DarkStar®

Lighting the path to network independence

Systems Guide
v3.5

XKL®

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1 **Introduction** 1

1.1 DarkStar Product Family 1
1.2 Hardware 1
1.2.1 DarkStar eVolocity Series100G DWDM 2
1.2.2 Optical Networking Systems 3
1.2.3 Amplification Systems (DLA & DMD-A) 5
1.3 Optical Configuration 7
1.3.1 System Provisioning 7
1.3.2 Installation 8
1.3.3 Maintenance 8
1.4 Optical Networking 8
1.4.1 Example of a DarkStar Optical Pathway 9
1.5 Network Design 10
1.6 Key Benefits 10

2 **Components** 9

2.1 Power 9
2.2 Fan Modules 9
2.3 Optical Interfaces 10
2.4 Operating System DXMOS 10
2.4.1 DXMOS Modes 10
2.4.2 Terminal Pager 11
2.4.3 Syntax Format 11
2.4.4 Abbreviations and Shortcuts 11

3 **System Installation** 13

3.1 Overview 13
3.2 Four-Post Rack Installation 14
3.3 Connecting Power 18
3.3.1 AC Power 18
3.3.2 DC Power 18
3.4 Factory Settings 19
3.4.1 System Factory Settings 19
3.4.2 Recommended Transceiver Sensitivity Levels 20
3.4.3 Amplifier Specifications 21

4 **Setup and Management Configuration** 23

4.1 Connect Consoles 23
4.2 Power-Up and Reboot 24
4.3 Configuring the System 26
4.3.1 Step 1 - Security and AAA Authentication 27

4.3.2 Step 2 - Network Time and Management IP Addresses 32
4.3.3 Step 3 - Controlling Line Protection 34
4.3.4 Step 4 - Configure SNMP Traps and Monitoring 34
4.3.5 Step 5 - Set up Remote Event Logging 35
4.4 Remote File Configuration 36

5 **Monitoring** 38

5.1 Hardware Monitoring 38
5.2 Module and Line Status 38
5.3 Amplifier Status 41
5.4 Temperature 44
5.5 Amplifier Configuration 45
5.5.1 EDFA Configuration 45
5.6 Error Detection 47
5.7 SNMP Traps 47

6 **Troubleshooting** 49

6.1 Introduction 49
6.2 Create a Saved Configuration for Backup 49
6.2.1 Operator Notification 50
6.3 Crash Recovery 50
6.3.1 Automatic Recovery from a Warm Restart 50
6.3.2 Automatic Recovery from a Cold Boot or Power Recycle 51
6.3.3 Manual Crash Recovery Only if Automatic Recovery Fails 51
6.3.4 Diagnosis 51
6.4 Console Procedures 51
6.5 Recovery Mode 53
6.6 Using the Debug Command 55
6.7 Hardware Procedures 56
6.7.1 Front Panel LEDs 56
6.7.2 Power Module Replacement 58
6.7.3 Fan Module Replacement 59

A **Configuration File** 60

A.1 Default Configuration File 60
A.2 Configuration Examples 61
A.3 Sample Configuration 62

B **Glossary of Terms** 64

Introduction

1.1 DarkStar Product Family

The DarkStar family of products is an integrated suite of fiber-optic networking systems used to create custom fiber-optic network topologies to meet virtually any business need. DarkStar products use both dense wavelength division multiplexing (DWDM) optical network hardware and management interface software to achieve data transmissions over extended distances at high data rates.

DarkStar networks allow businesses to circumvent the exorbitant cost of leasing services and equipment by taking advantage of the increasing availability and economy of unlit or dark fiber. By developing and managing a DarkStar network directly, businesses can create proprietary, carrier-class, fiber-optic networks with a significantly lower total cost of ownership.

DarkStar networks have been designed for use by network administrators. The operating system offers a simple, command-line interface with router-like operation that will be familiar to any enterprise network administrator.

- ***Network*** – A DarkStar network consists of at least two Darkstar optical networking systems acting as endpoints. Additional DarkStar networking systems, DarkStar amplifier systems, or DarkStar combiner systems can be added to enable extended network designs, and enhance transport performance.
- ***Amplification*** – DarkStar amplifier systems and amplifier components maximize the transmission distance of DarkStar networks. In general, a simple network with paired optical networking systems supports transmission distances up to 70km; systems employing amplification can achieve transmission distances up to 150km. By including inline amplifiers, transmission distances up to 2000km are possible.
- ***Redundancy*** – DarkStar systems can provide redundant failover through model features, component specifications, and network design. Consult XKL about the best ways to achieve redundant failover in your own network designs.

1.2 Hardware

DarkStar technology comprises these product families:

- DarkStar eVolocity Series 100G optical networking
  - DQM100, with 1 or 2 100G channels optically multiplexed on a single fiber pair.
  - DQT100, with 1 or 2 100G trunks running on separate fiber pairs. The DQT100 solution can grow to 48 or 96 channels by adding the DarkStar Mux/Demux products: DMD-P or DMD-A.
- DarkStar 10G optical networking
  - DSM10, with support for 10 10G channels (100G aggregate total) optically multiplexed on one or two fiber pairs. Options include preamp and booster EDFA support for up to 10 10G channels. The DSM10-2R and -4 provide four channels. The DSM10 solution can grow to 40 channels by adding the DarkStar Mux/Demux products: DMD-P or DMD-A.

    - DQM10, with support for 12, 24, or 36 10G channels (120G, 240G, or 360G aggregate total) optically multiplexed on one fiber pair. Options include preamp and booster EDFAs.
    - DQT10, with support for 12, 24, or 36 10G channels (120G, 240G, or 360G aggregate total) on separate fiber pairs within 1, 2, or 3 MPO cable assemblies. The DQT10 solution can grow to 48 or 96 channels by adding the DarkStar Mux/Demux products: DMD-P or DMD-A.
- DarkStar inline amplification
    - DLA, with support for up to two preamp EDFAs, and up to two booster EDFAs. The DLA includes tilt and equalization filters, mid-stage access for add/drop, and dispersion compensation options, all fully integrated.
- DarkStar mux/demux
    - The passive DMD-P and the active DMD-A appliances enable topology growth and are an integral system of DarkStar networks. These appliances provide 48 or 96 channel mux/demux and several filter options including 4-band or 6-band filter or optical service channel filter, as well as a channel monitoring tap. The DMD-P is completely passive. The DMD-A is active, providing amplification capabilities. The DMD-A also provides for path protection via the integrated optical switch.

DarkStar optical networking systems are responsible for transmission and reception of data over fiber-optic cable and form the core of any DarkStar network. The primary features of optical networking systems are:

- Single-mode and multi-mode interfaces and DWDM wave interfaces.
- Port densities of 4 ports per 1RU to 48 ports per 1RU, depending on the DarkStar model. (The DMD-A is 2RU.)
- Up to 96 DWDM channels per fiber pair.
- Optional integrated amplification (EDFAs).

Other key features include:

- Low power consumption: Every system in the DarkStar family is rated at 63-180W typical.
- Minimal rack space: Every system and device in the DarkStar family occupies 1RU of space in a standard equipment rack.
- Redundant cooling: All powered DarkStar products include hot-swappable fan modules.
- Redundant power: All powered DarkStar products include dual, hot-swappable power supplies.
- EDFA and Raman amplification solutions with adjustable gain.

1.2.1 DarkStar eVolocity Series100G DWDM

The DarkStar eVolocity platform comprises the DQM100 and DQT100 systems. All models in this series support 100G Ethernet. Instead of a crossbar switch, statistical multiplexing is used to manage Ethernet packets through the system.

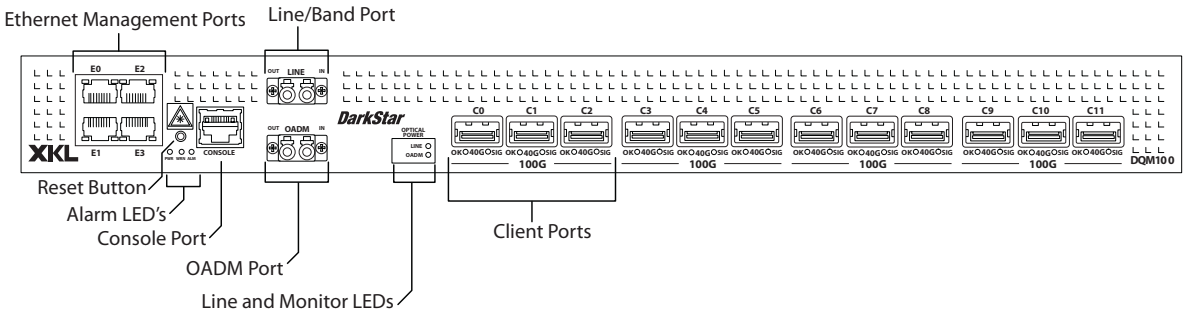
1.2.1.1 DQM100 Systems

Like all other DarkStar systems, eVolocity systems are packaged in a 1RU chassis. Depending on the model, there are one or two DWDM trunks (called “lines” on the DQM100 products) that use tunable CFP 100Gbps coherent transceivers. In the DQM100 model, there are two front panel access ports: a Line port and an OADM port (Optical Add Drop Multiplexer). The Line port is the egress/ingress port for the DWDM signal and the OSC. The OADM port is used to cascade DQM100 systems together. It is possible to configure a 40 channel system in 21RU of rack space using a DBC4 filter and 20 DQM100 2-wave systems.

The DQM100 system is configured with a single Line port on the front panel and provide access to one or two DWDM trunks and one OSC. The trunks that carry customer data and the OSC channel are combined on a single fiber pair.

The OADM port is used to grow the network beyond one system. Each DQM100 system has one or two (depending on the configuration) trunks or channels, and up to five systems may be cascaded to allow for a five- or ten-channel subsystem on a single fiber pair. Furthermore, the network can grow beyond these channels by connecting each group of systems to a single band port of the DBC filter, thus allowing for more than five or ten channels on the same fiber pair.

FIGURE 1-1. DarkStar® DQM100 2-Wave DWDM 100G



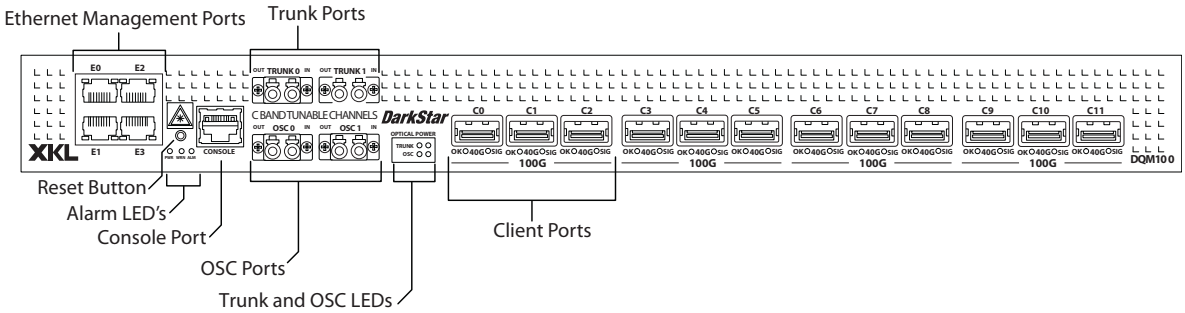
1.2.1.2 DQT100 Systems

There are four front panel access ports on DQT100 systems: two 100G data channels and two OSC ports. The 100G data channel can use either tunable 100G coherent transceivers or short reach transceivers. The solution that uses the short reach transceivers is not a DWDM solution. (Refer to XKL DQT100 application notes describing various use cases for this.)

The DWDM solution uses tunable 100G coherent transceivers. A few common network configurations based on the DQT100 systems are:

- A 96-channel solution that uses 48 DQT100-2 systems and a DMD96 Mux/Demux device.
- A 48-channel solution that uses 24 DQT100-2 systems and a DMD48 Mux/Demux device.

FIGURE 1-2. DarkStar® DQT100-2 DWDM 100G



1.2.2 Optical Networking Systems

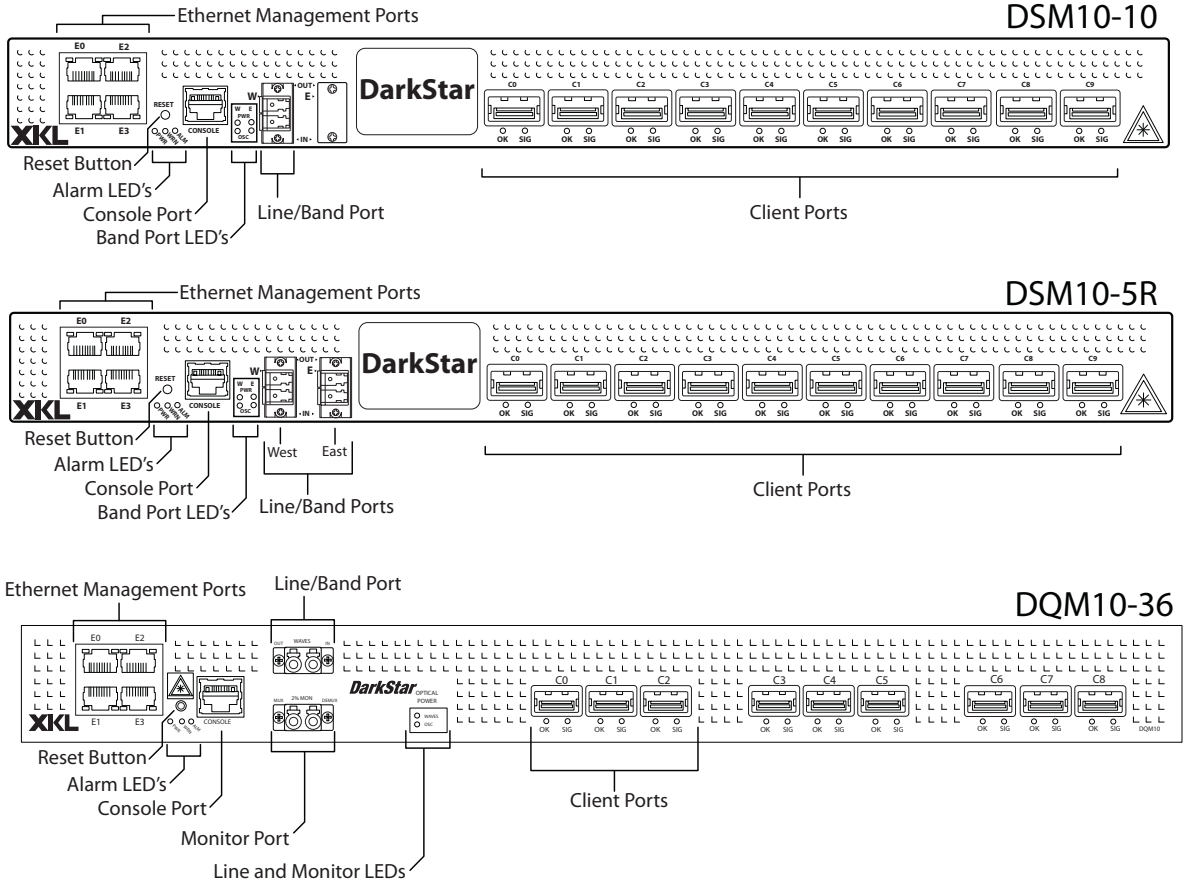
DarkStar optical networking systems transmit and receive data over fiber-optic cable and form the core of any DarkStar network. The following table compares the features of the DSM, DQM, and DQT systems.

For more information, see the "Factory Settings" on page 19.

TABLE 1-1. Optical Networking Systems Comparison

Feature	DSM10	DQM 10	DQT10	DQM100	DQT100
SFP+ client laser modules	✓				
QSFP+ client laser modules		✓	✓	✓	✓
SFP+ wave laser modules	4, 5, or 10	12, 24, or 36	12, 24, or 36		
CFP trunk laser modules				1 or 2	1 or 2
Client interface ports	4, 5, or 10	12, 24, or 36	12, 24, or 36	12 or 24	12 or 24
Redundant operation (power and cooling)	✓	✓	✓	✓	✓
Optional integrated amplification	✓	✓		✓	
Optional integrated dispersion compensators	✓	✓		✓	
40 Gigabit Ethernet client connections	40GBase-SR4	40GB ase -SR4 -LR4 -PSM4	40GB ase -SR4 -LR4 -PSM4		
100 Gigabit Ethernet client connections	100GBase-SR10	100GBase-SR10	100GBase-SR10		
LC-duplex DWDM line (optically multiplexed)	✓	✓		✓	
MPO-cabled waves (non-multiplexed)			✓		
LC-duplex trunk					✓

FIGURE 1-3. DarkStar® Optical Networking Appliances



1.2.3 Amplification Systems (DLA & DMD-A)

Depending on the DarkStar model, DarkStar networks and systems currently support two types of amplification, EDFA (Erbium Doped Fiber Amplifier) and Raman. Amplifiers generally serve three purposes in a system:

- ***Booster*** **–** Increase signal power into the fiber.
- ***Line Amplification*** **–** Increase repeater spacing.
- ***Pre-Amplification*** **–** Improve receiver signal power.

Each amplification type and its manner of deployment has unique characteristics and benefits. The amplification technology and configuration used depends on transmission distances, network topology, and fiber type, among other factors that are taken into account when building a system. In addition to standalone amplifiers, some amplification technologies may be directly integrated into optical networking systems.

DarkStar systems use DXMOS-recommended settings to control the amplifier by adjusting gain or power as necessary, instead of manually setting a gain or power value. DXMOS bases this on what has been configured with the path command, and will choose between two modes:

- DXMOS(AGC): Adjust the amplifier gain to obtain a maximum allowable power per channel.*
- DXMOS(APC): Adjust the amplifier output power to obtain a maximum allowable power per channel.*

*Maximum allowable power per channel is system, network, and topology dependent.

If you want to control the EDFA output manually, issue the amplifier commands (control output gain and control output power) to ensure a consistent quality of output signal. Each attempts to compensate for fluctuations in input power by adjusting some aspect of the amplifier's performance.

Information related to setting up an amplifier can be found in "Amplifier Configuration" on page 44. Amplification systems share much of the same hardware and software as other DarkStar products, requiring only one set of general operating instructions and commands to manage any DarkStar products efficiently. The following table compares the features of the two systems.

	• *An EDFA uses erbium-doped optical fiber as a gain medium to amplify an optical signal. Inside the EDFA, the input optical signal and the pump laser are combined and passed through the erbium-doped fiber, where the signal is amplified* • *A Raman amplifier is based on Raman gain, which results from the stimulated Raman scattering effect. Unlike an EDFA, Raman amplification uses the transmission fiber as the gain medium, instead of erbium-doped fiber, transferring the optical energy from a pump laser to the optical signal.*
	EDFAs and Raman amplifiers can produce high-energy signals that pose a risk to human eyesight. Furthermore, an improperly configured optical amplifier can damage optical receivers, both within the optical amplifier-equipped DarkStar systems and in remote systems connected to the optical amplifier-equipped system.

TABLE 1-2. Amplification Systems Comparison

Feature	DLA	DMD-A
Up to 4 EDFAs	✓	✓
Integrated dispersion compensators.	✓	✓
Integrated tilt and equalizer compensators.	✓	
Mid-stage access.	✓	
Up to 2 Raman amplifiers.	✓	

The DLA system, DarkStar Line Amplifier, is a fully integrated optical amplifier solution. All components in this system can be managed and controlled via the DXMOS operating system, which is the common operating system for all products in the XKL DarkStar family of optical networking solutions. The DLA system integrates all the required components to create a long-haul optical network, including EDFAs, Raman amplifiers, tilt and equalization filters, and dispersion compensation modules (DCM).

The optional integrated DCM is ideal for networks requiring dispersion compensation. These passive, Bragg grating-based filters provide the necessary dispersion compensation for any customer fiber type. Typically these modules are required for 10G or higher data rate signals using direct-detect transceivers.

The DMD-A system, DarkStar Mux/Demux with Amplifier, integrates a variety of DWDM mux/demux filters to create the ideal, low profile solution. All components in this system can be managed and controlled via the DXMOS operating system, which is the common operating system for all products in the XKL DarkStar family of optical networking solutions. The DMD-A system integrates 48-channel or 96-channel mux/demux filters, or band combiner filters, and optionally includes EDFAs, Raman amplifiers, and dispersion compensation modules (DCM), as well as an optical switch for path protection.

A DLA system employs EDFAs to implement optical amplification, allowing for increased distances between optical networking systems. A DMD-A system employs both EDFAs and Raman amplifiers to implement optical amplification, allowing for increased distances between optical networking systems.

FIGURE 1-4. DarkStar® DLA In-Line Amplification System (2U)

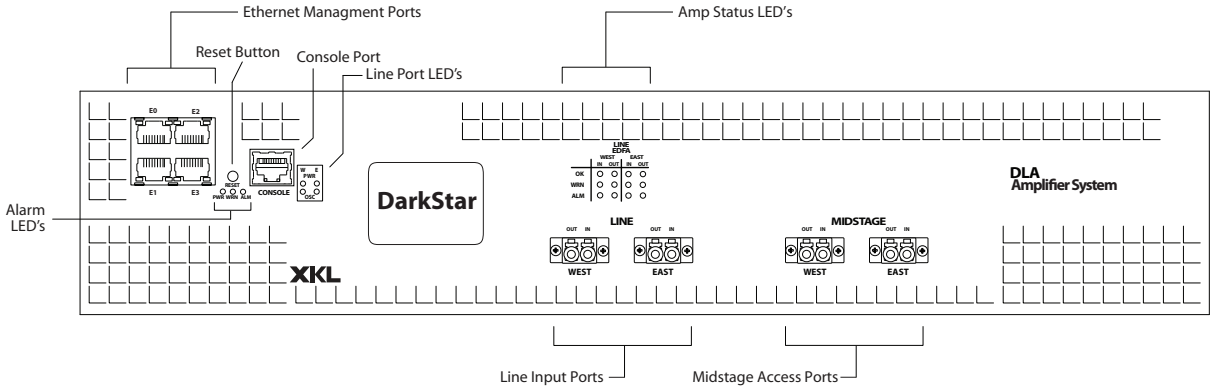
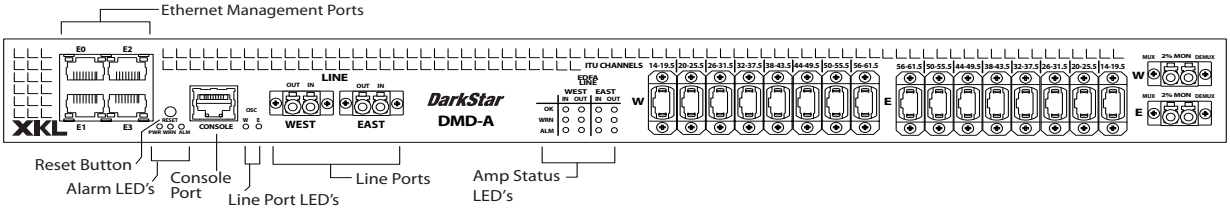


FIGURE 1-5. DarkStar® DMD-A Mux/Demux Amplification System



1.3 Optical Configuration

All DarkStar systems use the DXMOS operating system for management and control. The DXMOS console command line interface (CLI) is based on commonly-used router commands. The CLI enables the operator to configure the system and monitor it remotely. Operator console connection is via serial and Ethernet ports located on the front panel of the DarkStar system. Any DarkStar system can be used to access any other DarkStar systems in the network via the OSC. To learn more about provisioning and managing DarkStar modules, interfaces, and interface connections, see Chapter 4 - Setup and Management Configuration.

1.3.1 System Provisioning

Optical interfaces are software-configurable. Use DXMOS commands to configure each wave and client interfaces, and to assign routes for mapping clients to waves. Connections must be established physically first, and then configured in DXMOS, as detailed in the DarkStar Command Reference.

Depending on the DarkStar systems, traffic is managed one of two ways.

- Allocate one entire wave channel to each client signal: there is capacity to transmit whatever a client demands. In practice, a client channel may be idle more than half the time, leaving some of the assigned wave bandwidth unused.
- Use statistical multiplexing to allow multiple clients to share the available wave bandwidth. Client data frames are collected and queued for transmission on the wave. This provides better utilization of wave bandwidth at the expense of a brief delay in the transmission of client data. In periods of high demand, some client data may be dropped. Each client's priority can be set using the command line.

The OSC interface requires a static IPv4 or IPV6 address sharing the same IP subnet as the adjacent OSC port on the remote DarkStar system. DXMOS management features such as user accounts, DNS, access lists, RADIUS, TACACS+, AAA, and IP routes must be configured for successful connectivity, as detailed in "OSC/Ethernet Management Provisioning" on page 33.

1.3.2 Installation

Before installation, it is good practice to characterize the quality of the dark fiber. The DarkStar systems ship with all laser transceivers in place, with factory settings preset to the operating values as defined in "Factory Settings" on page 19. Please follow the XKL recommended operating conditions for transceiver receive power levels ("Recommended Transceiver Sensitivity Levels" on page 19). This will ensure the proper operation of the system. Use optical attenuators, or pads, as needed so that the DWDM and client transceivers have a receive power as specified. It is not possible to control the transmit power levels of any optical transceivers. If optical receive power levels are higher than the XKL recommendations, attenuators should be installed.

1.3.3 Maintenance

With the exception of CFP modules, laser modules are hot-swappable and can be replaced while the system is running. Follow the instructions in Chapter 6 - Troubleshooting to replace a laser module.

1.4 Optical Networking

Dense Wavelength Division Multiplexing (DWDM) optical networking hardware and management interface software achieves data transmissions over extended distances at high data rates. DarkStar networks are designed to be configured and managed by network administrators and technicians; no optical engineering expertise is required.

A DarkStar solution enables customers to build their own private optical network, with a separate management system for configuration and monitoring. Systems operate at OSI Layer 1, multiplexing multiple wavelengths across a single fiber optic link using Dense Wave Division Multiplexing (DWDM).

A DarkStar system has multiple interface transceivers connected to customer equipment through optical client ports on the front of the system. Each client interface can be separately configured to the encapsulation of the customer equipment attached to it. It converts the optical signal to an electrical signal that is connected to an internal "wave" DWDM interface transceiver.

Each DWDM interface transceiver in a DarkStar system uses a unique optical wavelength. Each interface is multiplexed onto a single fiber. Erbium Doped Fiber Amplifiers (EDFAs) are optional components of most DarkStar systems. These components enable DarkStar systems to extend the reach of optical signals.

Depending on the system, user configuration consists of setting the encapsulations of the client interfaces to match their attached customer equipment, and assigning or connecting a DWDM interface to each client interface.

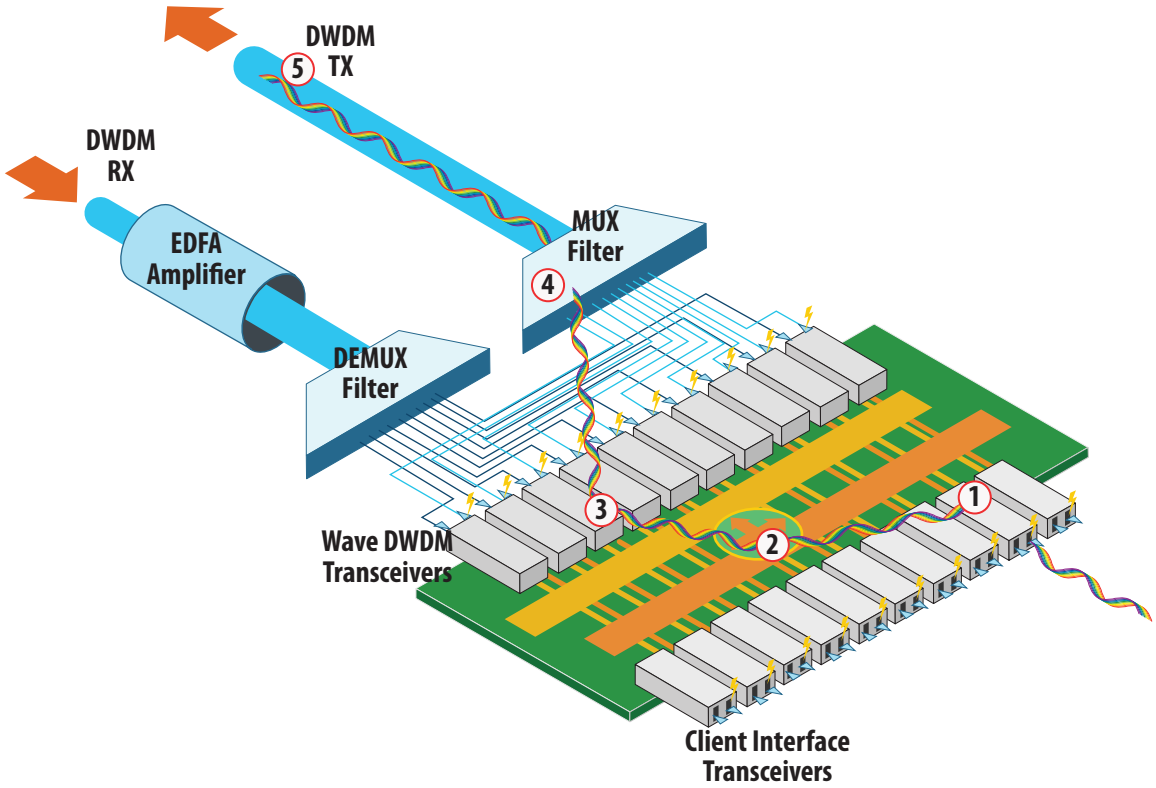
1.4.1 Example of a DarkStar Optical Pathway

As incoming optical signals pass through a DarkStar system, they are converted to electrical signals, and then back again. For example, Figure 1-6 illustrates the path of a signal through a DSM10-10 system.

A DarkStar client interface transceiver converts incoming traffic from optical to electrical signals, improving signal quality and enabling an electrical crossbar to switch the signal to a DWDM interface transceiver. A MUX filter combines the individual DWDM interface transceiver signals onto a single fiber.

EDFAs are pre-configured at the factory, and at bring-up time, the user can re-configure amplifier power and gain settings so that the receive power at each DWDM transceiver is at the optimal operating condition.

FIGURE 1-6. Optical and Electrical Signal Pathways Through a DSM10-10 System



For a signal transmitted from customer equipment:

1. A client interface transceiver receives a customer signal via the client optical port on the front of the DarkStar system. The user defines the encapsulation at the command interface.
2. The client interface transceiver converts the customer optical signal to an electrical signal for connection via the electrical crossbar. The electrical crossbar receives the customer signal and connects it to an internal DWDM interface transceiver. The connection between client and DWDM "wave" interfaces is configured by the user. As part of automatic path protection (APP) functionality, the electrical crossbar can be configured so that traffic will switch automatically to a fail-over channel if the connection is interrupted, and optionally can fall back again when the connection is restored. APP can be changed during system operation at any time.
3. A DWDM interface transceiver receives the electrical signal and converts it to an optical DWDM signal. Each DWDM interface transceiver has a unique optical wavelength.

4. A MUX filter multiplexes the individual DWDM interface transceiver optical wavelengths into a single fiber. At this point, all of the customer equipment inputs have been merged to a single transmission. The MUX filter also merges in the input from the OSC transceiver that carries DarkStar operator management commands between DarkStar systems.
5. The line/band port is the connection point for the fiber that will interconnect a pair of DarkStar systems.

To receive the transmitted signal, the optical pathway at the receiving DarkStar works in reverse.

1.5 Network Design

Requirements for designing a DarkStar network encompass more areas than can be detailed in this document. However, the following information provides a brief overview of key features and considerations in the design of a network. DarkStar systems can be used to build networks for metro, regional, or long-haul network access.

Most networks are point-to-point, ring, or mesh topologies. Networks designed around DarkStar systems are easily configured and flexible such that any of these topologies can be built from the same DarkStar solutions.

In any of these topologies:

- The minimum network design must connect (2) endpoints, but may be built out to accommodate designs as complex as needs require.
- Add-drop service may be incorporated at any node.
- Path protection (redundancy) is possible with the inclusion of a second fiber pair when using redundant DarkStar systems.
- Amplification can be included in network design to extend transmission distances.

Every DarkStar network is built around an optical budget that optimizes the amount of optical power required to transport light over required distances in a customer network. You can calculate your optical budget by using site installation metrics to determine the optical power required in a system. It is often mistakenly assumed that the more optical power a system offers, the better it will perform. In the world of optical networking, too much optical power can cause just as many problems with signal quality as too little. DarkStar systems can be configured accordingly with the correct specifications.

In designing and building an optical network, acquiring fiber access is an important consideration. Dark fiber is becoming increasingly available through a number of sources, including private network operators and municipalities, among others. There are also companies that specialize in assisting enterprises to locate or even install fiber services.

1.6 Key Benefits

DarkStar optical systems provide a wide-ranging solution to many data transmission issues.

TABLE 1-3. Key Benefits of DarkStar Systems

Feature	Benefit
Network & System	
Ease of deployment	Systems are delivered pre-configured for operation based upon the requirements and site installation details you provided, thereby facilitating and streamlining system deployment and network operation.
Seamless management	DarkStar products share hardware and software design elements, such as chassis design and software commands.
Latency	DarkStar networks offer low-latency performance for use in the most demanding, business-critical applications.

TABLE 1-3. Key Benefits of DarkStar Systems

Feature	Benefit
Integrated system	Networks are easier to manage than traditional line-card or cage-based solutions due to the flexible design and integrated components.
Hitless upgrades	DarkStar systems support hitless software updates. The customer can perform these updates in a scheduled maintenance window, but customer data is not interrupted during an operating system update.
Protection	DarkStar systems with the protection feature can be configured to provide protection over a backup line. In the event of a fiber cut, service is automatically switched to a backup line to minimize data loss.
Scalability	A DarkStar Band Combiner (DBC) allows a solution of up to 40 channels on a single fiber pair. A DarkStar Mux/Demux (DMD) allows a solution of up to 96 channels on a single fiber pair.
Extended transmission distances	The inclusion of amplifiers in a network may provide total transmission distances of up to 2000km, depending on your configuration.
Hardware	
Low power consumption	DarkStar systems are rated as low as 70W, typical.
Rackspace efficiency	Each system in the DarkStar family occupies only 1RU of space in a standard equipment rack.
Redundant cooling	All powered DarkStar products include hot-swappable fan modules.
Redundant power	All powered DarkStar products include 1+1 redundant, hot-swappable power supplies.
Software	
Intuitive interface	DarkStar systems offer router-like operation through an intuitive command-line interface familiar to any network administrator.
Field-upgradeable	DarkStar operating systems and gateware can be upgraded in the field. In addition, certain DarkStar models also include hardware upgrade capabilities.
Installer	An installer is provided to turn software updating into a seamless task.
Flash file system	An integrated flash file system facilitates data management: easy access, backups, simplified naming conventions, and the ability to boot any image, among other features. Files may be copied, uploaded, downloaded, and check-summed to ensure operational integrity.
Remote management	Systems can be accessed from anywhere. Moreover, any single DarkStar system can access all DarkStar systems in a network via the integrated OSC (optical service channel), collectively creating a remote system management network.
Remote and automated file configuration	System and configuration files can be hosted on a remote server to automate configuration of DarkStar systems. Use this feature to recover system settings upon reboot or to automatically provision multiple systems.
Management network services	The management network can be used to integrate network services with your system, including Simple Network Time Protocol (SNTP), Syslog, RADIUS, and Simple Network Management Protocol (SNMP) trap servers.
AAA support	Support for Authentication, Authorization, and Accounting (AAA) services provides increased network security.

Components

This chapter briefly describes DarkStar hardware components and introduces the DXMOS.

2.1 Power

DarkStar systems ship with two power supply modules. These supplies operate in a 1+1 redundant configuration. In the event that one power module fails, the system can operate on a single power module. Since power supply modules are hot-swappable, they can be replaced while the DarkStar system is running (as long as one power supply is connected and running). The general procedure for managing power supply modules is the same for all systems. Power supply modules use either AC or DC power.

For maximum availability, DarkStar systems should be connected to two power circuits. The circuits may be AC, DC, or a combination of AC and DC power. DarkStar products with AC power require no special wiring and can be connected to a standard outlet with 100-240VAC power using the included power cords. See Chapter 3 - System Installation for more about power connections.

Follow the instructions in Chapter 6 - Troubleshooting to replace a power supply module.

2.2 Fan Modules

DarkStar systems ship with two or three fan modules, depending on the DarkStar model. In the event of a fan module failure, the remaining fan modules are sufficient to adequately cool the system under normal operating conditions. Fan modules are hot-swappable and can be replaced and configured while the system is running. Each physical fan module contains two individual fan blowers.

DarkStar fan modules are variable-speed. When left in automatic control mode, fan speed is continuously adjusted to ensure that all temperature-critical components are maintained at or below individually specific control temperatures. If a fan module is removed (or fails), the speed of the other fans is automatically increased to compensate and ensure safe system operation.

Follow the instructions in Chapter 6 - Troubleshooting to replace a fan module.

2.3 Optical Interfaces

DarkStar systems include these optical modules, depending on the model:

TABLE 2-1. Optical Modules in a DarkStar System

Module	Location
Wave laser	DarkStar wave lasers, or DWDM lasers, are located inside the system. They are accessible via an access panel on the top of the chassis. (Do not open the chassis while the system is powered on.)
Client laser	Client lasers are accessible from the front panel of the DarkStar chassis.
OSC laser	Located beneath the top access panel of the DarkStar system chassis, this laser module is multiplexed into the line/band port. It works in conjunction with the four external Ethernet ports on the front of the DarkStar system chassis, allowing for remote management of all DarkStar systems in the network. An OSC interface shares the same IP subnet as the adjacent OSC port on the remote DarkStar system. Additionally, DXMOS features such as user accounts, DNS, access lists, RADIUS, AAA, and IP routes can also be configured through the OSC.
Statistical multiplexer	The switch processes up to twenty-four 10GbE client ports by scheduling frames to fill the available idle capacity of the two 100GbE trunk ports. Frames may be routed to other DQM100 systems and ports, and bandwidth may be controlled via classification settings through the switch.
Optical MUX and DEMUX filters	A MUX filter multiplexes individual DWDM interface transmitters to the line/band fiber; at the other end of the link a DEMUX filter distributes the optical signals out again to individual DWDM interface receivers.
[Optional] Amplifiers	A DarkStar system can be shipped with up to four optional erbium doped fiber amplifiers (EDFA). All customer optical signals are amplified. The OSC signal is not amplified by an EDFA.
Ethernet interfaces	The four Ethernet ports on the front of the DarkStar system are used by the management system to attach local operator equipment. They do not carry customer traffic.

2.4 Operating System DXMOS

DXMOS includes a Help feature for all commands. Type a question mark (?) at any system prompt or command line, or press tab at the end of incomplete commands.

2.4.1 DXMOS Modes

The DarkStar DXMOS has three modes that determine which commands are available. Disable mode allows all users to display limited information about a system. Enable mode allows users with appropriate permission to reconfigure some aspects of a system and display all information about the system. Configure mode is a subset of enable mode, in that all commands are accessible.Enable-mode requires a password and allows users to access a configure sub-mode to configure the system and perform system maintenance. Disable-mode users can only view the state of the machine, and can't change its operational state or configuration.

Configure mode is a particularly important, as it is used to set up and manage DarkStar systems and can be used to effect changes that impact customer traffic. The `configure` command level (indicated by the `CONF#` prompt) includes sub-level commands to configure specific features, each identified by its own prompt. For example, the `CONF-FAN[n]#` `fan` command configures a hot-swap fan module.

TABLE 2-2. Command Prompts

Prompt Format	Meaning
`>`	Default prompt for top level (disable mode) commands.
`#`	Default prompt for enable mode commands.
`CONF#`	Default prompt for configure commands.

At any sub level, the `exit` *command returns to the previous level, while* `end` *returns to enable mode.*

2.4.2 Terminal Pager

When enabled, the DXMOS terminal pager prints a set number of lines. Pressing the space key displays the next page of console output. The length of the page can be configured using the `terminal pager` command in configure mode. By default, the terminal pager is disabled.

2.4.3 Syntax Format

This guide uses the following conventions to represent DXMOS command-line syntax.

TABLE 2-3. Conventions for DXMOS Syntax

Format	Meaning
`localhost>`	All text appearing on the command line is represented by Courier Standard font.
`password`	Arguments supplied as free-form input (text, numbers etc.) are represented by Courier Standard italicized font.
`{client|osc|trunk}`	Curly braces denote required keywords and arguments. The vertical bar(s) between keywords and arguments denotes "or" and means one of multiple terms must be chosen as an option.
`[no] snmp-server enable traps [snmp|xkl|xkl-generic] host` *`address`*	Brackets denote optional keywords or arguments.

2.4.4 Abbreviations and Shortcuts

Commands may be abbreviated if the command is unique in the current mode. For example, `show connections` can be shortened to `sh conn`, but cannot be shortened to `s con` because there is more than one possible completion. The following keyboard shortcuts are available in DXMOS:

TABLE 2-4. DXMOS Keyboard Shortcuts

Shortcut	Action
CTRL+A	Go to the beginning of line.
CTRL+B	Go back one character.
CTRL+C	Cancel the current command line input.
CTRL+D	Delete the current character.
CTRL+E	Go to the end of line.
CTRL+F	Go forward one character.
CTRL+K	Delete all characters from the current cursor position to the end of the command line.
CTRL+N, ↓	Scroll forward through the command history.
CTRL+P, ↑	Scroll backward through the command history.
CTRL+R	Redraw the current command input (useful for restoring what was typed if the system writes output to the console while you enter a command).
CTRL+U	Clear the current command line contents and provide a new command prompt.
CTRL+V	Disregard any special meaning of the character following. The CLI already disregards most special characters and this shortcut is rarely required.
CTRL+Z	Discard the current command line and exit configure mode (equivalent to typing `end` at a configure mode prompt).
tab	Complete partially entered unique keyword. If more than one possible completion exists, tab displays list of choices.
?	Lists options for context-sensitive entered keywords. Displays information on additional command options.
; or !	Ignore rest of line. Use as an initial character to insert comments in the command line.

System Installation

3.1 Overview

Verify that you received the equipment listed in the packing slip, including user documentation and accessories package. Retain the shipping container and packing materials, they may be needed if the system is moved in the future.

The system is shipped complete and ready to run when power is applied. You do not need to open the chassis to install or configure line cards, transceivers, or fan or power modules.

In general, installation involves the following steps.

1. Install in a Rack

   The system requires only a single rack unit (1RU). Copper and fiber cables connect to the front of the system; power connections and fan outlets are at the back. A rack-mount kit is included for a 19-inch rack. Identify the rail, bracket, and fastener part numbers from the shipping documentation. Procedures shown here are for a 4-post rack mount system, separate instructions are included with the optional 2-post system.

   Provide slack to any cables attached to the DarkStar system, such as power, management, or fiber optic cables.

   A DarkStar system has rails that slide, thus providing access to the hatch on the top of the chassis. This hatch is used to hot-swap a failed DWDM laser transceiver (or OSC transceiver on certain DarkStar systems), as shown in Chapter 6 - Troubleshooting.

2. Connect a Console

   Connect the serial console cable and establish access. Once network connectivity is properly configured, you can administer the system from remote virtual (VTY) terminals, using Telnet or SSH (Secure Shell). VTY terminals connect via the Ethernet management ports on the front of the DarkStar.

3. Connect Customer Equipment

   Clean the fiber cables. Clean the fiber ends with an approved fiber cleaner (a fiber cleaner is included with the DarkStar). In a single step for each connector, clean the fiber and insert it in the laser module. Do not clean or insert both fibers at the same time.

   Connect the fiber cables. Each client port on the front of the system connects via fiber to customer equipment. Each client port is console-configured.

4. Connect Power

   The DarkStar has two power modules, and can operate normally on just one. For AC power, connect to a standard 100-240VAC outlet using the included power cords. **There is no power on/off switch; the DarkStar system boots as soon as power is connected.**

5. Verify System Operation

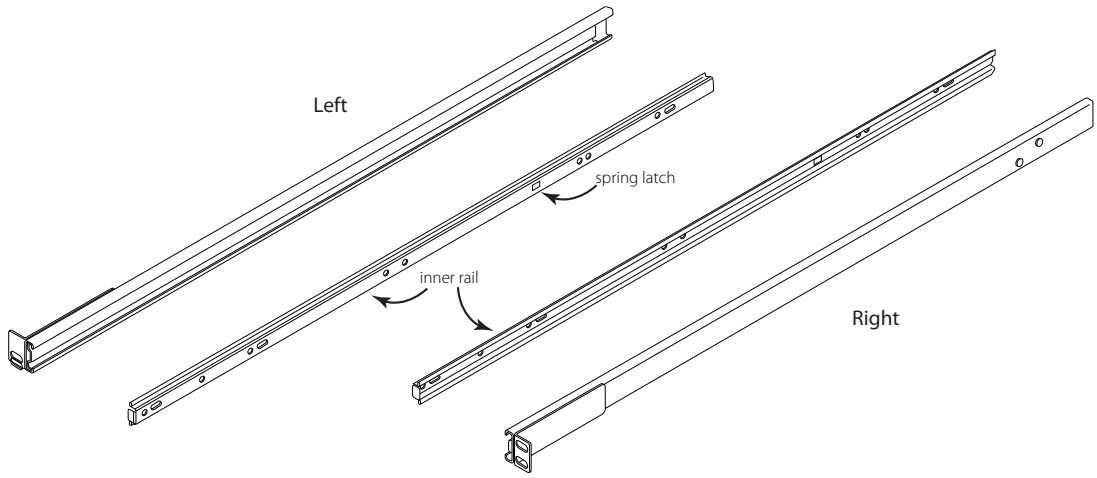
   Confirm the system is running normally by checking that the PWR LED shows green. The same status information is available at a console.

6. Verify Recommended Receiver Sensitivity Levels

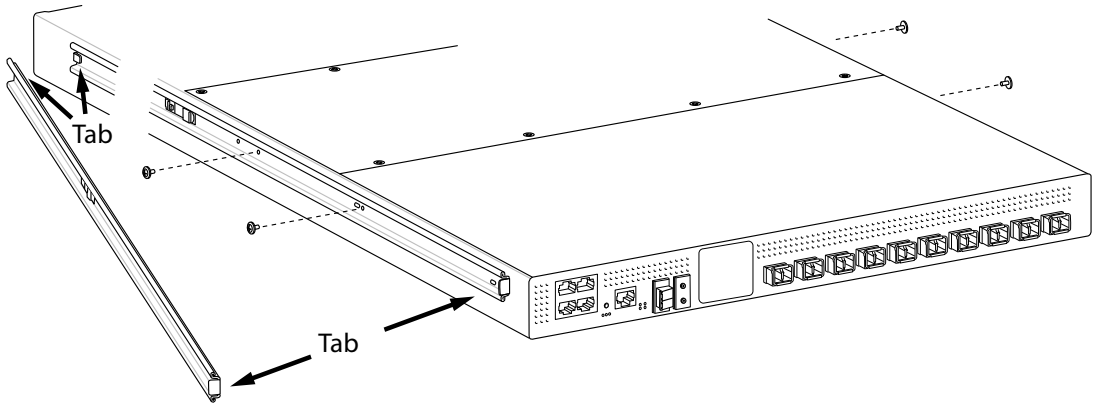
   DarkStar system optical settings are configured at the factory. After installation, verify that the receiver signal power still falls within the recommended sensitivity range for each transceiver type and, if necessary, use an external attenuator. See "Factory Settings" on page 19 for recommended sensitivity ranges.

3.2 Four-Post Rack Installation

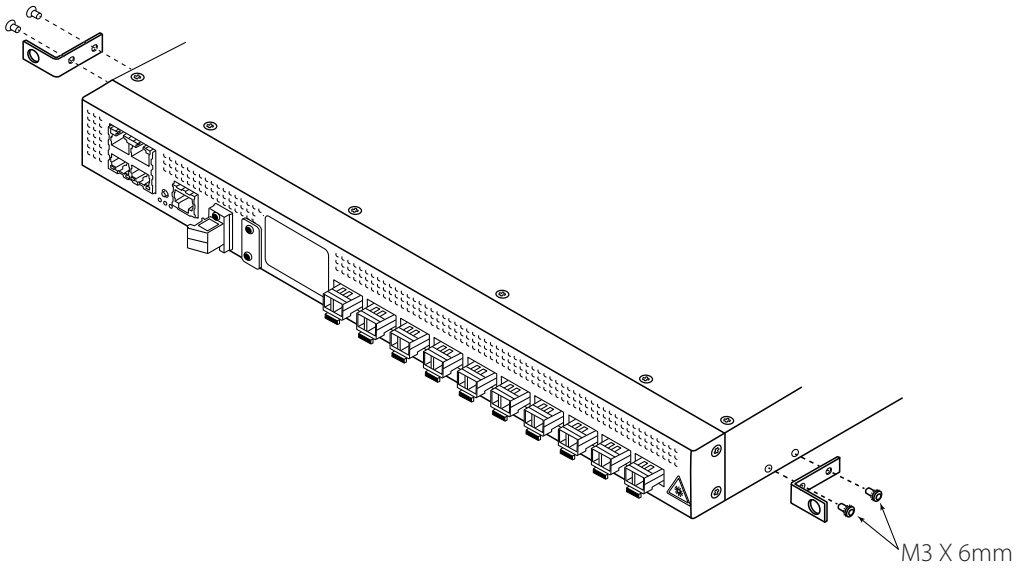
1. Locate the mounting rails and associated screws in the accessory package. The rails are labeled Left and Right. Press the spring latch on each inner rail and slide it out of the outer rail.



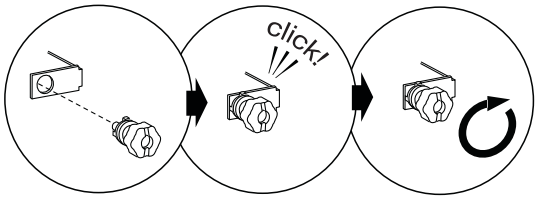
2. Attach the inner rails to the sides of the DarkStar by engaging the tabs near the rear of the DarkStar, then laying the rails alongside the DarkStar. Fasten the rails on each side with the supplied M4 screws (two screws for each side).



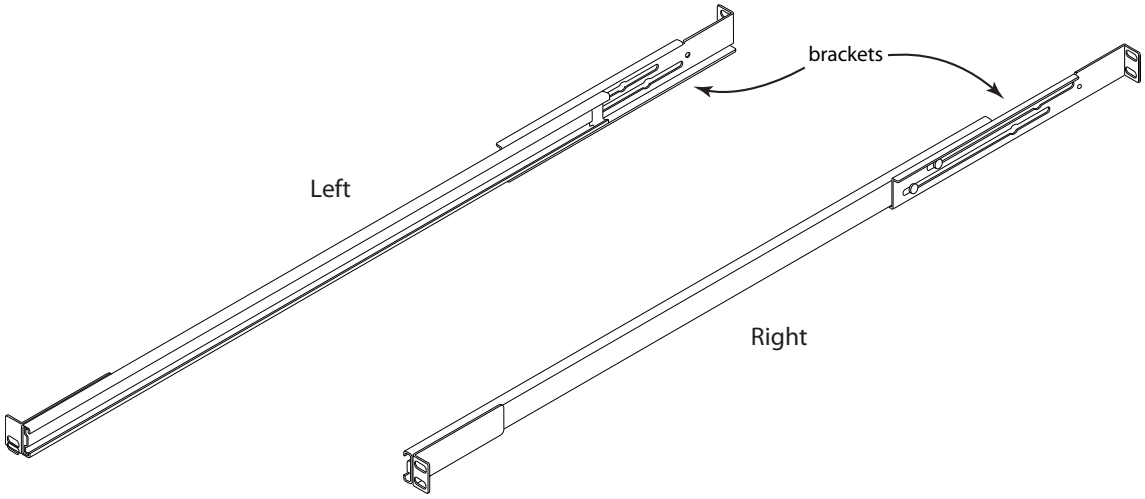
3. Fasten the L-shaped locking brackets to the DarkStar with two M3 × 6mm screws on each side.



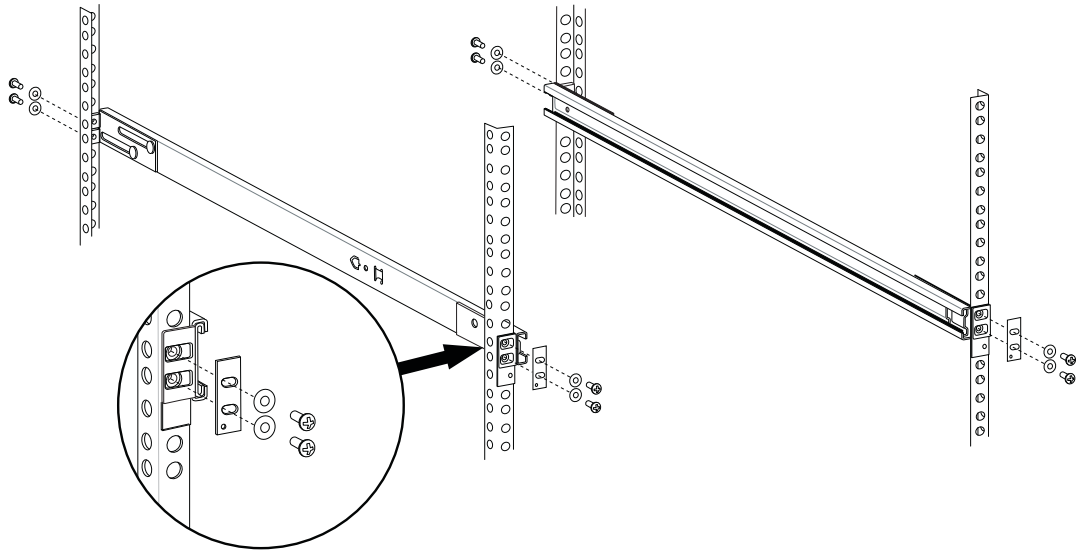
4. Snap the panel fastener into both L-shaped locking brackets.



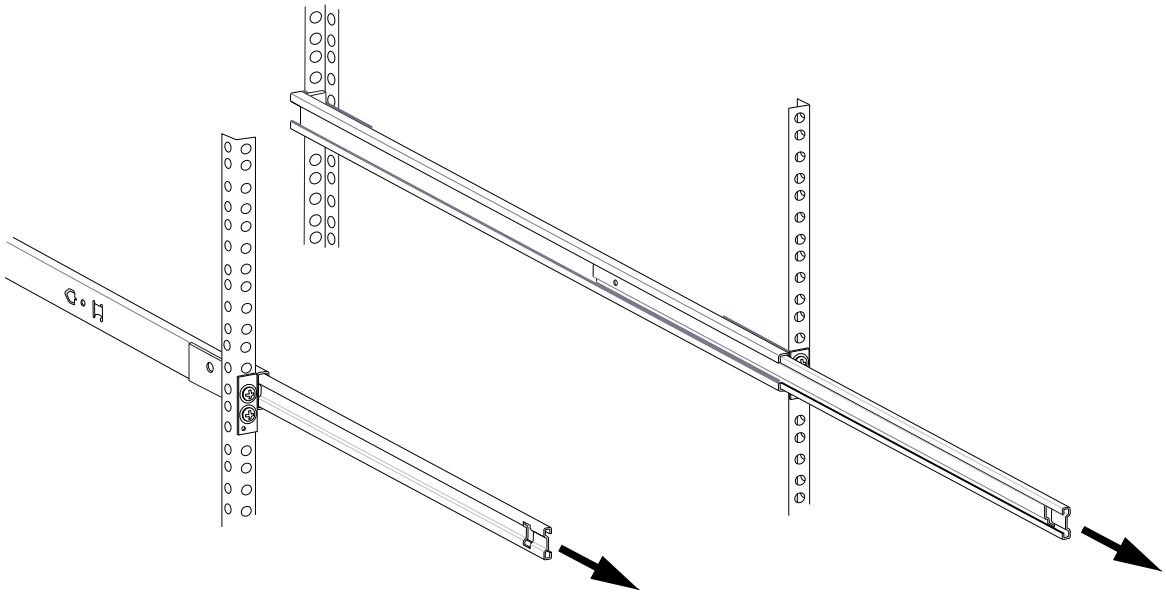
5. Place the brackets onto the outer rails.



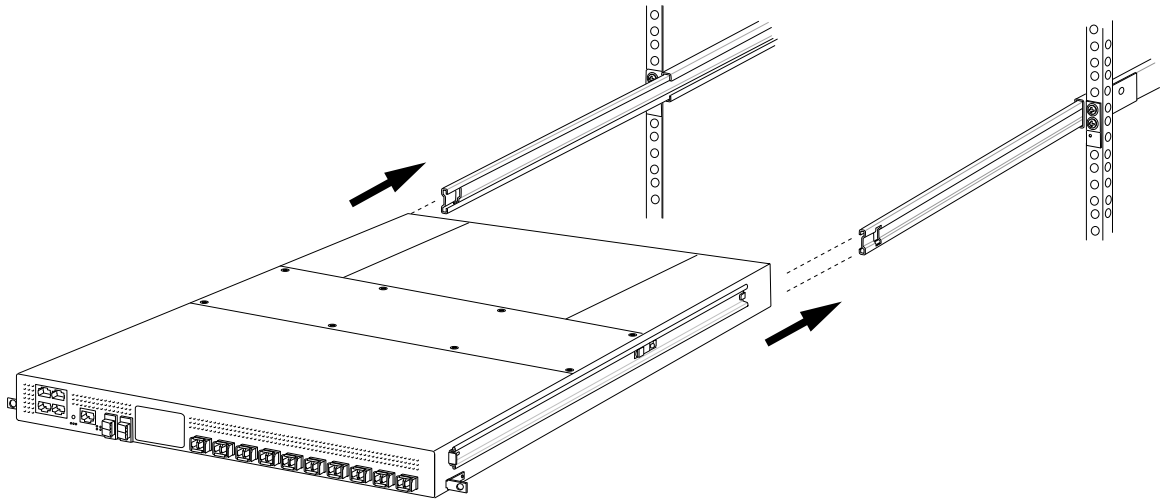
6. Install the outer rails in the 4-post rack, keeping the sides level and parallel. Place a thumb screw nut plate (see inset in illustration below) onto the front of each rail before attaching the screws to connect the rails to the rack, leaving them snug so that some adjustment to hole alignment can still be made after the chassis is installed. Use the 12-24 screws supplied in the accessory package.



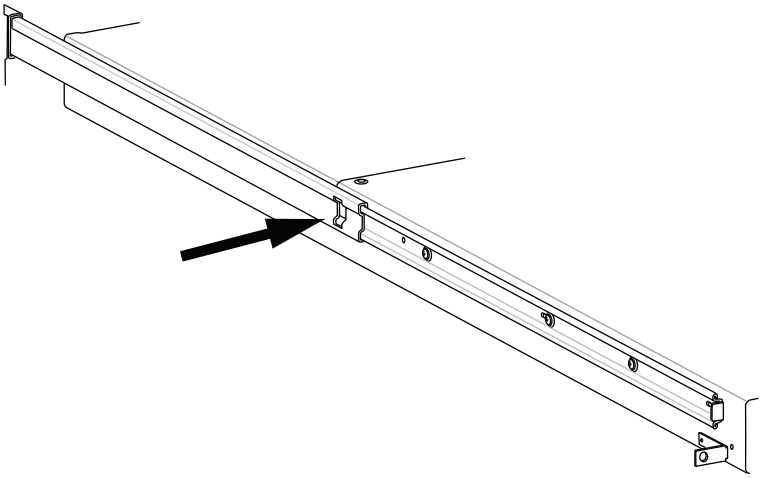
7. Extend the rails to maximum extension until they lock in position.



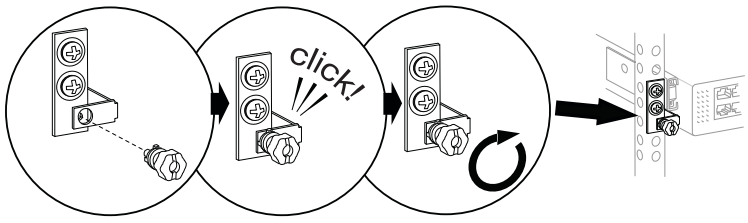
8. Use two people to lift the DarkStar and match the inner rails to the extended inserts. Slide the system into the rack until it clicks.



9. Press the square metal buttons on the sides of the rails and, at the same time, push the DarkStar the rest of the way into the rack.



10. After the system is completely pushed into the 4-post rack, snap the black thumb screws into the L-shaped locking brackets on the sides of the DarkStar, and screw them tightly into the nut plates on the rails.



3.3 Connecting Power

DarkStar systems ship with two power supply modules. These supplies operate in a 1+1 redundant configuration. In the event that one power module fails, the system can operate on a single power module. Since power supply modules are hot-swappable, they can be replaced while the DarkStar system is running (as long as one power supply is connected and running). The general procedure for managing power supply modules is the same for all systems. Power supply modules use either AC or DC power.

Follow the instructions in Chapter 6 - Troubleshooting to replace a power supply module.

For maximum availability, DarkStar systems should be connected to two power circuits. The circuits may be AC, DC, or a combination of AC and DC power. The following power combinations are supported:

- Two 100-240VAC
- Two 48VDC
- One 100-240VAC and one 48VDC

⚠	**Before connecting or disconnecting an installed power supply, make sure it is firmly seated in the DarkStar.**

3.3.1 AC Power

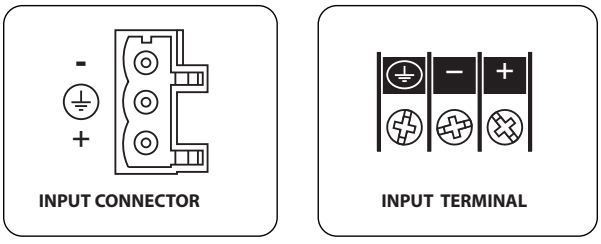
DarkStar products with AC power require no special wiring and can be connected to a standard outlet with 100-240VAC power using the included power cords.

3.3.2 DC Power

⚠	**Before connecting DC power, turn off the 48v DC supply. Failure to do so could result in serious personal injury or system damage.**

DC power connection may be a plug-in connector or an input terminal (see the illustrations below). To connect to the DC input terminal, 12-16 AWG (American Wire Gauge) stranded wire is recommended; 14 AWG wire is optimal for its size and flexibility.

FIGURE 3-1.



⚠	**When connecting wires to the Input Terminal, the ground connector GND must be connected first, and disconnected last.**

TABLE 3-1. DarkStar DC Power Connection Matrix

Reference	-48V Rail	+48V Rail
-	-48V	+48V RTN
⏚	GND	GND
+	-48V RTN	+48V

3.4 Factory Settings

This section contains initial system settings, as well as recommended transceiver power and sensitivity levels.

3.4.1 System Factory Settings

When a DarkStar system starts up, the saved configuration file is loaded. On first boot, the system applies factory configuration settings. This table lists the initial factory settings and any necessary customer actions at bring-up time.

TABLE 3-2. Initial Factory Settings

Feature/ component	Factory/default setting	Action Required
Boot	System boots from startup flash using the factory defaults described in this table, unless a saved configuration file exists.	Save the running configuration to flash (using the `write memory` command) or to a remote server (`write network`).
Console access	The serial console port is logged on and enabled. Establish a secure terminal configuration as soon as possible. The remote console port is not configured by default.	Assign a DNS server if required, using the `ip domain-name` and `ip name-server` commands. Enable remote console IP access using the `management {ethernet|osc}` and `ip address` commands. Enable secure console access using the `aaa authentication enable default` command.
Client modules	Client modules are ON (no laser shutdown).	No action required at bring-up.
Trunk modules	Trunk modules are ON.	No action required at bring-up.
OSC modules	Active. OSC lasers are ON (no laser shutdown).	No action required at bring-up.
DSM10/DQM10 systems: EDFA if present	EDFA is ON. Control mode is APC (Automatic Power Control).	No action required at bring-up. EDFAs are pre-set to the appropriate power per channel. This number varies, depending on the number of channels and presence (or absence) of dispersion compensation.

TABLE 3-2. Initial Factory Settings

Feature/ component	Factory/default setting	Action Required
DLA and DMD-A amplifier systems	Amplification is OFF. DXMOS-managed by default: This will put input (pre-amplifier) and output (booster) amps into APC (Automatic Power Control), except for a DLA system configuration where both a pre-amp EDFA and booster EDFA are present. In this configuration, the booster EDFA is in AGC mode (Automatic Gain Control). All input and output amps are disabled until explicitly enabled.	Configure the EDFAs: Enter the correct channel-count for each fiber path using the `path` configuration command. Enable each EDFA amplifier when ready.
Fan speed	The fan is set to automatic.	No action required at bring-up.

3.4.2 Recommended Transceiver Sensitivity Levels

The DarkStar system optical settings are configured at the factory to meet customer requirements. If there is a possibility that the system has been installed, perhaps temporarily, with relatively short fiber connections - for example, a few tens of meters - then it is good practice to verify that the transceiver signal power still falls within the recommended sensitivity range for that transceiver type and, if necessary, attenuate the incoming signal.

You can determine transceiver power levels using the `show modules summary` command, and attenuate an incoming signal by inserting a simple filter in the incoming fiber connector.

TABLE 3-3. Transceiver Specifications

Transceiver Type	Wave-length (nm)	Reach	Transmit Power (dBm)	Receiver Optical Power			Min OSNR (dB)	Connector Type	Note
				Min (dBm)	Optimum (dBm)	Max (dBm)			
CFP (100GBase-SR10)	850	100m	-7.6 to -1	-9.5		2.4	N/A	MPO/MTP-2x12	1
		150m							2
QSFP+ (40GBase-SR4)	850	100m	-1.7	-9.7	-4 ±2	N/A	N/A	MPO/MTP-1x12	1
		150m							2
SFP+ (10GBase-SR)	850	300m	-9.5 to -1	-17	-10 ±3	0	N/A	LC	3
			-5 to -1.5	-11	-5 ±2	-1			4
QSFP+ (40GBase-PSM4)	1310	1.4km	-0.5 to +3	-10	-4 ±2	N/A	N/A	MPO/MTP-1x12	
CFP (100GBase-LR4)	1310	10km	-2.5 to +2.9	-10.6		4.5	N/A	LC	
SFP+ (10GBase-LR)	1310	10km	-11 to -3	-19	-12 ±2	-3	N/A	LC	3
			-8 to 0.5	-12	-8 ±2	0.5			4
QSFP+ (40GBase-LR4)	1310	10km	+1.7 to +2.4	-11	-4 ±2	N/A	N/A	LC	
SFP (OC-3 CWDM OSC)	1510	100km	3	-42	N/A	-10	N/A	LC	

TABLE 3-3. Transceiver Specifications

Transceiver Type	Wave-length (nm)	Reach	Transmit Power (dBm)	Receiver Optical Power			Min OSNR (dB)	Connector Type	Note
				Min (dBm)	Optimum (dBm)	Max (dBm)			
SFP+ (DWDM 10GBase-ER)	C-Band	35km	-4.7 to +4	-14		-1	N/A	LC	5
CFP (DWDM 100G Coherent)	C-Band	1200km[6]	+1 to +4.4	-25	-6 ±2	6	15	LC	
SFP+ (DWDM 10GBase-ZR)	C-Band	2000km[7]	-3 to +1	-24	-10±2	-7	22*	LC	
XFP (DWDM 10GBase-ZR)	C-Band	2000km[7]	-1 to +3	-24	-15 ±2	-7	22	LC	

[1] OM3
[2] OM4
[3] Low (1-8.5Gbps)
[4] High (8.5-11.31Gbps)
[5] Fixed frequency
[6] EDFA and/or Raman amplification is required.The 1,200km transmission is "dispersion limited" which is based on the G652 fiber type. The transmission can be extended well beyond 1,200km with a DarkStar DLA System, due to healthy OSNR.
[7] EDFA and/or Raman amplification is required.
* The minimum OSNR is system dependent.

3.4.3 Amplifier Specifications

Factory default amplifier settings will depend on the configuration of your DarkStar, primarily the number of channels and if there is a dispersion compensation module (DCM). The following table lists the equations used to determine amplifier power settings.

TABLE 3-4. Determining Amplifier Power for DMD-A Systems

DMD-A EDFA	Output Power Calculation
Booster	EDFA Output Power (dBm) = 10G/100G Signal Power Per Channel (dBm) + 10 x log10 (Total No. of 10G/100G Optical Channels) + OSC Filter Insertion Loss (dB) + No. of Optical Switch x 50/50 Coupler Insertion Loss (dB)
Pre-amp	EDFA Output Power (dBm) = 10G/100G Optimum Received Power (dBm) + Filter Insertion Loss (dB) + No. of DCM x DCM Insertion Loss (dB) + 10 x log10 (Total No. of 10G/100G Optical Channels)

DarkStar systems may have EDFA and/or Raman amplifiers. The following tables list specifications for both types.

TABLE 3-5. Minimum Required Total Input Power (dBm) by DarkStar Model

Model	Minimum Input Power (dBm)
DSM10-2, DSM10-2R	-28
DSM10-4	-25
DSM10-5R	-24
DSM10-10	-22
DQM10-12	-18
DQM10-24	-15
DQM10-36	-13
DMD-A	Network dependent, maximum 96 channels.
*Input Optical Power measurements are for DarkStar systems operating at optimized link dispersion with a single pre-amplifier.	

TABLE 3-6. EDFA Optical Specification

Parameter	Min	Typical	Max
Minimum Wavelength Range (nm)	1528		1563
Total Operating Output Power (dBm)			
+12dBm EDFA Module (dBm)	-10		+12
+20dBm EDFA Module (dBm)	-10		+20
Optimal Designed Flat Gain (dB)		22	
Gain Setting Accuracy (dB)	-0.25		0.25
Variable Gain Range (dB)	17		29
Noise Figure, including connector loss @Optimal Gain, Maximum Output Power (dB)		5.5	
Gain Flatness over the Operation Wavelength			±0.75
Polarization Dependence Gain (dB)		0.3	0.5
Polarization Mode Dispersion (ps)			0.3
Dynamic Gain Tilt (dB)			0.9

TABLE 3-7. EDFA Detector Specification

Parameter	Min	Typical	Max
Minimum Wavelength Range (nm)	1528		1563
Total Operating Input Power (dBm)	-35		0
Total Operating Output Power (dBm)			
+12dBm EDFA Module (dBm)	-10		+12
+20dBm EDFA Module (dBm)	-10		+20
Optimal Designed Flat Gain (dB)		22	
Gain Setting Accuracy (dB)	-0.25		0.25

Setup and Management Configuration

This chapter describes how to power up and configure a DarkStar system.

4.1 Connect Consoles

The console serial port is a minimal RS-232 Data Terminal Equipment (DTE) configuration. Wiring for the 8-pin modular jack (RJ-45) that connects the RS-232 connector to the console is illustrated below. A console cable is provided with all DarkStar systems.

FIGURE 4-1. RJ-45 Pinout

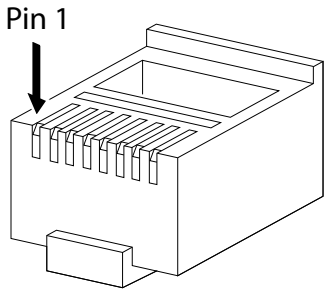


TABLE 4-1. Console Jack Pinout Configuration

Pin	Signal
1	No connection
2	No connection
3	TxD
4	Gnd
5	No connection
6	RxD
7	No connection
8	No connection

To establish access, connect the RS-232 port on a console terminal to the RJ-45 console port on the front of the DarkStar system. The console line supports 9600-8N1 communication:

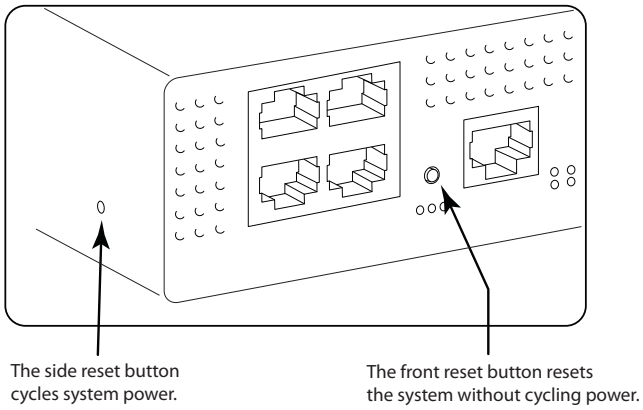
- 9600 baud
- 8 bits per character
- no parity
- 1 stop bit

4.2 Power-Up and Reboot

DarkStar systems boot when either of the two power supply modules are connected. Since DarkStar systems are designed for continuous operation, there is no power switch. Instead, there are two reset buttons. The side reset button cycles internal power and reloads software and gateware. The front reset button reloads software and gateware without cycling power.

Front-panel LEDs display system status and can help to monitor this process. See "Front Panel LEDs" on page 56 for a comprehensive table of LED patterns and their meanings.

FIGURE 4-2. Hardware Reset Buttons



To cycle power, use a non-conductive reset tool, such as the one provided with the system, to press and immediately release the side reset button.

- **Do not use a metal object (such as a paperclip) to depress the side reset button. Doing so may expose the operator to hazardous voltage or damage the DarkStar system.**
- **Cycling power disrupts customer traffic. It should only be done if a system has crashed or a you want to do a hard reset of all hardware.**

When you power up the system, it performs the following steps:

1. MiniBoot, a lightweight boot loader, loads from the startup gateware and executes a larger, more functional boot loader, Boot, from the startup boot location in the startup flash memory.
2. Boot attempts to obtain configuration information in the following order. Otherwise, DXMOS is started without configuration information, and DarkStar Factory Default settings are applied.
   - Boot configures from the flash configuration file (dxmos/config.dat) if the file exists.
   - If the file contains explicit commands to boot via DHCP (boot host dhcp), then Boot attempts to obtain a configuration file via DHCP and TFTP.

- If the attempt to configure via DHCP/TFTP fails, Boot follows the other commands in the flash configuration file.
- Otherwise, if there is no flash configuration file, Boot attempts to configure via DHCP/TFTP. If unsuccessful, Boot attempts "boot file /dxmos/dxmos.exe".

3. After a delay (10 seconds by default), Boot loads DXMOS from the image location specified in the configuration file or from the startup-image by default. Wait for Boot to load.
4. You are now ready to configure your system.

If changes are made to `running-config` *and the DarkStar system reloads without saving changes to* `startup-config`*, changes made to the* `running-config` *will be lost. As a result, when the system reboots, the previous* `startup-config` *will take effect and the loss of* `running-config` *changes may results in a loss of customer traffic.*

4.2.1. Boot and Recovery

The following tables summarize events that trigger boot and recovery scenarios and their effects on the DarkStar system.

TABLE 4-2. Boot & Recover Scenarios

Event	Power Cycle	Gateware Reload	Software Reload	Factory Settings Reload
Front button push and release	no	no	yes	no
Front button push and hold	no	yes	yes	no
Side button push and release	yes	yes	yes	no
Side button push and hold	yes	yes	yes	yes
DXMOS reload command	no	yes	yes	no
Power cycle (disconnecting both power supplies)	yes	yes	yes	no
DXMOS software fault	no	no	yes	no
Watchdog timeout	no	yes	yes	yes, only after several watchdog timeouts where DXMOS fails to run
Recovery mode (resulting from corrupted startup flash)	no	yes	yes	operator's choice
Failure to load startup gateware	no	yes	yes	yes

- "Push and release" means pushing the button and immediately releasing it.
- "Push and hold" means pushing the button and holding it in for at least 3 seconds.
- There are two hardware reset buttons on DarkStar systems, illustrated in Figure 4-2 on page 24.
- Pressing the side reset button always causes the system to cycle power, and always interrupts all customer traffic.

TABLE 4-3. Different Types of Reboot

Result	Action
To boot the system using factory default image, configuration, and gateware	Press and hold the side reset button for three seconds. The system status LEDs (green, amber, and red) on the front panel flash, then stay lit for a few seconds when the DarkStar system resets successfully. Note that booting from the factory default image interrupts customer traffic.
To reset the software only	Press and immediately release the front reset button. If the running configuration is identical to the startup configuration, software reset maintains power and the state of customer traffic.
To warm reboot (no power cycle)	Press and hold the front reset button for three seconds. If the running configuration is identical to the startup configuration, warm reboot reloads the system gateware and software, and maintains power and the state of all transport interfaces. The system status LEDs (green, amber, and red) on the front panel flash when the reboot succeeds. Warm reboot is the hardware equivalent of the DXMOS reload command.
To cold reboot (with a power cycle)	All of these options will interrupt customer traffic. • Perform an internal or external power cycle for a cold reboot. • Use the side reset button for an internal power cycle. • Disconnect both power cords for an external power cycle.
To determine whether a power cycle has occurred since the last reload, run the `show version` command. If the previous reload was a cold cycle, `Last reload due to internal power cycle` displays. Likewise, the message will indicate if it was an external power cycle. When managing a DarkStar system remotely, this information may be helpful in determining the cause of a power cycle.	

4.3 Configuring the System

The configuration file is saved to flash memory via a write memory command, and runs automatically at boot time. It not only includes system and network settings, but also configures management services such as SNMP and event logging that need to be in place for better troubleshooting.

Config files contain encrypted passwords. Make sure you keep an accurate record of the passwords. You will need them if/when you restore a saved configuration.

To create an effective running configuration file, you should follow the sequence in the table below. Refer to the Command Reference for more information about using any of the commands mentioned here.

TABLE 4-4. Create a Running Configuration File

Step	Command to Use
1. Security and AAA Authentication: Configure operator consoles for Telnet and SSH access, and AAA authentication.	• `user` • `transport input` • `access-class` • `access-list` • `tacacs-server` • `aaa authentication` • `password`
2. Configure network time and management IP addresses.	• `clock` • `host` • `hostname` • `ip domain name` • `ip name-server` • `ip route` • `sntp server` • `management` • `router rip` • `ip address`
3. Set up line protection.	`protection`
4. Configure SNMP traps.	`snmp-server`
5. Set up event logging.	`logging host`

4.3.1 Step 1 - Security and AAA Authentication

Direct access is available via console terminal connection. Once network connectivity is properly configured, it is also possible to administer the system from a remote virtual terminal (VTY) using Telnet or SSH (Secure Shell). In addition to using passwords for Telnet and SSH access, DarkStar systems may also be secured by setting passwords for enable mode and serial console access. The following steps need to be taken to secure your system:

1. Configure passwords for console or VTY access.
2. Configure enable mode passwords.
3. Build access control lists.
4. Configure SSH access.
5. Configure SSH Key replacement.
6. Configure Telnet access.

4.3.1.1 Console and VTY Access

Secure the console terminal (CTY) and the VTY line with either a password or username and password combination.

See "Configuring Security" in the Command Reference for more information about setting passwords and using other DXMOS security commands.

The following example illustrates how to set a password for an anonymous CTY connection. Setting the password will overwrite any previously set password on the CTY:

```
> enable
# configure
CONF# line console
CONF-LINE-CTY# password new-password
CONF-LINE-CTY# end
# write memory
Are you sure? [yes/no] yes
# logout
```

The following example illustrates how to remove a CTY password. After removing a password, you can either set a new password or leave the system unprotected (NOT recommended):

```
> enable
# configure
CONF# line console
CONF-LINE-CTY# no password
CONF-LINE-CTY# end
# write memory
Are you sure? [yes/no] yes
```

Local user accounts can be used by the console and the vty. The following illustrates how to create user accounts and enable them for the console. Setting 'login local' enables use of a local user/password data base, and supercedes use of the anonymous password.

```
> enable
# configure
CONF# user username password new-password
CONF# user another-user password another-password
CONF# line console
CONF-LINE-CTY# login local
CONF-LINE-CTY# end
# write memory
Are you sure? [yes/no] yes
#
```

The same pool of accounts is used to store users for both CTY and VTY access. Be aware that any user created for CTY access may also be used to login via VTY access, assuming VTY is configured for remote login via Telnet or SSH.

The following example illustrates how to stop using user accounts and instead use an anonymous login. Accounts will remain in the system and configure file, but cannot be used to access the machine through the console:

```
> enable
# configure
CONF# line console
CONF-LINE-CTY# login
CONF-LINE-CTY# end
# write memory
```

```
Are you sure? [yes/no] yes
#
```

If you set a single-login password for CTY or VTY access, it will remain in the configuration file, but will not remain in effect. The single-login password is not required while user accounts are active. However, if you then revert to single-login password again, gaining access will still require the single-login password you originally assigned. If login local is set, only the username/password pairs may be used at that time.

If the customer (startup) flash becomes unreadable for any reason, the DarkStar system enters recovery mode and reverts to factory settings. Telnet access is disabled and only the console can be used for diagnosis and repair.

4.3.1.2 Enable Mode Password

Setting a password for enable mode prevents unauthorized changes from being made to a DarkStar system's settings. An enable mode password will prompt for a password when the `enable` command is used.

The following example illustrates how to assign a password for enable mode. Assigning a password will override any previously set password:

```
> enable
# configure
CONF# enable secret password
CONF# exit
# write memory
Are you sure? [yes/no] yes
#
```

The following example illustrates how to remove a password for enable mode. After removing a password, you can either set a new password or leave the system unprotected while in enable mode:

```
# configure
CONF# no enable secret
CONF# end
# write memory
Are you sure? [yes/no] yes
```

4.3.1.3 Remote Connections

Three commands are used to enable remote access via either Telnet or SSH:

- The `password` command sets the password for VTY.
- The `login` command enables remote login over VTY.
- The `transport` command configures VTY to accept login attempts via the specified protocol.

The following illustrates the general process of configuring the DarkStar to allow remote (VTY) access:

1. The system has four copper Ethernet connections and one or two fiber Ethernet connections. Select a DarkStar Ethernet connection and configure its IP address to be compatible with (same subnet address) the local subnet. Connect the system Ethernet connection to the local subnet.

2. Remote access requires the transport input command to be issued at the line VTY configure prompt. You can specify "all" for both Telnet and SSH, "telnet" for Telnet only, and "ssh" for SSH only.

```
CONF-LINE-VTY# transport input all
```

3. Unlike the console, remote access requires some form of authentication. Local authentication can be by anonymous login, which needs an anonymous password and a login command.

```
CONF-LINE-VTY# password xkl
CONF-LINE-VTY# login
```

Local access can also use user/password accounts. Local user/password accounts are created as described in "Console and VTY Access" on page 27. For example:

```
CONF-LINE-VTY# user user1 password password1
CONF-LINE-VTY# user user2 password password2
```

After creating the local user/password database, enable it for use by issuing the login local command.

```
CONF-LINE-VTY# login local
```

4.3.1.3.1 Telnet Access

Telnet access is disabled until the Virtual Terminal (VTY) password is set. VTY lines must also be configured to accept connections via Telnet. VTY lines can be accessed via any configured Ethernet port.

Be aware that if AAA new-model is set, then AAA access rules apply instead of the requirements outlined here.

- The `password` command sets the password for VTY.
- The `login` command enables remote login over VTY.
- The `transport` command configures VTY to accept login attempts via the Telnet protocol.

The following example illustrates how to configure remote Telnet access to all configured Ethernet ports:

```
> enable
# configure
CONF# line vty
CONF-LINE-VTY# password new-password
CONF-LINE-VTY# login
CONF-LINE-VTY# transport input telnet
CONF-LINE-VTY# end
# write memory
Are you sure? [yes/no] yes
#
```

4.3.1.3.2 SSH Access

A DarkStar system supports both SSH and Telnet remote console access. SSH can add additional security protection. Customers that have isolated and protected their DarkStar management network sufficiently find that Telnet is acceptable for day-to-day use. Both SSH and Telnet can be configured upon first boot of the DarkStar system; setup is similar in each case.

A DarkStar system ships with the necessary SSH public and private keys pre-installed in its file system, and boots initially with SSH remote console access disabled. To enable SSH on a VTY console line, ensure that the line already has a password (use the `password` command), enable remote login (use the `login` command), and configure SSH as a transport type (use the `transport` input ssh command).

SSH hostkeys are used for SSH authentication. The authentication credentials are handled silently by the DarkStar system. SSH console clients, whatever their platform, do not require additional SSH key generation or management to access the DarkStar system. On first console access, an SSH client will ask the console operator to confirm the SSH access request; subsequent SSH console access requests authenticate silently.

The following example illustrates how to configure remote SSH access to all configured Ethernet ports:

```
> enable
# configure
CONF# line vty
CONF-LINE-VTY# password new-password
CONF-LINE-VTY# login
CONF-LINE-VTY# transport input ssh
CONF-LINE-VTY# end
# write memory
Are you sure? [yes/no] yes
#
```

4.3.1.3.3 SSH Key Replacement

A DarkStar system ships with SSH keys already in place. To replace the DarkStar SSH keys, you must generate new SSH keys and transfer them to the DarkStar system. The new SSH keys become activated at the next reload of DXMOS.

A DarkStar system stores its SSH keys in its file system. The public and private keys are referred to by their well-known names "hostkey-public" and "hostkey-private"; the actual filenames in the DarkStar file system are:

- hostkey-private is equivalent to writing "dxmos/hostkey-private.dat"
- hostkey-public is equivalent to writing "dxmos/hostkey-public.dat"

You can generate new SSH keys using any keygen utility that can create DSA key pairs for the SSH v2 protocol. Instructions for generating keys vary by platform. For example, the keygen utility for Linux is ssh-keygen, and similar tools exist for other platforms.

Only DSA keys are supported by the DarkStar systems. RSA keys will not work.

You must activate your new SSH keys by reloading DXMOS using the `reload` command. This forces a warm boot of the DarkStar operating system without disturbing existing traffic, and activates your new SSH keys. At the first ssh access request after the reload, each client detects the change in the DarkStar keys and asks the console operator to take action, for example by verifying that access is required or by confirming that the previously saved SSH public key should be removed. Subsequent ssh access requests negotiate silently, as before.

The following example illustrates how to copy SSH keys to a DarkStar system:

```
> enable
# tftp get 10.15.1.98 id_dsa hostkey-private
Are you sure? [yes/no] yes
# tftp get 10.15.1.98 id_dsa.pub hostkey-public
```

```
Are you sure? [yes/no] yes
#
```

4.3.1.3.4 Access Control Lists

ACLs (Access Control Lists) may be used to enhance security and mitigate opportunities for denial-of-service attacks. This feature is particularly important if the DarkStar system is not on a private management network and/or remote Telnet/SSH access is enabled. (Refer to the Command Reference for more information about setting up ACLs.)

Incoming router traffic is compared to ACL entries based on the order that the entries occur in the router. The router searches for matches and denies traffic if no match is found. There is an implied denial for traffic that is not permitted. A single-entry ACL with only one deny entry has the effect of denying all traffic. Since new statements are automatically added to the end of the list, it may be helpful to place frequently used entries at the top of the list.

The following example illustrates how to enable an ACL on the VTY:

```
> enable
# configure
CONF# access-list 1 permit 10.4.0.0/16
CONF# do show running-config access-list

running-config:
access-list 1 permit 10.4.0.0/16
```

Instead of designating single-password Telnet or SSH access, you may alternatively create user accounts, each with its own username and password. Multiple accounts may be used with Telnet, SSH, or both, depending upon settings enabled through the `transport input` command.

4.3.1.4 AAA with RADIUS and TACACS+

RADIUS and TACACS+ use a remote server to manage a database of user/password accounts, along with other security properties. When remote AAA is used, it supersedes/hides/replaces the local database access configuration; DXMOS queries a RADIUS or TACACS+ server that provides centralized authentication, authorization, and accounting services.

The use of AAA services also allows more precision and control when using local login methods.

The TACACS+ protocol uses TCP and is not compatible with the earlier TACACS protocol that uses UDP as a transport.

4.3.2 Step 2 - Network Time and Management IP Addresses

In this step, you configure the system time and several items related to the system IP address. Settings include:

- Clock time and system date.
- Loopback addresses
- IP address, including hostname, ip domain-name, ip name-server, and ip address.

4.3.2.1 Date and Time

DarkStar systems ship with the clock set to Universal Time (UTC). The clock command sets system date and time. When a DarkStar system is in configuration mode, this command sets the time zone and Daylight Saving Time (DST) rules. You can manually configure the clock, or automatically configure it from the SNTP server time.

The following example illustrates how to manually set the system clock, in this case to Pacific Standard Time (UTC-8), then Pacific Daylight Time (UTC-7):

```
> enable
# show clock
23:59:59 UTC Mon Mar 30 2009
# configure
CONF# clock timezone -8 0
CONF# clock summer-time usa
CONF# exit
# write memory
Are you sure? [yes/no] yes
# clock set 17:01:30 30 march 2009
# show clock
17:01:33 UTC-7 Mon Mar 30 2009
```

If you run an SNTP server on a management network reachable by the DarkStar system, XKL recommends enabling clock updates by running the `sntp server hostname` command.

4.3.2.2 Loopbacks

A system loopback address is a virtual IP address. It is not associated with a specific physical interface; rather, it serves as a global IP address for the DarkStar system.

A loopback address can ensure access to a DarkStar system regardless of the state of physical interfaces. As long as routing is configured and at least one physical interface remains active, it is possible to access a DarkStar system via its loopback address.

If there is a loopback address, it is used as the source address for outbound IP messages instead of the IP address of the physical interface. However, if the loopback address is unconfigured, the IP address of the physical interface is used. DarkStar systems respond to inbound traffic using the destination IP, which may be a physical interface address or the loopback address, as determined by the sender.

Because a loopback address provides a consistent identity, it may be helpful to use it with protocols such as TFTP, SNMP, SNTP, Syslog, RADIUS, TACACS+, and outbound Telnet. The loopback address is established using the same configuration commands as for a physical interface, the only difference being that the device name is `loopback`.

The following example illustrates how to configure a loopback address:

```
# configure
CONF# management loopback 0
CONF-MGMT-LOOP[0]# ip address 172.16.1.192/32
CONF-MGMT-LOOP[0]# exit
```

4.3.2.3 OSC/Ethernet Management Provisioning

You can configure any unused Ethernet to connect to the DarkStar system management network.

The following example illustrates the process for configuring a management Ethernet. It defines an IP address and subnet mask for management Ethernet 0. A management OSC is configured similarly:

```
> enable
# configure
CONF# management ethernet 0
CONF-MGMT-ETH[0]# ip address 192.168.0.1/24
CONF-MGMT-ETH[0]# end
# write memory
Are you sure? [yes/no] yes
```

IPv6 addresses are assigned using IPv6 Stateless Address Autoconfiguration (see RFC 2462). This requires that there be at least one IPv6 router accessible on the local link. The router should be configured so that the router advertisement has the 'O' flag set and the 'M' flag cleared. The prefix-information option in the router advertisement should have both the 'L' and 'A' flags set.

After Ethernet configuration is completed, the DarkStar system can be integrated into your management network. See the "DarkStar DXMOS Command Reference" for additional management network configuration commands.

4.3.3 Step 3 - Controlling Line Protection

A protected configuration has two different fiber paths between the same two systems, a primary and a backup. Protection uses the backup fiber path when the primary fiber path is disrupted. The outgoing signal is split so the same data are sent on both paths. On input, an optical switch selects which fiber is connected to receivers. The fiber designated as primary remains connected unless its associated OSC monitor reports loss of signal, whereupon the operating system switches to connect the secondary (backup) fiber to receivers. To minimize loss of data, switching to the backup fiber is usually accomplished in less than 50 milliseconds. The switching event is logged. After the primary fiber is restored, the operator can command the DarkStar system to re-select its use.

When the protection feature is present, it is enabled by default. An operator may disable protection (not recommended) with the `protection disable` command in the DarkStar configure mode. The protection condition can be written to the config file to maintain it across reloads. See the Command Reference for more information about the protection commands.

4.3.4 Step 4 - Configure SNMP Traps and Monitoring

DarkStar systems support both the SNMPv1 and SNMPv2c versions of SNMP. To monitor detailed DarkStar system status, use the XKL-proprietary SNMP management objects and traps defined in the current XKL MIB (can be obtained at http://www.xkl.com).

To monitor a DarkStar system using SNMP, first configure DarkStar SNMP settings and enable SNMP asynchronous alarms and alerts ("traps"), then configure your monitoring system to recognize XKL-specific traps and to access XKL management objects in the SNMP database.

Use the `snmp-server` command to configure SNMP settings and enable SNMP traps. The flow for setting up SNMP is shown below.

The `community` *`string`* argument is required to set up monitoring.

```
# configure
CONF# snmp-server community string
```

Then set up trap generation.

```
CONF# snmp-server enable traps [snmp|xkl|xkl-generic]
CONF# snmp-server host address [Community Name]
```

Additionally, you can specify a contact and location for the community string and disable the use of SNMP v. 2c. Refer to the Command Reference for more information.

TABLE 4-5. SNMP Parameters for Initial Configuration

Parameter	Definition
`community` *`string`*	Start a read-only SNMP agent using the community string specified by *`string`*.
`enable traps [snmp|xkl|xkl-generic]`	Turn on sending of SNMP traps. (A host address is also required.) If no traps are specified, they are all turned on. • `snmp` - Turn on only SNMP standard traps • `xkl` - XKL-specific traps (listed in the table below) • `xkl-generic` - XKL-generic traps
`host` *`address`*	Send SNMP traps to a specific host, specified by *`address`*, which is either a hostname or an IP address. Multiple hosts may be specified, but only one per invocation of this command.
`host` *`address [Community Name]`*	Specify a *`Community Name`* to cause traps to use this community string rather than the global `community` *`string`* specified for SNMP read operations.

4.3.5 Step 5 - Set up Remote Event Logging

You can store log information to a syslog server and to a circular log buffer.

4.3.5.1 Syslog

DarkStar systems can send logging information to a syslog server.

The following example illustrates logging messages to a syslog server:

```
# configure
CONF# logging host ip-address-of-syslog-server
CONF# exit
# write memory
Are you sure? [yes/no] yes
#
```

The following illustrates sending periodic heartbeat “MARK” messages to a syslog collector:

```
# configure
CONF# logging syslog mark interval in minutes
CONF# exit
# write memory
Are you sure? [yes/no] yes
#
```

When "MARK" is enabled, a line similar to the following appears in the syslog server logs at the specified interval:

```
Oct 31 17:54:20 10.15.1.153 localhost (Uptime: 0:01:38:36) -- DXM MARK --
```

4.3.5.2 Circular Log Buffer

DarkStar systems can store log messages in a volatile circular buffer. When a circular buffer becomes full, it continues to store data by overwriting the oldest recorded messages. Therefore, a full circular buffer will only contain the most recent log messages.

The following example illustrates how to enable the circular log buffer:

```
# configure
CONF# logging buffer buffer-size-in-messages
CONF# exit
```

The following example illustrates how to view the contents of the log buffer:

```
# show log
0:01:45:15: Authentication Success 10.15.1.98
0:01:46:17: Authentication Failure 10.15.1.98
0:01:46:22: Authentication Success 10.15.1.98
```

4.4 Remote File Configuration

Once the management network is provisioned, DarkStar systems are capable of remotely acquiring a configuration file via DHCP and TFTP for semi-automated configuration. This method of configuration is attempted when no `startup-config` file is present in flash memory or when the `boot host dhcp` command is issued and saved in startup-config.

In this context, the DarkStar system acts as a DHCP client and broadcasts discovery requests. The DHCP offer and subsequent download of the configuration file can be managed on a single DHCP/TFTP server or separate DHCP and TFTP servers.

To effectively use DHCP configuration, two separate files must be properly deployed on the DHCP/TFTP server(s):

- The first file is the *DarkStar configuration file*, which must be hosted on a TFTP server. This file can be created during manual configuration of the DarkStar system. Once a configuration file is created, it can be modified outside of the DarkStar system using any text editor.
- The second is the *DHCP server configuration file*, which configures the server to provide the DHCP offer when it receives a DHCP discovery request from the DarkStar system. It is essential that the information in the server configuration file match the client identifier or source MAC address sent by the DarkStar system during DHCP discovery.

It is important to note that "01:" will always be prepended to an interface's MAC address when it is used as the DHCP client identifier. The same syntax must be used in the DHCP server configuration file. The information included in the DHCP server configuration file must correspond to the parameters (or absence of parameters) in the boot host dhcp command stored in `startup-config`.

When the command `boot host dhcp` *`interface_id`* is present in the configuration file, the DarkStar Boot program prepends `01:` to the MAC address associated with the named interface; it uses the resulting string as the client identifier option in the discovery messages sent on every active interface. This information may be useful in identifying a system by one unique address regardless of which actual interface contacts the dhcp server. Note that the server's configuration file must include that string in an option dhcp-client-identifier entry.

If Boot finds a `boot host dhcp` command in startup-config without a specified client-id interface, then Boot broadcasts a DHCP discovery message on all active DarkStar management Ethernet modules, and in each instance the client identifier will be the MAC address of the interface from which discovery is broadcast. In this scenario, you may use any active interface's client identifier or source MAC address in the corresponding DHCP server configuration file. Be aware, however, that if the Ethernet interface or MAC address that you designate in the file is unable to reach the DHCP server, no DHCP offer can be made and the configuration process will fail.

The following example illustrates a portion of the required configuration of a Unix/dhcpd-based server. The following sample would be added to the server's `etc/dhcpd.conf` file:

```
host dxm-sea-01 {
hardware ethernet 00:A0:E3:00:01:A8;
next-server 10.3.0.250;
filename "config-00.01.a8";
}
```

In the example above, `00:AO:E3:00:01:A8` is the MAC address of an active Ethernet interface that can reach the DHCP server. Static IP configuration and other configuration parameters should be included in the file `config-00.01.a8` that is placed in the TFTP server's directory. The TFTP server is specified in the `next-server` parameter.

In all cases, the DarkStar system only uses the offered IP address temporarily and then releases it after obtaining the configuration file.

If the DarkStar system is multihomed and capable of reaching DHCP servers on more than one of its connected Ethernet ports, you can specify a configuration file bound to a particular `dhcp-client-identifier` as illustrated in the following example. In this case, `boot host dhcp ethernet 0` should be added to the startup-config of `dxm-sea-01`, where the MAC address of Ethernet 0 on dxm-sea-01 is `00:A0:E3:00:01:A6`. This modification allows the DHCP server to provide a single configuration regardless of which DarkStar system management interface is used to obtain the configuration:

```
host dxm-sea-01 {
next-server 10.3.0.32;
option dhcp-client-identifier 01:00:A0:E3:00:01:A6;
filename "config-00.01.a6";
}
```

The DHCP server must directly connect to the subnet associated with the DarkStar management port, or a system on that subnet must act as a DHCP relay.

5

Monitoring

This chapter describes how to monitor a DarkStar system using DXMOS commands.

5.1 Hardware Monitoring

DarkStar `show` commands allow you to monitor system activity any mode: disable, enable, and configure.

TABLE 5-1. show modules, show management, and show environment Commands

Command	Description
`show modules`	Displays current operational warning and alarm status for client interfaces.
`show management`	Displays Ethernet interface parameters.
`show amplifier`	Displays status of amplifiers, settings, and alarms.
`show environment temp`	Displays temperatures and operational temperature ranges for various DarkStar components.
`show environment fan`	Displays cooling fan module parameters.
`show environment power`	Displays power module parameters.

5.2 Module and Line Status

Use the `show modules summary` or `show management summary` command to monitor all client, wave, OSC, and Ethernet interfaces. To report in detail on a particular interface, use the `show modules verbose` or `show management verbose` command.

The following example shows what is reported with the `show modules summary` command.

```
localhost# show modules summary

Interface   Admin Line     Rate     RxPow       Ch.  Transceiver Last Line Chng.
----------- ----- -------- -------- ----------- ---- ----------- ---------------
OSC 0 (W)    Up    Up       N/A       -18.4 dBm N/A N/A                N/A
OSC 1 (E)    Down  Alarm    N/A      <-42.0 dBm N/A N/A                N/A

localhost# show management summary
```

```
Interface            Admin  Line   Type      IP Address
-------------------- ------ ------ --------- ----------------------------------
Ethernet 0           Up     Up     LAN       10.15.2.212/16
Ethernet 1           Down   Down   LAN
Ethernet 2           Down   Down   LAN
Ethernet 3           Down   Down   LAN
Ethernet 4 (OSC 0)   Down   Up     LAN
Ethernet 5 (OSC 1)   Down   Down   LAN
```

For a detailed status report on the client 5 module, use the command `show modules client 5 verbose`, as shown in the next example.

```
localhost# show modules client 5 verbose

Detailed information for transport interface Client 5
  Description: .....................
  Vendor: ........................... AVAGO
  Part Number: ...................... AFBR-79EIDZ
  Manufacturing Date: ............... 160116
  Serial Number: .................... QG0206M4
  Module Type: ...................... QSFP+
  I2C Address: ...................... 2,3,80
  General Status:
    Administrative State: ............ UP
    Last Cleared Time Stamp: ......... 2016-10-24 11:49:31
    I2C Transaction Error Count: ..... 0
  Sensor Readings and Thresholds:
    Laser Temperature: ............... 36 C
      High Alarm: .................... 75 C
      High Warn: ..................... 70 C
      Low Warn: ...................... 0 C
      Low Alarm: ..................... -4 C
    Supply Voltage: .................. 3.296 V
      High Alarm: .................... 3.630 V
      High Warn: ..................... 3.465 V
      Low Warn: ...................... 3.135 V
      Low Alarm: ..................... 2.970 V
    Tx Laser Bias Current: ........... Reported By Lane (below)
      High Alarm: .................... 10.0 mA
      High Warn: ..................... 9.5 mA
      Low Warn: ...................... 1.0 mA
      Low Alarm: ..................... 0.5 mA
    Tx Laser Output Power: ........... Reported By Lane (below)
      High Alarm: .................... <-40.0 dBm
      High Warn: ..................... <-40.0 dBm
      Low Warn: ...................... <-40.0 dBm
      Low Alarm: ..................... <-40.0 dBm
    Rx Laser Input Power: ............ Reported By Lane (below)
      High Alarm: .................... 3.3 dBm
      High Warn: ..................... 2.3 dBm
      Low Warn: ...................... -9.5 dBm
      Low Alarm: ..................... -13.5 dBm
  Lane 0:
    Description: .....................
```

```
  Signal Type: ..................... 10G Ethernet
  Wavelength: ...................... 0850.00 nm
  General Status:
    Transmitter: ................... OK
    Receiver: ...................... OK
    Total Down/Error Time: ......... 0d 00:00:00
    Time Since Last State Change: .. 0d 02:40:11
  Sensor Status:
    Rx Laser Input Power: .......... OK
    Tx Laser Output Power: ......... OK
    Tx Laser Bias Current: ......... OK
  Sensor Readings and Thresholds:
    Rx Laser Input Power: .......... -0.7 dBm
    Tx Laser Output Power: ......... -2.4 dBm
    Tx Laser Bias Current: ......... 6.7 mA
Lane 1:
  Description: ....................
  Signal Type: ..................... 10G Ethernet
  Wavelength: ...................... 0850.00 nm
  General Status:
    Transmitter: ................... OK
    Receiver: ...................... OK
    Total Down/Error Time: ......... 0d 00:00:00
    Time Since Last State Change: .. 0d 02:40:12
  Sensor Status:
    Rx Laser Input Power: .......... OK
    Tx Laser Output Power: ......... OK
    Tx Laser Bias Current: ......... OK
  Sensor Readings and Thresholds:
    Rx Laser Input Power: .......... -0.3 dBm
    Tx Laser Output Power: ......... -2.3 dBm
    Tx Laser Bias Current: ......... 6.5 mA
Lane 2:
  Description: ....................
  Signal Type: ..................... 10G Ethernet
  Wavelength: ...................... 0850.00 nm
  General Status:
    Transmitter: ................... OK
    Receiver: ...................... OK
    Total Down/Error Time: ......... 0d 00:00:00
    Time Since Last State Change: .. 0d 02:40:11
  Sensor Status:
    Rx Laser Input Power: .......... OK
    Tx Laser Output Power: ......... OK
    Tx Laser Bias Current: ......... OK
  Sensor Readings and Thresholds:
    Rx Laser Input Power: .......... -0.5 dBm
    Tx Laser Output Power: ......... -2.4 dBm
    Tx Laser Bias Current: ......... 6.8 mA
Lane 3:
  Description: ....................
  Signal Type: ..................... 10G Ethernet
  Wavelength: ...................... 0850.00 nm
  General Status:
```

```
    Transmitter: ..................... OK
    Receiver: ........................ OK
    Total Down/Error Time: ......... 0d 00:00:00
    Time Since Last State Change: .. 0d 02:40:11
  Sensor Status:
    Rx Laser Input Power: .......... OK
    Tx Laser Output Power: ......... OK
    Tx Laser Bias Current: ......... OK
  Sensor Readings and Thresholds:
    Rx Laser Input Power: .......... -0.1 dBm
    Tx Laser Output Power: ......... -2.3 dBm
    Tx Laser Bias Current: ......... 7.0 mA
```

5.3 Amplifier Status

Use the `show amplifier` command to display a cursory status report of all amplifiers in the system. To generate a detailed report, use the `show amplifier all` command.

The following example shows what is reported with the `show amplifier summary` command.

```
localhost# show amplifier summary

                                  Admin  Ctrl   Control   RxPow   TxPow   Module
Amplifier                Role     State  Mode   Setpoint  (dBm)   (dBm)   State
-----------------------  -------  -----  ----  ---------  ------  ------  -------
       East output EDFA  Booster   Down   AGC   22.0 dB    -49.3   -33.0     LOS
        West input EDFA   Preamp   Down   APC  -10.0 dBm   -47.0   -27.7    Warn
```

For a detailed status report on the amplifiers, use the command `show amplifier all`, as shown in the next example.

```
localhost# show amplifier all

Detailed information for Amplifier East output EDFA
  Module Status
    State .................. LOS
    Control mode ........... DXMOS-managed (AGC/Automatic gain control)
    Setpoint ...............   22.0 dB

    Case temperature .......   24.6 C
  Pump Status
    Pump bias current ......    1.0 mA (Disabled)
    Pump EOL bias current ..  739.9 mA
    Pump temperature .......   25.0 C
  Signal Levels
    Input power ............  -49.4 dBm
    Total output power .....  -33.0 dBm
    Signal output power ....  -55.7 dBm
    Signal gain ............   -6.4 dB
  Alarms
    LOS/Loss of signal
  Module Identification
    Position ............... East output EDFA
    Label ..................
    Role ................... Booster
```

```
    Path ................... East midstage input to East line output

Detailed information for Amplifier West input EDFA
  Module Status
    State .................. Warn
    Control mode ........... DXMOS-managed (APC/Automatic power control)
    Setpoint ...............  -10.0 dBm
    Case temperature .......   22.7 C
  Pump Status
    Pump bias current ......    0.0 mA (Disabled)
    Pump EOL bias current ..  916.3 mA
    Pump temperature .......   25.0 C
  Signal Levels
    Input power ............  -46.9 dBm
    Total output power .....  -26.6 dBm
    Signal output power ....  -47.1 dBm
    Signal gain ............   20.3 dB
  Alarms
    LOS/Loss of signal
    HCT/High case temperature
    LCT/Low case temperature
  Module Identification
    Position ............... West input EDFA
    Label ..................
    Role ................... Pre-amplifier
    Path ................... West line input to West midstage output
```

For a status report on the traffic flow over a physical client module, use the command `show vifs client n`, as shown in the next example. The first sample is a summary report.

```
localhost# show vifs client 0

Client 0 (lc11.c0_0):
  Summary Information:
    Nominal Rate: ............. 10G
    Priority Class: ........... 2
  Summary Status:
    Administrative Status: .... OK
    Rx Status: ................ OK
    Tx Status: ................ OK
    Module Status: ............ OK
  Counters:
    Rx Frames Accepted: .......  914e06  (100.0%)
    Rx Frames Dropped: ........       0  (  0.0%)
    Tx Frames Accepted: .......  914e06  (100.0%)
    Tx Frames Dropped: ........       0  (  0.0%)
  Module Lane Map:
    VIF/   - Module/  Status    RxStatus  RxPow   TxStatus  TxPow   Ch/Lambda
    Lane     Lane                          (dBm)             (dBm)       (nm)
    ------------------------------------------------------------------------
      C0/0 -   CM0/0  OK        OK           0.1  OK          -2.2     850 nm
```

The following is an example of the `verbose` command.

```
localhost# show vifs client 0 verbose

Client 0 (lc11.c0_0):
  Summary Information:
    Nominal Rate: ............. 10G
    Priority Class: ........... 2
  Summary Status:
    Administrative Status: .... OK
    Rx Status: ................ OK
    Tx Status: ................ OK
    Module Status: ............ OK
  Internal Status:
    Rx Ready: ................. OK
    Rx Locked to Data: ........ OK
    Rx Sync: .................. OK
    Tx Ready: ................. OK
  Module Status:
    Rx LOS: ................... OK
    Rx LOL: ................... OK
    Rx Power: ................. OK
    Tx Disabled: .............. OK
    Tx Fault: ................. OK
    Tx LOS: ................... OK
    Tx LOL: ................... OK
    Tx Power: ................. OK
  Counters:
    Rx Frames Accepted: .......  720e06  (100.0%)
    Rx Frames Dropped: ........       0  (  0.0%)
    Rx Frames Malformed: ......       0  (  0.0%)
    Rx Frames Total: ..........  720e06
    Tx Frames Accepted: .......  720e06  (100.0%)
    Tx Frames Dropped: ........       0  (  0.0%)
    Tx Frames Total: ..........  720e06
  Module Lane Map:
    VIF/   - Module/  Status    RxStatus  RxPow   TxStatus  TxPow   Ch/Lambda
    Lane     Lane                         (dBm)             (dBm)       (nm)
    ------------------------------------------------------------------------
      C0/0 -   CM0/0  OK        OK           0.1  OK          -2.2     850 nm
  Lane Power Thresholds (dBm):
    VIF/   | RxLow   RxLow   RxHigh  RxHigh | TxLow   TxLow   TxHigh  TxHigh
    Lane   | Alarm   Warn    Warn    Alarm  | Alarm   Warn    Warn    Alarm
    -------|--------------------------------|-------------------------------
      C0/0 |  -13.5    -9.5     2.3     3.3 | <-40.0  <-40.0  <-40.0  <-40.0
  Lane Tuning Bounds:
    VIF/   | Minimum  Minimum  Minimum | Maximum  Maximum  Maximum | Width
    Lane   |  (nm)     (GHz)   Channel |  (nm)     (GHz)   Channel | (GHz)
    -------|---------------------------|---------------------------|------
      C0/0 |       -        -        - |       -        -        - |   0.0
```

5.4 Temperature

The `show environment temp` command displays a series of temperature thresholds for various components in a DarkStar system, as well as the current temperature reported by each component. The temperature thresholds define the safe operating range of each component.

TABLE 5-2. Temperature Thresholds

Threshold	Description
`Low Alarm`	Temperature has dropped below regular operational parameters for that component. Continued operation at this temperature may damage the component. The component may need to be replaced.
`Low Warning`	Temperature of system is falling toward levels that may cause damage to a component, but have not yet exceeded safe levels. Warnings indicate that there might be a problem with the component and that it should be closely monitored.
`Fan Ctrl`	Under normal circumstances DXMOS will control the fans to maintain components at or below this temperature.
`High Warning`	Temperature of system is rising toward levels that may cause damage to a component, but have not yet exceeded safe levels. Warnings indicate that there might be a problem with the component and that it should be closely monitored.
`High Alarm`	Temperature has risen above regular operational parameters for that component. Continued operation at this temperature may damage the component. The component may need to be replaced.
`Critical`	Temperature of system has exceeded safe levels. The component will be shut off immediately to prevent possible damage to other DarkStar components

In addition to the temperature sensors provided by individual components of the DarkStar system, there is a shutdown sensor embedded in the DarkStar circuit board. If the shutdown sensor reaches 100°C, the DarkStar system will automatically power off nearly all internal circuitry. The DarkStar system will restore normal power when the sensor cools to less than 90°C.

The following is an example of `show environment temp` output.

```
localhost# show env temp


Temperature                    Curr  Low   Low   Fan   High  High  High
Sensor Id                      Temp  Alrm  Warn  Ctrl  Warn  Alrm  Crit
-----------                    ----  ----  ----  ----  ----  ----  ----
CPU 0                            32     0     5  none    80    85   100
Inlet 0                          25     5    10  none    55    60    60
Mid-board 0                      27     5    10  none    55    60    60
Loader 0                         24     5    10  none    55    60    60
OSC 1 (E)                        33    -5     0    50    65    70    70
East input EDFA Case Temp        -1     0     0    60    65    70    71
East output EDFA Case Temp       25     0     0    60    65    70    71
West input EDFA Case Temp        23     0     0    60    65    70    71
```

5.5 Amplifier Configuration

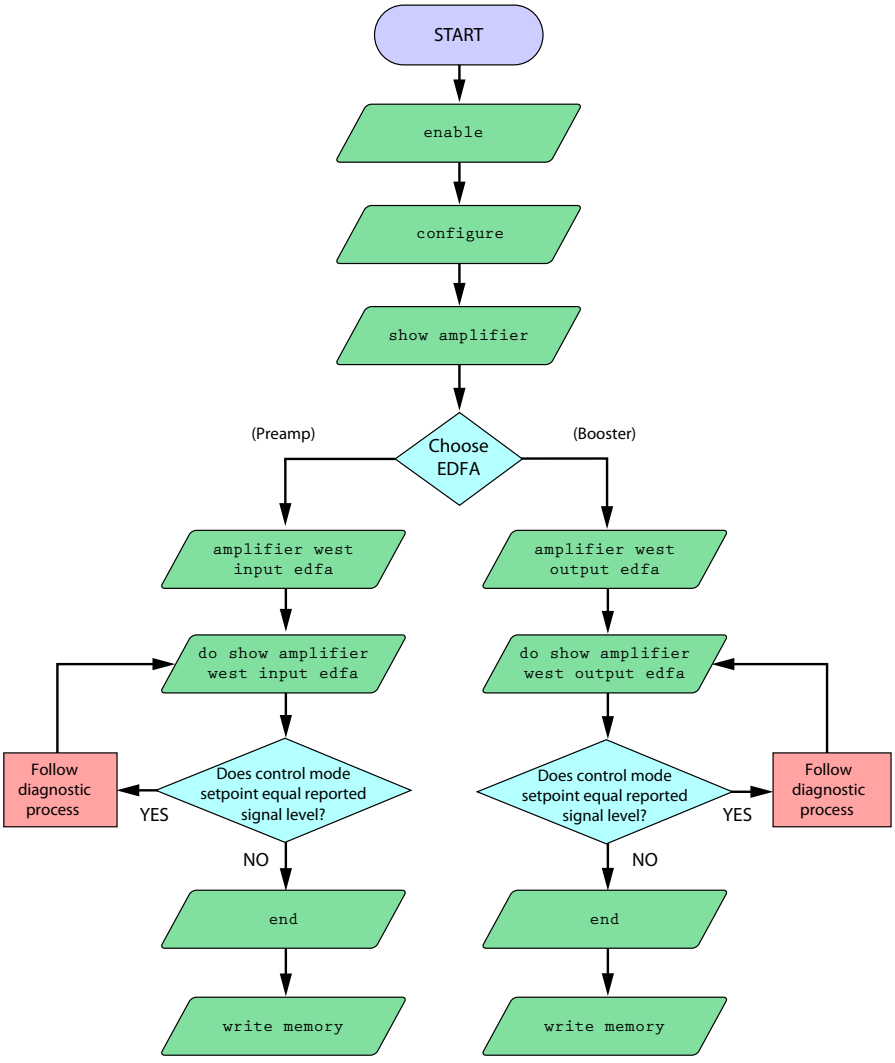
Certain DarkStar systems support two types of amplification: EDFA and Raman. Chapter 1 provides an overview of these systems and their characteristics. For more information, see the DarkStar Optical Specifications document.

When the system comes up, both EDFA and Raman amplifiers (if present) start automatically (`no shutdown`) and come up to factory pre-set gain and power levels.

5.5.1 EDFA Configuration

EDFAs do not need to be manually configured: DXMOS does this automatically. However, looking at the manual procedures can be helpful to understanding how the amplifiers are set. Figure 5-1illustrates a sample command-line flow used to configure and operate either amplifier.

FIGURE 5-1. EDFA Command Line for Manually Setting EDFA



The following example shows the commands for manually configuring an EDFA pre-amplifier.

```
localhost_dmd-a# conf

localhost_dmd-a CONF#  amplifier input edfa
localhost_dmd-a CONF-AMP[input edfa]# do show amplifier input edfa

Detailed information for Amplifier Input EDFA
  Module Status
    State .................. Down
    Control mode ........... DXMOS-managed (APC/Automatic power control)
    Setpoint ...............    7.8 dBm
    Case temperature .......   26.1 C
  Pump Status
    Pump bias current ......    0.0 mA (Disabled)
    Pump EOL bias current ..  636.3 mA
    Pump temperature .......   25.0 C
  Signal Levels
    Input power ............  -17.0 dBm
    Total output power .....  -24.4 dBm
    Signal output power ....  -25.1 dBm
    Signal gain ............   -7.4 dB
  Alarms
     None
  Module Identification
    Position ............... Input EDFA
    Label .................. labcons15-PREAMP
    Role ................... Pre-amplifier
    Path ................... Line input to Channel outputs
localhost_dmd-a CONF-AMP[input edfa]# control output power -5.0
localhost_dmd-a CONF-AMP[input edfa]# no shutdown

Amplifier Input EDFA: DXMOS enabled the EDFA
Amplifier Input EDFA: Pump is active
Amplifier Input EDFA: State change: Up
localhost_dmd-a CONF-AMP[input edfa]# do show amplifier input edfa

Detailed information for Amplifier Input EDFA
  Module Status
    State .................. Up
    Control mode ........... Automatic power control (APC)
    Setpoint ...............   -5.0 dBm
    Case temperature .......   25.9 C
  Pump Status
    Pump bias current ......   58.1 mA (Up)
    Pump EOL bias current ..  636.3 mA
    Pump temperature .......   25.0 C
  Signal Levels
    Input power ............  -17.0 dBm
    Total output power .....   -5.1 dBm
    Signal output power ....   -5.6 dBm
    Signal gain ............   11.9 dB
  Alarms
     None
```

```
Module Identification
  Position ............... Input EDFA
  Label .................. labcons15-PREAMP
  Role ................... Pre-amplifier
  Path ................... Line input to Channel outputs
```

5.6 Error Detection

Error detection is at the physical layer of the network stack. DarkStar systems rely on signal integrity indicators from the laser interfaces and Clock and Data Recovery (CDR) circuitry to monitor and detect signal errors.

The most common indicators used to monitor the integrity of incoming optical signals, in order of precedence, are:

- **Loss of Signal (LOS):** The receive optical power of a DarkStar module asserts an LOS when the incoming signal level falls below a threshold. Threshold levels are not configurable and are module specific.
- **Loss of Lock (LOL):** DarkStar systems may have Clock and Data Recovery (CDR) circuitry. If equipped, and the CDR circuitry fails to lock on a signal, the DarkStar system may report LOL against the module or interface. LOL may indicate a mismatch between the actual signal and the assigned encapsulation, and can occur in the receive or transmit direction.

Use the `show modules` command to view the line status of transport interfaces and other fault conditions that can interfere with data integrity.

5.7 SNMP Traps

RFC 1213 defines the standard SNMP MIB format and the mandatory "public" SNMP objects and groups. The XKL MIB also defines the types of XKL-specific traps. For details see the XKL MIB at https://www.xkl.com/resources/documentation/; XKL-specific SNMP traps are listed in the Command Reference.

The XKL MIB groups XKL-specific objects into the following groups. See the XKL MIB at https://www.xkl.com/resources/documentation/ for more information.

TABLE 5.3. XKL MIB Groups

Object Group	Description
SysOS	Operating System information
Transport	Transport interface definition and environmental factors.
Hardware Components	Fan and power unit configuration and status.
Switch Complex	Switch connection status.
Sensor	Power and temperature sensor readings.
Protection Group	Protection status and active path.
EDFA	EDFA amplification configuration and optical/electrical status.
Raman	Raman amplification configuration and optical/electrical status.

The following MIB example shows how, if you have enabled traps and configured your monitoring system, you can be warned of a sensor temperature change (via the XKL trap `xklTempStatusChange`) and can monitor the Celsius temperature at that point (via the XKL object `xklSensorTemp`).

```
xklSensorTemp OBJECT-TYPE
    SYNTAX  Integer32
    MAX-ACCESS  read-only
    STATUS  current
    DESCRIPTION
"Temperature of the sensor (Celsius)"
    ::= { xklSensorEntry 3 }
```

The trap `xklTempStatusChange` notifies a sensor temperature change event. Note that this trap can be triggered by any of the sensor objects `xklSensorDescription`, `xklSensorTemp`, or `xklSensorStatus`.

```
xklTempStatusChange NOTIFICATION-TYPE
    OBJECTS { xklSensorIndex, xklSensorDescription, xklSensorTemp,
xklSensorStatus }
    STATUS  current
    DESCRIPTION
"Temperature status has changed"
    ::= { xklProTraps 6 }
```

Troubleshooting

6.1 Introduction

This chapter provides troubleshooting information related to the operation of DarkStar systems and networks. It covers:

- Good practices for setting up the system and running configuration so that important incident notifications reach the event log and SNMP.
- Good crash recovery procedures so that the system returns as quickly as possible to a known good state.
- Console procedures for reviewing and revising the state of the system and its network connections.
- Hardware procedures for interpreting LED patterns and booting via the hardware reset buttons.
- How the system switches to recovery mode in the face of catastrophic error.

In normal operations, many day-to-day problems are related to configuration changes for either the system and its management services, or the local IP network it communicates with. Please be aware that this chapter covers issues that you may experience as you initially set up and learn to operate a DarkStar system or network. If you experience issues beyond the scope of this guide, especially if you experience a loss of customer traffic, contact an XKL representative for professional technical support.

6.2 Create a Saved Configuration for Backup

Ideally, you should have three saved configurations, as described below.

TABLE 6-1. Saved Configuration Files

Purpose	Description
For local boot	A valid, current running configuration saved in system flash memory (use `write memory`). This restores a good system configuration ready for when the system automatically recovers.
For remote boot	A similar accurate configuration saved on a TFTP server (use `write network`).
For backup	An accurate configuration, on a TFTP server, that can be called in manually if both the local and the remote boot config files become damaged.

TFTP is a simple file transfer protocol without a strong guarantee of integrity when copying a file. When fetching a critical file with TFTP, you should:

1. TFTP transfer to a temporary file.

2. Verify the checksums (use the checksum command).
3. Copy the file to the final destination.

Config files contain passwords. Make sure you have an accurate record of the passwords that are required to access the system.

In addition:

- Configure an SNMP server that watches for unplanned restart traps. If any are seen, the system should be examined (see "Diagnosis" on page 51).
- Use SNMP input to compile a database of wear metrics, such as temperatures, currents, optical power, etc., so that degrading components can be identified and scheduled for replacement before they fail. Most DarkStar laser, power, and fan modules can be field-replaced without disturbing customer traffic.

6.2.1 Operator Notification

In most situations, the operator is notified of a system event via the console, and the restart is notified by SNMP traps. The startup configuration is reloaded and restart is automatic, without operator intervention. Make sure that all useful notifications and logging are enabled, so that you receive them.

- Enable system event logging using the config mode `logging` command. The console event log buffer is cleared when the system reloads, so you should direct output to a log file as well as to the console.
- Configure SNMP to send system alerts ("traps" in SNMP) by using the config mode command `snmp-server`, and selecting trap types `xkl` and `xkl-generic` (otherwise, by default, SNMP will send you all possible SNMP network traps).
- Enable the AAA feature (using the `aaa new-model` command) so that TACACS+ logs an auditable account of configuration changes. The log may help your diagnosis by showing who issued what commands in the period leading up to the crash.
- A crash dump file (`/dump/dump.exe`) is generated by default on an unscheduled restart (not on a `reload` command); your technical support team may need it for diagnosis.

6.3 Crash Recovery

In the unlikely event of a system crash, a DarkStar system is designed to notify the operator and to automatically recover with (as far as possible) no loss of customer traffic through the switch complex.

Avoid the temptation to get operational again by cycling power to force a cold boot. Cycling power disrupts customer traffic. It should only be done if a hard reset of all hardware is desired, or if a warm reload does not resolve a particular situation.

6.3.1 Automatic Recovery from a Warm Restart

No operator action is needed. The system will restart itself, using the configuration you have previously saved (see above) in system flash memory. Traffic is not affected, even though the system may not be responding to commands, and you may lose the console for a while. The system's management software (DXMOS) runs separately from the switch; failure of software or corrupted flash memory on the management side does not affect traffic through the switch.

You cannot make changes to the running configuration until DXMOS has reloaded.

The warm restart event is notified to the event log, and also via SNMP. An unexpected warm restart creates a system dump file (/dump/dump.exe). Investigate all warm restart events as quickly as possible.

A warm restart resulting from software failure detected by hardware does not *create a system dump file.*

6.3.2 Automatic Recovery from a Cold Boot or Power Recycle

No operator action is needed. Traffic is disrupted since power is lost on all interfaces. Once the console has come back, you should verify (using show interface) that optical traffic has resumed. Check the report output for LOL and LOS markers that show the optical signal is lost. Check the receive laser power levels: if they are around -40dBm, then no light is reaching them.

No system dump file is available.

6.3.3 Manual Crash Recovery Only if Automatic Recovery Fails

If the system can't restart due to a corrupt or invalid saved config file, or corrupted system flash memory, you need to manually intervene during the boot process. From the console, enter `CTRL+C` before the boot process completes. Review "Power-Up and Reboot" on page 24, and "Recovery Mode" on page 53 for more information on the boot process.

6.3.4 Diagnosis

You should be able to provide the following information to your technical support team to help them diagnose the cause of the crash:

- The crash notification from the console, if it is available.
- The system dump file /dump/dump.exe. The file must be uploaded to a TFTP server, then transferred to XKL via email or FTP upload (the file is large), for analysis. The dump file must be debugged by XKL.
- The syslog, from the syslog server, leading up to the crash. This syslog is persistent; the console event log buffer clears when the system reloads.
- The output of a show tech command, which itemizes the status of all system resources.
- A review of any environmental issue (power, cooling, physical activity in the rack or nearby racks) at the crash location before the crash.

6.4 Console Procedures

Most troubleshooting is done from remote consoles, using `show` commands to assess the status of the system or network, and configuration (config) commands to revise configuration settings. Issues fall into two categories:

- ***System Issues.*** Many system issues are due to errors or changes in management configuration settings. This includes operator authentication and authorization, console connection, and access issues to external servers, such as SNMP, caused by invalid IP addressing or other management server connectivity failure.
- ***Networking Issues.*** Many networking issues are due to IP addressing problems or changes, and to interruptions in access to external IP servers. Optical interface problems may be due to faulty fiber connections, or to changes in interface configuration on the local or the remote DarkStar system.

The following tables list symptoms, possible causes, and possible solutions for both system and networking issues.

TABLE 6-2. System Troubleshooting Matrix

Symptom	Possible Cause	Possible Solution
Operator unable to run commands	Incorrect authentication or authorization of operator.	Review and revise AAA settings for authentication and authorization. Check passwords in use.
Operator loses existing access to commands	• Password change. • Warm boot from an older config file may have re-activated older passwords.	Review and verify operator passwords in use.
No serial connection / no activity at console	Incorrect or faulty cable.	Check connection and reseat if necessary.
	Faulty cable connection.	Replace with good cable.
Link LED is on, but the activity LED remains off	Wrong IP address assigned to Ethernet interface.	In `CONF-MGMT-ETH[n]#` mode, use the `ip address` command to correct addressing issues.
	Ethernet ports administratively shut down.	Issue a `no shutdown` command to restart.
	Remote routing problems.	
OSC trunk LED dark, OSC line state flapping/ bouncing	Faulty fiber connection between DarkStar systems.	Clean and reconnect fiber connections.
	OSC interface is administratively down.	In `CONF-MGMT-OSC[n]#` mode, issue a `no shutdown` command.
	Insufficient optical signal to noise ratio in long--haul configuration.	Contact XKL technical support.
System unreachable via OSC	• No IP address assigned to OSC interface. • Bad or missing IP routes.	In `CONF-MGMT-OSC[n]#` mode, issue an `ip address` command to correct IP addressing.
SNMP fails to run	Incorrect SNMP configuration or SNMP server unreachable.	• Verify and revise SNMP server IP address(es). • Verify and revise SNMP configuration.
DXMOS fails to load / 600-second timeout	Incorrect TFTP boot configuration.	Boot DXMOS from flash image, correct the boot TFTP configuration entries, save the corrected configurations in `startup-config` or a remote DHCP config, then reload DXMOS.
	TFTP server unavailable or unreachable.	Either correct TFTP server availability or boot DXMOS from flash image.
	Incorrect configuration data (e.g. wrong IP address, wrong routes, etc.)	Verify that systems interposed between this system and the TFTP server are configured to forward packets.
Miniboot (embedded in gateware) or Boot fails	Corrupted gateware or Boot on startup flash chip.	Contact XKL technical support.

TABLE 6-3. Networking Troubleshooting Matrix

Symptom	Possible Cause	Possible Solution
Module down	Fiber not connected.	Make sure fiber is connected.
	Dirty fiber.	Connect with clean fiber.
	Failed laser module(s).	Replace failed component. DarkStar modules are hot-swappable.
CFP modules fail to initialize	• Corrupted gateware. • Slow initializing module. • Broken module.	Issue a `clear module trunk` command. If module fails to reset, contact XKL technical support.
LOS (Loss of Signal) or LOL (Loss of Lock) on client or trunk modules	• Incorrect encapsulation type. • Incorrect switch configuration.	Verify encapsulation types at transmit and receive endpoints and ensure they are the same.
System reports erroneous transport interface power values	External BERT is connected at different clock rate from system.	Synchronize BERT.
	Excessive uncompensated dispersion in the link.	Compensate link dispersion.
Insufficient receive optical power / Insufficient transmit optical power / module status flapping up/ down	No trunk module transmission.	Run diagnostics and/or replace laser.
	Laser administratively disabled.	Verify optical receive power and interface state using a `show module` command. If necessary, execute `no laser shutdown` to enable the affected module(s).
	Low optical power from customer equipment.	Investigate external customer equipment.
	Laser failure.	Replace laser module.

6.5 Recovery Mode

Recovery mode is a rare occurrence. You can manually enter recovery mode using the `/recovery` boot command switch. DXMOS enters recovery mode automatically at startup, if the `startup-config` file is detected to be unreadable, or contains corrupted data.

All telnet and SSH access to the system is disabled in recovery mode. Only the console can be used to attempt recovery without dropping customer traffic. In recovery mode, there is a limited set of commands to load a remote backup copy of the configuration. Typically, the configuration is stored as a local file in `/dxmos/config.dat`, but it may be acquired from remote sources by Boot during system startup.

The table lists commands available in recovery mode.

TABLE 6-4. Recovery Mode Commands

Command	Description
`configure`	Enter configure mode to configure an Ethernet interface in advance of issuing a `configure network` command.
`configure network` *`IPaddress FilePath`*	Download a remote configuration backup when a management Ethernet interface is already configured.

TABLE 6-4. Recovery Mode Commands

Command	Description
`continue`	In cases where flash memory is unreadable or corrupt, and a backup configuration is unavailable, continue DXMOS startup without a configuration.
	Continuing system startup without a configuration may cause loss of customer traffic, and will leave management interfaces unconfigured. Configuration settings must then be applied using manually-issued commands at the console.
`drop-to-boot`	Revert to the system boot loader to access Boot facilities.
`ping/ping6`	Test IPv4/IPv6 connectivity.
`reload`	Reload all system software and gateware from flash memory.
`show`	Display information about the recovery mode system configurations.

You can recover a DarkStar system from a configuration file stored on a remote server, but the system must be physically cabled to a live management network for this process to work. If the remote configuration file matches the running configuration, customer traffic on the DarkStar system will not be interrupted.

XKL strongly encourages you to maintain current copies of your configuration using the `write memory` and `write network` commands whenever configuration changes are made.

The following example shows system recovery using the boot command `/recovery` switch. Modify the example with installation-specific values to implement recovery.

Here, the operator defines an IP route to a TFTP server, verifies the routing table, and then uses the `configure network` command to retrieve a system configuration backup file (`config-backup.dat`). The system displays the file contents (not shown in this example) to allow the operator to confirm that this is the desired backup configuration file. (Note that there is a space before the "/recovery" keyword.)

```
Boot> boot file /dxmos/dxmos.exe /recovery
[ 08:56:53 Slot 4, Ethernet 0: link is up.    Status per MII reg 1: 0x782D]
[ 08:56:53 Slot 4, OSC 0: link is up.    Status per MII reg 1: 0x780D]
[Loading ..........................................................]
[File entry-vector is at 7700,,1000, length is 4]
[PDVA at 7706,,0]
[Free pages from 33207 through 1777777]
[Disabling the watchdog timer for this program.]
[Setting "Recovery" flag.]
[Sending control flags to the program: o1000000200]
[Clearing program flags and context]
[19-Oct-2016 08:57:05 UT-7:00: Starting at 7700,,1000]
Starting DXM Operating System (DXMOS), XKL LLC
3.4.0-fba2ea3533a9 r-dxmos-3.4 Oct 12 2016 12:02:04
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Initializing hardware...
```

```
Detecting hardware with MXP board 00099-03
Initializing environmental loader:
 Running startup-gateware
Done
Power NOT Cycled
Mounting file system...
User enabling TX laser on management interface: OSC 0
User enabling TX laser on management interface: OSC 1
The system has entered recovery mode either due to startup flash read failure,
or manual user operation. To prevent dropping customer traffic, the software
did not modify the switch board configuration. Use the configure network
command to recover the system configuration if you have a backup of it.
Please see the DarkStar User Guide for more details.

recovery-mode# configure
recovery-mode CONF# management ethernet 0
recovery-mode CONF-MGMT-ETH[0]# ip address 10.15.2.212/16
recovery-mode CONF-MGMT-ETH[0]# exit
Interface Ethernet 0 address set to 10.15.2.212
recovery-mode CONF# ip route 0/0 10.15.0.254
recovery-mode CONF# exit
recovery-mode# show ip routes
Codes:  C - Connected, S - Static, R - RIP
Current Route Table:
Org  Dest IP/CML         Cost  Source           NextHop          Sending To
 C   10.5.2.0/24         0/0   10.5.2.202       10.5.2.202
 S   0.0.0.0/0           1/1   0.0.0.0          10.15.0.254
recovery-mode# configure network 10.15.1.99 backup.cfg
Determining file type...
Connecting...
File transferred successfully.
...Completing flash write.
;;;;;;;;
version 3.4.0
...[snipped contents of configuration file]...
The system will now proceed using this configuration.
  Are you sure? [yes/NO] yes
recovery-mode# Loading gateware XIC
LoaderPIO_Write: done  439,052 bytes  1.50 sec  293 Kbps
Fan Module 0 online, initializing
Fan Module 1 online, initializing
Fan Module 2 online, initializing
localhost> ;;;;;;;;
localhost> version 3.4.0
 ...[snipped contents of configuration file]...
 localhost>
localhost>
```

6.6 Using the Debug Command

The `debug` command is an XKL diagnostic tool that displays detailed trace information about DarkStar system functions and network operations. In a production network, using `debug` can generate a high volume of trace information at the console and may degrade system performance, so XKL recommends the following:

- Use the `debug` command only when working with XKL technical support to diagnose a specific problem with your system.
- Avoid using `debug` in a production network. The system gives high priority to bug requests, so using `debug` may impact business applications.
- To monitor system operations, use the `show` commands, `logging` command, and SNMP traps to monitor system operations and events, rather than `debug`.

If a `debug` command is running, use the `undebug all` command (or `no debug all`) followed by a `<CR>` to instantly quiet all debugging output. You can type these commands at the console even if the console seems overwhelmed with debug trace messages and fails to echo your keystrokes.

6.7 Hardware Procedures

The LED and reset button procedures outlined here can also be performed from a remote console, using the `show`, `configuration`, and `reload` commands. Please see the DarkStar DXMOS Command Reference for details of these commands.

If necessary, fan and power modules can be hot-swapped, following the procedures later in this section.

6.7.1 Front Panel LEDs

The pattern of LED lights on the front panel of DarkStar systems indicates system status, including environmental and boot status. The `show led` command shows these LED patterns at a remote operator console.

FIGURE 6-1. LED Outputs

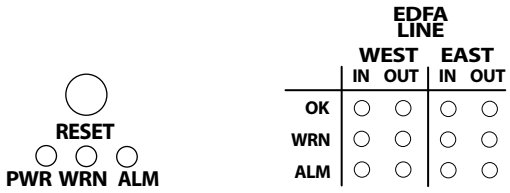


TABLE 6-5. LED Legend

LED Status	Meaning
○	Steady off
●	Steady on
◐	Flashing

TABLE 6-6. Front Panel LED Patterns

PWR (green)	WRN (amber)	ALM (red)	Meaning
○	○	○	No power or both power supplies down.
●	○	○	System fully operational.

TABLE 6-6. Front Panel LED Patterns

PWR (green)	WRN (amber)	ALM (red)	Meaning
○	○	●	One of the following conditions exists: • Maximum temperature exceeded. • FPGA load failure. • A load failure of both the startup and factory flash.
●	◐	○	One of the following conditions exists: • One power supply down or absent. • Temperature alarm. • One or more fan failures. • Fan controller 0, 1, or 2 absent.
◐	◐	◐	One of the following conditions exists: • Initial power up. • Warm reload in progress.
●	●	●	Cold reload in process.
OK (green)	**WRN (amber)**	**ALM (red)**	**Meaning**
○	○	○	No power or line is down.
◐	○	○	The amplifier has been administratively disabled.
●	○	○	Line is fully operational.
●	●	○	Loss of signal.
●	◐	○	A non-LOS alarm.
◐	◐	◐	Amplifier is resetting, or booting up after a reset.
○	○	●	Loss of power and a non-LOS alarm.

In addition to loss of signal (LOS) alarms, there are several different types of amplifier/line alarms that you may see in a report. Table 6-7 lists the types of alarms and their corresponding code.

TABLE 6-7. Non-LOS Amplifier Alarms

Abbreviation on Report	Name	Meaning
LOS	Loss of signal	The input power has dropped to a level that the EDFA can no longer amplify effectively.
AOP	Abnormal output power	The output power deviates by more than ??? from the expected level, or the output is muted.
HCT	High case temperature	The case temperature is dangerously high.
LCT	Low case temperature	The case temperature is dangerously low.
APT	Abnormal pump temperature	The pump temperature deviates by more than ??? from ???.

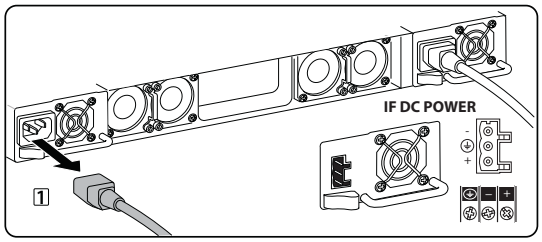
TABLE 6-7. Non-LOS Amplifier Alarms

Abbreviation on Report	Name	Meaning
HPB	High pump bias current	The pump bias current has risen to above the end-of-life current specified by the manufacturer.
HBR	High back reflection	The level of back-reflection is dangerously high.

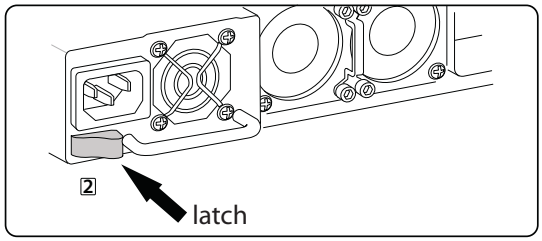
6.7.2 Power Module Replacement

Before adding or removing a power supply module, disconnect the power cord (AC power) or turn off the 48v supply (DC power). Failure to do so could result in serious personal injury or system damage. When removing a power cord, release any retaining bail with care, and re-secure the bail after re-inserting the power cord.

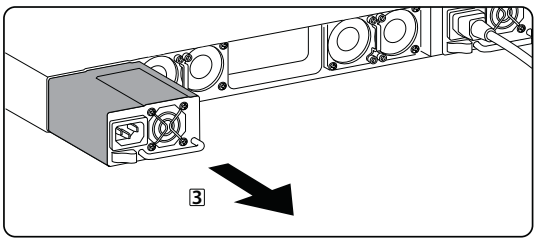
FIGURE 6-2. Replacing Power Supply Modules



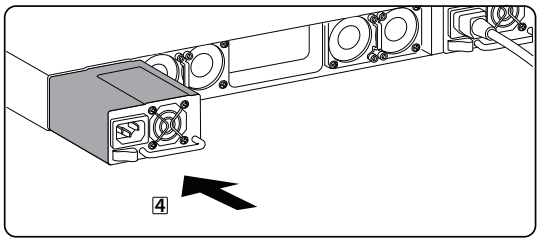
1 Unplug the power cord from the power supply module.



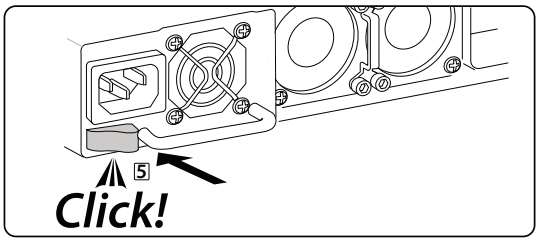
2 Disengage the latch that secures the module in the chassis.



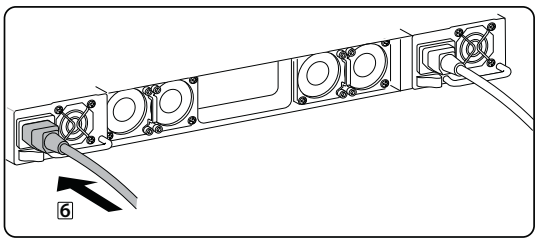
3 Pull the module out of the chassis.



4 Insert the replacement module in the chassis.



5 Snap the latch into place to secure the module. You may need to lift up or push down slightly on the module to get it to snap into place.

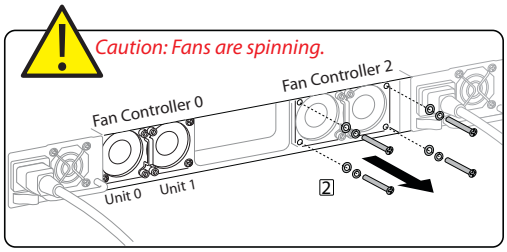


6 Reconnect the power cord to the power supply module.

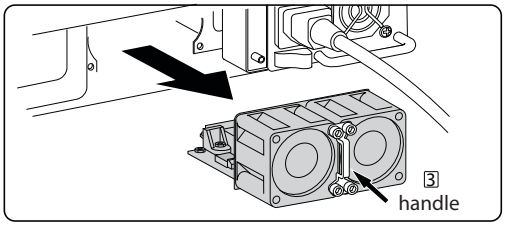
6.7.3 Fan Module Replacement

FIGURE 6-3. Replacing Fan Modules

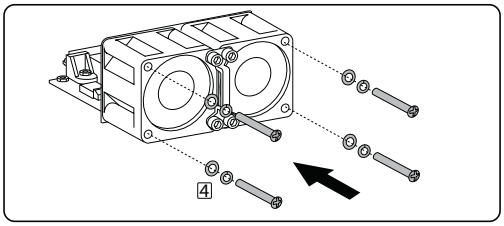
1 Locate the fan module in question. The show environment fan command describes the physical location of each module and fan.



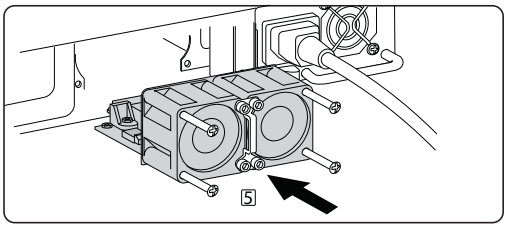
2 Using a Phillips-head screwdriver, remove the four (4) screws that hold the module in place.



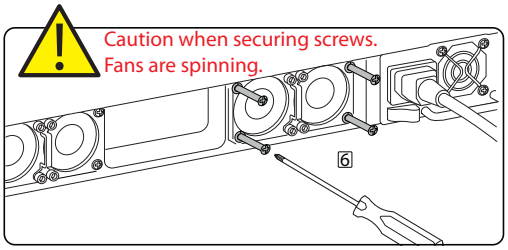
3 Grasp the module by its handle and pull it out of the chassis.



4 Reinsert the screws with washers and spacers into the replacement module.



5 Insert the replacement module in the chassis, making certain it is squarely aligned.



6 The module will be energized the moment it is seated if the system is powered. Fasten the (4) screws that hold the module in place.

Configuration File

A.1 Default Configuration File

The following illustrates a configuration file for a DMD-A system with two paths and three EDFAs. The default configuration file is created when you run `write memory` on a system that has not yet been configured.

Many default configuration settings don't get written to a configuration file until that particular setting has been edited in the command line interface.

```
;;;;;;;;
version 3.5.0
enable
configure
line console
exit
line vty
exitclock summer-time off
hostname localhost
management ethernet 0
exit
management ethernet 1
exit
management ethernet 2
exit
management ethernet 3
exit
management osc 0
no laser shutdown
exit
management osc 1
no laser shutdown
exit
amplifier east input edfa
shutdown
control managed
exit
amplifier east output edfa
shutdown
control managed
```

```
exit
amplifier west input edfa
shutdown
control managed
exit
! banner motd should be last in the configuration file for safety.
! A malformed MOTD with a missing ending delimiter will result in
! undefined behavior of any configuration statements after the MOTD.
```

A.2 Configuration Examples

The following examples illustrate how you might configure various aspects of your system.

View the current configuration by running a `show running-config` command.

```
# show running-config
running-config:
;;;;;;;;
version 3.4.0
enable
configure
... ...
```

Configure secure console access

There are several services available for authorization, and you should carefully review the options when configuring secure access in your own environment. In some circumstances, incorrect security configuration may have the effect of locking an operator out of the system.

```
tacacs-server host yourhost
tacacs-server key supersecret
aaa authentication login default group tacacs+
line console
user someuser password apassword
line vty
password 5 somepassword
login
... ...
```

Set system clock and host name

```
clock timezone -8 0
clock summer-time usa
sntp server 10.15.1.99
hostname localhost
```

Identify a DNS server

```
ip domain-name some.domain.com
ip domain-name domain.com
ip name-server fd16:c32:da21:c01:209:5bff:fee1:5a7e
ip name-server 192.168.0.1
ip host flood fd16:c32:da21:c01:209:5bff:fee1:5a7e
ip host flood 192.168.0.1
```

Assign IP addresses for remote console access

This example assigns an IP address to Ethernet 0:

```
management ethernet 0
ip address 192.168.0.1/16
exit
```

Enable the OSC modules

By default, OSC modules are enabled.

```
management osc 0
no laser shutdown
exit
management osc 1
no laser shutdown
exit
```

Define SNMP service host and traps

```
snmp-server community public
snmp-server enable traps xkl
snmp-server enable traps xkl-generic
snmp-server host somehostname
```

Set the console log size

```
logging mark 1
logging buffer 512
```

A.3 Sample Configuration

The following shows the configuration of a point-to-point switch setup from Seattle to Redmond, with the local system located in Seattle.

```
running-config:
;;;;;;;;
version 3.5.0
enable
configure
line console
break
exit
line vty
password 5 a37762eca3bf1aa0928b3a3c29b049bd
transport input all
login
exit
clock timezone -8 0
clock summer-time usa
hostname labcons15_dmd-a
ip domain-name xkl.com
ip name-server 10.4.1.99
management ethernet 0
ip address 10.4.2.215/16
```

```
ipv6 address fd10:4:1::215/64
exit
management ethernet 1
exit
management ethernet 2
exit
management ethernet 3
exit
management osc 0
no laser shutdown
description labcons15-OSC0
ip address 192.168.0.6/24
ipv6 address fd99:15:1::215/64
exit
management osc 1
no laser shutdown
description labcons15-OSC1
exit
amplifier input edfa
description labcons15-PREAMP
no shutdown
control managed
exit
amplifier output edfa
description labcons15-BOOSTER
no shutdown
control output power 8.0
exit
path input channel-count 10g 10
path input label labcons15-PATH-in
path output channel-count 10g 10
ip route 10.15.0.0/16 10.4.1.99 92
snmp-server community public
snmp-server enable traps snmp
snmp-server enable traps xkl
snmp-server enable traps xkl-generic
snmp-server host 10.4.1.99
snmp-server host 10.4.1.98
sntp server 10.4.1.99
logging host 10.4.1.99
! banner motd should be last in the configuration file for safety.
! A malformed MOTD with a missing ending delimiter will result in
! undefined behavior of any configuration statements after the MOTD.
```

Glossary of Terms

AAA – Authentication, Authorization, and Accounting
AAA commands are a set of commands used to configure who has access to what and set up how server use is logged.

ADM – add-drop multiplexer
A network device that can combine signals or separate out particular wavelengths. For example, a multiplexer can add one or more lower bandwidth signals to an existing high bandwidth data stream and simultaneously extract other low bandwidth signals and redirect them to another network path.

active optical device
An optical component that requires external power to operate. Active devices include transceivers and amplifiers.

ambient temperature
The temperature of the medium surrounding an object. Typically, room temperature and ambient temperature are the same.

AON – all-optical network
A network environment that uses optical switches and fibers to manage multiple optical channels for switching, routing, or distribution.

ARP – Address Resolution Protocol
To communicate, a system needs both an IP (network) address and a MAC (media access control, or hardware) address. When only the IP address is known, ARP sends a message asking for the equivalent MAC address.

attenuation
As a light signal travels through fiber, optical power is reduced, or attenuated, as the light scatters or is absorbed in the fiber. The main factor of attenuation is the distance traveled, but there is also attenuation every time the signal passes through a splice, splitter, connector, or any other component. Not all active components result in attenuation; however, all passive components do. DarkStar products include both passive and active components. Passive components in DarkStar systems that introduce attenuation include connectors, splitters/couplers, filters, and dispersion compensation modules (DCM).

BERT – bit error ratio test
A BERT is a testing method that measures the bit error ratio, which is a percentage that indicates the reliability of a digital transmission. There are several ways to run a BERT, but all involve sending a test pattern to a receiver that expects and verifies the same pattern. DarkStar DXMOS includes commands to set up, run, and configure a BERT.

boot
To instantiate an operating environment. The operating environment may be instantiated with identical software/firmware/gateware components as were previously running, or with updated components. See the DarkStar Command Reference for more information on booting, rebooting, and reloading DarkStar systems. *See also* reboot.

Boot
A required program in Darkstar systems that initializes the control processor and boots DXMOS.

C-band
The "conventional" band is the range of optical wavelengths from 1530-1565 nm, and is the band used by most DWDM systems. Amplifiers work well in the C-band, and fiber cable is most efficient in this range.

center wavelength
Depending on the context, "center wavelength" has slightly different definitions. In lasers, it's the peak measurement that contains most of the optical power, which is not necessarily the exact center wavelength. In filters, it's an expression of the portion of the signal that passes energy through a filter, and is referred to as FWHM. *See also* FWHM – full width at half maximum.

channel
A communications path or the signal that is transmitted through a medium. Multiplexing combines several channels for data communications.

CIDR – classless inter-domain routing
A flexible method of allocating and routing IP addresses that conserves available IP space. A CIDR address has two parts: one specifies the network, the other specifies the host within that network.

cladding
The material surrounding the core of an optical fiber that helps to focus the light signal through the fiber. Since the cladding has a lower refractive index than the core, transmitted light is forced to travel down the core. The cladding is then covered by a protective coating that is either 250 or 900 microns thick.

Class 1M
DarkStar systems use Class 1M lasers. The IEC and AINSI have defined classes of laser safety, with respective recommended safety protocols. The IEC defines Class 1M as "Not known to cause eye or skin damage unless collecting optics are used." Though Class 1M is generally safe, never look directly into any laser beam, regardless of its classification.

CLI – command line interface
A text-based interface for interacting with a computer system. DarkStar users configure the system and obtain information about the system using the CLI. The DarkStar system provides the CLI to a console through a serial connection or to a networked terminal through a Virtual Terminal (VTY).

client
"Client" is a local connection in (and out) of a system, and "clients" or "client ports" are the optical transceivers exposed on the front panel of a Darkstar transponder system. These ports are used to connect the Darkstar to local customer equipment such as routers and other network services. Client optics are typically either multi-mode with wavelengths at around 850nm or single-mode with wavelengths at around 1310nm. In contrast to a wave, a client transceiver is less powerful: clients operate at frequencies up to100 GHz; waves typically operate at frequencies above 190 THz. *See also* trunk and wave.

core
The light-conducting central portion of an optical fiber, with a higher refractive index than the cladding. The core can be made of either glass or plastic, depending on the application. Optical networking uses glass fiber.

crossbar switch
A switch with a matrix of connections between inputs and outputs. Original switches had physical metal bars that were the input and output paths, and crosspoints were where an input and output connection crossed. Today, if the switch has M inputs and N outputs, its matrix contains M × N crosspoints, or places where the bars cross.

cross-phase modulation
When multiple signals are traveling together, their interaction can cause a change in the refractive index and distort the signal. Sometimes abbreviated as XPM.

CTY – console terminal
A serial terminal port that is provided by a DarkStar system and is used to access the command line interface (CLI).

CWDM – coarse wavelength division multiplexing
Similar to DWDM, coarse wavelength division multiplexing combines several wavelengths into a single signal. There are typically eight combined wavelengths, as opposed to potentially 80 available with DWDM. CWDM requires less power and less expensive lasers, but cannot transmit over the longer distances available with DWDM. Optical data transport in DarkStar systems use DWDM.

dB – decibel
As light travels a distance, or through any kind of splice, connection, component, etc., it loses optical power (attenuation). This loss is measured using the unit-less dB. Attenuation dB is a logarithmic scale, and the equation for dB is 10 base log the ratio of input intensity/output intensity. There are some standard estimates that are useful for planning a system, e.g., assume a 0.5 dB loss for each splice. dB is also used to express the amount of amplification.

dBm – decibel-milliwatts
Used to express optical power, dBm is an abbreviation for the power ratio in decibels (dB) of the measured power referenced to one milliwatt (mW).

DBC – DarkStar band combiner
A DarkStar band combiner uses an optical multiplexer and demultiplexer to combine and separate bands on a single fiber. Using a DBC, multiple DarkStar systems can be combined to provide larger transport capacities on a single fiber.

dichroic filter
An optical filter that selectively passes light according to wavelength. Light that is not passed through the filter is reflected. Dichroic filters are often used in DWDM systems.

dielectric
A nonconducting or insulating substance that resists passage of electric current. An example is all-dielectric self-supporting (ADSS) fiber optic cables, which can be strung along live power lines and weigh less than traditional wire cables.

diffraction grating
An optical component often found in DWDM systems, the grating can act as a sort of directional filter.

diode
An electronic device that conducts electricity in one direction only. The simplest semiconductor devices are diodes. A laser diode, on the other hand, is a fairly complex component that converts an electrical signal to an optical one. Two basic types of laser diodes are Fabry-Perot (FB) and distributed feedback (DFB).

dispersion
The spreading of a light signal as it passes through a fiber cable (though not all light signals spread). Dispersion can have several causes. Modal dispersion is related to the angle at which a wavelength enters the fiber. Because several wavelengths can be sent simultaneously, not all of the wavelengths will have the same entry angle. If it enters at a shallow angle, it will travel faster. If it enters the fiber at a higher angle, it is reflected off the core boundary many times, slowing it down. Chromatic dispersion is when the wavelengths spread out from each other, due to their differing rates of propagation. By the time the signal is received, it is wider than when it was sent.

DMUX – demultiplexer
A device that separates two or more signals previously combined by multiplexing equipment.

DSF – dispersion shifted fiber
A single-mode fiber with a refractive index that is designed to control chromatic dispersion in the 1500nm range.

DWDM – dense wavelength division multiplexing
A process where different optical wavelengths are combined into one optical signal. This is a way to combine many signals from different sources and transmit them on one fiber, all at the same time. In the C band, 40 channels of 100GHz channel spacing or 96 channels of 50GHz channel spacing is a common DWDM solution. *See also* WDM – wavelength division multiplexing

EDFA – erbium doped fiber amplifier
A device that amplifies an optical signal by sending it through a fiber that has been doped with trivalent erbium ions. The erbium ions are excited by a separate laser that pumps it with energy to stimulate the erbium. As the signal interacts with the stimulated erbium, it emits photons at the same wavelength as the original signal, amplifying it.

Fast Ethernet
Fast Ethernet is a standard that offers speeds of 100Mbps over Cat-3 or UTP. It preserves many of the attributes of Ethernet, including frame format, MAC mechanisms, and MTU. Also called 100BASE-T.

Fibre Channel
A technology for transmitting high-speed data between computer devices (over optical fiber or copper). Fibre Channel was developed by a committee and has become popular in data storage networks. It is optimized for connecting servers to shared storage devices and connecting storage controllers and drives.

FPGA – field programmable gate array
An integrated circuit that can be programmed by a designer or end-user, depending on the application.

FWHM – full width at half maximum
In filters, this is an expression of the specific portion of a signal that passes energy through a filter. It is the width of the signal at half of its maximum (peak).

FWM – four wave mixing
A phenomenon of inter-modulation that occurs in non-linear mediums such as optical fibers. The interaction of two or more wavelengths produces one or more new wavelengths. This distortion can create transmission problems, such as interference and signal noise.

Gbps
Gigabits per second, or one billion bits per second.

GHz – gigahertz
Unit of frequency that equals one thousand million hertz.

GigE – Gigabit Ethernet
GigE is a backbone of LAN technology offering data speeds up to 1000Mbps, or one gig per second. GigE can use either a shared or switched medium.

graded-index fiber
Sometimes called gradient-index, an optical fiber in which the refractive index of the core decreases toward the cladding. Since the refractive index is higher at the core, a light signal is constantly re-directed to travel as closely to the core as possible. This helps to minimize modal dispersion. Used in multi-mode fiber.

hot-swappable
The ability to add or remove a component from a system without first removing the power to the system. Some components in DarkStar systems are hot-swappable.

hubbed ring
A network topology where all channels originate and terminate from a central, or hub, node. The other nodes on the ring, sometimes called satellite nodes, add and drop one or more channels. The added and dropped channels terminate at the node, while the channels that are not being dropped, sometimes called express channels, are passed through optically, without being electrically terminated.

Hz – hertz
Unit of current or wave frequency; one hertz is one cycle per second.

ICMP – Internet Control Message Protocol
A protocol that is used to send error and diagnostic messages to hosts on an IP network. These messages are used to monitor and diagnose problems on an IP network. Ping and traceroute use ICMP functionality.

intermediate reach
Optical systems that operate from 3 to 15km are intermediate reach systems.

insertion loss
The attenuation, expressed in dB, that results from inserting a component into a fiber link. A component is any added item that interrupts the fiber, such as a connector, splice, coupler, or filter. The loss is the reciprocal of the ratio of signal strength after the inserted component and the signal strength before the inserted component. *See also* dB – decibel.

IP address
A unique number used by devices to identify and communicate with each other on a computer network using the Internet Protocol (IP) standard.

jitter
Small and rapid variations in the timing of a signal or waveform due to noise, changes in component characteristics, voltages, and circuit synchronization.

Kbps
Kilobits per second, or one thousand bits per second.

KHz
Kilohertz, or 1,000 cycles per second.

lambda
The Greek letter used in optics to denote wavelength. In optical communications, wavelength is measured in nanometers (nm).

LAN – local area network
A high-speed, low-error data network covering a relatively small geographic area. Ethernet, FDDI, and Token Ring are widely used LAN technologies.

LOL – loss of lock
An event that occurs when an interface cannot lock to the data rate of a signal. DarkStar systems may have Clock and Data Recovery (CDR) circuitry. If equipped, and the CDR circuitry fails to lock on a signal, the DarkStar system may report LOL against the module or interface. LOL can occur in the receive or transmit direction.

line
The multiplexed Trunk/Wave DWDM and optical service channel (OSC) signal.

LOS – loss of signal
The receive optical power of a DarkStar module asserts an LOS when the incoming signal power falls below a threshold. Thresholds are not configurable and are module specific. LOS can be caused by many different things, including a bad connection, bad cable, or a malfunctioning transmitter.

loss budget
Not to be confused with *power budget*, the loss budget is an estimate of how much loss can be expected in a connection between a transmitter and its corresponding receiver. If the actual losses exceed this estimate and impact the power budget, the signal may be too degraded for the receiver to accurately process it. Losses due to distance, splices, amplifiers, or any other type of infringement are included in the loss budget. Sometimes called a link budget.

MAN – metropolitan area network
A network that covers an area larger than a LAN, usually a city area. A MAN can be a few city blocks or an entire urban area. MANs are smaller than wide area networks (WANs) and are often used to connect multiple network backbones. London uses MANs for their CATV systems, and some universities refer to their network as a MAN.

material dispersion
The dispersion due to the different wavelength velocities contained in a signal as it travels through the fiber.

Mbps
Megabits per second, or one million bits per second.

MBps
Megabytes per second, or one million bytes per second. A byte is typically composed of eight bits.

MD5 hash
A digital "fingerprint" produced from a string of text by the Message-Digest algorithm 5 (MD5). Such hashes are commonly used for cryptographic purposes. DarkStar systems use MD5 to encrypt plaintext passwords before storing them.

MHz
Megahertz, or one million cycles per second. *See also* Hz – hertz.

MIB – Management Information Base
A database that describes the objects in a network. The MIB is hierarchal, and contains information about managing and monitoring each object. The MIB describes each object using five mandatory characteristics, and sometimes contains additional optional information. This information is used by the Simple Network Management Protocol (SNMP).

MSDP – Multicast Source Discovery Protocol
A networking protocol that connects multicast routing domains and allows them to discover sources from other domains.

MTBF – mean time between failure
A measure of the time a user might reasonably expect a device or system to function correctly before a fault occurs. This measurement depends on the definition of "failure" or "fault" for a particular device or system . For networking equipment, "failure" usually means any time the unit is not functioning. MTBF assumes immediate repair (or resolution) of the issue, and does not refer to a unit failing irreparably.

multimode fiber
An optical fiber that supports transverse guided modes for a given optical frequency and polarization. The number of guided modes is determined by the wavelength and the refractive index profile of the fiber. The core is larger than singlemode, so each mode has a different reflection angle. In multimode fiber, signals tend to disperse over longer distances, so it is best for shorter applications. A multimode fiber core is either 50µ or 62µ in diameter. *See also* single-mode fiber.

MUX – multiplexer
A device that combines multiple signals into a single signal. DarkStar systems can be combined to multiplex up to 40 signals into a single output. *See also* DMUX – demultiplexer.

muxponder system
A transponder system with added optical mux/demux filters. Sometimes a muxponder system is referred to as an aggregation of lower data rates to a higher data rate. So with this definition, the statistical multiplexer in DarkStar DQM100 systems is a muxponder *device*. Any DarkStar system that includes the optical mux/demux filters, like the DSM10, DQM10, DQM100, is a muxponder *system*.

nm - nanometer
Unit to express optical wavelength, a nanometer is one billionth of a meter (0.000000001 m). DarkStar systems transmit DWDM signals in the "conventional" C-band of 1530-1565 nm.

NAS – network attached storage
A central data storage system attached to the network that it serves. *See also* SAN – storage area network.

network topology
The map of a network that describes the pattern of links connecting pairs of nodes. A node has one or more links to other links. The simplest topology is a point-to-point link between two devices. Common network topologies are bus, ring, and star layouts.

NZDSF – non-zero dispersion-shifted fiber
A dispersion-shifted single mode fiber that has the zero dispersion point outside of the actual 1550 nm window used to transmit signals. NZ-DSF is designed to maximize bandwidth while minimizing fiber nonlinearities and helps minimize certain types of distortion, including FWM, SPM, and XPM. *See also* DSF – dispersion shifted fiber.

OA – Optical Amplifier
A device that amplifies an input optical signal without converting it to electrical form. Two common types of optical amplifiers are Raman and EDFA.

OADM – optical add-drop multiplexer
A passive optical network device that can combine signals or separate out particular wavelengths. This is used to add and drop wavelengths into and out of an optical signal without converting them back to electrical form. For example, a multiplexer can extract one or more signals of a particular wavelength from the incoming fiber and simultaneously insert different signals (of the same wavelengths) in the outgoing fiber. The extracted signals can be redirected to another network path if they are sent through an optical switch. *See also* ADM – add-drop multiplexer and OMD – optical mux/demux.

OC – Optical Carrier
A series of standardized transmission bandwidth for signals that can be carried on SONET optical networks. There are eight categories, such as OC-1, OC-3, OC-12, and OC48. The suffix is a multiple of 51.84 Mbps, so OC-1=51.48 Mbps, OC-3 = 155Mbps, and so on. *See also* SONET – Synchronous Optical Network.

OMD – optical mux/demux
A filter that multiplexes (combines) multiple signals into one fiber and demultiplexes (splits) multiple signals into multiple distinct signals. Unlike an OADM, the OMD does not allow any signals to pass. *See also* OADM – optical add-drop multiplexer.

optical power budget
Not to be confused with *loss budget*, the power budget is an estimate of how much loss can be tolerated in a connection between a transmitter and its corresponding receiver. The power budget is determined by comparing the power output of the transmitter with the minimum input power requirements of the receiver.

optical receiver
An opto-electric circuit that detects incoming lightwave signals and converts them to the appropriate electronic signals for processing by a receiving device. Components of a receiver include a light-detecting device (photodiode), an amplifier, and connections to other devices. A receiver is often combined with a transmitter to create a transceiver.

OSC – optical service channel
An optical channel that connects adjacent DarkStar systems. The OSC provides network connectivity between the management planes in DarkStar systems. The OSC is an out-of-band communication channel.

OSI model
The Open Systems Interconnection model is a standard for networking system architecture, and is intended to ensure compatibility between diverse communication systems. The model breaks networking into seven layers, with each layer serving the one above it. *See also* physical network layer.

OSNR – optical signal-to-noise ratio
Used to quantify the degree of optical noise interference on optical signals, the optical signal-to-noise ratio (OSNR) is the ratio of signal power to noise power in an optical channel.

OTDR – optical time domain reflectometer
An instrument used in design and diagnostics that locates faults or infers attenuation in optical networks. It works by sending a series of signals into a fiber, then measuring the strength of the backscatter, or amount of light that is reflected back. From this, the OTDR can calculate the attenuation in a fiber, and locate a bad splice, break, bend, or other disruption in the fiber cable.

passive optical device
A component that does not require external power to manipulate or react to optical output. Passive devices include optical mux/demux modules, splitters, attenuators, and connectors.

photodiode device
A semiconductor device that converts light to electrical current. A photodiode device can contain lenses and filters, and their surface area varies. Photodiodes are used extensively in fiber-optic networking, optical amplifiers, optical receivers and transmitters. It is actually a type of photodetector.

physical network layer
The first (lowest) layer of the OSI reference model, Layer 1. This layer is where the actual raw data is transmitted. Optical technologies such as DWDM work at the physical layer. *See also* OSI model.

PMD – polarization mode dispersion
The discrepancy that occurs when the two polarizations in a signal travel at a different speed from each other. The resulting pulse spreading can be a problem in high-speed systems. PMD can be caused by imperfections in the fiber (not exactly round) or from outside stresses, such as temperature and vibration.

PMD compensation systems
Since PMD is random and varies with conditions, compensation systems are very complex and expensive. They work by splitting the signal into its two polarizations and applying a delay to synch them back up.

PON – passive optical network
A network that is usually a shorter distance, these are called passive because there are no active electronic parts once the signal is sent through the network. A PON connects a single fiber to an unpowered splitter that then sends the signal to multiple destinations. PONs are often used for CATV systems and connecting Internet and cable to homes.

PRBS – pseudo random bit sequence
Used in BERT testing, a pseudorandom binary sequence (PRBS) is a sequence of bits (1 and 0), produced with a deterministic algorithm. Consequently, PRBS is statistically close to a random sequence. PRBS is used in BERT testing to determine the reliability of digital communication systems. Most DarkStar systems can generate a PRBS signal to test a link. *See also* BERT – bit error ratio test.

protection interface
The secondary interface in an Automatic Path Protection (APP) system. The protection interface takes over if the signal on the working interface is interrupted.

QSFP - quad small form-factor pluggable
A type of optical transceiver. The transceiver is compact and contains four lanes of up to 10Gbps. These modules can be removed from the system without powering down.

Raman amplifier
An optical amplifier that uses Stimulated Raman Scattering (SRS). Unlike EDFA devices, the signal is amplified using a nonlinear interaction between the signal and a pump laser within an optical fiber. Both types of Raman amplifiers (distributed and lumped) use fiber as the gain medium: a distributed amplifier uses the transmission fiber as the gain medium by multiplexing a pump wavelength with signal wavelength, and requires a minimum span of 100km; a lumped Raman amplifier uses a dedicated, shorter length of fiber to provide amplification. Raman amplifiers can be inserted into an existing system to upgrade it, can be tailored to work in different regions of the spectrum, and produces a stronger signal with less noise.

reboot
Replace a previous operating system with a fresh copy (of itself or something else). In a Darkstar system, a cold reboot refreshes (or replaces) all gateware and DXMOS, and disrupts traffic. A warm reboot replaces only the gateware by which the control processor is implemented and DXMOS; DWDM/data plane traffic is undisturbed. *See also* boot.

refractive index
When light passes through a material, it *refracts*, or changes direction. The refractive index is calculated by dividing the velocity of light in a vacuum by its velocity in the material. Fiber cable is manufactured using specific materials to control refraction.

regenerative repeater
A device that regenerates optical signals by converting incoming optical pulses to electrical pulses, cleaning up the electrical signal to eliminate noise, and converting them back to the optical domain for output. Signals are amplified, reshaped, retimed, and retransmitted. Sometimes called a regenerator or 3R regeneration.

revertive switching
A process that switches the signal back to the original working interface when that interface becomes available.

RIP – Routing Information Protocol
The RIP is an interior gateway protocol that helps routers dynamically adapt to changes of network connections by describing which network each router can reach and how far away those networks are.

SAN – storage area network
A secure information infrastructure that connects computer storage devices to remote servers in such a way that the devices appear to be locally attached to the operating system. The SAN enables any-to-any connection of servers and storage systems.

SFP – small form-factor pluggable transceiver
An optical transceiver that is compact and hot-swappable. Rather than having to open up a system and replace boards, the SFP can be pulled out and replaced without powering down the system. There are SFPs for different applications, such as 1310 or 1550 nm, single-mode or multi-mode, SFSW, and SFP+.

short reach networks
An optical network designed to operate effectively at distances of up to 3km. A typical use for a short reach network is in metropolitan areas and data centers. It is expected that short reach networks will continue to become less expensive and grow in capacity, providing an efficient solution to growing data needs.

single-mode fiber
A small-core optical fiber through which only one mode can propagate. Since dispersion is nonexistent, single-mode fibers are good for longer distances and have a higher bandwidth, making them popular in CATV networks, and larger LANs such as universities and colleges.

SNMP – Simple Network Management Protocol
An application layer protocol for exchanging management information between network devices. SNMP allows network administrators to monitor performance, troubleshoot problems, and plan for growth.

SONET – Synchronous Optical Network
An ANSI transport protocol for fiber-optic transmission systems, originally developed to transport voice and data over the same lines. The protocol allows many different data streams from many different sources to be quickly transmitted at the same time over optical fiber. A major benefit of SONET is that it allows for a ring topology with a working ring and a secondary, backup ring. When there is a failure in the working ring, SONET automatically detects it and transfers the workload to the secondary ring, and this is called "self-healing". SONET was initially developed by the telecommunication industry and has since been adopted worldwide - it's now an ANSI standard in the U.S., and SDH is the international equivalent.

spectral width
Light is made up of a spectrum, and laser light is focused in a very small amount of that spectrum. The spectral width is a measure of the amount of a spectrum in a wavelength. An LED has a much less-focused signal, and has a typical spectral width of 50-60 nm. A laser, on the other hand, has a spectral width of less than 5 nm.

SPM – self phase modulation
A high intensity ultra-short light signal in a fiber can cause spectral broadening or compression of the signal.

static routes
Manually-defined paths between devices in an IP network. Static routes use less processing power and bandwidth than dynamic routing. However, since any status changes must be entered manually, static routing is not appropriate for managing larger networks.

statistical multiplexing
Sometimes called "statistical time division multiplexing", a method of allocating bandwidth based on demand. Instead of all channels being given the same priority (whether or not they are carrying traffic), those channels with traffic are given first priority for transmitting.

step-index fiber
Fiber that has a uniform index of refraction throughout the core, and a sharply lower index near the cladding. Used primarily in single-mode fibers, but is sometimes used in multi-mode.

survivability
The ability of a network to maintain or restore an acceptable level of performance during failures. Typical situations can be hardware malfunctions, software crashes, hacking attacks, and issues related to power surges.

switch
Switch is used differently, depending on the XKL product:

A crossbar switch is a feature of the DQM10 and DQT10 systems: the crossbar switch allows a specific client to be connected to a specific wave, and vice versa. With the appropriate settings of switches in two systems, local client 3 can be connected to wave 7; at the remote system, wave 7 can be connected to client 14.

The eVolocity DQM100 system handles switching in a different way: each frame incoming from a client is labeled with the destination system and destination client to which the frame will be delivered. Labeled frames are sent between systems. The receiving system inspects the labels on incoming frames. A frame intended for the receiving system is delivered to the indicated client. Other frames are forwarded toward the intended destination system.

TCP/IP – Transmission Control Protocol/Internet Protocol
The basic language of the Internet, "TCP/IP" refers to the two layers of communication. TCP manages the packets of data that make up a message, IP manages computer addresses and directs messages to the correct destination.

TFTP – Trivial File Transfer Protocol
A simple protocol for transferring files, TFTP can only read and write. Because it does not have any authentication capability, TFTP is most commonly used to copy and read files within a local area network.

transport interface
Any kind of transmitting/receiving medium that carries data.

transponder system
A system that takes optical signals at one wavelength and converts them to optical signals at another wavelength. The optical signals are full duplex as are the associated electrical signals. A transponder may convert the optical signals to electrical signals in the process. For a DarkStar system, a crossbar ASIC or an aggregation FPGA (the statistical multiplexer) is added to allow routing of electrical signals. In a traditional optical transport system, a pair of transceivers are placed back-to-back without any capability to reroute the electrical signals, i.e., no crossbar or statistical multiplexing.

trunk
Darkstar systems provide one or more "trunks" or "trunk ports". Trunk ports carry the optical signals originating from the wave transceivers in a Darkstar transponder system; when the signal originates from a Darkstar multiplexing transponder, the trunk carries a DWDM signal. When the signal originates from a Darkstar filterless transponder, each fiber pair on the trunk port carries a single channel. Adjacent Darkstar systems are connected at their trunk ports using optical fiber cable. Often, a trunk may travel a moderate distance (tens of kilometers) between systems. *See also* client and wave.

tunable laser
A laser that can be adjusted to transmit a selected wavelength. When used in DWDM, tunable lasers can provide more efficient optical wavelength allocation. Even though they are more expensive, they are economical for spares, since they can be tuned to replace several varieties of fixed-wavelength laser.

VCSEL – vertical-cavity surface-emitting laser
A laser diode that is structured vertically. Due to the manufacturing process, VCSELs can be made in bulk and tested at various points during manufacture, lowering their cost. They also require less energy and produce a more circular signal that works well with optic fibers. Their lower output means that they are most commonly used in local-area and metro-area networks (LANs and MANs).

VIF – virtual interface
An aggregation of one or more physical interfaces.

VTY – virtual terminal
The interface that allows network managers to log on to a DarkStar system from a remote computer/terminal using an IP network.

WAN –wide area network
A physical or logical network that serves a broad geographic area (a region, a state, or larger) and often leases transmission lines from common carriers. A WAN is often made up of several LANs (local area networks) and can include a MAN (metro area network). *See also* LAN – local area network and MAN – metropolitan area network.

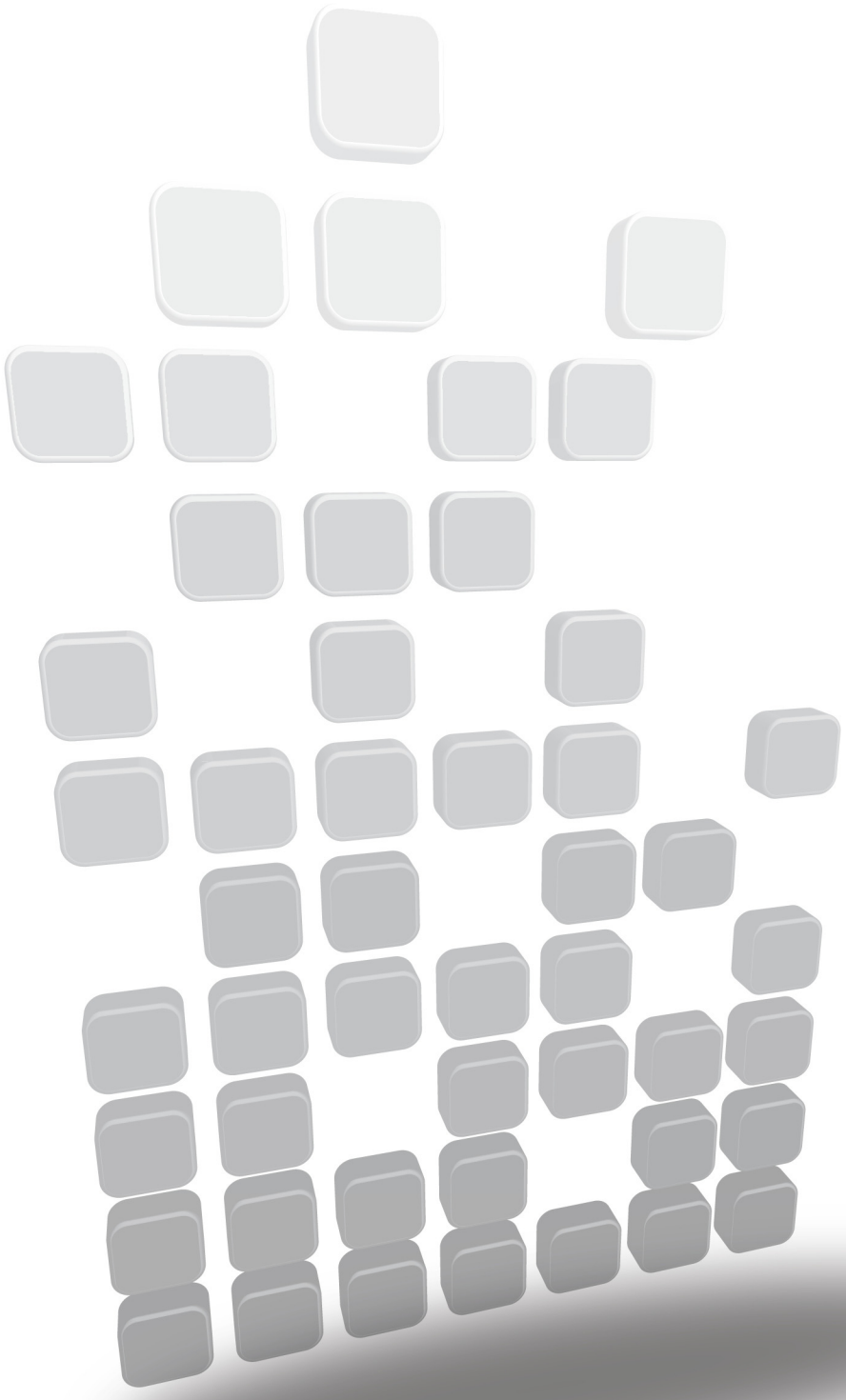
wave
A "wave" is a signal carried by a trunk. "Waves" or "wave ports" are the optical transceivers connected to the trunk ports in a Darkstar transponder system. (Wave transceivers typically use DWDM optics.) A wave is associated with a client by creating a connection in the switch. When this association is made, the signal received by the client is regenerated and retransmitted by the wave into the trunk. Conversely, the signal received by the wave is regenerated and retransmitted by the associated client. In a DQM10 or DQT10 system, multiple waves, each a different frequency, are carried by the trunk. As the trunk may span a moderate distance, a wave transceiver is generally more powerful than a client transceiver. In an eVolocity DQM100 system, the one (logical) wave carries frames of different conversations in a time-multiplexed manner. These waves can be multiplexed by frequency so that several can be carried on one trunk. *See also* trunk and client.

warm reboot
Reboot where the controller firmware and software are reloaded, but the power and state of transport interfaces and switches remain on. The data plane is unaffected by warm reload.

WDM – wavelength division multiplexing
A process where optical signals with different wavelengths are combined, transmitted together, and separated again. This is a way to combine up to 8 signals from different sources and transmit them on one fiber, all at the same time. DWDM is similar but with higher wavelength density. *See also* DWDM – dense wavelength division multiplexing.

working interface
The primary interface in an Automatic Path Protection (APP) system. If the signal on the working interface is interrupted, the protection (secondary) interface takes over. Not all DarkStar systems offer APP.

XPM – cross-phase modulation
When multiple signals are traveling together, their interaction can cause a change in the refractive index and distort the signal.



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