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## 1. References

- IT-3384/AB: Technical Specification for a new trajectory measurement system for the CERN Proton Synchrotron.
- TMS design documents systemDesign, pupeFpgaDesign, pupeBoardDesign.
- TMS Development and Support website at: <https://portal.beam.ltd.uk/support/cern/>.

## 2. Introduction

This TMS Maintenance Manual provides information on installing and maintaining the TMS. It is useful to read the TmsOverview document to gain an overall understanding of the system and its operation.

## 3. System Power Up/Down

The system has been designed so that there is no special power up sequence. All of the systems components can be powered up in any order. The individual Module Controllers can be simply switched off. The System Controller should be powered down by issuing the “poweroff” command or by using the power switch on the front panel.

## 4. Hardware Installation

The system has a modular in structure and has fairly simple installation requirements. The PUPE 19inch rack units, the network switch and the System Controllers should be installed in suitable 19inch rack enclosures. The units are fan cooled and take and send air in and out of the front and rear panels.

All IEC power sockets should be connected to the local mains as appropriate.

### 4.1. System Controller

The system controllers second Ethernet ports should be connected to the Ethernet switch using CAT-5E Ethernet leads. We recommend using port 9 on the switch. The first Ethernet port on each System Controller can now be connected to the sites LAN as needed.

The System controllers have IPMI facilities that enable them to be accessed at the BIOS level from a remote web browser for bare metal configuration and software installation. However, its is also possible to connect a VGA monitor, keyboard and mouse to them to provide a direct console interface. Conventional PC style connectors are provided for this purpose. In order for the IPMI interface to be accessed it needs an IP address either manually configured or configured using DHCP.

The BIOS settings on the system controllers are set to defaults except from the settings for the fans which are set to WorkStation 4-pin mode (older SuperMicro 4U System Controllers). The BIOS is entered by pressing the DEL key at the start of the boot sequence. The on-board raid controller is set so that the hard-disks are set to a non-raid mode. The system uses software raid under Linux. The raid controller is configured by pressing CTRL-I at the appropriate place in the boot sequence.

### 4.2. Module Controllers

The Module Controllers used can be one of: PP 410/032-12, PP 712/083-13 or PP B14/043-10 from Concurrent Technologies.

Within each PUPE 8 slot rack, the Module Controller card should be installed in the right most slot. It's rear transition module should be installed behind it to provide the additional I/O interface. The switches SW1,SW2,SW3 and SW4 on the transition module should all be set to on to enable the back panel Ethernet ports. The correct rear transition module to match the CPU board in question should be used. For the PP 712/083-13 and PP B14/043-10 boards the ADPP5/005-10 rear transition board can be used.

The module controllers should have their on-board BIOS configured prior to use. This can be done by making use of the break-out cables supplied that allow the attachment of a VGA monitor and keyboard to the board. The BIOS settings should be configured to factory defaults with the following changes, the F2 key is used to enter the BIOS settings menus:

For the PP 410/032-12:

1. Enable the "PXE Boot Firmware" to use the Ethernet port A for boot in the "Advanced/PCI Configuration" screen.
2. Setup BIOS to retry boot indefinitely. This is done using the "Auto-retry On Boot Fail" option in the "Boot Features" menu.
3. In the "Boot" menu you will need to add the Gigabit Ethernet device as the first boot device. This is named: "PCI BDEV". Note you will have to save the CMOS settings and re-enter the BIOS setup screen after enabling the "PXE Boot Firmware" option in 1 to be able to see the "PCI BDEV" device in the list of boot-able devices.
4. Save BIOS settings as user defaults.

For the PP 712/083-13:

1. Set the "PXE Boot" to use the Ethernet port A for boot in the "Main/Boot Features" screen.
2. Setup BIOS to retry boot indefinitely. This is done using the "Auto-retry On Boot Fail" option in the "Main/Boot Features" menu.
3. Save BIOS settings as user defaults.

For the PP B14/043-10:

1. Press the "F2" key repeat-ldly during power up to get into the BIOS setup.
2. Enable "PXE Boot" and "Eht 1" for boot in the "Main/Boot Features" screen.
3. Setup BIOS to retry boot indefinitely. This is done using the "Auto-retry On Boot Fail" option in the "Main/Boot Features" menu.
4. Save BIOS settings as user defaults using F4.

The Ethernet port on the rear of each Module controller should be connected to the Ethernet switch using CAT-5E Ethernet leads. We recommend connecting these to the switch ports 1,2,3,4.

### 4.3. PUPE Boards

The PUPE engine modules should be installed in the remaining 7 slots. The far right PUPE engine should have an additional timing front panel situated to the right of it in the back-plane next to the module controller. Connections from this timing front panel should be made to the PUPE board as described in the Timing front panel table below.

The Proton Synchrotron's timing and analogue data leads can now be connected to the LEMO-00 connectors on the PUPE timing panels and the PUPE board panels.

<i>Timing Connector</i>	<i>PUPE Connector</i>	<i>Old Connections</i>	<i>Description</i>
T1	J13	J26	Not Used
T2	J14	J19	CYCLE_START
T3	J16	J13	CYCLE_STOP
T4	J17	J20	CAL_START
T5	J19	J17	CAL_STOP
T6	J20	J22	INJECTION

T7	J22	J16	H_CHANGE
T8	J23	J27	FREF
T9	J26		Not Used
T10	J27		Not Used

Within each TMS rack module the timing bus IDC lead should be connected across the boards at the front of the system. The far left most PUPE, at the end of the timing bus, should have its HDR\_TERM\_ENABLE jumper JP5 installed to terminate the timing bus.

## 5. System Requirements

There are a few requirements on the local networking infrastructure to support the TMS system. The local LAN should support the following services:

<i>Item</i>	<i>Description</i>
DHCP for System Controllers IPMI cards	This is optional. If the local DHCP server supplies an IP address for the System Controllers IPMI cards then it is possible to manage and install software on the System Controllers remotely. The IPMI interface implements a HTTP interface for management and control.
DHCP for System Controllers main Ethernet Interface	This should provide the IP Address, NetMask and host name for the System Controller. It should also provide the DNS's IP Address and the Time Servers IP Address.
DNS Service	This provides the host name to IP Address lookup for the hosts.
NTP Service	This provides a time reference for the system to keeps its date and time correct.
Gateway	This is optional. This will provide access to remote systems from the TMS system for automatic software updates etc.

## 6. Software Installation

All of the TMS software is available on the Internet and can provided on a single USB stick for installation on the System Controllers. The software is based on a standard Centos 7 Linux system with the addition of some TMS RPM software packages.

A basic description of a bare metal install follows:

### 6.1. CentOS-7 Install

We recommend at least 50G of disk space for a reasonable installation. The system will take about 15GBytes. The Linux installation will need its own separate disk partition or partitions to run from. The installation system will allow you to shrink or remove any existing partitions as needed to make way for the Linux partitions.

You can either accept default disk partitioning or manually partition using "Standard Partition" type. We

normally manually partition using the standard partition type. We recommend having two disk drives configured as a RAID-1 array. This can be accomplished using a hardware RAID controller with suitable configuration or using Linux software RAID setup during installation.

New systems employ an EFI BIOS. This requires a separate EFI partition where the primary boot code for all bootable systems is installed. The following partitioning schemes include the EFI BIOS partition. This is not needed on older BIOS boot systems.

There are two main partition types. The new GPT one and the older BIOS one. On newer systems it is recommended to use the new GPT type where possible. This is needed for EFI boot.

A suitable manual partition scheme, with example partition numbers, is listed below. This has two bootable Linux root file systems allowing us to update to a new version of Linux while keeping the old system there to help if you have any issues. It also allows us to install the new system while still running the old system.

<i>Partition</i>	<i>Filesystem</i>	<i>Filesystem Type</i>	<i>Location</i>	<i>Size</i>
1	EFI Boot	vfat	/boot/efi	200M
2	root	ext4	/	50G
3	root	ext4	/old	50G
4	swap	swap		8G
5 (Optional)	home	ext4	/home	Whats left

If using software RAID-1 create identical partitions on each hard disk and then create a RAID-1 array for each couple of partitions. In the case of the swap partitions do not make them into a RAID array, simply use them as two separate swap partitions.

### CentOS-7 distribution

The TMS system has been tested using the following CentOS-7 release image:

CentOS-7-x86\_64-DVD-1708.iso

This is available from CentOS-7 mirrors or at:

[http://portal.beam.ltd.uk/dist/centos7/CentOS-7-x86\\_64-DVD-1708.iso](http://portal.beam.ltd.uk/dist/centos7/CentOS-7-x86_64-DVD-1708.iso)

This can be copied to a suitable USB stick using the Linux dd command (with appropriate disk device name):

```
dd if=CentOS-7-x86_64-DVD-1708.iso of=/dev/sd...
```

### Basic Installation Instructions

1. If using hardware RAID configure the SATA hard disks as a RAID-1 disk array.
2. Insert the CentOS-7 USB boot stick/disk.
3. Boot from USB disk. You will likely need to hit a key when the system is booting to tell the BIOS to boot from a USB disk. Some BIOS's will enter a "Boot Device Selection Mode" if you press a suitable key (F12 sometimes). Other BIOS's will require you to enter the BIOS setup and set the device boot order such that the USB Hard Disk is first.

4. As CentOS boots enter in the Language to use then "Continue".
5. Click on "Installation Destination"
6. Select the disk to install onto. "Select "I will configure partitioning" then click on "Done".
7. You can set up RAID partitions here or you could have configured hardware RAID devices previously.
8. Select "Standard partition" rather than LVM partitions to simplify things.
9. Add the partitions as wanted, see the table above. Using a blank size makes this partition use what is left of the disk space.
10. Click on "Done" when finished.
11. In the "Software Selection" area select: "KDE Plasma Workspaces". Then select "Legacy X Windows System Compatibility", "Development Tools" and "KDE Applications". Click on "Done". Or for a Gnome based desktop: select "Gnome Desktop". Then select "Legacy X Windows System Compatibility", "Development Tools" and "GNOME Applications". Click on "Done".
12. Click on "Begin Installation" when the system has worked out software dependencies.
13. While the installation is happening: click on "Root password" and set.
14. While the installation is happening: click on "User Creation" and add a first user.
15. When installation is complete, close installation program and shutdown system from the "F" start menu..
16. When powered up will boot into CentOS-7. Accept the license at this stage.
17. When logged in, as root update the system: "yum update"
18. See: <https://centos.org/> or <https://linoxide.com/how-tos/centos-7-step-by-step-screenshots/> for full details.

### **Install issues**

On the Old Supermicro server the original TMS uses and as we have for support, there is an issue with the display driver. This lists an error: "[drm:radeon\_dvi\_detect [radeon]] \*ERROR\* DVI-I-1: probed a monitor but no|invalid EDID" and does not show an X display once the system is installed. To get around this once the system has been installed:

1. Boot the system with the additional kernel command line argument: "video=DVI-I-1:d" or "nomodeset". This can be done at the grub boot page by pressing the "e" key and adding the text to the kernel command line there.
2. Once the system has booted modify the /etc/default/grub file change the kernel args line to: "GRUB\_CMDLINE\_LINUX="crashkernel=auto video=DVI-I-1:d". You can add the "rhgb quiet" options as well if wanted.
3. Run: "grub2-mkconfig -o /boot/grub2/grub.cfg" to configure grub.

## **6.2. Install TMS Software on a TmsServer System**

The main TmsServer running the core TMS server programs requires a 32bit version of the TMS system for the Pupe module controllers. Perform the following installation:

1. Install repository information: "yum-config-manager --add-repo <https://portal.beam.ltd.uk/dist/tms/i686/tms.repo>"
2. Install TMS software: "yum install tms-server". This will install the necessary 32bit server packages. (32bits is needed as some of the module controllers only have 32bit CPU's).

3. We assume the main Ethernet interface will be configured using the DHCP server of the local network. If not it can be configured using the NetworkManager network icon on the task bar.
4. Configure the second network interface using the NetworkManager network icon on the task bar. It should be set to start on boot and have a static IP address of: 192.168.100.1 netmask: 255.255.255.0.
5. Setup the system: “cd /usr/tms/config; ./tmsSetup”. This will alter system configuration settings for the TMS.
6. Edit the system configuration files as needed. This includes: /etc/tmsServer[1234].conf.
7. Add the state table info in /usr/tms/stateTables
8. Add the rootfs and config for each TMS Module Server using the /usr/tms/config/tmsSetupModuleController <num> <MAC address>.
9. Start the system running: /usr/tms/bin/tmsRestart.

Check the system logs and correct any configuration errors. The tmsControlGui program can be used to check the operation of the system.

All of the TMS software is installed in the /usr/tms directory on the System Controller.

### **6.3. Install TMS Software On a Client System**

The main TmsServer running the core TMS server programs requires a 32bit version of the TMS system for the Pupe module controllers. However, client systems can install the 64bit version of this software. To do this perform the following installation:

10. Install repository information: “yum-config-manager --add-repo <https://portal.beam.ltd.uk/dist/tms/tms.repo>”
11. Install TMS client software: “yum install tms-clients”. This will install the necessary client packages. Alternatively just the development library can be installed using “yum install tms-devel”

All of the TMS software is installed in the /usr/tms directory on the client system.

## **7. Software and FPGA Firmware Updates**

All of the TMS software is packaged as Linux RPM files. This makes system maintenance and software updates relatively easy. By default the system is set to access the BEAM TMS software repository on the TMS support website at BEAM for TMS software. If the TMS has access to the Internet, then it is very easy to update the software.

To update the system software automatically over the Internet, perform the following:

1. Log into the system controller as root.
2. Run the command “yum update”
3. Run the command: “tmsRestart” to restart the TMS daemons on the System Controller and Module Controllers.

To update a system manually from RPM package files, perform the following:

1. Download the RPM package files from: <http://portal.beam.ltd.uk/dist/tms>

2. Log into the TMS System Controller as root.
3. Copy the RPM package files onto the System Controller. This can be done using the “scp” program or by using NFS mounted directories.
4. Update the packages using the command “rpm -U <package file name> <package file name> ...”
5. Check the configuration files “/etc/tmsServer[1-4].conf” and “/usr/tms/rootfs-\*/etc/tmsPuServer.conf” and edit if necessary.
6. Run the command: “tmsRestart” to restart the TMS daemons on the System Controller and Module Controllers.

The TMS software packages are as follows:

<i>Package Name</i>	<i>Description</i>
tms	Common TMS software required bits.
tms-clients	The TMS GUI control clients. These can be installed on client workstations as well as the main TMS Server system.
tms-server	The main TMS Server programs that implement the running system.
tms-mcsys	The simple, network boot Fedora Core 6 based OS for the Module Controllers.
tms-fpga	The TMS PUPE FPGA firmware.
tms-doc	The TMS Documentation files

The packages will have file names with the following pattern: <packageName>-<version>-<release>.<arch>.rpm.

## 8. System Controller Configuration and Management

The system controller's are setup, by default, to obtain their network configuration from the local network systems DHCP server. The only local configuration required is that required for the TMS system itself. Two script files are provided to perform this local configuration. These files are situated in the /usr/tms/config directory and are called are:

- **tmsSetup:** This script will setup the System Controller for operation. It assumes a second network interface has been configured with the appropriate network settings for the local “tmsnet” used to communicate with the Module Controllers. It also configures and enables some local network services to allow the Module Controllers to boot from and get information from the System Controllers. These include: DHCP and TFTP.
- **tmsSetupModuleController:** This script will set up a module controller for use. It will create a root file system for the controller and configure it for operation. The tmsSetupModuleController script takes two parameters. The first parameter is the module controller number to configure. This should be a number in the range 1-4. The second parameter is optional. If provided it is the Ethernet MAC address of the Module Controller. The Ethernet MAC address needs to be configured initially for the ModuleControllers to boot. This is used to setup the System Controllers DHCP server to provide boot information to the Module Controller.

## 9. Configuring the system

The `/etc/tmsServer[1234].conf` files should be created/edited to enable the appropriate number of TmsServer processes depending on the number of rings in use.

The “Ring” parameter in these, should be set to the ring number and the Master parameter should be set to 1 for the master TmsServer (normally the one for ring 1) and 0 for all others. The PUPE PU channels for each ring should now be configured in the appropriate `/etc/tmsServer[1-4].conf` files.

Assuming the base module controllers root file systems has been configured, then the tmsPuServer's configuration files need to be configured (`/usr/tms/rootfs-[1-4]/etc/tmsPuServer.conf`). In these the “Rings” parameter should be set to the number of rings in use and the PUPE boards and locations configured. See the TmsPuServer manual for more information.

Once configured the tmsRestart program can be used to restart the system.

## 10. Accessing The System Controller

The system controller provides a local GUI interface for local logins as well as a secure shell interface for remote logins.

Once you are logged in you can use all of the normal Linux commands.

The system controller normally has two RAID1 file system partitions. The “/” partition is used for all of the system and TMS software. The “/home” partition is used for any user data.

The /data directory is exported using NFS to the Module Controllers and thus forms a shared file system for all TMS components.

## 11. Accessing the Module Controllers

The Module Controllers run a cut-down network boot Linux system based on a vanilla Linux kernel and the Centos 7 system as used on the System Controller. They run on their own private network, tmsnet, and are only accessible from the System Controller.

To login to the system first login to the system controller and then use the “telnet” command to log onto an individual Module Controller. The Module controller host names will be: tmsmod1.tmsnet, tmsmod2.tmsnet, tmsmod3.tmsnet and tmsmod4.tmsnet. The Module Controllers only support a login ID of root with no password. The tmsnet network is configured as a class C network with an IP network address of 192.168.100.X.

A set of basic Linux command line programs are provided for access to the systems using the Busybox utility. Note that the root file system, for the Module Controllers, is mounted from the System Controller in a read only fashion. This file system is situated in the `/usr/tms/rootfs-?` Directories on the system controller. The Module Controllers root file system files can thus be modified on the System Controller only. The Module controller also mounts `/usr/tms` and the “/data” directories from the System Controller. The /data file system is mounted read/write and is useful for shared data and test purposes.

## 12. Using a second System Controller

A second System Controller would normally be un-plugged from the local “tmsnet” network. If it is need to take over from the other system controller the Ethernet lead can be simply plugged in and the other System Controllers lead removed. Note that the Module Controllers will need to be re-booted to connect to the new System Controller.

It would also be possible to configure the system with different IP addresses on the local “tmsnet” and provide a script to switch servers and or perform other functions.

## 13. System Hardware Maintenance

1. The systems fans should be replaced about every 4 years of continuous running.
2. The systems disk drives should be replaced about every 4 years of continuous running. Ideally one should be replaced every 4 years on a alternate 2 year cycle.

## 14. System Software Maintenance

Apart from the standard TMS software, the only information stored on the System Controllers is the TMS State/Phase table library and the logical to physical pick-up number configuration table. It is recommended that this information is stored on a separate system and written to the TMS system using the standard TMS API calls. It is possible, however, to backup this configuration information if required.

This information is stored in the following files and directories:

- /etc/tmsServer[1234].conf
- /usr/tms/rootfs-?/etc/tmsPuServer.conf
- /usr/tms/stateTables/\*

The system logs all messages to the system log file in /var/log/messages. If required this information can be emailed to a user or sent to another systems syslog daemon. See the standard Linux documentation on how to do this.

## 15. Security

The Module Controllers sit on a private network that is only accessible from the System Controller. The Module Controllers have little security, the System Controller provides the security layer.

The System Controller provides the normal high standard of security that Linux provides. The system is quite secure by default, but further measures can be applied if required.

Its should be noted that the default “root” and “tms” users passwords should be changed at the earliest opportunity.

## 16. Replacing a Hard disk

If Linux software RAID is used, the status of the RAID 1 disk system can be ascertained by running the command “cat /proc/mdstat”. This should display something like below.

```
Personalities : [raid1] [raid6] [raid5] [raid4]
md3 : active raid1 sdb2[1] sda2[0]
      232588992 blocks [2/2] [UU]

md1 : active raid1 sdb1[1] sda1[0]
      10482304 blocks [2/2] [UU]

unused devices: <none>
```

The TMS system has two separate partitions on the hard disks. One is for the OS (/) and one is for general user data (/home). The status of the RAID1 partitions is identified by the [UU] field. The 'U' character indicate that all is well.

When replacing a hard disk make sure that both disks are functioning Ok in the RAID array or else make sure that the faulty disk is removed.

When a new disk is installed it will need to be partitioned to match the existing disk. The fdisk program can be used for this. Once the correct partition types and sizes have been added to the hard disk, the system can be told to add the two new partitions to the existing raid1 array. This can be done with the following command: “mdadm /dev/md3 -a /dev/sdb2”. The appropriate raid device entry should be used in place of “/dev/md3” and the appropriate device name should be used in place of “/dev/sdb2”.

The raid reconstruction will take a while to complete, but the system can be used while this process is happening.

## 17. Fault Management

The TMS system is equipped with an internal diagnostics system that can help detect and diagnose system faults. In order for this to function at least the main System Controller needs to be operational. The following lists possible faults and reasons in importance order.

### 17.1. System Controller does not boot

There could be a number of reasons for the system controller not booting. As it is based on PC architecture conventional PC diagnostics can be used. Some things to test are:

- Check that the mains power is connected and the plugs fuse is intact.
- Check that the system fans come on. If not this indicates a power supply failure.
- Check that the BIOS screen is displayed. If a monitor is attached the BIOS screen should be displayed. If the IPMI remote monitoring system has been configured, then the BIOS screen can be viewed remotely using a web browser using the IPMI cards IP address as a URL. Check the BIOS screen for error reports. This may indicate a CMOS battery failure or a hard-disk failure.

Remedy: Move to second System Controller and diagnose fault in the system controller.

### 17.2. System Controller is not accessible over the network

- Check that the network lights on the rear are lit indicating a network connection.
- Using a monitor or IPMI remote monitoring system login to the system directly and check that the networking devices have been configured with there IP address correctly. The “ifconfig” command can be used to do this.

Remedy: Move to second System Controller and diagnose fault in the system controller.

### 17.3. The TMS system is not accessible using the standard TMS API

This could be due to a failure of the **tmsServer** or **boapns** programs.

- Log into the the TMS system using a ssh login or directly via the console or IPMI remote monitoring system as root. Use the “ps” command to check that the **tmsServer** and **boapns** programs are running. Look at the end of the “/var/log/messages” file for any reported problems.

Remedy: restart the whole TMS software/FPGA firmware environment with the “tmsRestart” command.

#### **17.4. The TMS Systems test API function reports that there are errors system errors**

If the “tmsServer” program is running, then the TMS self test system can be invoked to test the remainder of the system. The self test system will perform a set of simple tests on the system to see if all is functioning and return the status of each test.

This will perform basic tests on the System Controller, such as disk space available, memory space available etc. If there are any Module Controllers missing this will be shown.

### **18. System Power Usage**

The systems power usage was tested in a simulated running condition. The system was set up to receive timing signals and data from the TMS Test Signal generator and set to process data from that source. No clients were accessing the data.

The test setup was as follows:

Date	2007-09-28
Software	0.3.13
Firmware	0.3.14
Mains Voltage	234 Volts

The Power usage with different boards in a single TMS module.

Power Supply and Fans only	32 Watts
Power Supply, Fans and Module Controller	56 Watts (Up to 103 Watts)
Power Supply, Fans, Module Controller and 1 PUPE	60 Watts
Power Supply, Fans, Module Controller and 2 PUPE's	95 Watts
Power Supply, Fans, Module Controller and 3 PUPE's	140 Watts
Power Supply, Fans, Module Controller and 4 PUPE's	170 Watts
Power Supply, Fans, Module Controller and 5 PUPE's	190 Watts