.torn/tornserv target´.
```

Figure 12 **Connecting Multi to Target Server**

10 How to Take Advantage of RAD6000 Features

This section discusses features of the RAD6000 processor and how an application program can use VxWorks services to take advantage of these features. The first part provides an overview of the RAD6000 architecture. It is followed by a discussion of the functions provided by the VxWorks RAD6000 Board Support Package. Note that, wherever possible, the standard VxWorks BSP templates were used in implementing these functions. In these cases, you will be referred to the VxWorks documentation.

10.1RAD6000 Processor Architecture Overview

As mentioned in a previous section, the RAD6000 is a radiation–hardened version of IBM's RSC processor that was the precursor to the PowerPC. It is a 32–bit, pipelined, RISC processor capable of executing up to four instructions each cycle. This section will provide a brief overview of some of the features that are useful for developers to understand. For a more complete discussion of the RAD6000 processor and its instruction set architecture, please refer to the *POWER Processor Architecture*.

Note that throughout this section, bits are numbered using IBM notation where bit 0 refers to the most significant bit. Also, the RAD6000 stores data in memory such that the most significant byte always has the lowest address.

10.1.1 Registers

The RAD6000 has 32 fixed–point general purpose registers (GPRs), each of which is 32–bits wide; 32 floating–point registers (FPRs), each of which is 64–bits wide; and 9 special purpose registers, each of which is 32–bits wide. Detailed descriptions of these registers can be found in the *POWER Processor Architecture* document. This section will provide a brief overview of the function of some of these registers.

The contents of all of these registers can be viewed during operational debug by using either the AdaMULTI debugger or IBM's RISCWatch tool, described in Section 11.

10.1.1.1 RSC Address Space and Segment Registers(SR)

Within the RSC there are four main address spaces. They are:

- Local Memory (includes RAM, EEPROM and SUROM)
- IOCC
- EICR
- IO (VME or PCI)

There are 16 special purpose registers used to these address spaces. They are called segment registers. These registers determine what type of address space is being accessed (e.g. – memory vs. I/O, IOCC space). Each of the four address spaces is accessed using a unique segment register that is configured to properly access that particular address space. Bits 0 and 1 are system control bits defining system state. Bits 2 to 11 select system facilities such as the IOCC. Bits 12, 13 and 26 mediate IOCC operationsm while bit 24 provides access to IOCC facilities. Bits 14 to 23 and bit 27 are reserved, and bits 28 to 31 are used as an address extension for the address.

Address Space	Segment Register	Segment Register value

Local Memory	0 and 0xF	0x00000000
EICR	0xD	0x80000000 (I/O = 1)
IO (VME or PCI)	0xC	0x82000000 (I/O = 1, BUID = 0x20)
IOCC	0xE	0x82000080 (I/O = 1, BUID = 0x20, IOCC = 1)

Table 6 Segment Register Values for RSC Address Space

The other segment registers can be configured to access other address spaces such as AMB, PLASMA, and QHSS.

.

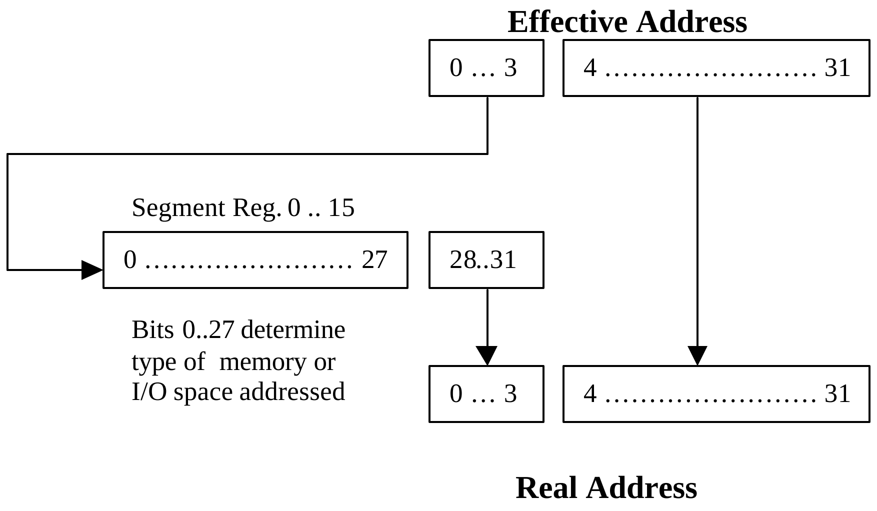


Figure 13 Converting effective address to real address

Example

```
temp = *0x70089ad0;        /*C*/
-> l  r3,0x14(r4)          # assembler load instruction
```

when r4 = 0x70089abc
and sr7 = 0x82000009

has an effective address of 0x70089ad0 and accesses address 0x90089ad0 on the I/O bus.

It's the I/O bus because of the 0x82000000 in the segment register and it's 0x90000000 because of the lower nibble of the segment register.

10.1.1.2 Generating an RSC Interrupt

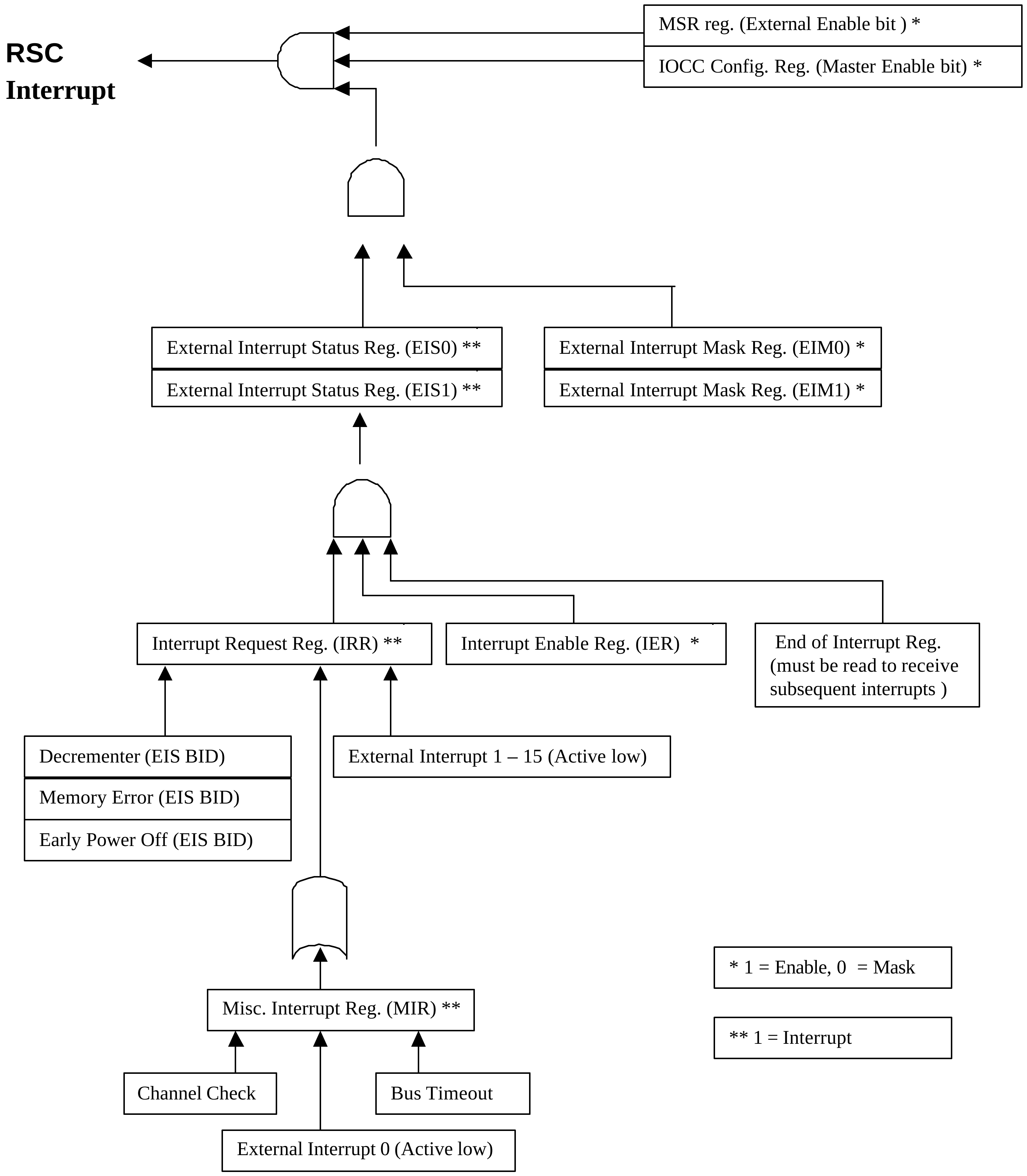

RSC
Interrupt
MSR reg. (External Enable bit) *
IOCC Config. Reg. (Master Enable bit) *
External Interrupt Status Reg. (EIS0) **
External Interrupt Status Reg. (EIS1) **
External Interrupt Mask Reg. (EIM0) *
External Interrupt Mask Reg. (EIM1) *
Interrupt Request Reg. (IRR) **
Interrupt Enable Reg. (IER) *
End of Interrupt Reg. (must be read to receive subsequent interrupts)
Decrementer (EIS BID)
Memory Error (EIS BID)
Early Power Off (EIS BID)
External Interrupt 1 – 15 (Active low)
Misc. Interrupt Reg. (MIR) **
Channel Check
Bus Timeout
External Interrupt 0 (Active low)
* 1 = Enable, 0 = Mask
** 1 = Interrupt

Figure 14 Generating RSC Interrupts

10.1.1.3 Address Spaces

10.1.1.3.1 Memory Address Space (RAM and SUROM)

Segment Reg. 0	**Effective Address 0xxxxxxx**	Segment Reg = 00000000
Segment Reg. 0xF	**Effective Address Fxxxxxxx**	Segment Reg = 00000000

Typical Usage:

00000000	Unused by OS, SUROM Status Area
00000100	Interrupt Vector Table
00002000	Unused by OS, SUROM Workspace
00002700	bootline, exc panic
00003000	Unused by OS, used for I/O Driver Data
00008000	HAT (for a min configuration)
00010000	PFT (for a min configuration)
00020000	TCW (32 K)
00050000	VxWorks & User Code and Data
___________ _	LIO RAM Size (S1) = 00400000
00400000	End of populated memory (4MB typical)
08000000	End of addressable real memory (128MB)
___________ _	
fff00000	SUROM
___________ _	LIO SUROM Size (S3) = 00010000
fff10000	End of populated SUROM (64KB typical)
fff80000	End of populated SUROM (128KB max)

10.1.1.3.2 IOCC Address Space (RAD6000 & LIO Regs)

Segment Reg. 0xE	**Effective Address 0xExxxxxxx**	Segment Reg = 82000080

Usage:

00000000	LIO Registers
00000400	Primary PCI
00010000	RAD6000 Registers
00500000	End of utilized addresses

10.1.1.3.3 EICR Address Space (RAD6000 Interrupt Regs)

Segment Reg. 0xD **Effective Address 0xDxxxxxxx** Segment Reg = 80000000

Usage:

00000000	RAD6000 Registers
00000040	End of utilized addresses

10.1.1.3.4 PCI I/O Address Space

Segment Reg. 0xC **Effective Address 0xCxxxxxxx** Segment Reg = 82000000

Segment Reg. n **Effective Address nxxxxxxx** Segment Reg = 8200000m
(where n is segment 1 to b, and m is between 1 and f)

Usage:

00000000	LIO and RAD6000 Registers (1K)
00000400	PCI Primary I/O Space Registers on PCI chips are mapped here
____________ _	LIO RAM Size (S1) = 00400000
00400000	End of PCI Primary PCI Space (Typical)
____________ _	LIO Base Address (BA2) = C0000000
c0000000	Start of Extended PCI I/O Space (Typical) Some chips, such as PLASMA, have address ranges here
ffffffff	End of Extended PCI I/O Space

10.1.1.3.5 PCI Memory Address Space

Segment Reg. 0xC **Effective Address 0xCxxxxxxx** Segment Reg = 82000000

Segment Reg. n **Effective Address nxxxxxxx** Segment Reg = 8200000m
(where n is segment 1 to b, and m is between 1 and f)

Usage:

00000000	RAD6000 RAM for 1p DMA
____________ _	LIO RAM Size (S1) = 00400000
00400000	End of populated memory (4MB typical)
00400000	PCI Memory Space Smaller address ranges are mapped here such as SuMMIT RAM
10000000	PCI Memory Space Larger address ranges are mapped here such as AMB & PLASMA
____________ _	LIO Base Address (BA2) = C0000000

Usage:

C0000000	End of PCI Memory Space (Typical)

10.1.1.3.6 EICR Addressable Registers

00000000 EIM0 (External Interrupt Mask 0..31)

00000004 EIM1 (External Interrupt Mask 32..63)

Bit 0 is msb, bit 31 is lsb, when a bit is 0 then the corresponding interrupt level is masked from interrupting the RAD6000 instruction flow. When a bit is 1, then the corresponding interrupt level will interrupt the RAD6000 when the interrupt becomes set in the EIS register.

00000008 EESR (External (DMA) Error Status)

0000000C EEAR (External (DMA) Error Address)

External errors detected by the RAD6000 are reported to the EESR. The address causing the error is reported to the EEAR. The first occurrence of the error is kept in the registers until they are read. Once read they may be updated by the hardware.

EESR [3] = AD	DMA Address Exception (out of range)
EESR [4] = UD	Uncorrectable ECC error on DMA
EEAR [0..7]	Syndrome of from ECC of erroneous 8-byte word
EEAR [8..31]	Effective address of erroneous 8-byte word divided by 8

00000010 EIS0 (External Interrupt Status)

00000014 EIS1 (External Interrupt Status)

External interrupts to the RAD6000 are reported to the EIS so that the external interrupt handler can determine which interrupt level is active.

00000018 MESR (Machine Check Error Status)

0000001C MEAR (Machine Check Error Address)

Memory errors detected by the RAD6000 are reported to the MESR. The address causing the error is reported to the MEAR. The first occurrence of the error is kept in the registers until they are read. Once read they may be updated by the hardware.

Note: A machine check clears the Machine Check Enable bit (ME) in the Machine State Register (MSR). Software must set it back to a one to enable the next machine check. The occurrence of a machine check condition while this bit is clear will result in a Checkstop (RAD6000 stops execution).

MESR [0] = DTM	Error occurred while in diagnostic mode
MESR [1] = LS	Processor load or store (not DMA)
MESR [3] = AE	Address exception (out of range)
MESR [4] = SR	Attempted store to SUROM
MESR [5] = UE	Uncorrectable ECC error
MEAR [0..7]	Syndrome of from ECC of erroneous 8-byte word
MEAR [8..31]	Effective address of erroneous 8-byte word divided by 8

00000020 DEB (Decrementer EIS Bit ID)

The RAD6000 decrementer interrupts when it counts down to zero and rools over to 0xffffffff. It defaults to exgternal interrupt level 0, but can be moved to another level by writing to this register. The value of this register is the interrupt level used by the decrementer. Valid values are 0 to 63.

00000024 MEEB (Memory Error EIS Bit ID)

The RAD6000 reports machine check (memory) errors and single bit errors as external interrupts when in diagnostic mode. The value of this register is the interrupt level used. Valid values are 0 to 63.

00000028 SBSR (Single Bit Error Status)

0000002C SBAR (Single Bit Error Address)

Single bit (correctable) memory errors detected by the RAD6000 are reported to the SBSR. The address causing the error is reported to the SBAR. The first occurrence of the error is kept in the registers until they are read. Once read they may be updated by the hardware.

SBSR [0] = CE	Correctable ECC error
SBAR [0..7]	Syndrome of from ECC of erroneous 8-byte word
SBAR [8..31]	Effective address of erroneous 8-byte word divided by 8

00000030 SCCR (Storage Control Reg)

Operation in diagnostic mode results in the generation of an external interrupt for memory related machine check errors and for single bit errors. Cache and ECC checking can be disabled for testing purposes.

SCCR [0]	Diagnostic Mode
SCCR [2..3]	Invert address bits 6..7 respectively
SCCR [4]	Disable RAD6000 cache
SCCR [5]	Disable extenal cache (not used)
SCCR [6]	Invert address parity on reads
SCCR [7]	Disable ECC checking on reads

00000034 EPOWEB (Early Power Warning EIS Bit ID)

The RAD6000 has an external interrupt line reserved for power-off warnings. It is usually tied inactive. If used (possibly for other purposes) it can be mapped to any interrupt level. Valid values are 0 to 63.

10.1.1.3.7 IOCC Addressable Registers

00400010 Configuration Reg – VME configuration

The IOCC design allows variations and performances that optimize its usage across multiple machine environments. This register establishes the specific personalization.

CR[0] = ME	Master Enable – must be set to receive any interrupt
CR[1]	Reserved
CR[2..3]	Clock Control – The RBI interprets this field depending on the setting of bit 14. When bit 14 is zero (configuration data applies to PIO operations), this field represents “turbo” clock control. When the value stored is ’01’ the CPU runs at the oscillator frequency divided-by-2 (usually 20 MHz), overriding the value in the Clock Control field (bit 15) (Bread Board only). The other values of ‘00’ and ‘1x’ have no effect; the CPU frequency stays as defined by bit 15. On the EM/Flight

configuration, the system clock frequency is controlled as specified in the description for bit 15.

When bit 14 is a one (configuration data applies to 3P DMA operations), the RBI takes this field as the most significant bits of the VMEbus address modifier code for third party DMA. In the RVIO architecture, the processor controls the VMEbus until the PIO transfer completes, regardless of whether another device wants the bus.

CR[4..5]	AML – used as the least significant two bits of the VMEbus modifier code for third party DMA or PIO depending on the setting of bit 14
CR[6-7]	LIM – used as third party DMA data width when bit 14 is a one.
CR[8]	Reserved – must be 0
CR[9..11]	TCW Table size - in the RVIO, the card ID and VMEbus Slave / Address Control register are implemented such that the TCW extent cannot be exceeded. Therefore, the RBI ignores this field.
CR[12]	Reserved
CR[13]	Bus hold / 3P K bit - When bit 14 is a zero, this bit is used by the RVIO to retain ownership of the VMEbus between transfers (bus hold). When bit 14 is a one, the RBI passes this bit on to the IOC as the privilege bit for third party DMA.
CR[14]	PIO / 3P Select – The RBI uses this bit to define whether the AML and LIM bits (bits 4 through 7) are being set for PIOs (when bit 14 = 0) or third party DMA (when bit 14 = 1).
CR[15]	Clock Control – The RBI uses this bit with bits 2 and 3 to control the system clock rate with 0 (reset state) indicating quarter speed (divide-by-8, 5 MHz) and 1 indicating half speed clock (divide-by-4, 10 MHz) for the Bread Board. For EM / Flight, 0 indicates divide-by-16 (2.5 MHz) and 1 indicates divide-by-8 (5 MHz) if bits 2-3 = 00 or 1x. If bits 2-3 = 01 then 0 indicates divide-by-4 (10 MHz) and 1 indicates divide-by-2 (20 MHz).
CR[16-31]	Reserved

00400010 Configuration Reg – ASCM / LIO configuration

The IOCC design allows variations and performance that optimize its usage across multiple machine environments. This register establishes the specific personalization. This register is set up by hardware and SUROM code.

CR[0] = ME	Master Enable – must be set to receive any interrupt
CR[1]	Reserved
CR[2..3]	Master PCI Bus Timeout Error Control: 00 – 256 PCI Clock Cycles 01 – 512 PCI Clock Cycles 10 – 1024 PCI Clock Cycles 11 – 2048 PCI Clock Cycles
CR[4]	PCI Bus Timeout Error Checking Disable – when this bit is set to a one the LIO disables checking for PCI Bus Timeouts and PCI Data Phase Timeout errors.

	CR[5]	Error Holdoff Function Disable – When this bit is to a one the Error Holdoff Function is disabled.
	CR[6]	RSC I/O Bus Data Parity Checking Disable – When this bit is set to a one the LIO ignores parity errors detected on the RSC_I/O_DA_BUS.
	CR[7]	Wrap Enable – this bit determines whether IOCC Mode PIOs to internal architected registers should be handled internally or externally via the PCI Bus for diagnostic purposes. 0 – PIO executed internally 1 – PIO executed as PCI Bus operations (writes are subject to same restrictions as external PCI masters).
	CR[8]	Reserved
	CR[9..11]	TCW Table size - in the RVIO, the card ID and VMEbus Slave/Address Control register are implemented such that the TCW extent cannot be exceeded. Therefore, the RBI ignores this field.
	CR[12-14]	Reserved
	CR[15]	DMA Master Enable – This bit shall be used as master enable for first party DMA transfers. 0 = 1P DMA disabled for all channels 1 = 1P DMA not globally disabled, individual channel enables controlled by DMA Enables register.
	CR[16-31]	Reserved
00400024	TCW Anchor Reg	
00400040	I/O Limit Reg	
004y0060*	Channel Status Reg – VME bus master / ASCM LIO configurations	
	CSR[0-3]	Control and Status – This field contains control and status and may be set by both the control program or the IOCC. Values between x’0-3’ are control channel operations while values between x’4-15’ are error codes. Bit 3 is controlled by channel enable and disable commands (see reg. 004y0070 below).
	CSR[4] for	DMA Slave Flag – this bit is set to a value of 0 to personalize a channel bus master data transfer operation.
	CSR[5]	Reserved
	CSR[6]	Prevent Channel Disable on Error
	CSR[7-11]	Reserved
	CSR[12-15]	Buffer Number
	CSR[16-23]	Authority Mask
	CSR[24-31]	Reserved
004y0060*	Channel Status Reg – VME bus slave	
	CSR[0-3]	Control and Status – This field contains control and status and may be set by both the control program or the IOCC. Values between x’0-3’ are control channel operations while values between x’4-15’ are error codes. Bit 3 is controlled by channel enable and disable commands (see

reg. 004y0070 below).

CSR[4] Reserved

CSR[5] System Memory – this bit selects whether system memory or bus memory is to take part in a DMA slave transaction. 1 = DMA slave transfers to system memory and 0 = DMA slave transfers to bus memory.

CSR[6] Enable Terminal Count Flag

CSR[7] Direction Flag – this bit selects the direction of a DMA slave transfer. 0 = transfer data from memory to the I/O device, 1 = transfer data from the I/O device to memory.

CSR[8-19] Next Tag Field

CSR[20-31] Length Count Field – this field contains a length count for the data transfer.

004y0064* DMA Address Reg – VME bus master

N/A

004y0064* DMA Address Reg – VME bus slave

This register contains the VME bus memory address for the DMA slave operation.

004y0068* Channel Buffer Invalid Reg

N/A - this register exists only for buffered mode implementations

004y0070* Channel Enable(load)/Disable(store)

This register allows system initiation and suspension of DMA slave and bus master operations. The **enable** command initializes a channel to accept requests by changing the channel status field in the Channel Status register from the disabled (B’00x0’) state to the enabled (Bx’00x1’) state. This command is coded as a load instruction. The **disable** command initializes a channel to disables operation for a particular channel by changing the channel status field in the Channel Status register from the enabled (B’00x1’) state to the disabled (Bx’00x0’) state. This command is coded as a store instruction (data is ignored).

004y0078* DMA Slave Buffer Flush

N/A - this register exists only for buffered mode implementations

00400080 Interrupt Enable Reg (IER)

00400084 Interrupt Request Reg (IRR)

00400088 Misc Interrupt Reg

0040008C End Of Interrupt Reg (EOI)

Following presentation of an I/O interrupt to the system External Interrupt Source (EIS) register, the IOCC automatically masks off that interrupt so the presentation is only made once. An end of interrupt command re-enables this mask, causing any active interrupts to be presented to the system EIS register. On a store the data is ignored, on a load the data is indeterminate. This command should be issued at the end of all Interrupt Service Routines (ISR).

00400004 Ack Interrupt, VMEbus SYSFAIL Interrupt

00410004	Ack Interrupt, VMEbus IRQ1 Interrupt
00420004	Ack Interrupt, VMEbus IRQ2 Interrupt
00430004	Ack Interrupt, VMEbus IRQ3 Interrupt
00440004	Ack Interrupt, VMEbus IRQ4 Interrupt
00450004	Ack Interrupt, VMEbus IRQ5 Interrupt
00460004	Ack Interrupt, VMEbus IRQ6 Interrupt
00470004	Ack Interrupt, VMEbus IRQ7 Interrupt
00480000	SUROM Remap Reg
00480004	Real-Time Interrupt Control Reg (Aux clock)
00490004	VMEbus Slave A32 Control
004A0004	VMEbus Slave A24 Control
004B0004	VMEbus Interrupt Register
00C00000	TCW Table, 1 MB of memory mapped to I/O space by TCW Anchor Register

* y = 0 - f

10.1.1.4 Machine State Register (MSR)

The MSR is arguably the most important register to the RAD6000, as it defines the operational state of the processor. It is generally not of interest to application program developers as its state is maintained by VxWorks. However, an understanding of it is necessary while developing and debugging start–up code, interrupt handlers, and device drivers. It can also help in tracking down unexpected problems.

Table 7 provides a list of all of the bits of the MSR and their valid values. You will probably want to refer back to this table in later sections as the effects of these bits on various RAD6000 features is explained.

Bit(s)	Name	Value	Result
0–15	Reserved		
16	External Interrupt Enable (EE)	0	External interrupts are disabled.
		1	External interrupts are enabled.
17	Program State (PR)	0	Privileged instructions are allowed.
		1	Privileged instructions are invalid.
18	Floating–Point Available (FP)	0	Floating–point instructions are invalid.
		1	Floating–point instructions are allowed.
19	Machine Check Enable (ME)	0	Machine check interrupts are disabled.
		1	Machine check interrupts are enabled.
20	Floating–Point Exception Interrupt Enable (FE)	0	Program interrupts for floating–point enabled exception are disabled.
		1	Program interrupts for floating–point

Bit(s)	Name	Value	Result
			enabled exception are enabled.
21–23	Reserved		
24	Alignment Check (AL)	0	Alignment checking is disabled.
		1	Alignment checking is enabled.
25	Interrupt Prefix (IP)	0	The interrupt table is located at 0x00000000.
		1	The interrupt table is located at 0xFFF00000.
26	Instruction Relocate (IR)	0	Instruction address translation is disabled.
		1	Instruction address translation is enabled.
27	Data Relocate (DR)	0	Data address translation is disabled.
		1	Data address translation is enabled.
28-31	Reserved		

Table 7 Machine State Register

10.1.2 Interrupts

The RAD6000 uses a table in memory that is 0x1F00 bytes long to determine how to respond to an interrupt. Each entry in the table is 0x100 bytes long and corresponds to one of the available interrupt types. When the processor takes an interrupt of a given type, it branches directly to the address associated with that entry.

This interrupt table can be located in either ROM space or RAM space, depending on the state of the Interrupt Prefix (IP) bit (bit 25) of the Machine State Register (MSR). If this bit is set to 1, the interrupt table is in ROM space and starts at address 0xFFF00000. If it is set to 0, the interrupt table is in RAM space and starts at address 0x00000000. Note that the first 0x100 bytes of this table are not used by the processor itself, although the VxWorks operating system may use some of these addresses. **Table 8** shows the address offset from the beginning of the table for each type of interrupt. The remaining addresses (0x900 - 0x2000) are reserved and must not be used.

Offset	Type	Description
0x100	System Reset Interrupt	Executes in response to RAD6000 hardware reset.
0x200	Machine Check Interrupt	Executes in response to uncorrectable memory errors only if the Machine Check Enable (ME) bit (bit 19) of the MSR is set to 1.
0x300	Data Storage Interrupt	Executes in response to errors during a data load or store, such as I/O access errors or memory protection violations.
0x400	Instruction Storage Interrupt	Executes in response to errors during an instruction fetch, such as a memory protection violation.
0x500	External Interrupt	Executes in response to an external interrupt.
0x600	Alignment Interrupt	Executes in response to an unaligned data access only if the Alignment Check (AL) bit (bit 24) of the MSR is set to 1.
0x700	Program Interrupt	Executes in response to unrecognized, invalid, or privileged

Offset	Type	Description
		instructions.
0x800	Floating Point Unavailable Interrupt	Executes in response to the execution of any floating–point instruction only if the Floating–Point Available (FP) bit (bit 18) of the MSR is set to 1.

Table 8 Interrupt Offsets and Descriptions

When the processor takes an interrupt, it performs the following steps:

1. Places the address of the current or next instruction, depending on the type of interrupt, into SRR0.

2. Places interrupt–specific information into bits 0–15 of SRR1.

3. Places a copy of bits 16–31 of the MSR into bits 16–31 of SRR1.

4. Sets certain bits of the MSR to specific states, depending on the type of interrupt.

5. Branches to the entry in the interrupt table corresponding to the type of interrupt.

VxWorks provides default interrupt handlers for all of these interrupt types and you will probably not need to replace them. If you do decide to replace them, refer to the *POWER Processor Architecture* document for details on each type of interrupt processing.

However, you may want to write your own interrupt handlers for external interrupts. The Board Support Package you are using will come with default interrupt handlers for all of the attached external devices, such as the serial bus, VMEbus, etc. However, you may want to replace these and / or write interrupt handlers for external devices you attach to your RAD6000. The RAD6000 supports up to 16 external interrupts, mapped to one of 64 interrupt levels. When an External Interrupt occurs, the processor branches to offset 0x500 of the interrupt table as described above. This handler saves the machine context and then reads the External Interrupt Status (EIS) register to determine which external interrupt occurred. If an interrupt handler for that interrupt is installed, it is then called as a subroutine from the External Interrupt handler. When that handler returns, the External Interrupt handler restores the machine context and returns to the interrupted code.

10.2The RAD6000 Board Support Package

This section describes the functions provided with all RAD6000 BSPs. Some BSPs support additional functionality, as appropriate for that board. These functions, if available, are documented in an appendix to this document.

10.2.1 External Interrupts

If you are familiar with VxWorks, you are probably familiar with the VxWorks routine **`intConnect`**, which is normally used to attach an interrupt service routine (ISR) to an external interrupt. On the RAD6000, however, that routine is reserved solely for VME–based BSPs. Other BSPs use the function **`sysIntConnect`**. This routine expects the interrupt level and the address of the ISR to be given as parameters.

Ada Syntax:

```
function sysIntConnect (
           intLevel    : integer
           functionPtr : system.address)
  return Status;
```

C Syntax:

```
STATUS sysIntConnect (
        int   intLevel,
        void *Handler);
```

```
N.B. If you are using this routine to connect your ISR to an external interrupt
you must read the IOCC End of Interrupt register at the end of your ISR to
receive subsequent interrupts.

C Syntax:
  temp = *IOCC_EOI;

Ada Syntax:
  temp := rscFns.IOCC_End_Of_Int;
```

To disable an external interrupt, use the function **`sysIntDisable`**, passing in the interrupt level as a parameter.

Ada Syntax:

```
function sysIntDisable (
          intLevel : integer)
  return Status;
```

C Syntax:

```
STATUS sysIntDisable (
        int intLevel);
```

To enable an external interrupt, use the function **`sysIntEnable`** passing in the interrupt level as a parameter.

Ada Syntax:

```
 function sysIntEnable (
           intLevel : integer)
   return Status;
```

C Syntax:

```
STATUS sysIntEnable (
        int intLevel);
```

10.2.2 Serial Port I/O

The serial I/O device driver, located in the file “tyCoDrv.c” in your BSP directory, follows the standard VxWorks conventions. During initialization, VxWorks by default maps the serial port to stdin, stdout, and stderr, which allows application programs to use the C stdio library without any additional setup.

In addition, several board–specific ioctl() requests have been added. These are:

FIOASYNCGETLCR	Places the current value of the Line Control Register (LCR) in the variable pointed to by arg.
FIOASYNCSETLCR	Sets the value of the LCR to arg.
FIOASYNCGETMCR	Places the current value of the MODEM Control Register (MCR) in the variable pointed to by arg.
FIOASYNCSETMCR	Sets the value of the MCR to arg.
FIOASYNCGETMSR	Returns the current value of the MODEM Status Register (MSR) in the variable pointed to by arg.

For more information about the VxWorks serial I/O device driver, refer to the VxWorks documentation.

10.2.3 DMA I/O

The RAD6000 supports both slave and master DMA operations. In order to take advantage of DMA I/O, the Translation Control Word Table (TCW) must have been properly configured when VxWorks was built. Refer to 6.5.3 to learn how to do this.

Note that the VME–based RAD6000 BSP supports slightly different functionality than other BSPs. See the appropriate appendix for more information.

10.2.3.1 TCW Table Management

The TCW table is used by the RAD6000 to map bus addresses to local addresses for DMA operations. During initialization, **sysHwInit** calls a routine to initialize the TCW table. This routine invalidates all of the TCW entries. Before doing any DMA operations, the proper TCW entries must be set up. The following routines have been provided to help application programs manage this resource:

```
STATUS sys[Vme]TcwMap (
        void *busAdrs,
        void *localAdrs,
        int   pages,
        int   protection);
```

This routine maps the given number of 4 Kbyte pages of I/O memory starting at *busAdrs* to local memory starting at *localAdrs*. Both addresses must be on page boundaries. The *protection* parameter should be either TCW_READ_ONLY or TCW_READ_WRITE. These values are defined in the “rscvme.h” header file located in your BSP directory.

```
STATUS sys[Vme]TcwInvalidate (
        void *busAdrs,
        int   pages);
```

This routine invalidates TCW entries that are no longer being used.

Note that both of these routines will return ERROR if the TCW table is not large enough to map the given bus address. Refer to Section 6.6.3 for instructions on how to set the size of the TCW.

10.2.3.2 Slave (1P) DMA

Not much has to be done for DMA operations in which the RAD6000 is not the master. During initialization, the board is configured to allow Slave (1st Party) DMA operations. However, until I/O address space has been mapped to local memory using **sysTcwMap** as described above, the RAD6000 will not respond to Slave DMA requests on the bus. In addition, the following two routines are provided:

```
void sys[Vme]1pDmaEnable (void);
```

This routine enables the 1st party DMA channel to allow 1st party DMA to occur.

```
void sys[Vme]1pDmaDisable (void);
```

This routine disables 1st party DMA.

Note that the initialization enables Slave DMA operations, so **sys1PDmaEnable** need only be called if **sys1PDmaDisable** has been previously called.

10.2.3.3 DMA Status

The following routine can be called by application programs to determine the status of either the Master or Slave DMA channels:

```
unsigned long sys[Vme]DmaStatus (
               int party);
```

The *party* parameter must be either DMA_1P or DMA_3P[2], both of which are defined in "rscvme.h" or "rad6k.h". The routine returns the contents of the requested status register.

10.2.4 Timers

The timer library follows the standard VxWorks template. The RAD6000's internal timer (also known as the Decrementer) is used for the VxWorks system clock. The RBI timer is used for the auxiliary clock. By default, the system clock runs at 60 hz and the auxiliary clock at 100 hz.

For more information on the VxWorks timer routines, refer to the VxWorks documentation. For more information about the RAD6000's Decrementer, refer to the *POWER Processor Architecture* document.

10.2.5 Cache

The cache library follows the standard VxWorks conventions. However, the RAD6000's cache is write-through and can never be disabled. Therefore, the only routine in this library that actually does any work is cacheInvalidate. However, since all DMA operations go through the cache anyway, even this routine should never need to be called. This library is provided solely for compatibility with VxWorks programs written for other platforms. For more information, refer to the VxWorks documentation.

[2] Third party DMA is only supported in the RAD6K VME configuration

10.2.6 Memory Protection

The RAD6000 BSP does not have the standard VxWorks memory management library. Instead, support has been added to provide page level memory protection of RAM. Because all memory protection on the RAD6000 is implemented through its Virtual Memory Management Unit, VxWorks runs on the RAD6000 with virtual addressing. However, each virtual address has been mapped directly to the same physical address, so there is no need to provide routines to convert between virtual and physical addresses. The memory management tables are initialized during **sysHwInit** and virtual addressing is turned on at that time. All pages of memory are initialized to allow both read and write accesses. To change the protection for a given page, the following routine is provided:

```
STATUS rscSetPageProtect (
        void *pageAdrs,
        int   protection);
```

This routine sets the level of memory accesses that are to be allowed for the given page. The protection parameter should be PAGE_READ_ONLY or PAGE_READ_WRITE. Attempting to write to a page that has been set to PAGE_READ_ONLY will cause a Data Storage Interrupt.

11 Debugging with RISCWatch

11.1Using the RISCWatch tool

RISCWatch is a commercially available tool (made by IBM) to interact with the RSC or RAD6000 chip directly. It provides machine level debug capabilities. RISCWatch for the RAD6000 is only available on RS/6000 platforms with Microchannel busses NOT a PowerPC.

RISCWatch comes with installation instructions and a User Reference Manual. The installation instructions are accurate. The Reference Manual is accurate, except for the section on Rexx language support. This version does not support Rexx scripts.

If your RAD6000 board runs at less than 5 MHz system clock frequency, replace the oscillator on the RISCWatch Microchannel adapter board with a slower one. Lockheed Martin has had good results with a 2.54 MHz oscillator in place of the 12.5 MHz. This will greatly slow screen updates when using RISCWatch, but it is necessary if your board runs at very slow frequencies. One way to minimize delay is to use the tty screen for inputting commands and only updating displays when necessary.

Once RISCWatch is installed and /usr/lpp/dash/bin is on your path (as directed during installation), you can start it up.

```
+------------------------------------------------------------------------
=>dash
Choose option 5, RSC2.3 with NO Indus
> setclock 4
+------------------------------------------------------------------------
```

When RISCWatch starts it runs a profile if it is available in the local directory. It must be named ”profile.x”. You may place commands always preformed in this file. One of these should be ”setclock 4” which slows the clock on the Microchannel adapter and provides reliable interaction. RISCWatch will also run a file called fkeys1.x if it is available. Use this to define fkeys as you like.

```
 +------------------------------------------------------------------------
  | e.g. profile.x
  |   setclock 4
  |   TBD
  |
  | e.g. fkeys1.x
  |   TBD
  |
 +------------------------------------------------------------------------
```

Ok, so what can you do with RISCWatch?

```
 +------------------------------------------------------------------------
  | Ctl/Action (Rt. Ctl key) Switch from command line to screen interaction
  | bp x’addr’               Set breakpoint at address, one breakpoint at a time
  | disasm                   Display memory contents as disassembled code
  | load                     Load an object file in XCOFF format, sorry no EABI
  | mema                     Display or update memory contents
  | ocs off                  Establish RISCWatch control of RAD6000
  | ocs on                   Disable RISCWatch control of RAD6000
  | rscreg                   Displays general and special RAD6000 registers
  | run                      Start execution
  | step                     Execute one instruction
  | stop                     Stop execution
 +------------------------------------------------------------------------
```

RISCWatch cannot update special purpose registers directly including the program counter due to the pipelined nature of the RAD6000 processor.

In order to load an XCOFF program and execute it via RISCWatch it is necessary to do the following:

```
+------------------------------------------------------------------------
 | e.g. Load XCOFF file ”test” which was compiled and linked to 0x1000
 |   > load test                    (load program)
 |   > alter x’100’ x’48001002’     (place jump to 0x1000 at reset vector)
 |   > rscinit                      (reset RAD6000 and get it ready to run)
 |   > run                          (execute program)
+------------------------------------------------------------------------
```

Sometimes you may want to have RISCWatch physically attached, but not use it to control the RAD6000 processor. You may disable control with:

```
+------------------------------------------------------------------------
 | > osc on                 (enables RAD6000 On Chip Sequencer, OCS)
+------------------------------------------------------------------------
```

To reestablish control over the RAD6000:

```
+------------------------------------------------------------------------
 | > osc off                (disables RAD6000 On Chip Sequencer, OCS)
+------------------------------------------------------------------------
```

Two things to note: ”ocs off” during execution often destroys the state of some RAD6000 special registers, although you can often tell what was going on from the remaining registers. The ”ocs on/off” state stays set in the adapter board even after RISCWatch is exited.

```
+------------------------------------------------------------------------
 | If you start RISCWatch and cannot access the RAD6000, but you believe
 | it is properly connected, try ”ocs off” before panicking.
+------------------------------------------------------------------------
```

There is a reliable way to run programs without constant RISCWatch interaction, but allowing you to break in, poke around, and restart the processor. All internal clocks stop along with the execution, so the RAD6000 can be restarted without knowing it was stopped. Any external I/O that has not been independently halted will continue to cause interrupts that the RAD6000 cannot handle while stopped.

Speaking of interrupts, that is just where RISCWatch is most handy. When installing a new interrupt handler, it is likely to contain a bug or two as all untested programs do. If that handler fails such that other interrupts cannot be handled, the debugger, shell, and network all stop. RISCWatch can interact with the RAD6000 allowing you to stop execution, step through the handler and test without relying on ”hang the computer, try again” debugging methods.

```
+-----------------------------------------------------------------------------
 | Starting the RAD6000 processor via RISCWatch:
 |   Attach RISCWatch
 |   > ocs off
 |   Reset RAD6000 processor
 |   > alter x'100' x'4bf00102'       (place jump to SUROM reset vector)
 |   > rscinit                        (reset RAD6000 and get it ready to run)

 |   > bp x'addr'                     (Set breakpoint at address)
 |   > run                            (execute boot code)
+-----------------------------------------------------------------------------
```

The result should be the same as disconnecting RISCWatch and resetting the processor. However, you can later use "stop" and "run" without losing information in the RAD6000.

One may also step through boot code by using the same method.

```
+-----------------------------------------------------------------------------
 | Stepping through boot code via RISCWatch:
 |   Attach RISCWatch
 |   > ocs off
 |   Reset RAD6000 processor
 |   > alter x'100' x'4bf00102'       (place jump to SUROM reset vector)
 |   > rscinit                        (reset RAD6000 and get it ready to run)
 |   > step                           (execute branch into boot code)
 |   > step                           (execute first instruction of boot code)
+-----------------------------------------------------------------------------
```

11.2Using the RISCWatch tool with an LIO-type RAD6000SC board.

If the user desires to perform the above actions when communicating to an LIO type (sometimes referred to as Pathfinder) board, an extra step is required. Prior to envoking RISCWatch with the *dashtest* command, it is necessary to us the following sequence on the AIX host command line with the COP cable connected to the target board:

1. `>liosel <LIO Address> <Enter>`
where LIO Address is a number from 0-31 determined by the 5-bit card address associated with the RAD6000 card of interest in the backpannel. In this manner, RISCWatch sessions to different RAD6000 units may be established without the need to switch cabling.

2. `>dashtest <Enter>`
Follow instructions in the IBM RISCWatch guide and above for usage.

liosel is a tool which is delivered by LMFS with each RAD6000 SUROM object code delivery.

11.3Private RAM Array

The Private RAM is used as working storage in the RSC I/O Sequencer. This data can be very useful during debug sessions. **Table 9** shows the organization of the PRAM. It can be viewed from RISCwatch by typing **pramarr** at the command line.

Item	Loc (Hex)	Bits	Reset State	RTX Acc	Description

IOCFG	00	00:15	0000	Y	IOCC Config Reg (00:15 | | x'0158 ')
ASR0	00	16:31	0000	Y	Arb Status Reg 0
DMA_FLAGS	01	00:01	0	Y	Bit flags used by 3P DMA
ECC_FLAGS	01	02:05	0	Y	flags used by ECC recovery routine
ASR1	01	16:31	0000	Y	Arb Status Reg 1
ASR2	02	16:31	0000	Y	Arb Status Reg 2
ASR3	03	16:31	0000	Y	Arb Status Reg 3
ASR4	04	16:31	0000	Y	Arb Status Reg 4
ASR5	05	16:31	0000	Y	Arb Status Reg 5
ASR6	06	16:31	0000	Y	Arb Status Reg 6
ASR7	07	16:31	0000	Y	Arb Status Reg 7
ASR8	08	16:31	0000	Y	Arb Status Reg 8
ASR9	09	16:31	0000	Y	Arb Status Reg 9
ASR 10	0A	16:31	0000	Y	Arb Status Reg 10
ASR 11	0B	16:31	0000	Y	Arb Status Reg 11
ASR 12	0C	16:31	0000	Y	Arb Status Reg 12
ASR 13	0D	16:31	0000	Y	Arb Status Reg 13
ASR 14	0E	16:31	0000	Y	Arb Status Reg 14
ASR 15	0F	00:31	00000000	Y	Arb Status Reg 15
3PASR0	10	00:31	00000000	Y	3P ASR extension ch 0
3PASR1	11	00:31	00000000	Y	3P ASR extension ch I
3PASR2	12	00:31	00000000	Y	3P ASR extension ch 2
3PASR3	13	00:31	00000000	Y	3P ASR extension ch 3
3PASR4	14	00.31	00000000	Y	3P ASR extension ch 4
3PASR5	15	00:31	00000000	Y	3P A5R extension ch 5
3PASR6	16	00:31	00000000	Y	3P ASR extension ch 6
3PASR7	17	00:31	00000000	Y	3P ASR extension ch 7
3PADR0	18	00:31	00000000	Y	3P Address / TCW# ch 0
3PADR1	19	00.31	00000000	Y	3P Address / TCW# ch I
3PADR2	1A	00.31	00000000	Y	3P Address / TCW# ch 2
3PADR3	1B	00:31	00000000	Y	3P Address / TCW# ch 3
3PADR4	1C	00:31	00000000	Y	3P Address / TCW# ch 4
3PADR5	1D	00:31	00000000	Y	3P Address / TCW# ch 5
3PADR6	1E	00:31	00000000	Y	3P Address / TCW# ch 6

3PADR7	1F	00:31	00000000	Y	3P Address / TCW# ch 7
TID	20	16:31	0000	Y	Transaction ID Reg (mask 0:15 to 0's)
DAR	21	00:31	00000000		Data Address Reg
DSISR	22	00:31	00000000		DSI Status Reg
RTCL *	23	00:25	00000000	Y	RTC Lower Reg (related hardware counter)
RTCU *	24	00:31	00000000	Y	RTC Upper Reg (related to RTCL)
DMAEN	25	00:31	00000000	Y	DMA Enable / IP-3P Reg
DMAMAP	26	00:31	00000000	Y	DMA MAP
IOLIM	27	00:31	00000000		I / O Limit Reg
DMAS3	28	00:31	00000000		3P DMA Scratch register
DMAS4	29	00:31	00000000		3P DMA Scratch register
DMAS5	2A	00:31	00000000		3P DMA Scratch register
DMAS6	2B	00.31	00000000		3P DMA Scratch register
DEC *	2C	00.31	00000000	Y	Decrementer (Related hardware counter, effects Interrupt regs)
EIM0	2D	00:31	00000000		Ext Int Mask 0 Reg
EIM1	2E	00:31	00000000		Ext Int Mask 1 Reg
EOIM	2F	00:31	FFFFFFFF	Y	EOI Mask (IEIPL0), (set all bits to 1 on reset)
EPOW0	30	00:31	00000000	Y	EPOW 0 Reg (updated on stores to EPOWEB Reg)
EPOW1	31	00:31	00000000	Y	EPOW 1 Reg (updated on stores to EPOWEB Reg)
	32	00:31	00000000		Spare
	33	00:31	00000000		Spare
	34	00:31	00000000		Spare
	35	00:31	00000000		Spare
	36	00:31	00000000		Spare
LED_DISPLAY	37	00:31	0000FFF0		LED display constant
HEX _SEC	38	00:31	3B9ACA00	Y	I billion nanosecond constant
IOORG	39	00:06	00000000		TCW Table Extent Mask
IOORG	39	08:19	00000000		TCW Table Anchor Address (represents system address bits 5-16)
EIER	3A	00:31	00000000		Ext Interrupt Enable Reg
SRRO	3B	00:31	00000000		Save / Restore Reg 0
SRR1	3C	00:31	00000000		Save / Restore Reg 1
SDR0	3D	00:31	00000000	Y	Storage Desc Reg 0 (mask bits 16-31 to all ‘0’s)

EIS0	3E	00:31	00000000	Y	Ext Int Source 0 Reg (read value is fcn of other regs)
EIS1	3F	00:31	00000000		Ext Int Source 1 Reg
EEAR	40	00:31	00000000		External Check Error Address Reg
MEAR	41	00:31	00000000		Machine Check Error Address Reg
IIM	42	00:16	0000		Internal Int Mask Reg
IVEC	43	08:31	000000	Y	Int Vector Reg (Packed DECB, MEEB, EPOWEB (buid 0))
	44	00:31	00000000		Spare
	45	00:31	00000000		Spare
	46	00:31	00000000		Spare
PlO_Cache	47	00:31	00000000		PlO Preempt data save Reg
	48	00:31	00000000		Spare
	49	00:31	00000000		Spare
SBAR	4A	00:31	00000000		Single Bit Error Address Reg
ECCSTAT	4B	00:31	80000000		ECC Status Reg (SCCR | | SBSR | | EESR | | MESR)
SRWD0	4C	00:31	00000000		Save/Restore Word 0
SRWD1	4D	00:31	00000000		Save/Restore Word 1
SRWD2	4E	00:31	00000000		Save/Restore Word 2
SRWD3	4F	00.31	00000000		Save/Restore Word 3
	50	00:31	00000000		Spare
	51	00:31	00000000		Spare
	52	00:31	00000000		Spare
	53	00:31	00000000		Spare
DMAS0	54	00:31	00000000		DMA Scratch Reg 0
DMAS1	55	00:31	00000000		DMA Scratch Reg 1
DMAS2	56	00:31	00000000		DMA Scratch Reg 2
	57	00:31	00000000		Spare
LEDPTR	58	00:31	00000000		LED Pointer
SCRATCH	59	00:31	00000000		Scratch within a routine
SCRATCH	5A	00:31	00000000		Scratch within a routine
SCRATCH	5B	00:31	00000000		Scratch within a routine

Table 9 Private RAM Memory Map

* - architected registers