MCS Documentation for LWA-1 CDR

Steve Ellingson *on behalf of the Virginia Tech MCS Development Team*

Nov 10, 2009

Summary of Status

- For MCS, "hardware design" consists primarily of selection of computers, computer components, and networking equipment; and verifying performance. Hardware design for MCS (excluding data recorders (MCS-DR); see below) is complete.

- MCS/Scheduler software is available in a functional pre-alpha release status. Subsystems SHL and ASP are fully supported. DP is partially supported.

- The most demanding speed requirement for MCS is the ability to re-point a "calibration beam" within 5 ms, repeating at every 60 ms (LWA Memo 146). We have confirmed that MCS will be at least 2 orders of magnitude faster than necessary, and is limited primarily by network throughput.

- MCS-DR has been designed and demonstrated. Up to 5 TB can be acquired at 115 MB/s from each of the 5 outputs of the DP subsystem. This corresponds to about 10 hours of continuous acquisition per beam, plus TBN/TBW, and exceeds the requirement of 112 MB/s (corresponding to TBN at its highest rate). It should be noted that these tests were done using a second computer emulating DP, since DP is not yet available.

- Two of the five MCS-DR computers have been procured. Unfortunately, the COTS computer used in the MCS-DR design was discontinued before the remaining three were ordered. A replacement has been identified, but not yet tested.

- MCS-DR software is available in a functional pre-alpha release status. The primary difference between this software and the software used to validate the MCS-DR design is the implementation of the MCS Common ICD, which allows MCS-DRs to be controlled by MCS as individual level-1 subsystems.

- Software development for MCS/Executive and MCS/Task Processor remains in the planning stage and no releasable software is available. We consider this to be on schedule. The risk involved in these software components is very low relative to the risk associated with MCS/Scheduler and MCS-DR, which have been our focus. Furthermore, it should be noted that the station can be controlled via a bash-scriptable command line interface using only MCS/Scheduler.

MCS Specification, Requirements, and Design Documentation

The documents cited below are included as an attachments. Note that the most recent documentation is always available at the "Virginia Tech LWA Contributions" web site, http://www.ece.vt.edu/swe/lwavt/.

MCS is described in the following documents:

- S. Ellingson, "MCS Subsystem Definition," Ver. 2, LWA Engineering Memo MCS0004, Feb. 23, 2009. [online] http://www.ece.vt.edu/swe/lwavt/. *Note:* Paragraph 4 of Section 3 ("Data Recording") is no longer applicable due to the adoption of DRSUs as the standard medium for data storage/transfer; see MCS0007.

- S. Ellingson, "MCS Architecture," Ver. 4, LWA Engineering Memo MCS0007, Nov 7, 2009. [online] http://www.ece.vt.edu/swe/lwavt/.

The MCS Common ICD is the basis for passing of command and status information between MCS and other LWA-1 Level-1 subsystems:

- S. Ellingson, "MCS Common ICD," Ver. 1.0, Long Wavelength Array Engineering Memo MCS0005, April 4, 2009. [online] http://www.ece.vt.edu/swe/lwavt/.

MCS software: Software for MCS/Scheduler (the core component of the MCS, which interacts with all other subsystems and provides the interface to the higher level functions) is in a functional pre-alpha release status. Anyone can download and experiment with this software. No releasable development of software for the other two MCS computers ("Executive" and "Task Processor") has been done.

- S. Ellingson, "MCS/Scheduler Software Version 0.4 (pre-alpha)," MCS0021, Nov 7, 2009. [online] http://www.ece.vt.edu/swe/lwavt/. *The release tarball includes a comprehensive readme file documenting the software, including numerous test cases. The readme is included as an attachment to this document.*
- *See also "System Diagnostic & Emulation software" below.*

MCS Data Recorder (MCS-DR) is a complete subsystem within MCS, but treated internally by MCS as five distinct Level-1 subsystems (corresponding to the five MCS-DR PCs).

- C. Wolfe, S. Ellingson & C. Patterson, "MCS Data Recorder Preliminary Design & Verification," MCS0018, Aug 26, 2009. [online] http://www.ece.vt.edu/swe/lwavt/. Also available as LWA Memo 165. *Note changes since this memo are documented below.*
- C. Wolfe, S. Ellingson & C. Patterson, "MCS-DR Storage Unit," MCS0019, Sep 23, 2009. [online] http://www.ece.vt.edu/swe/lwavt/.
- C. Wolfe, S. Ellingson & C. Patterson, "Interface Control Document for Monitor and Control System Data Recorder," MCS0020, Oct 10, 2009. [online] http://www.ece.vt.edu/swe/lwavt/.
- C. Wolfe, "MCS Data Recorder Operating System Version 0.8 (pre-alpha)," MCS0022, Nov 10, 2009. [online] http://www.ece.vt.edu/swe/lwavt/. *The release tarball includes a comprehensive readme file documenting the software. The readme is included as an attachment to this document.*

System Emulation & Diagnostic Software. The software identified below is not part of the MCS design baseline, but has been developed to assist with MCS development, testing, and integration. This software is made freely available to assist in the development of other subsystems with respect to integration with MCS.

- A. Srinivasan and S. Ellingson, "Python code for direct communication with subsystems," MCS0015, Aug 7, 2009. [online] http://www.ece.vt.edu/swe/lwavt/.
- A. Srinivasan and S. Ellingson, "MCS ICD Compliance Check Software," MCS0013, July 31, 2009. [online] http://www.ece.vt.edu/swe/lwavt/.
- A. Srinivasan and S. Ellingson, "MCS Common ICD Emulation Software for SHL," MCS0012, Aug 7, 2009. [online] http://www.ece.vt.edu/swe/lwavt/.
- S. Ellingson, "MCS Common ICD Network Check Software," MCS0009, Ver. 2, Apr 4, 2009. [online] http://www.ece.vt.edu/swe/lwavt/.

Summary of Component Cost, Size, and Power

MCS not including Data Recording (MCS-DR):

Item	Description	Power	Cost		Status (Nov 10, 2009)
Scheduler	computer [1,2]	750W	$1916	2U	Purchased; at VT
Executive	computer [1,2]	750W	$1916	2U	Not yet ordered
Task Processor	computer [1,2]	750W	$1916	2U	Not yet ordered
Gateway	managed switch [3]	50W	$1528	1U	Purchased; at VT
Command Hub	managed switch [3]	50W	$1528	1U	Not yet ordered
Other [4]	(misc)		$1000	2U	
	TOTAL	2350W	$9804	10U	

[1] Dell R5400; see attached quote and technical specifications
[2] May be possible to consolidate these 3 PCs into 2 PCs. Thus, this is worst case
[3] Dell PowerConnect 6224; see attached quote and technical specifications
[4] See explanation below. Mostly contingency

MCS-DR:

Item	Description	Power	Cost		Status (Nov 10, 2009)
Data Recorder PC#1	computer [1]	360W	$1799	4U	Purchased; at VT
Data Recorder PC#2	computer [1]	360W	$1799	4U	Purchased; at VT
Data Recorder PC#3	computer [2]	350W	$1989	4U	Ordered; awaiting shipment
Data Recorder PC#4	computer [2]	350W	$1989	4U	Not yet ordered
Data Recorder PC#5	computer [2]	350W	$1989	4U	Not yet ordered
10GbE NICs [3] (2 @ $595 each)			$1190		2 installed (VT M&S)
(3 @ $595 each)			$1785		3 ordered (VT M&S)
1GbE NICs [8] (5 @ $85.99 each)			$ 430		2 installed (VT M&S)
					3 on-hand (VT M&S)
Video cards [9] (2 @ $135.99 each)			$ 272		2 installed (VT M&S)
Video cards [10] (3 needed, $135.99)			$ 408		Not yet ordered
CXP4 cables (5 @ $105 each)			$ 525		Not yet ordered [6]
DRSU x 5	data storage [4]	500W	$1750	2U	2 Purchased; at UNM [5]
		750W	$2625	3U	3 not yet ordered
Other [7]	(misc)		$1000	4U	
	TOTAL	3020W	$19550	29U	

[1] Dell Studio XPS 435MT, see attached quote for technical specifications. Also see note below
[2] Dell Precision T1500; see attached quote and technical specifications. This is the candidate replacement for the above computer; see note below.
[3] Myricom 10G-PCIE-8A-C+E.
[4] The data recorder storage unit (DRSU) is documented in MCS0019 and MCS0020. Each DR PC uses one 1U DRSU; thus up to 5 can be used simultaneously. The numbers indicated in the above table assume 5 DRSUs at the current cost of $875/ea. We assume the project office will provide these.
[5] In addition, VT has one DRSU plus a prototype DRSU (both procured using VT M&S) that will remain at VT.
[6] VT has two of these, which will remain at VT for development.
[7] See explanation below.
[8] Intel Pro 1000 PT PCIe (x1) NIC, Model No. EXPI9400PTBLK. This is included only as a

backup to the 10GbE NIC, is not supported, and should not normally be needed.

[9] ATI FireMV 2250 256MB DDR2 PCIe (x1) video card, Model No. 100-505179. This is needed even if video is not desired, because the 10GbE NIC displaces the existing video card and the motherboard's BIOS requires that a video card is present.

[10] Comment above will likely also apply to the T1500. The video card needed for the T1500 has not yet been determined. Using the ATI card cited above as worst case for cost.

Note: The MCS-DR design has been completed and fully verified for the Dell Studio XPS 435MT. However, this model was discontinued in the time between our request for the remaining 3 MCS-DR PCs and the time that UNM placed the order. We believe that the Precision T1500 will be an acceptable replacement but we have not yet verified this.

Note: At PDR we proposed tape storage for MCS-DR. Due to the low cost and large capacity offered by the removable DRSUs, we no longer recommend tape storage of data in the station.

Note: Suggested accessory for rack mounting of MCS-DR PCs #1-#5 is Bud Industries Model SA-1752-BT, $73.50/ea.

Note: "Other" above denotes cables (other than those indicated), cable management, power strips and power cord extenders, rackmount hardware (but not racks), plus contingency.

Plan for Completion

We forsee no difficulties in meeting the LWA-1 system readiness milestones promulgated by the Project Office after PDR; in particular, the December 2010 "Full Station" milestone, which we interpret as being "initial operational capability" (IOC) in terms previously used in this project. The following is a list of top-level tasks to be completed:

- Validate the new MCS-DR PC (i.e., the Dell T1500 proposed to replace the Dell Studio XPS 435MT).
- Complete MCS/Scheduler software, including support for DP and MCS-DR.
- Complete MCS/Executive software.
- Complete MCS/Task Processor software, including the user applications described in Section 5 ("Application Software") of MCS0004.

Version History

Nov 10, 2009 (Ver. 1)

List of Attachments

1. MCS0004 (MCS Definition)
2. MCS0007 (MCS Architecture)
3. MCS0005 (MCS Common ICD)
4. “readme” file from MCS0021 (MCS/Scheduler Software Version 0.4)
5. MCS0018 (MCS-DR Design & Verification)
6. MCS0019 (MCS-DR Storage Unit)
7. MCS0020 (MCS-DR ICD)
8. “readme” file from MCS0022 (MCS-DR OS Version 0.8)
9. Vendor summary documentation on Dell R5400
10. Vendor summary documentation on Dell PowerConnect 6225
11. Vendor summary documentation on Dell Studio XPS 435MT
12. Vendor summary documentation on Dell T1500

MCS Subsystem Definition
Ver. 2

Steve Ellingson*

February 23, 2009

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1 Scope of Work

MCS stands for "monitoring and control system". With the current allocation of ONR FY07 funds plus the currently-planned allocation of FY08 funds, Virginia Tech will develop MCS for the first LWA station ("LWA-1") to a sufficient level to facilitate LWA-1 "initial operational capability" (IOC). Here are some caveats:

1. Although this work is specific to LWA-1, the development will be such that that replication of the MCS design (including hardware and software) for subsequent LWA stations will be straightforward.

2. Selected capabilities that might not be necessary or desired for subsequent stations – e.g., specific capabilities intended to support the design or integration of other subsystems, and support for "outrigger" antennas for use in station commissioning experiments – will be accommodated, with the extent of the accommodation being at the discretion of Virginia Tech.

3. The development will be such that the integration of the station MCS with a future multistation "LWA-wide" MCS will be straightforward. However, the specification or development of the "LWA-wide" MCS is outside the scope of this work.

4. All MCS hardware that is installed in LWA-1 will purchased by the LWA Project Office (informally, this has been referred to as the "pile of parts" cost). Materials and supplies which are used to develop MCS – but not intended for installation in the station – will be purchased by Virginia Tech. However, some of what is purchased by Virginia Tech for MCS development may, at Virginia Tech's discretion, be provided to the Project Office for installation in LWA-1.

This statement of work is intended as elaboration for project management purposes only. Existing official documents take precedence all matters pertaining to administration and contracts.

2 MCS Functions

The following is a brief summary of the functions that MCS performs.

1. **Monitoring** of the station "state", the progress of commanded activities, and status information provided by integrated subsystems.

2. **Logging.** MCS will maintain a record of activity, including commands received; the beginning, ending, and changes in the status of observations; key changes in system or subsystem state (e.g., error conditions reported, actions taken); and so on.

3. **Control.** MCS converts commands from users into commands issued to station subsystems. Users do not interact directly with LWA subsystems. "Control" also includes the commanding of LWA subsystems to perform certain tasks which might occur independently of explicit user commands; e.g., diagnostics which are performed periodically, or which are automatically initiated when certain conditions are detected.

4. **Data Recording.** In lieu of a station-level data aggregation and communication (DAC) subsystem (not funded by the project office), MCS will provide a rudimentary data recording capability. See Section 3 for elaboration.

5. **User Interface**, including remote operation. See Section 4 for elaboration.

6. **Application Software**, including diagnostic and operational aids. See Section 5 for elaboration.

Data reduction is outside the scope of this work, except for certain limited capabilities which are intrinsic to monitoring and diagnostic features identified elsewhere in this document. The data product delivered to users is essentially the data which is produced by the digital processing (DP) subsystem, plus metadata captured by (or generated by) MCS.

3 Data Recording

According to the station architecture document [1], LWA stations are to have a data aggregation and communication (DAC) subsystem that is responsible for the routing of data from digital processing, and further says "The DAC includes separate output to facilitate local recording of output directly to disk. For example, this would allow continued operation of the station should data path to the LWA central processing facility be interrupted, or not yet implemented." However, DAC is currently an "orphan" – i.e., no institution is working on it, and no ONR FY07 and 08 funds are available for its development. In its place, University of New Mexico agreed to provide a network interface allowing off-site network communication, and Virginia Tech agreed to implement a rudimentary local data recording capability as part of the LWA-1 MCS.

The MCS interim data recording capability will accept output from DP via 10 Gb/s ethernet connections. Each connection nominally operates at less than 100 MB/s (800 Mb/s), although transfer rates up to 200 MB/s (1600 Mb/s) should be possible. The maximum duration of sustained recording depends on the transfer rate as well as the amount of disk drive storage. Also, the fraction of drive space that is available for sustained transfer diminishes with increasing transfer rate.[1] An educated guess is that at least 500 GB will be available per ethernet input, assuming 100 MB/s transfer per ethernet input. At 200 MB/s, the available storage for sustained transfer is difficult to predict but is likely to be significantly less.

It is important to note that MCS-DR will only *record* data from DP; it will not necessarily *reformat* the data, nor will it necessarily reorder data packets from DP should they arrive out of order. Thus, the data available to users will be in the same form and the same order received from DP by MCS-DR, at least in the initial realization of the system.

There will ultimately be four ways in which data can be recovered from the data recording computers. (1) Through an LTO-type tape drive which is part of MCS, (2) Through an internal station network directly into a user-provided PC, (3) Through an MCS-provided USB port directly to a user-provided external hard drive, and (4) Through the external internet connection to a remote computer. Option (3) will be implemented first, and is intended primarily as a stopgap measure. Option (4) may be restricted based on availability of the connection and priorities for its use.

It should be noted that it will probably not be possible to offload data – using any of the four techniques described above – while an observation is underway. It may be possible to "array" the data recording PCs so that some can be offloading while others are recording.

It is anticipated that the total amount of storage provided by data recording PCs will be limited to a few terabytes. Thus, a protocol will be established to automatically delete data from previous observations in order to make room for upcoming observations. The time required to offload data could result in significant "down time" for certain observing modes, and will need to be considered when planning observations.

4 User Interface

1. The primary physical interface with users will be via a network connection. Users which are on-site may access MCS using personally-owned computers connected to an internal ethernet connection. Users which are off-site may access MCS through the external internet connection. In this sense, there will be not normally be a distinction between users which are physically present at the station, and users which are accessing MCS via an external internet connection.

[1] This is because transfer to hard drives tends to be most efficient when the drive is empty of data, and tends to degrade as more data is placed on the drive.

For security and safety reasons, certain functions may be restricted for users which are not physically present.

2. The primary logical interface with users will be via selected standard internet protocols. Command line operation via the secure shell (ssh) protocol will be provided for both monitoring and control. To use this facility, users will login to a Linux-based operating system using personal accounts set up for them by the MCS system administrator.[2] An http-based monitoring-only capability will also be available to permit monitoring via a web browser. Other protocols and capabilities will be provided at the discretion of Virginia Tech.

3. Some application software will be provided. See Section 5 for specific information.

4. Dedicated computer(s) to serve as a station "console" or "status display" are not within the scope of this work, but software suitable to implement those functions on computers provided by the LWA Project Office will be provided. This will be essentially the same software described in items 2 and 3. It is recommended that at least one computer be permanently installed in the station as a local user console, and that this computer also have a second wall-mounted large-screen monitor that continuously displays the output of the default monitoring application.

5. Users will be able to obtain any information which is monitored or logged by MCS.

6. Users will be able to issue commands. The specific commands which can be issued will depend on the user, as identified by that user's login. Not all users will be allowed to use all commands.

7. A group of commands will be provided for the definition and scheduling of observations. See Section 6 for additional information.

5 Application Software

Some application software will be provided. This software will not be required to operate the station, and is intended only as a convenience to users. Specifically, this software will (1) provide a graphical user interface (GUI) alternative to the basic/default command line method of operation, and (2) provide an example for others who wish to develop more elaborate application software.

The applications will communicate with MCS using only the standard methods described in Section 4, item 2. The applications will be developed primarily in Python, and will use an open-source GUI toolkit. In some cases ANSI C will also be used. An effort will be made to develop this software in such a way that all common operating systems and distributions are supported either explicitly or through a straightforward porting mechanism (e.g., recompilation). However, the software will be developed using Ubuntu Linux, and the applications will be tested and validated only for this OS/distribution.

The following is a list of application software that will be provided as part of the LWA-1 IOC MCS. These applications will be available in both command line and GUI versions, except as indicated.

1. Monitoring application. Provides selected subsets of all possible data. Possible subsets could be: A summary status display (i.e., something suitable for a wall-mounted monitor); Data summarizing the status of a specific observation; a table of measured total power for each antenna (useful as a diagnostic); and so on. Command line application provides same information, but in numerical form only and without continuous updating.

2. Scheduling application. Provides a graphical interface for defining and scheduling an observation. For additional information on observing, see Section 6. Not available as a command line application. An "off-line" version of this application will also be provided as an aid in planning observations.

[2]The system administrator will be a Virginia Tech designee until IOC. This responsibility should at that time be formally transferred to an LWA Project Office representative.

3. Frequency-domain analyzer (max-hold, median, mean). By antenna, or by beam. Variable spectral resolution and integration time. The command line version will provide the same information, but in numerical form only and without continuous updating.

4. Time-domain analyzer. By antenna, or by beam. Variable bandwidth and integration time. The command line version provides same information, but in numerical form only and without continuous updating.

5. Time-frequency analyzer (i.e., spectrograms). By antenna, or by beam. Variable temporal and spectral resolution. The command line version provides same information, but in numerical form only and without continuous updating.

6. Sky map. Provides a low-resolution image of the sky in brightness temperature at the selected frequency, location, and time. Can be set to update in near-real-time. Provides also position (RA/Dec as well as current Az/El) of the Sun, Sag A, Cas A, Cyg A, and Tau A. Predicts antenna temperature. The command line application provides same information, but in numerical form only and without continuous updating.

7. Command line "help" application; essentially, "man" pages for all MCS commands.

6 User Observing Paradigm

The term "observation" may have multiple definitions in the context of an LWA station. In this section, we define an "observation" as the allocation of LWA station resources over a specified time period to a user, for the purpose of collecting science data. The sequence of events for an observation are as follows:

1. The user plans the observation. Parameters that must be determined include start and end times; configuration (choice of beamformer, TBN, or TBW, for example); pointing vs. time, center frequency, bandwidth, and integration time for specified beam(s); and so on. Users will not normally need to know site specifics or details of the digital signal processing to plan an observation. For example, to define a beam pointing, the user will have to provide RA/Dec and center frequency, but not Az/El, per-antenna delays, or FIR coefficients.

2. The user defines the observation using the on-line or off-line application software described in Section 5, item 2. If the off-line application is used, the process must be completed using the on-line application.

3. MCS determines if the observation is allowed. For example, if the observation is part of an approved proposal, MCS compares the observation request to information from the approved proposal. MCS also determines if the observation is possible; i.e., within the capabilities of the station, taking into account current status such as subsystem failures. The observation is then either accepted or rejected.

4. MCS conducts the observation. The observation can be monitored in near-real-time as described in Section 4.

5. Data acquired from the digital processing (DP) subsystem will be recorded as explained in Section 3. Metadata associated with the observation will also be recorded. Primary source of metadata will be MCS log entries pertaining to the observation (indicating progress of the observation and error conditions (if any) encountered) and station "state" information that may be needed to analyze or interpret the data at a later time; for example, details of station configuration, array geometry, maintenance conditions, and so on.

6. At some point after the observation is completed, the user is responsible for offloading data and metadata; see Section 3.

"Fire and forget" operation will be supported; that is, users will not be required to be logged in order for commands (including observation commands) to begin or complete execution.

7 Document History

- Version 2 (Feb 23, 2009):
  - Indicating explicitly that MCS-DR only records data from DP, and does not reformat it.
  - More specific comments on MCS-DR transfer rates and storage, based on project-level decisions to use 10 Gb/s ethernet.

References

[1] S. Ellingson, "Long Wavelength Array Station Architecture Ver. 1.0," Long Wavelength Array Memo Series No. 119, November 19, 2007. [online] http://www.phys.unm.edu/∼lwa/memos.

MCS Architecture
Ver. 4

Steve Ellingson*

November 7, 2009

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2 Document History **5**

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1 Architecture

MCS stands for "monitoring and control system". MCS is defined in [1]. The purpose of this document is to describe the architecture of MCS (not discussed in [1]) and to provide the next lower level of design detail.

Figure 1 shows the MCS architecture, as well as interfaces to adjacent subsystems. First, note that here we use the term "MCS" to refer to both MCS (the upper shaded region) as well as the MCS Data Recorder ("MCS-DR"; the lower shaded region). Excluding MCS-DR for the moment, note that MCS consists of three computers and two switches. These are described below:

- The *Scheduler* is a computer whose primary function is to issue commands and receive status from other LWA subsystems. The command and status communications are though the *Command Hub*, using the "MCS Common ICD" [2] augmented by the corresponding subsystem ICDs. The term "scheduler" is a bit of a misnomer, since it does not actually do scheduling, but rather keeps time, issues commands necessary to implement instructions from the Executive, parses the stream of incoming response messages. The Scheduler manages the Command Hub. The Scheduler handles tasks that are extremely time-sensitive and that must be coordinated on timescales down to milliseconds.

- The *Executive* is the computer which exercises top-level control over MCS as well as the station. It is responsible for interpreting observation requests and, from these, generating the data which becomes the content of command messages issued by the Scheduler. This includes numerically-intensive operations such as computation of FIR filter coefficients. It updates the MCS and station MIBs accordingly. The Executive manages the Gateway. The Executive manages tasks that are moderately time-sensitive and that must be coordinated on timescales down to seconds.

- The *Task Processor* is a computer which exists primarily to host applications which are not "time critical" and therefore can be "offloaded" to reduce the processing burden of the Executive. The Task Processor is the primary interface with users, managing command line and GUI interactions. Prominent among these are observation scheduling, including the reduction of scheduled observation data from "user friendly" form to parameterized instructions that can be interpreted by the Executive. The Task Processor is also responsible for the scheduling and interpretation of internal diagnostics (both automatic or user-directed), and manages MCS-DR. In general, the Task Processor handles tasks that do not need to managed at resolutions of seconds or less.

- The *Gateway* is a managed switch which, under the control of the Executive, regulates the flow of network traffic between the Shelter LAN and the various computers of MCS and MCS-DR. The Gateway is managed to prevent traffic from the Shelter LAN from interfering with MCS operation, as well as to provide a layer of security between the shelter LAN (and external network) and MCS-internal devices. The Gateway is also used to regulate the flow of data between the MCS-DR computers and users who are retrieving data or otherwise utilizing MCS-DR computers.

- The *Command Hub* is a managed switch which, under the control of the Scheduler, regulates the flow of network traffic between the Scheduler and subsystems, utilizing the "MCS Common ICD" interface [2]. The Command Hub is managed in order to guarantee sufficient allocation of bandwidth between connected devices, and to avoid any connected devices from interfering with MCS operation by "jabbering" or exhibiting other problematic behaviors beyond the control of MCS.

MCS-DR consists of 5 identical computers as shown in Figure 1. Four of these computers receive data streams from DP corresponding to the output of each of the four station beams. The fifth computer receives the DP output data stream corresponding to TBW/TBN output. Each MCS-DR

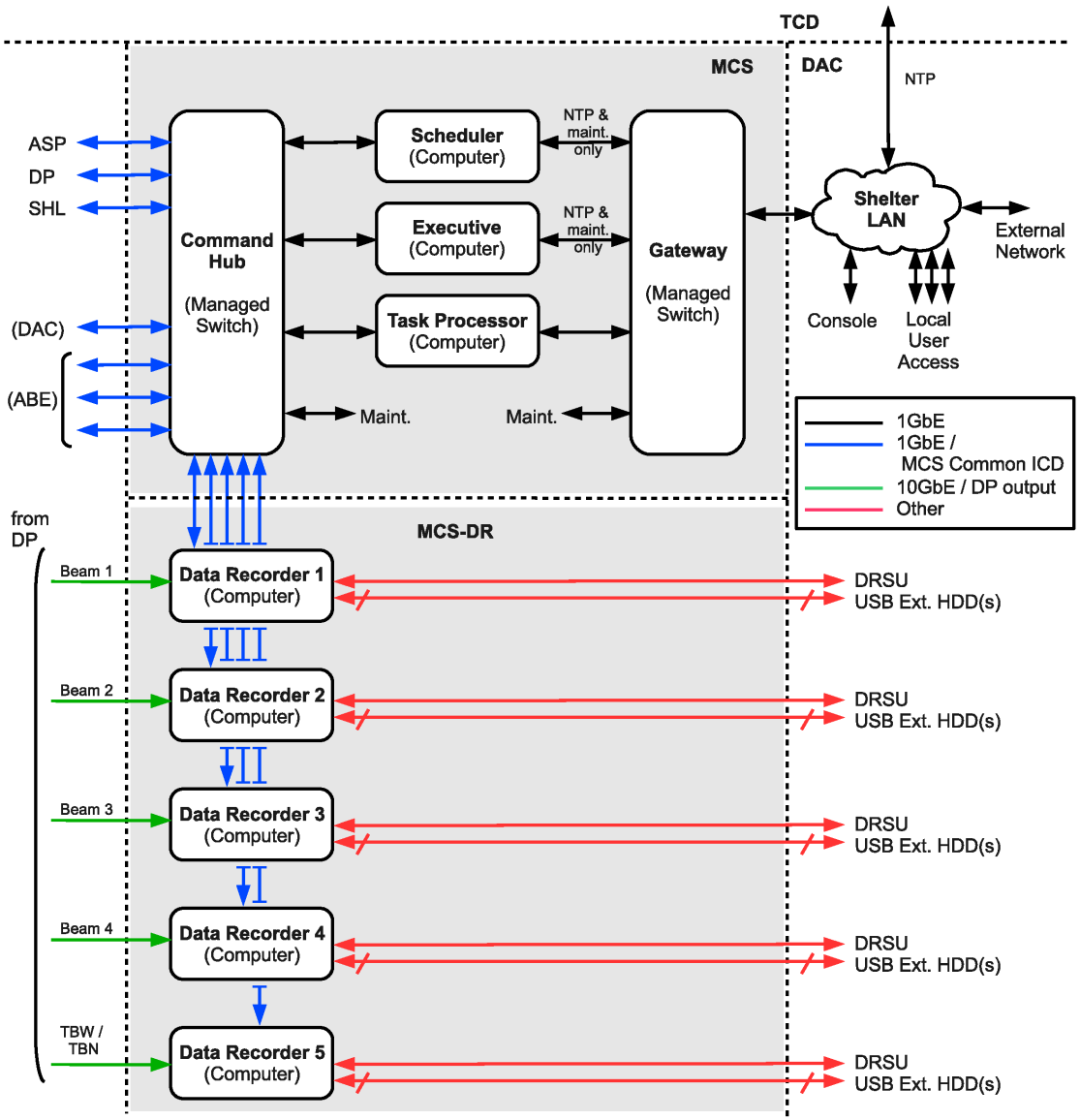

Figure 1: MCS architecture and interfaces to adjacent subsystems. "DAC" refers to "Data Aggregation and Communications" (not currently implemented in LWA-1). "ABE" refers to "alternative back ends" (not currently defined, but taken into account to facilitate future expansion). "DRSU" refers to "data recorder storage unit" (see text). "Maint." refers to (1) access ports to allow connection of laptop-type computers for development, integration, and troubleshooting activities, and (2) data paths available for the same purposes.

computer is connected to a separate, removable data recorder storage unit ("DRSU"). A DRSU is a hard drive array having total storage of 5TB, connected to an MCS-DR computer via an eSATA cable. All data acquired by an MCS-DR computer is streamed directly to its associated DRSU. For additional information, see [3, 4].

When not being used for data recording, MCS-DR computers are also available for general purpose computing by MCS, or by users (under MCS control). See [1] for additional details on how MCS-DR is to be used.

Note that the shelter LAN and physical access for local users are not part of MCS. (It presumed that these will eventually be subsumed into the DAC subsystem.) Also note that a "console" (that is, a permanently-installed computer for operation of the station by local users) is not part of MCS. For elaboration, please see [1].

2 Document History

- Version 4 (Nov 7, 2009):
  - Revised architecture diagram to remove PPS and 10 MHz interfaces into MCS/Scheduler (determined that NTP will suffice).
  - Revised architecture diagram to replace LTO tape drives with DRSUs.
- Version 3 (Feb 25, 2009):
  - Revised architecture diagram to indicate an "MCS Common ICD" connection to SHL. J. Craig indicates that SHL will have a computer which in turn will control SHL-PCD and SHL-ECS.
- Version 2 (Feb 23, 2009):
  - TBW/TBN input to MCS-DR now indicated as 10 Gb/s.
  - J. Craig indicates that PCD will require an unknown number of "MCS Common ICD" interfaces. These have been added.

References

[1] S. Ellingson, "MCS Subsystem Definition," Ver. 2, Long Wavelength Array Engineering Memo MCS0004, Feb. 23, 2009. [online] http://www.ece.vt.edu/swe/lwavt/.

[2] S. Ellingson, "MCS Common ICD," Ver. 1.0, Long Wavelength Array Engineering Memo MCS0005, Apr 04, 2009. [online] http://www.ece.vt.edu/swe/lwavt/.

[3] C. Wolfe, S. Ellingson & C. Patterson, "Interface Control Document for Monitor and Control System Data Recorder," MCS0020, Oct 10, 2009. [online] http://www.ece.vt.edu/swe/lwavt/.

[4] C. Wolfe, S. Ellingson & C. Patterson, "MCS-DR Storage Unit," MCS0019, Sep 23, 2009. [online] http://www.ece.vt.edu/swe/lwavt/.

MCS Common ICD
Ver. 1.0

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April 4, 2009

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1 Introduction and Scope

MCS stands for "monitoring and control system". As described in the LWA station architecture document [1], MCS monitors and controls ASP ("analog signal processing"), DP ("digital processing"), and other subsystems. The purpose of this interface control document (ICD) is to define a common interface between MCS and connected subsytems.

Compliance with this ICD is necessary, but not sufficient for integration with MCS. As explained below, this ICD provides a framework for the interface between MCS and subsystems which are directly connected to it, including electromechanical interfaces and protocol information. It is expected that subsystems connecting to MCS will cite this ICD in their subsystem-specific ICDs, and then specify subsystem-specific information as extensions within this framework.

This ICD does not apply to the interface between DP and the interim data recording capability being provided by MCS, described in Section 3 of [2].

2 Summary

1. The sole physical interface with MCS will be a single 1000BASE-T (full-duplex gigabit ethernet) connection over Category 6 ("Cat-6") cable terminated in RJ45 connectors.

2. The sole protocol interface with MCS will be UDP, with direct passing of messages using sockets.[1] IP addresses are static and defined in a separate document. Port assignments are defined in a separate document. The term "message" is defined henceforth to mean a single command or response, containined entirely within the data field of one or more UDP packets. A message will normally correspond to a single use of a "send()" or "recv()" function (with syntax dependent on the programming language, of course). Message structure is defined in Section 4.

3. The interface will operate according to a "polling" paradigm. Connected subsystems will never *initiate* communications, and will only respond to an MCS message to the extent required by the applicable ICD(s). Subsystems shall not communicate with subsystems other than MCS over this interface.

3 MIB

"MIB" stands for "management information base".[2] The MIB provides a means for organizing subsystem status information that is jointly understood by communicating subsystems.

The MIB has an index/outline structure, as demonstated by the MIB fragment in Figure 1. (Note this fragment is an example only, shown only for the purposes of explaining the MIB concept.) In this fragment, each line is an "entry", consisting of an "index" (e.g., 2) and a "label" (e.g, A2). Each MIB index/label possibly also has an associated data value. A "branch" is a set of entries with a common index/label; for example, branch 2 (also known as "A2") contains the data values B21 = 3.4, D221 = "PRR", and E22 = 7. Other examples: Branch 2.1 contains the data value B21 = 3.4 only, and branch 2.2 (also known as "C22") contains data values D221 = "PRR" (D221) and E222 = 7. Note that entries with "sub-entries" are for organizational purposes only (making it possible to refer to multiple entries using a single index/label), and do not contain data. For example, entries 2 and 2.2 have labels only and contain no data.

[1] For the uninitiated, see http://en.wikipedia.org/wiki/User_Datagram_Protocol and/or http://docs.python.org/library/socket.html.

[2] The use of this term is a nod to the MIB concept used in the SNMP protocol, but the two MIBs are not the same, and in fact are different in many respects.

index	label	data	remarks
2	A2		
2.1	B21	3.4	5 bytes, ASCII, base-10, decimal point allowed
2.2	C22		
2.2.1	D221	PRR	3 bytes, ASCII, alphanumeric
2.2.2	E222	7	2 bytes, ASCII, base-10 integer

Figure 1: A MIB fragment, provided as an example only.

MIB labels must consist only of letters (case is significant), integer numbers, and the underscore character. Spaces are not allowed. The length must be less than or equal to 40 characters.

Data referenced by MIB entries need not be ASCII, and can be raw binary. If raw binary, then the subsystem ICD must specify whether this is big- or little-endian. An example of the use of raw binary would be to represent the coefficients for a digital filter. The filter can be represented as a MIB branch where each entry is the raw bit values for one coefficient, or the entire filter can be represented as a *single* entry consisting of all coefficients concatenated into a contiguous sequence of bits.

Each subsystem communicating with MCS using this ICD must specify a MIB as part of a subsystem-specific ICD. This MIB consists of MCS-required MIB entries, plus additional MIB entries which are subsystem-specific. The MCS-required MIB entries are specified below.

1. MCS-RESERVED

    1.1. SUMMARY [7 bytes, ASCII/Alphanumeric]. Summary state of subsystem. Valid values are as follows:

    * NORMAL
    * WARNING (issue(s) found, but still fully operational)
    * ERROR (problems found which limit or prevent proper operation)
    * BOOTING (initializing system; not yet fully operational)
    * SHUTDWN (shutting down system; not ready for operation)

    1.2. INFO [maximum 256 bytes, ASCII]. When MIB entry 1.1 is WARNING or ERROR, this entry should begin with a list of MIB labels, separated by single spaces, and terminated by the character "!" (exclaimation mark). The MIB labels should be those containing values indicating the problem condition. A human-readable text string which further explains WARNING and ERROR values may be included following the character "!". Any unused bytes at the end of the INFO string should be spaces. Use of this MIB entry when 1.1 is not WARNING or ERROR is subsystem-specific.

    1.3. LASTLOG [maximum 256 bytes, ASCII]. Last internal log message. Human-readable text string, with format specified in the subsystem-specific ICD. A timestamp of some form should be included near the beginning of the string. Any unused bytes at the end of the string should be spaces.

    1.4. SUBSYSTEM [3 bytes, ASCII/Alphanumeric]. 3 character string identifying the subsystem; e.g., "DP ", "ASP". All strings beginnning with the characters "MC" are reserved. Other strings are assigned by the LWA Systems Engineer.[3]

    1.5. SERIALNO [maximum 5 bytes, ASCII]. A string identifying the specific subsystem hardware "serial number". This string is assigned by the subsystem manufacturer in coordination with the LWA Systems Engineer.

[3]One possible use of this entry is to facilitate subsystem discovery; e.g., MCS can send a RPT command message to "ALL" requesting MIB entry 1.4, and see who responds.

1.6. VERSION [maximum 256 bytes, ASCII]. Version number of locally-installed software. May include additional information or elaboration; if so, the "principal" version number must appear first and be followed by a single space. Any unused bytes at the end of this string should be spaces.

1.x *Additional MIB entries beginning "1." TBD*

x. *MIB entries numbered 2 or higher are subsystem-specific, and are defined in the associated ICDs*

4 Message Structure

Messages are contained entirely within the payload fields of UDP packets. The maximum size of a message is 8192 bytes. A message is subdivided into fields as defined below. All fields are required (except as indicated), contiguous, and must appear in the order indicated and with the number of bytes indicated. Unless indicated otherwise, data are right-justified in their fields, and padded with the character " " (space).

1. DESTINATION [3 bytes, ASCII/Alphanumeric]. This is the intended recipient of the message. Valid values are "ALL" (to be interpreted as "all subsystems receiving this message"), "ASP", "DP " (note blank in third position), and "MCS". *(Other values will be added as necessary.)* Subsystems shall ignore any message not addressed to either the subsystem or "ALL".

2. SENDER [3 bytes, ASCII/Alphanumeric]. This is the subsystem sending the message. Valid values are the same as for DESTINATION.

3. TYPE [3 bytes, ASCII/Alphanumeric]. This field indicates the type of message. A list of message types is given in Section 5.

4. REFERENCE [9 bytes, ASCII/Numeric] (base-10 integer). MCS assigns reference numbers to messages. Reference numbers are assigned sequentially station-wide, so connected subsytems should not interpret gaps in the sequence as missed messages. Responses to MCS command messages use the same reference number appearing in the command message.

5. DATALEN [4 bytes, ASCII/Numeric] (base-10 integer). This is the number of bytes in the DATA field.

6. MJD [6 bytes, ASCII/Numeric] (base-10 integer). Integer part of the modified Julian day (MJD). For example: For Dec 28, 2008 UT this is "54828". See additional information below.

7. MPM [9 bytes, ASCII/Numeric] (base-10 integer). Milliseconds past UT midnight; see "MJD". (Note that there are 86,400,000 milliseconds in a UT day, except for days with a leap second.) See additional information below.

8. There is always a space following the MPM field.

9. DATA. [Variable length, variable format]. The contents of this field depend on the message TYPE; see Section 5.

The purpose of the MJD and MPM fields is primarily to confirm to the recipient that the sender has a consistent understanding of what time it is, and also to provide a convenient mechanism for keeping or seaching logs. Subsystems may use this information to set local clocks, with the understanding that the accuracy of these times (due to non-deterministic OS- and transmission-related delays) is probably not better than a few milliseconds, and could be intermittently much worse. Unless explicitly indicated in associated subsystem ICDs, MJD and MPM should not be interpreted as the time at which the command is to take effect, nor should these be interpreted as being precisely the time at which the condition reported in a response was observed. If it is necessary to convey this information precisely, those times can alternatively be indicated separately as part of the DATA

field. MJD/MPM should reflect the "best available estimate" of station time as known to the sender. A satisfactory "best available estimate" can be obtained simply by calling an appropriate time function immediately prior to assembling the message and sending it, and it is expected that this time will represent the time at which the message was actually transmitted to within a few milliseconds.

See Section 6 for examples of command and response messages.

5 Message Types

Messages from MCS are commands. Commands can request action, information, or both. Connected subsystems respond as specified by the message TYPE definition. The following is a list of message TYPEs that are common to all MCS interfaces. ICDs between MCS and specific subsytems may specify additional message TYPEs.

- "PNG" = Ping. The purposes of the command message are (1) to confirm that a commanded system is functioning, and (2) to disseminate or confirm time information. Upon receiving this message, the commanded subsytem (1) verifies that its local time is consistent with the time given in the received command message, updating if neccessary; and (2) responds with a PNG response message. The DATA field of the command message is empty, the DATA field of the response message is limited to the standard response indicated below. See Section 6 for an example.
- "RPT" = Report. The purpose of this message TYPE is to provide a flexible method for reporting subsystem status. In the command message, the DATA field contains a label corresponding to MIB entry or branch, indicating that the commanded subsystem should respond with the current values of the MIB for that index/branch. The MIB data is provided as a contiguous block of data, with no delimiters or terminators (this is to avoid difficulties with raw data being interpreted as special characters). MIB entries that have variable length are sent padded to their maximum length. MCS shall not send an RPT command that results in a response message whose length exceeds the maximum specified by this ICD. See Section 6 for an example of the use of this command.
- "SHT" = Shutdown. The purpose of this command is to direct the system to shut down. If the DATA field is empty, then the shutdown should be "orderly"; e.g., tasks which are currently executing may be allowed to complete or be "gracefully" terminated. If the DATA field contains the string "SCRAM", then the subsystem should be shutdown as rapidly as possible; e.g., tasks which are currently executing should simply be abandoned.[4] If the DATA field contains the string "RESTART", then the subsystem should immediately restart after shutdown is complete. The data field "SCRAM RESTART" is permitted and has the expected effect.

The controlled subsystem shall respond to every message with a matching DESTINATION (or "ALL") with a "response message". This is demonstrated by example in Section 6. The response message shall be transmitted within 3 seconds of receipt of the associated message from MCS. If the DESTINATION field is not a match (or "ALL"), then the controlled subsystem shall ignore the message. The DATA field of a response message has the following structure:

1. R-RESPONSE [1 byte, ASCII]. This is the character "A" to indicate that the command was accepted, or the letter "R" to indicate that the command was rejected.
2. R-SUMMARY [7 bytes, ASCII]. This is MIB entry 1.1.

[4]The intent of the "SCRAM" option is provide a quicker method for shutting down the station to save time during integration, commissioning, and maintenance activities, when many power-up/power-down cycles may be required and there is no risk of data loss. (It is anticipated that the option will exist to simply cut power to a subsystem, but that that this will be facilitated specifically through station PCD.)

3. R-COMMENT [variable length, ASCII]. The definition of this field depends on R-RESPONSE and the message TYPE. If R-RESPONSE is "R", then this field shall be used to send error codes or log messages, as specified by the subsystem ICD or other subsystem design documents.

6 Command/Response Examples

For clarity in the following examples, single quotes (') are used in lieu of spaces and "@" is used to represent a byte of raw binary data.

6.1 PNG Command/Response

The following is an example of a PNG command sent from MCS to DP. MCS sends a message packet containing the payload
`DP'MCSPNG'''''1391'''0'54828'12345678'`
which is interpreted as follows:

- DESTINATION is the DP subsystem.
- SENDER is MCS.
- TYPE = "PNG"
- REFERENCE = 1391
- DATALEN = 0, so the DATA field is empty.
- MJD = 54828, so Dec 28, 2008 UT.
- MPM = 12345678. Dividing by 3600×1000 gives the number of hours past UT midnight; in this case, about 3.4.
- Mandatory space following the MPM field.
- The DATA field is empty.

In response, DP sends the message
`MCSDP'PNG'''''1391'''8'54828'12345698'A'NORMAL`
which is interpreted as follows:

- DESTINATION is the MCS subsystem.
- SENDER is DP.
- TYPE = "PNG"
- REFERENCE = 1391 (same as the command message, so MCS can identify it)
- DATALEN = 8, so the DATA field is 8 bytes long.
- MJD = 54828 (same as the command message since the response occurs the same UT day)
- MPM = 12345698; this is DP's estimate of when this response was sent.
- Mandatory space following the MPM field.
- The DATA field contains the 8-byte string "`A'NORMAL`", indicating that the associated command message was accepted, and that the value of MIB entry 1.1 (SUMMARY) is "NORMAL".

6.2 RPT Command/Response

The following is an example of an RPT command sent from MCS to DP. This example assumes the MIB fragment shown in Figure 1. MCS sends the message
`DP'MCSRPT'''''1391'''3'54828'12345678'B21`
which is interpreted as a request for the data value associated with MIB index 2.1.

In response, DP sends the message
`MCSDP'RPT'''''1391'''5'54828'12345698'A'NORMAL''3.4`
in which DP is indicating that B21 = 3.4. Note that all 5 bytes of data value (per the specification of Figure 1) are sent.

The following example is different only in that multiple values are requested simultaneously using a single branch index. MCS sends the message
`DP'MCSRPT'''''1391''3'54828'12345678'C22`

In response, DP sends the message
`MCSDP'RPT'''''1391''5'54828'12345698'A'NORMALPRR'7`
in which DP is indicating that D221 = "PRR" and E222 = 7. Again, note that all bytes of the data value (per the specification of Figure 1) are sent. This is particularly important as MCS will simply count bytes to parse the DATA field into MIB entry data.

7 Document History

- Version 0.2 (Feb 23, 2009):
  - Julian day (JDAY) changed to mean Julian day (MJD).
  - Fixed error in specification of left- vs. right-justification.
  - Pointed out in the definition of MPM that a UT day can have have a leap second.
  - More specific guidance for MIB labels (allowable characters, lengths, etc).
- Version 0.3 (Mar 20, 2009):
  - Fixed error in representation of MJD.
  - Fixed error in which MCS-RESERVED MIB labels "SUBSYSTEM" and "SERIALNO" were both index 1.4.
  - Settled on use of UDP over TCP. References to TCP have been removed.
  - Maximum size of a packet payload set to 4050 bytes.
  - The field "DATALEN" has been added to indicate the length of the DATA field.
  - MJD and MPM now are now interpreted simply as the time at which the message is sent. Specification of times at which commands are to become effective, or for which responses indicate the observed conditions, must be indicated separately in the data field.
  - Added a new field "CKSUM", which is a CRC32 checksum for the packet payload.
  - The DATA field of response messages has been standardized to include an explicit indication of accept/reject by the controlled subsystem.
  - Clarified policy on use of multi-packet messages.
  - Using single quotes (') in place of periods (.) to represent spaces in command-response examples.
- Version 0.4 (Mar 29, 2009):
  - INFO (MIB index 1.2) contains MIB *labels* (not *indices*) to elaborate on MIB index 1.1.
  - Some editing intended to untangle the use of the terms "message", "packet", and "payload".
  - "Multipacket" messages are no longer an option. References to NPKTS and INDEX have been removed.
  - Fixed errors in RPT response examples. Also modified examples to reflect above change.
  - Included some guidance on the meanings of the "MJD" and "MPM" fields.
  - Standardized response times to all messages to be within 3 seconds.
  - Clarified that subsystems must ignore messages that have invalid checksum, or which are not addressed to it or "ALL".
  - Edited description of "SERIALNO" field.
- Version 1.0 (Apr 4, 2009):
  - Maximum message length increased from 4050 bytes to 8192 bytes.
  - Removed CKSUM field from message format. Examples updated accordingly.

References

[1] J. Craig, "Long Wavelength Array Station Architecture," Ver. 2.0, Long Wavelength Array Memo 161, February 26, 2009. [on-line] http://www.phys.unm.edu/∼lwa/memos.

[2] S. Ellingson, "MCS Subsystem Definition," Ver. 2, Long Wavelength Array Engineering Memo MCS0004, Feb. 23, 2009. [online] http://www.ece.vt.edu/swe/lwavt/.

MCS/Scheduler Software
Version 0.4
S.W. Ellingson
Nov 7, 2009

Major changes in this version

1. Increased dimension of cmd[] and dest[] in msei.c to prevent the "[7] FATAL: subsystem <> not recognized" error reported on some systems.

2. Minor editing of this (readme) file in preparation for CDR review.

Introduction

This is software developed for the MCS "Scheduler" computer. The Scheduler computer accepts commands from the MCS "Executive" computer (or, for development/testing purposes, something emulating the Executive) and interfaces with subsystems (or things emulating subsystems). Also provided are software and scripts which can be used to demonstrate and evaluate the software, including control programs and a subsystem emulation program.

Note that the software is designed such that everything can be run on a single computer without modification; the difference between "scheduler and subsystems on separate PCs" operation and "everything on a single PC" operation is simply whether interprocess communications are directed to separate computers using network IP addresses, or to local processes using the loopback (127.0.0.1) IP address, respectively.

The software is written entirely in ANSI C and was developed on Ubuntu Linux 9.04 (AMD64 Desktop). Shell scripts (provided) are used for demonstration and testing. Subsystem emulators (also provided) are written in Python.

This software is considered "pre-alpha". Specifically, it is functional and released to facilitate review and comment; but not all required features are implemented. This software exists in the author's Subversion archive as revision 35.

Limitations of this release of the software include:

-- Only SHL, ASP, DP, and the mock subsystems (NU1, NU2, etc.) are explicitly supported. It is probably possible to PNG, RPT, and SHT other subsystems, but this has not been tested. The mock subsystems behave as actual LWA subsystems, but are limited to the commands PNG, RPT, and SHT and implement only the MCS-RESERVED branch of the MIB.

-- The DP commands DRX, BAM, and FST are not yet supported. Implementation of other DP commands and the MIB assume implementation of changes to the DP ICD to which JPL has agreed; however, these changes have not yet been published. (Some of these are noted below under "Other Notes & Issues"; others are documented in various emails.)

-- The software currently sends commands to subsystems as quickly as possible, without regard for scheduling. That is, the Scheduler (ironically) does not yet respect requests to queue tasks until a predefined future time. The task queue architecture for doing this exists and is used; it is simply that the Scheduler does not yet use scheduled time as a criterion for when to send commands to subsystems.

-- A fully-functional emulator is provided for SHL, which makes comprehensive testing of the software as an interface to SHL very simple. A limited "generic" emulator is also provided, which makes possible limited testing of the interface to ASP and DP. The generic emulator fully supports the mock subsystems.

File Inventory

readme.txt
-- This file.

readme_SHL_EI.txt
-- How to use MCS/Scheduler as an Engineering Interface for SHL (applicable to ASP, DP, etc. as well)

makefile
-- "$ make" compiles everything needed and places executibles in target directory.

ms_init.c
-- Using a script (specified in the command line), this process initializes locally-maintained MIB files, launches subsystem handling processes (ms_mcic's), sets up interprocess communications (using POSIX message queues), launches the scheduler's executive process (ms_exec), and terminates.

ms_exec.c
ms_exec_log.c
-- The scheduler's executive process. On the user side, accepts commands via a TCP connection at port 9734 (can be changed; see LWA_PORT_MSE in LWA_MCS.h). Communicates with subsystem handlers (ms_mcic's) via POSIX message queues.

ms_mcic.c
ms_mcic_mib.c
ms_mcic_SHL.c
ms_mcic_ASP.c
ms_mcic_DP_.c
-- Code for the subsystem handler process "ms_mcic". One instance of ms_mcic is launched for each subsystem to be managed.

dat2dbm.c
-- This program converts initial subsystem MIBs from human-readable text format to the "dbm" format used by the scheduler software. (See the section "Why dbm Files?" below for more information.) Called by ms_init once for each subsystem.

LWA_MCS.h
LWA_MCS_subsystems.h
-- Header files used by the software above.

ms_makeMIB_ASP.c
ms_makeMIB_DP.c
-- Automates process of creating a text-format MIB init files for ASP and DP (required by ms_init), respectively.

That's it for actual MCS/Scheduler software. The following programs are support programs to facilitate testing and development:

msei.c
-- Program that can be used to send commands to the Scheduler software (specifically, to ms_exec) in lieu of MCS/Executive.

ms_mdr.c
ms_mdre.c
-- Programs that can be used to read the dbm-format MIB files used by MCS/Scheduler software. ms_mdr displays all content of a MIB file. ms_mdre displays only a specified entry (handy especially for use in scripts). In all cases, the time of last update is indicated.

test1.sh
test2.sh
test3.sh
test4.sh
test5.sh
test6.sh
test7.sh
-- Shell scripts used to demonstrate and test the software. See the "Quick Start" and "Defined Test Cases" sections below for more information.

ms_shutdown.sh
-- A simple shell script that kills ms_exec and any ms_mcic processes in the event that these processes have not (or cannot) be shut down in an orderly way.

NU1_MIB_init.dat

```
NU2_MIB_init.dat
NU3_MIB_init.dat
NU4_MIB_init.dat
SHL_MIB_init.dat
-- These are human-readable/editable text-format MIB files used by ms_init (via dat2dbm) to generate dbm-
format MIB files for SHL and the mock subsystems (NU1, NU2, NU3, and NU4).  (The corresponding file for
ASP is generated by ms_makeMIB_ASP.c)  These files tell MCS/Scheduler the necessary details about the
structure of the subsystem's MIB.

mch_minimal_server.py
-- A python script which can be used to emulate a minimally-functional MCS Common ICD-compliant
subsystem.  One of the command line arguments is the subsystem three-letter name, so this script can be
used to emulate any subsystem, although at a very limited level.


Quick Start
===========

In the procedure below, the software is compiled and a simple test is performed to demonstrate the
functioning of the software.

(1)  If not done already, place all files in a single directory and cd to that directory.

(2)  Make the software ($ make).  Although it is very popular, not all computers will have the necessary
gdbm library (used to handle the dbm-format MIB files) installed, and others will call it by another
name. If make complains about this being unavailable, see the "Troubleshooting" section below.

(3)  Ensure that ports 1738 and 1739 are not in use on your computer.  (On Ubuntu,
"$ cat /etc/services" shows you a list of all committed ports.)  If these ports are in use, you will need
to modify test1.sh; simply change all instances of these ports to ports which are available.

(4)  Run test1.sh ("$ sh ./test1.sh" should do it).  This script does the following things:
-- Launches a subsystem emulator for a minimal (mock) subsystem called NU1.
-- Brings up MCS/Scheduler with NU1 as a defined subsystem.
-- Shows the current value of SUMMARY for NU1 ("UNK" for unknown) using ms_mdre.
-- Sends NU1 a PNG.
-- Shows the new value of SUMMARY for NU1 ("NORMAL") using ms_mdre
-- Shuts down MCS/Scheduler and the NU1 subystem emulator
The console output will look something like this ("**" indicates comments added here which do not
actually appear in the output)

$ ./ms_init test1.dat
[1] I am ms_init (v.20090802.1)
[1] ms_init_filename: <test1.dat>
[1] mibinit NU1
[5] I am dat2dbm (v.20090816.2)
[5] exit(EXIT_SUCCESS)
[1] mcic NU1
[6/6388] I am ms_mcic (v.20090825.1)
[6/6388] NU1 specified
[6/6388] IP_ADDRESS <127.0.0.1>
[6/6388] TX_PORT = 1738
[6/6388] RX_PORT = 1739
[1] From NU1's MQ: <I'm up and running>
[1] From NU1's MQ: <I saw a PNG>
[1] WARNING: ms_init_file command <> not recognized (ignored)
[1] Completed ms_init start-up script
[1] Handing off to ms_exec
[2] I am ms_exec (v.20090825.1)
[1] exit(EXIT_SUCCESS)

** ms_init ("[1]") runs, sets everything up, launches ms_exec ("[2]"), and quits.
** "[6]" is the ms_mcic process talking.

$ ./ms_mdre NU1 SUMMARY
UNK
090825 18:02:55
```

```
** "UNK" means unknown.  The time (UT, yymmdd hh:mm:ss) of last update is shown in the next line.

$ ./msei NU1 PNG
[7] ref=2, bAccept=1, eSummary=0, data=<Task has been queued>

** msei ("[7]") instructs MCS/Scheduler (via ms_exec) to send PNG to NU1.  msei does not wait for, or
provide, a response.

$ ./ms_mdre NU1 SUMMARY
NORMAL
090825 18:03:04

** note MIB entry has now been updated to NORMAL (note also time).

$ ./msei MCS SHT
[6/8053] Directed to shut down. I'm out...
[7] ref=0, bAccept=1, eSummary=5, data=<Starting shutdown>

** MCS can be sent PNG and SHT commands just like subsystems.  If you tell MCS to SHT, ms_exec will shut
down the ms_mcic's and associated message queues in an orderly way, and then exits itself.

Killed python(8044) with signal 15
```

(5) Check out the file mselog.txt, which is a log file created by ms_exec. It should look something like this:

```
$ cat mselog.txt
090825 18:02:56  55068  64976782 N I am ms_exec (v.20090825.1) [2]
090825 18:02:56  55068  64976782 N Command line: ms_exec 1
090825 18:02:56  55068  64976782 N Added subsystem MCS
090825 18:02:56  55068  64976782 N Added subsystem NU1
090825 18:03:04  55068  64984790 T         2 1 NU1 PNG |
090825 18:03:04  55068  64984790 T         2 2 NU1 PNG |
090825 18:03:04  55068  64984796 T         2 3 NU1 PNG |
090825 18:03:05  55068  64985803 N Starting shutdown...
090825 18:03:05  55068  64985803 T         3 1 NU1 SHT Request ms_mcic shutdown|
090825 18:03:05  55068  64985804 T         3 2 NU1 SHT Request ms_mcic shutdown|
090825 18:03:06  55068  64986804 N Deleting tx msg queue for NU1
090825 18:03:06  55068  64986804 N ms_exec shutdown complete
```

The first 5 columns are: yymmdd hh:mm:ss (UT), MJD, MPM, "N" (for "info" messages) or "T" (for "task progress" messages). Info messages conclude with remarks. Task progress ("T") messages have 5 more columns: REFERENCE, task progress, subsystem, command, and remarks. Task progress is indicated as a number (defined in LWA_MCS.h). Here, 1 (LWA_MSELOG_TP_QUEUED) means the task has been queued by ms_exec, but not yet sent to the ms_mcic, 2 (LWA_MSELOG_TP_SENT) means the task has been sent to the ms_mcic, and 3 (LWA_MSELOG_TP_SUCCESS) means the task has completed successfully (i.e., ms_mcic reports that the subsystem responded, and that it has successfully updated the local MIB). The pipe ("|") symbols are used to denote the end of a data field.

(6) Check out the current MIB for NU1 (as known to the scheduler) using ms_mdr ($ ms_mdr NU1). It should look something like this (This is a wide display so if you see line wrapping, increase the width of your display):

```
$ ./ms_mdr NU1
MCH_TX_PORT                     1 0.2         1738                              a5     NUL    |090825
18:02:55
INFO                            1 1.2         UNK                               a256   a256   |090825
18:02:55
SUBSYSTEM                       1 1.4         UNK                               a3     a3     |090825
18:02:55
MCS-RESERVED                    0 1           NUL                               NUL    NUL    |090825
18:02:55
SERIALNO                        1 1.5         UNK                               a5     a5     |090825
18:02:55
MCH_RX_PORT                     1 0.3         1739                              a5     NUL    |090825
```

```
18:02:55
LASTLOG                         1 1.3         UNK                               a256   a256   |090825
18:02:55
SUMMARY                         1 1.1         NORMAL                            a7     a7     |090825
18:03:04
MCH_IP_ADDRESS                  1 0.1         127.0.0.1                         a15    NUL    |090825
18:02:55
VERSION                         1 1.6         UNK                               a256   a256   |090825
18:02:55
[8/6607] exit(EXIT_SUCCESS)
```

The columns are: MIB label, "0" or "1" (indicating branch or value, respectively), MIB index, value, a format indicator (for internal use only), another format indicator (for internal use only), and the UT date/time. Note most MIB entries are "UNK" (unknown) because we never asked for them. Only SUMMARY has been updated (as a result of the PNG command). Several MIB entries ("MCH_IP_ADDRESS", "MCH_TX_PORT", and "MCH_RX_PORT") were not part of the initial MIB, but are added by ms_init (via dat2dbm). The entries stored in dbm files are in no particular order, and ms_mdr makes no attempt to sort them.

Defined Test Cases

Shell scripts are provided to evaluate the software:

test1.sh
This is the script used in the "Quick Start" section, above.

test2.sh
Similar to test1.sh, except the entire MIB (not just summary) is updated. Thus, demonstrates the "RPT" command. Witness the results using "$ ./ms_mdr NU1" to see the updated MIB, and "$ cat mselog.txt" to see the log.

test3.sh
Similar to test2.sh, except does this for a system of *four* mock subsystems. These subsystems are called NU1, NU2, NU3, and NU4. These mock subsystems come up with unique MIB values so as to allow the user to verify that MCS/Scheduler is accessing the correct subsystem; for example, VERSION for NU3 is "NU3-1".

test4.sh
Brings MCS/Scheduler with the four mock subsystems NU1, NU2, NU3, and NU4. Then, sends each 120 "PNG" commands as quickly as possible. This tests MCS/Scheduler's ability to juggle this without overflowing an internal task queue or experiencing some other load-related error. To verify success, check mselog.txt and make sure that there are no "task progress" indicators greater than 3; i.e., that all tasks terminate with status "3" ("LWA_MSELOG_TP_SUCCESS").

test5.sh (SHL demo)
Brings up SHL (using the MCS0012 emulator, but easily modified to accomodate the actual SHL), updates a few MIB entries using RPT, and tests the SHL-specific commands. You have to install the MCS0012 into a subdirectory "Emulator_SHL" first; see the comments at the top of the script.

test6.sh (Crude ASP demo)
Brings up ASP (using the generic python-based subsystem emulator, but easily modified to accomodate an ASP-savvy emulator or the actual ASP), updates a few MIB entries using RPT, and tests ASP-specific commands. Also demonstrates use of ms_makeMIB_ASP.c to generate an initial MIB for ASP. Note that the emulator won't recognize the ASP-specific MIB entries and commands, but at least you'll see that that MCS/Scheduler is recognizing the commands and handling the errors being returned by the emulator in a reasonable way.

test7.sh (Crude DP demo)
Brings up DP (using the generic python-based subsystem emulator, but easily modified to accomodate an DP-savvy emulator or the actual DP), updates a few MIB entries using RPT, and tests DP-specific commands. Also demonstrates use of ms_makeMIB_DP.c to generate an initial MIB for ASP. Note that the emulator won't recognize the DP-specific MIB entries and commands, but at least you'll see that that MCS/Scheduler is recognizing the commands and handling the errors being returned by the emulator in a reasonable way.

Modifying Test Cases for Network Operation

==========

As mentioned above and explained in the scripts, the difference between running everything on one computer (e.g., for development and test) and running processes on different computers (e.g., the actual operational condition, where ms_exec and the ms_mcic's are on one computer, and the subsystems are on other computers) is trivial -- just replace the loopback IP (127.0.0.1), whereever it appears in the test scripts (test#.sh), with the appropriate IP address.

Why dbm Files?

The reader may be curious as to why this software uses the "dbm" facility as opposed to some other method (e.g., ASCII files, packed/binary files, XML, SQL) to store MIB information. The primary reason is that the dbm facility provides a C-friendly database capability that is lightweight, compact, very fast, requires no separate server (in contrast to something like SQL), and is very popular and well-documented. Also, Python enthusiasts should note that Python can easily read/manipulate dbm files ("batteries included", as always).

Troubleshooting / Known Bugs

-- For problems related to the dbm library, the book "Beginning Linux Programming" (N. Matthew and R. Stones, 4th Ed, Wrox Press, 2008) is recommended. The dbm library is not necessarily preinstalled on all *nix distributions, and sometimes goes by different names; the book will be helpful in figuring how to get dbm installed if you are using something other than Ubuntu 9.04.

-- User-side communication with the ms_exec process is via a TCP socket connection. If ms_exec process is restarted within a few seconds of being killed, it is possible that the operating system will not yet have released the socket address. In this case, ms_exec will experience a fatal error during start up, including a console message reading something like "ms_exec: Address already in use", possibly also referring to an error in the "bind()" operation. If this happens, simply kill all Scheduler processes (you can use ms_shutdown.sh for this) and wait a few seconds longer before beginning again. Note that this is not a bug; it simply reflects the fact that the operating system requires several seconds to free socket addresses even when the associated sockets are properly and explicitly closed.

-- If the software behaves strangely, then it could be because some leftover process(es) from a previous (aborted) test are getting in the way. A simple way to make sure this is not the case is as follows:
```
$ sh ./ms_shutdown.sh
$ killall -v python
```
Wait a few seconds, then try again. This kills any ms_init, ms_exec, and ms_mcic processes, as well as anything that was started using "$ python ..." (e.g., the subsystem emulators).

-- The function LWA_time2tv() currently assumes that the number of milliseconds in a day is a constant. This will eventually produce intermittent small errors since this is not exactly true.

-- The message "[1] WARNING: ms_init_file command <> not recognized (ignored)" is of no consequence (just a wart I have yet to fix...).

Other Notes & Issues

-- I assumed that the argument for DP's CLK command is supposed to be uint32 (as opposed float32, which is what the DP ICD says).

-- The DP ICD (v.G) says TBN filter codes go from 1..6 in the command description, but indicate 1..7 in the appendix. I have assumed latter is correct (changes nothing other than what appears as "help" in msei).

-- The program which generates DP initial MIB text files -- ms_makeMIB_DP.c -- currently initializes values to numbers which are "interesting" (i.e., not all zero or NUL) so that it can be verified that ms_mdr and ms_mdre are able to read non-trivial values. Eventually, this should be undone.

MCS - Data Recorder Preliminary Design & Verification

Christopher Wolfe*, Steve Ellingson, Cameron Patterson

August 26, 2009

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1 Introduction

1.1 Purpose

The MCS-DR, or "monitoring and control system - data recorder" is a data capture and storage system for the LWA radio telescope project implemented using general-purpose, commercially available off-the-shelf (COTS) components. A preliminary design for the MCS-DR has been completed and validated. Specifically, we have demonstrated the ability to reliably record up to 10 hours of data at 115 MiB/s. This document will summarize progress made in design and testing of the MCS-DR and will describe the hardware and software components that make up the MCS-DR.

1.2 Background

MCS-DR is part of MCS "monitoring and control system". The MCS, in turn, is part of the LWA "Long Wavelength Array". The MCS-DR records the data generated by the LWA's Digital Processing (DP) subsystem, and each individual computer is connected by 10-Gigabit Ethernet (10 GbE) to one of five possible inputs from the DP [1]. MCS controls storage and retrieval of data to and from MCS-DR. The design of each computer in the MCS-DR subsystem is identical except for configuration files.

1.3 Document Conventions

Numbers, units, and their associated prefixes and suffixes conform to the standard of IEC 60027-2 [2]. Specifically, the prefixes Ki, Mi, Gi, and Ti refer to 2^{10}, 2^{20}, 2^{30}, and 2^{40}, respectively. Likewise, the prefixes K, M, G, and T refer to 10^3, 10^6, 10^9, and 10^{12}, respectively. If a unit specifies a binary size or rate, an uppercase B represents a byte, whereas a lowercase b indicates an individual bit (i.e. MB = Megabyte, or 1,000,000 bytes, and Kb = kibibit or 1,024 bits).

1.4 Summary of Current Status of MCS-DR Development

The MCS-DR PC hardware selection's suitability has been verified in each of three critical aspects. The three critical aspects are writing to disk, moving data through memory and kernel function calls, and moving data from the physical network into system memory – all at the target data rate

of 115 MiB/s. This exceeds the highest rate required, which is 112 MiB/s (corresponding to TBN mode at it's largest specified bandwidth). Tests have verified the ability to record data streams at 115 MiB/s for a period of at least ten hours. The absolute ceiling on recording speed has not been established, but may be in the neighborhood of 150 MiB/s on average, or 200 MiB/s with optimal circumstances such as short recordings at the very beginning of the drive.

The MCS-DR PC is able to listen for and respond to a set of message types from MCS. The message types which are currently implemented allow for initiation of recording, data verification, and other development and testing functions. It is anticipated that some of these commands will become part of an MCS-DR ICD. Ultimately, each MCS-DR PC will have "subsystem status", be fully compliant with the MCS Common ICD, and be regarded by MCS in exactly the same way as the other major LWA station subsystems (e.g.: SHL, ASP, DP, and so on).

2 Design Overview

The following sections describe in greater detail the hardware and software components of the MCS-DR PC design, as well as the tests and methods used to verify different aspects of the design. The first section presents a brief overview of the hardware and software components and subsequent sections discuss factors that played a role in hardware selection and software organization.

2.1 Hardware Brief

Figure 1 outlines the hardware organization for an individual MCS-DR PC. Each MCS-DR PC is comprised of a stock Dell PC with two add-in cards and an external RAID enclosure. The stock PC is a Dell Studio XPS™model 435MT computer. The Studio XPS™435MT is based on the Intel® Core™ i7-940 processor which has four Hyper-threaded™cores operating at 2.93 GHz. At the time of purchase, the system was customized to have 6 GiB of Tri-Channel DDR3 SDRAM memory operating at 1066 MHz. The system HDD is a Seagate 1 TB 7200 RPM SATA-II hard disk drive with 16 MiB of cache memory. The Studio XPS™435MT also includes an onboard Intel gigabit Ethernet (GBE) adapter which is used for communication with the station MCS.

For storage, an American Media Systems® Venus-T5™ eSATA RAID external enclosure is connected to the system via the eSATA cable supplied with the enclosure. The Studio XPS™435MT system has an built-in eSATA port, but this was unsuitable for the needs of the MCS-DR PC (see discussion in Section 2.3 later this document), and an eSATA adapter was used instead. A Silicon

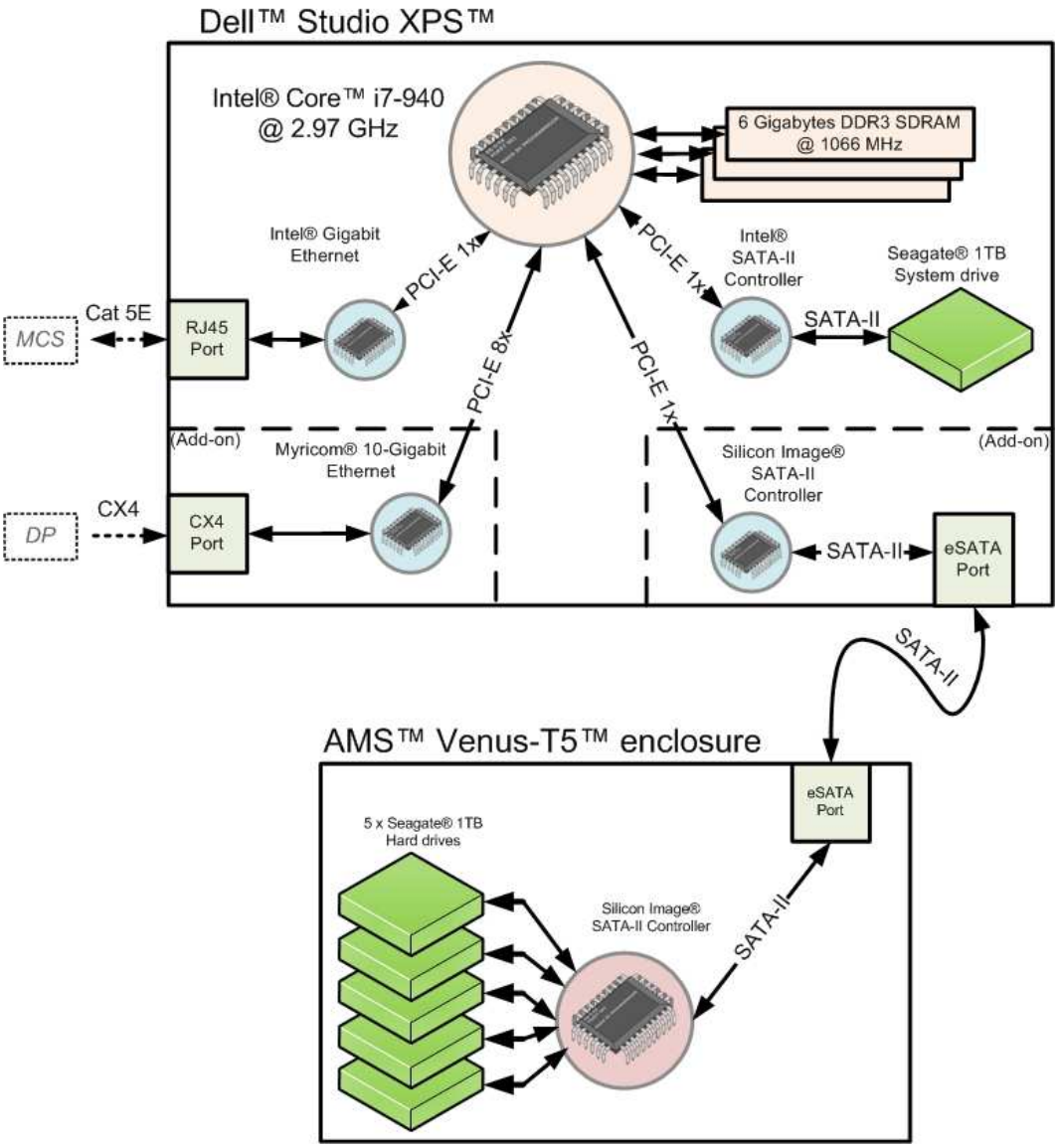

Figure 1: MCS-DR PC System Overview

Image® PCI-E ("PCI express") 1x external SATA-II adapter based on the SteelVine™series of storage controllers is added to the stock system. The eSATA adapter came packaged with the Venus-T5™ RAID enclosure. The enclosure contains five hot-swappable Seagate 1 TB 7200 RPM SATA-II hard disk drives, and provides a total storage capacity of 5 TB less file system and formatting overhead. This is the configuration that has been implemented and verified.

An alternative to the Venus-T5 enclosure being considered for the delivered version is a rack-mountable 1U SATA II enclosure. This option would reduce the server rack space required for the MCS-DR, and would facilitate easy removal and replacement of data storage while keeping the drives together. Testing of this option is will begin shortly.

The MCS-DR PC's high speed Ethernet interface is a Myricom® model 10G-PCIE-8A-C+E 10 gigabit Ethernet adapter. The adapter is a PCI-E 8x adapter which connects to the network via a 10GBase-CX4 physical interface. The cables used to connect the MCS-DR PC to the DP subsystem are Myricom® 10G-CX4-1M 10GBase-CX4 copper cables.

2.2 Software Brief

The MCS-DR PC software is a BSD-Sockets based Linux application operating in a polling paradigm. The software is written in ANSI C, and is a single process, though interacting with the host computer requires short-lived child processes in a few instances. The software uses the Posix.1b real-time extensions library (librt[1]) for asynchronous transfers to and from disk, and for queuing messages from MCS. Figure 2 illustrates the organization of the software and outlines the scope of the application within the MCS-DR PC. The operating system is Ubuntu Desktop 9.04 AMD64. The main processing loop of the application polls a socket for command messages from MCS. Upon receiving commands to start a specific operation, the main loop enables components of the data path necessary for receiving data from the network, writing data to disk, reading data from disk, and transmitting data to the network. The main processing loop then checks each portion of the data path to see if action is required to move data along, taking action where necessary. Once an operation is complete, the data path is disabled and the system is returned to the idle state, making it available for future operations. To interact with the host computer and operating system, the software contains functions which gather environment and machine status information such as CPU and hard drive temperatures, free disk space, and so forth, as well as functions to format the drive array, mount partitions, and perform general maintenance functions.

[1]Documentation available online at http://compute.cnr.berkeley.edu/cgi-bin/man-cgi?librt+3

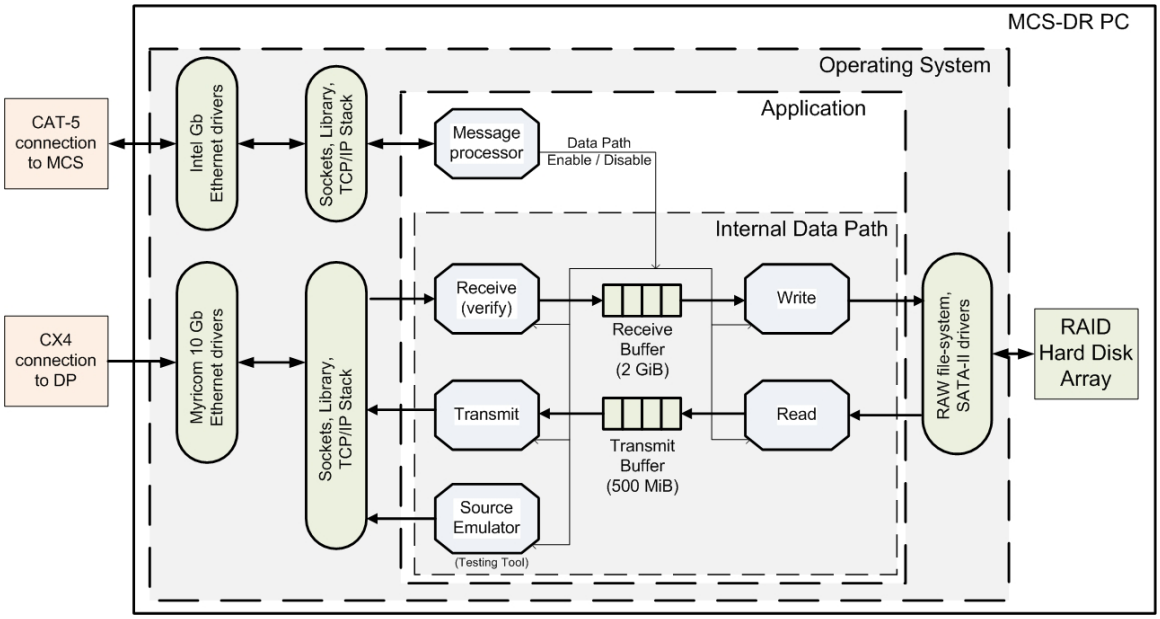

Figure 2: MCS-DR PC System Software Overview

Initial tests with the ext2 file system yielded inconsistent results. Consequently, we implemented a custom file system based on raw access to the drive array. The file system used by the software is a flat file system with a simple bitmap structure written to the beginning of the drive, and the remaining space available for file storage. The current (validated) file system supports as many as 1023 recordings, all of which combined may be up to 4.9 TiB in size. The file system can be easily modified to support an arbitrarily large number of files.

The benefits of using a raw file system are two-fold. Bypassing the ext2 file system allows writing contiguously without having to periodically update inodes and inode tables. Also, it allows rapid file deletion, and formatting – operations that could take hours with ext2. Because speed is critical, kernel caching is disabled for file reads and writes. The Linux kernel's caching algorithms are optimized for random access, but data streams are recorded sequentially. Tests with caching enabled were unable to meet the rate requirement. Tests with caching disabled, however, were able to meet and exceed the requirements.

2.3 Hardware Considerations

The MCS-DR PC must be capable of recording data streams at a sustained rate of 112 MiB/s with data payload sizes depending on the data source and operational mode. The hardware for the MCS-DR PC was selected such that the speed of all components of the internal data path exceeded this requirement. The only deviation from this is with the hard drives, where the speed requirement is met by having 5 drives in RAID 0 instead of one drive capable of the desired rate.

The Core™ i7 series of processors from Intel® fit the need for a variety of reasons. In addition to providing four distinct cores, each of which is Hyper-threaded to provide two virtual cores, for a total of eight virtual cores, the i7 does away with traditional bus-based architecture, which allows for high-speed serial communication between the CPU and peripherals. With three independent memory channels operating at 1066 MHz each, the Core™ i7 processor fits well with the intended usage profile of the MCS-DR.

The computer chosen for the MCS-DR is the Studio XPS™ desktop pc from Dell™. Based on the Core™ i7-940 processor, with 6 GiB of high speed DDR3 memory, it also offers a built-in eSATA connection, three PCI-E 1x slots, one PCI-E 16x slot, and a 1TB hard drive suitable for containing the operating system and system software. In addition to meeting the hardware requirements, the Studio XPS™ is cost-effective option starting at around $750.00 USD, which is on track with the target unit price of around $2000.00 USD per MCS-DR PC when combined with a low-cost (approx. $675.00 USD w/ drives) RAID configuration and the Myricom 10 GbE Ethernet adapter (approx. $495.00 USD).

For storage, the American Media Systems® Venus-T5™ external SATA-II enclosure was selected. With high-speed stream recording, hard drives, rather than the busses they are attached to, tend to be the bottleneck. Since the Venus-T5™ is capable of supporting five drives, the effective maximum stream rate is multiplied by five for a RAID level 0 configuration. The enclosure was selected because it complies with the SATA-II standard yielding a theoretical maximum transfer rate of 300 MiB/s – well in excess of the requirements of the MCS-DR PC. Initially, the onboard Intel SATA-II eSATA port was to be used to connect the RAID enclosure to the system. However, the controller does not support SATA port-multiplication and thus was unable to make use of all 5 drives in the Venus-T5 enclosure. Fortunately, though, the Venus-T5 ships with a 2-port PCI-E 1x eSATA adapter which supports port-multiplication. Testing confirms that it meets the needs of the MCS-DR.

The final hardware component of the MCS-DR is a 10 GbE adapter from Myricom®. Each MCS-DR PC records data from one of the outputs of the station DP. The 10G-PCIE-8A-C+E from

Myricom offers 10 Gb/s transfer rates, large receive off-loading, automatic checksum generation, and an open-source API for software interfacing (as well as open-source, Linux-friendly drivers).

2.4 Software Considerations

As a low-cost alternative to available commercial data capture options, it was desired to avoid proprietary technologies and their consequent licensing royalties. As a result, the software of the MCS-DR (including its operating system) is based exclusively on public domain and open source software.

The reception of UDP datagrams and actual recording of UDP datagrams occur in different portions of the MCS-DR PC's data path. The first of these, the "Receive" portion, is responsible for moving data from the network adapter into the application's memory space. At the hardware level, the Ethernet adapter uses DMA[2] transfers to place packet data into system memory. The act of receiving from the socket copies the data into an intermediate buffer where it is then removed by the "Write" portion of the data path as it writes the data to the hard drive array. Because of the magnitude of the transfer rates involved, efficiency and economic use of the CPU and memory is critical. Consequently, the data is only copied once from the time it arrives in system memory until the time it is written to the hard drives. Tests (See Section 3) have shown that the system supports transferring data this way at data rates exceeding 450 MiB/s, and that the performance bottleneck of the system, as expected, is with the hard drives themselves.

3 Testing and Verification

Several key aspects of the prototype system have been characterized, and have been tested to ensure they meet the requirements set forth in the "MCS Subsystem Definition" [1].

3.1 Hard Drive Performance

The draft design of the MCS-DR PC included Seagate's 7200.11 series of 1 TB drives, but problems with meeting the required rates prompted us to use Seagate's SV35.5 series of 1 TB drives instead. With the 7200.11 series drives having a maximum sustained transfer rate of 120 MiB/s, and with five

[2]Direct Memory Access

drives in a RAID 0 configuration, the limiting factor should have been the SATA-II bus. However this was not the case, and sustained transfer rates for the RAID as a whole were limited to about 120 MiB/s. Most of this loss was due to the way Linux caches writes to the drive, but part was due to the non-optimal factory tuning of the drives' firmware. When testing the SV35.5 series with the same options, the performance was approximately the same. However, more recent tests circumvented kernel cache usage and were able to achieve rates up to 150 MiB/s for several hours. Tests of the 7200.11 series have not yet been performed with this option. However, given the negligible increased cost of the SV35.5 option, we do not plan to consider the 7200.11 series further.

The test itself consisted of opening several files on the RAID array and writing known data that was easily verified afterwards. The blocks of data written to the files consisted of either 3900 bytes or 1008 bytes, the first 8 of which were used as a serial identifier, while the remaining bytes were filled with an 8-bit counter value, increasing by one for each successive byte and rolling over to 0 after 255. Each time the block was written to the file, the serial identifier was incremented by 1 before writing the block again. This test was performed several times for varying durations, and the maximum sustained transfer rate was approximately 120 MiB/s when using the kernel cache for all tests shorter than ten hours. For tests in which the kernel cache was bypassed, a maximum sustained transfer rate has not been established, though tests indicate this number to be at least 150 MiB/s for all tests shorter than 8 hours.

3.2 File System Performance

The MCS-DR uses a software RAID level 0 array with a custom, raw-mode file system. Other file systems were considered before selecting a raw file system. Knowing that the journaling operations of the ext3 file system would require too much overhead, the first choice of file systems was ext2 for simplicity. Initial testing had established that the ext2 file system was capable of meeting the 112 MiB/s requirement, but the need to bypass kernel caching made working with ext2 files difficult. Tests were run with the xfs, fat32[3], and raw file systems. The xfs test yielded a transfer rate of 75 MiB/s, and the fat32 test resulted in an inconsistent 70 MiB/s, and tests of the raw file system achieved rates of 150 MiB/s.

[3]It should be noted that the fat32 file system would not have supported the full 5 TiB capacity of the RAID array

3.3 Memory and CPU Testing

The first tests which incorporated socket-based communication aimed at verifying that the CPU and memory could maintain sufficient transfer rates. By creating a socket connection to "localhost", the test was able to send UDP datagrams from one part of the data path and have them received in another. Because the Linux socket library copies the data from application memory into system memory when sending, and from system memory to application memory when receiving, this test effectively measured the maximum transfer rate of the CPU and memory under the same usage pattern as the MCS-DR requires. Like the hard drive benchmarking tests, packets consisting of a serial identifier, and a series of 8-bit counter values were used. In this case, however, the exhaustive checking of the entire packet would have perturbed the results of the test, and only the serial identifier was verified. The noted maximum transfer rate was 465 MiB/s with 500 byte packets. The performance limitation in this scheme comes not from the overall data rate, but rather it exists as a relationship between the size of the packets and the number of packets transfers required per second. With arbitrarily large packets, the limit approaches the maximum memory bandwidth of the system, and as the packets get smaller, the overhead of kernel IO_MMU[4] calls required to copy the data dominates. Since the minimum packet size of TBN, TBW, and DRX packets is the TBN packet size of 1008 bytes, 500 bytes was arbitrarily chosen as being sufficiently smaller than the packets of interest as to ensure that success of the test would imply that any larger sized packet transfer would also meet the data rate requirements.

3.4 Network Performance

Testing has been performed which verified the network adapter's ability to meet the system requirements. Two sets of tests were performed. The first, preliminary tests of hardware driver and functionality were included as part of the driver package from by Myricom. The included loopback test measures transfer speeds of the network adapter. This test was run for four hours and for ten hours, with the transfer rate approaching 4 Gib/s in both cases. The second set of tests were the duration tests described in the next section. The successes of both series of tests are sufficient to validate the network hardware selection because they utilize all of the hardware components essential to the MCS-DR PC's core functionality.

[4]Input Output Memory Management Unit

3.5 Complete System / Duration Testing

To perform the complete system and duration test, the hardware from a second MCS-DR PC was used to emulate the DP subsystem and provide a stream of data for the MCS-DR PC under test. The duration tests involved streaming data from the emulated DP and having it recorded on an MCS-DR PC. Tests confirmed that the hardware is capable of the required rates. The test was to generate packets with a specific pattern on the emulated DP, transmit them to MCS-DR PC under test, and record the packets to disk. Following the recording part of the test, the recorded file was then checked to confirm that no errors were introduced in the data transfer/storage process. This test used the TBN packet size of 1008 bytes, the first eight of which indicate a serial identifier, and the remaining 1000 bytes were patterned with an 8-bit counter value that rolled over to 0 when it reached 255. For ten hours, packets were transmitted at a data rate of 115 MiB/s, and the resulting recording was successfully verified to match the transmitted pattern.

4 Ongoing and Future Efforts

Several tasks still remain to be completed before the MCS-DR will be CDR-ready, though testing so far indicates that no identifiable and significant risk remains. Software changes will likely be a matter of reworking the interface and command set to suit the MCS and other subsystems. Outstanding tasks include:

- Documentation Tasks
  - MCS-DR ICD and MIB specification
- Software Tasks
  - MCS Common ICD compliance verification
  - Application 1st "Release" Candidate
  - Source code review and validation
  - Doxygen source code documentation
  - Regression testing
  - Evaluate possibility of USB-bootable image with RAID internal to Studio XPS system
- Hardware Tasks

  - Evaluate/test 1U rack-mount enclosure to replace Venus T5
  - Re-testing of 7200.11 series drives but with cache disabled. (time permitting)
  - Establish maximum rate sustainable for 2, 4, 6, 8, and 10 hour observations. (time permitting)

- Candidate Future (Post-CDR or Post-IOC) Development Tasks
  - Linux VFS-compliant file system extension to allow mounting of MCS-DR PC's custom, raw file system.
  - Explore possibility of servicing multiple DP sources from a single MCS-DR PC
  - Compact version of MCS-DR consisting of rack-mountable PC with only internal drives (entire MCS-DR in this form would be very easily transportable and would still provide 2-3 TiB (4-6 hours worst case) of recording)

5 Document History

- Version 0.4 (Aug 26, 2009):
  - Fourth draft of document.
  - Updated Title, Figures, Ongoing and Future Efforts, Software Brief
  - removed typos
- Version 0.3 (Aug 26, 2009):
  - Third draft of document.
  - Included discussion of file system changes
  - extraneous content removed
- Version 0.2 (Aug 23, 2009):
  - Second draft of document with changes in RE: hardware, software, and testing.
- Version 0.1 (Jul 14, 2009):
  - Initial draft of document.

References

[1] S. Ellingson, "MCS Subsystem Definition," Ver. 2, Long Wavelength Array Engineering Memo MCS0004, Feb. 23, 2009. [online] http://www.ece.vt.edu/swe/lwavt/.

[2] International Electrotechnical Commission, "Letter symbols to be used in electrical technology Part 2: Telecommunications and electronics," Third Ed., 2005. [online] http://www.iec.ch/

MCS-DR STORAGE UNIT

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1 PURPOSE

This document will describe the parts and required assembly of an MCS-DR RAID array. The RAID array must neither be formatted nor partitioned as the MCS-DR uses a custom file system. Accessing and manipulating data currently requires a custom application, though plans for a future linux file system driver are being developed.

2 HARDWARE SPECIFICATION

The MCS-DR's RAID storage unit consists of a 1U rack-mount RAID enclosure, and 5 streaming-tuned hard disk drives. All of the cables and screws required to mount the drives in the enclosure are included with the enclosure, as well as an eSATA cable suitable for connecting the unit to the MCS-DR PC. The enclosure itself is a DAT Optic, Inc. RM5S2P, available from http://www.cwol.com/serial-ata/sata-port-multiplier-encl-rack-mount.htm The drives installed in the enclosure are Seagate SV35.5 model ST31000525SV. They are available from PC Connection at the following URL: http://www.pcconnection.com/IPA/Shop/Product/Detail.htm?sku=9876607.

3 ASSEMBLY

Figure 1. The RAID enclosure.

To open the enclosure, remove 1 black screw (A), 2 silver screws (B), and slide the top cover back. Note that the rack mount tabs for the front sides of the enclosure are included in the kit, but not installed in the unit shown (C).

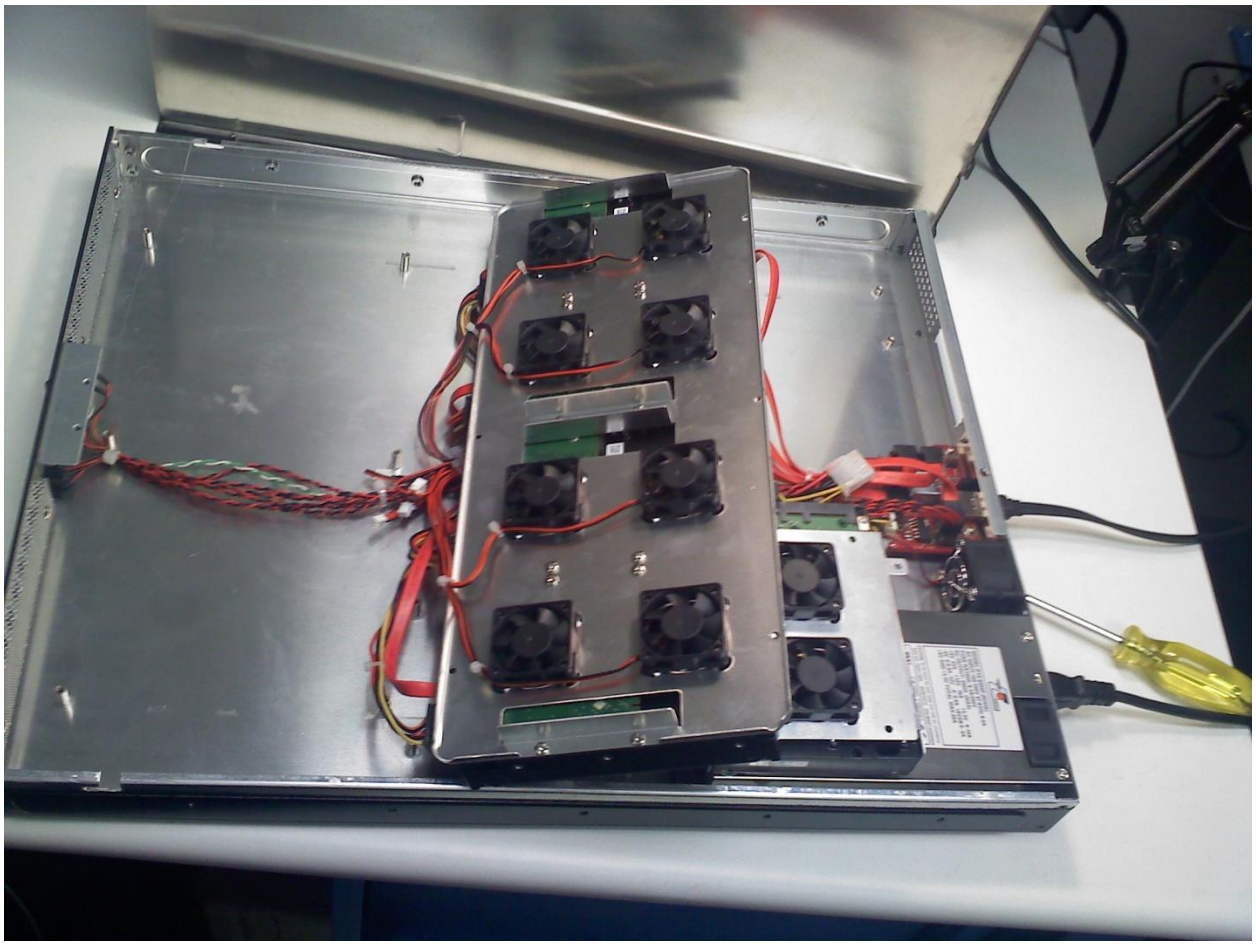


Figure 2. Mounting the first four drives.

The first four drives mount on a raised aluminum tray at the front of the unit. The tray is mounted to standoffs with 6 flush-seated machine screws. remove these screws, and flip the tray back towards the end of the unit. Each of the four drives is mounted to the tray with four coarse thread machine screws. Be sure to mount the drives with the SATA and power connectors towards the back of the unit (when upside-down, as shown, the connectors are towards the front of the chassis).

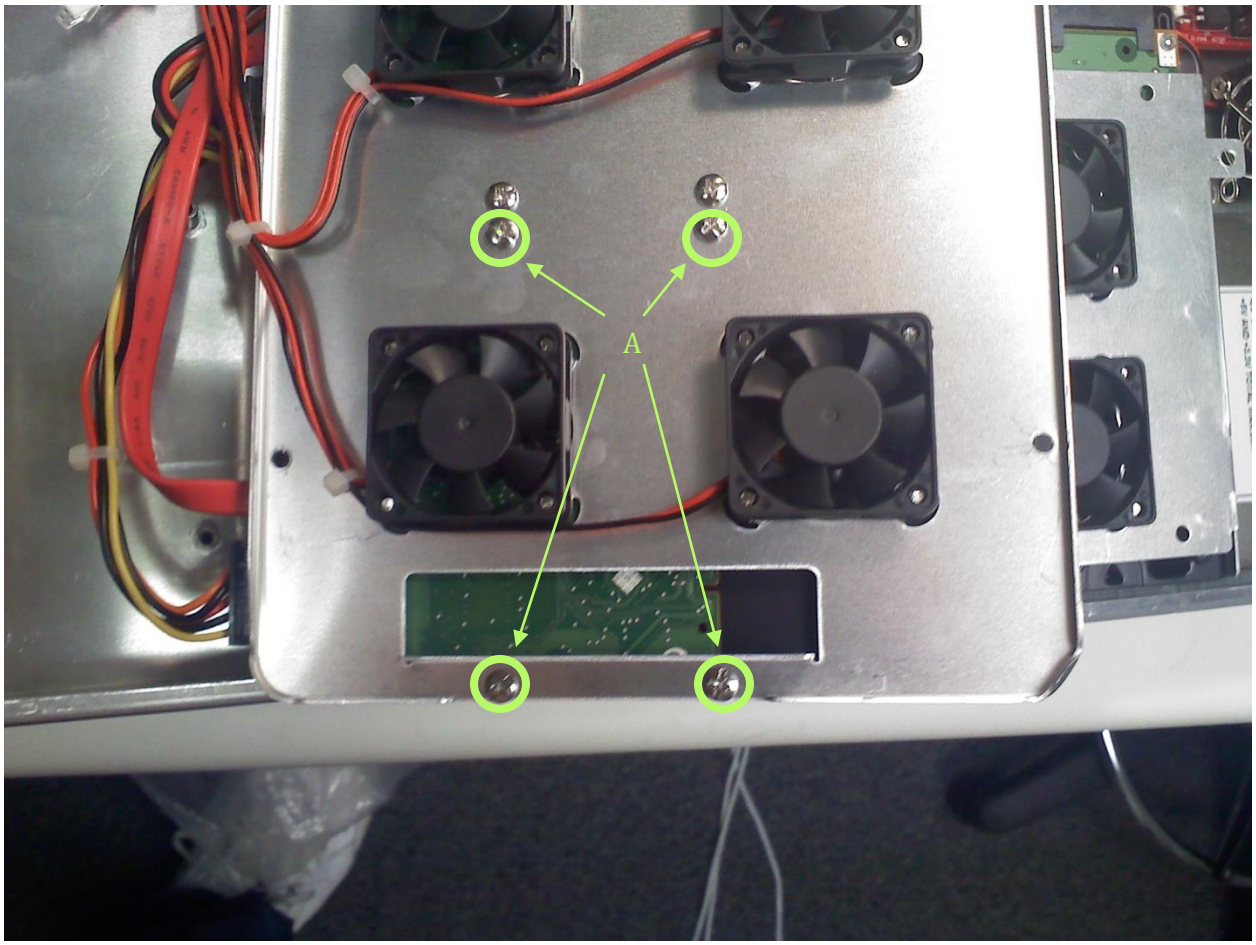


Figure 3. Mounting the first four drives.

Here is a close-up shot showing the mounting screws for one of the four drives which mount on the tray. Be sure to thread all four screws before tightening as the drives may not align very well otherwise. Once all four drives have been mounted, connect the SATA cables and power cables.

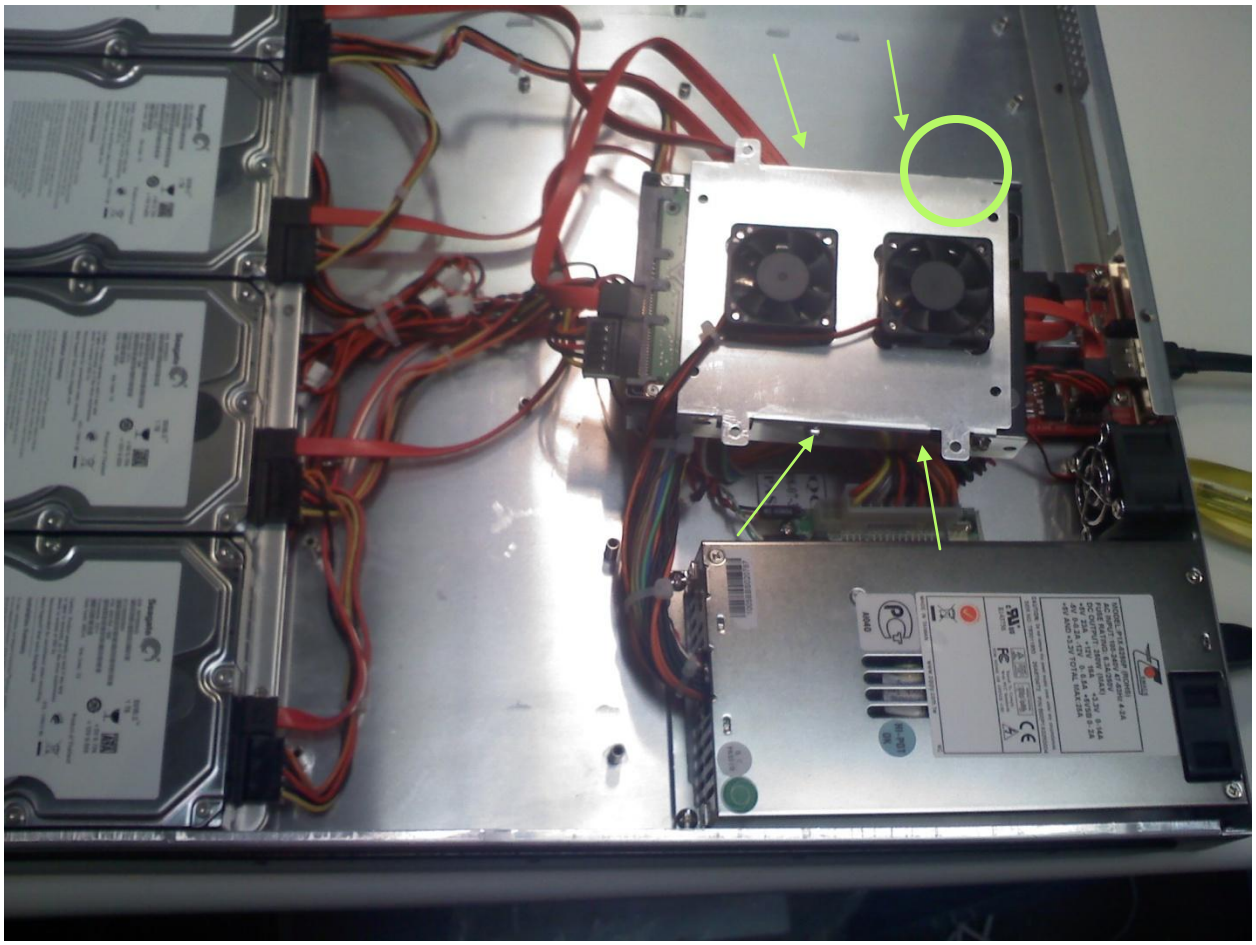


Figure 4. Mounting the fifth drive.

The fifth drive mounts on the smaller aluminum tray near the power supply. Remove the four pancake-head machine screws and flip the tray towards the back of the unit. The clearance between the cables for the 1st and 2nd drives and the small aluminum tray is insufficient, and folding one of the four tabs to be parallel with the drive's side wall was necessary. In the figure above, this is the circled area showing the tab already bent. Like the first four drives, four course thread machine screws mount the drive to the tray, but in this case, they screw in to the side of the drive as opposed to the bottom. These screws' positions are approximately indicated by the green arrows.

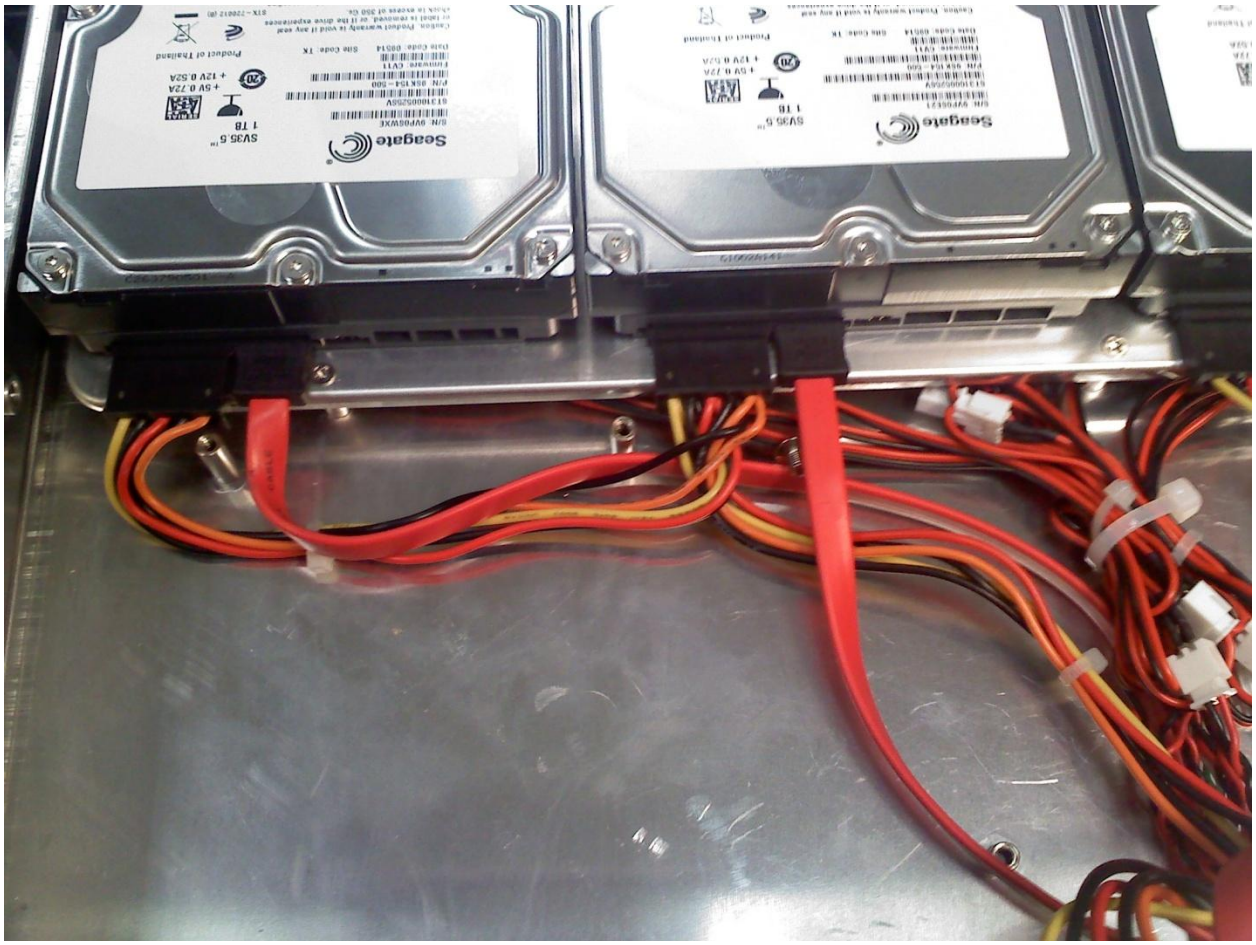


Figure 5. Cable arrangement.

The cables for the first and second drives must be routed to go under the rear aluminum tray as shown. Be careful not to bend the cable sharply or allow the metal edges to rest against the cables with too much pressure.

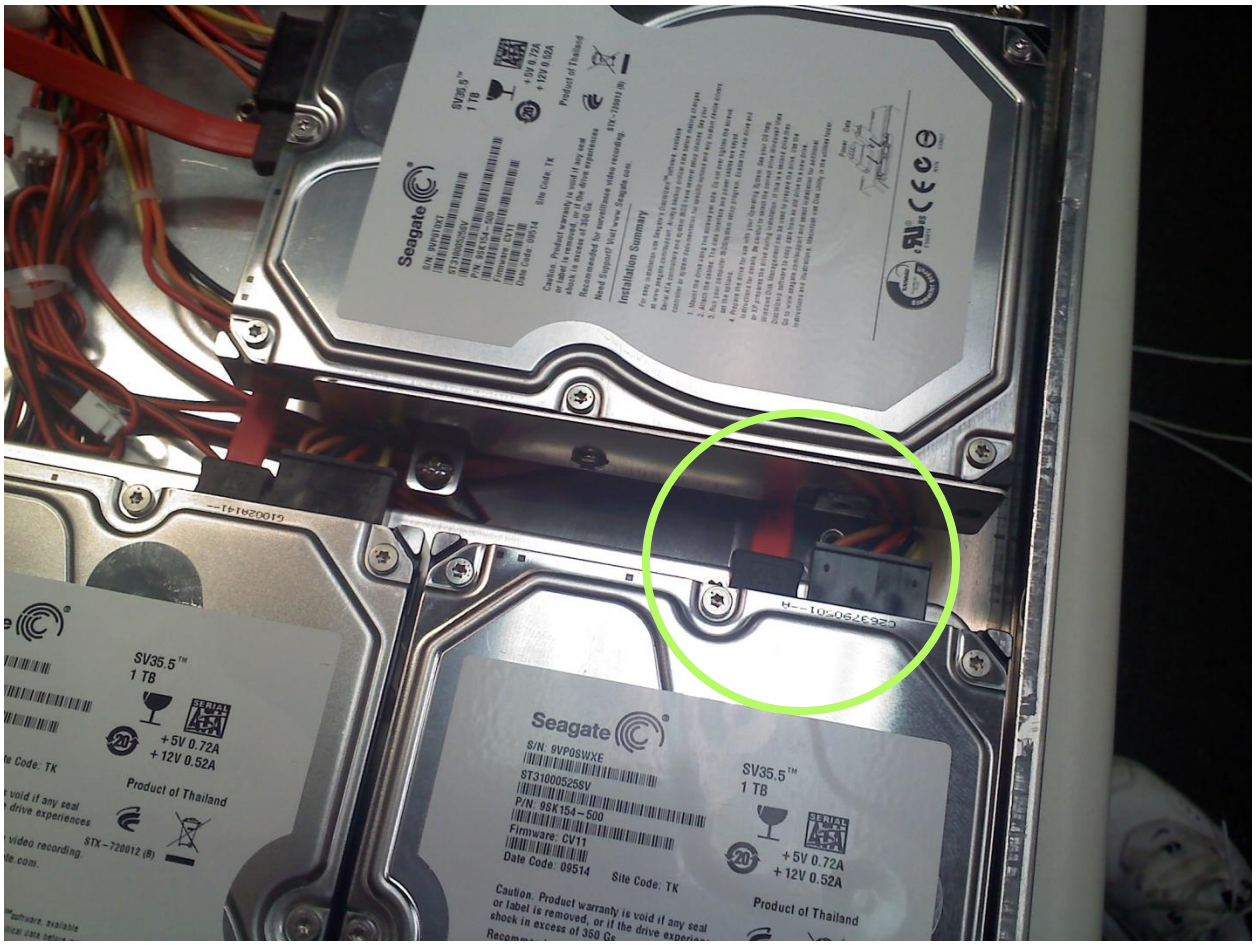
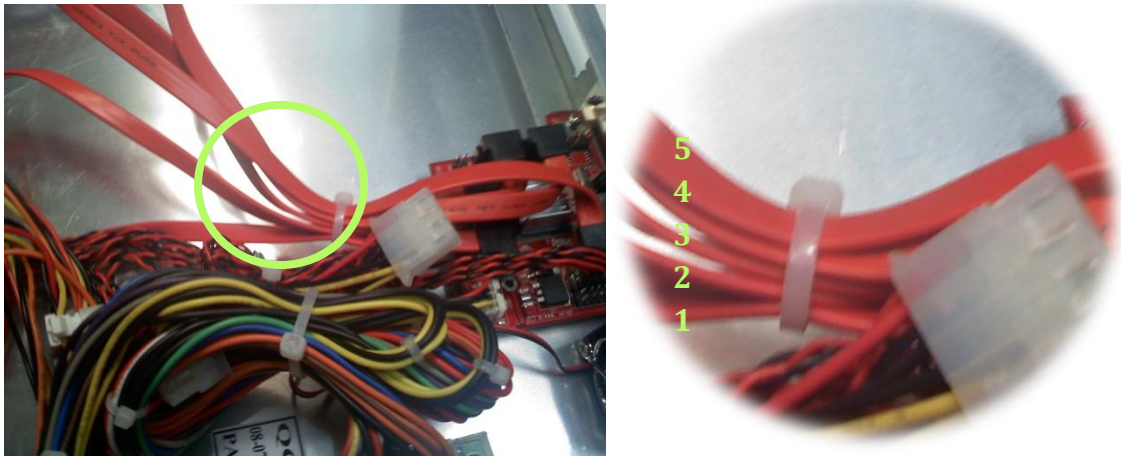


Figure 5. Cable arrangement with fifth drive in place.

This image shows the rear tray mounted and position of the cabling. The green circled area highlights the tab on the rear tray that had to be folded, and how the SATA and power cables must be routed underneath the rear tray.

a.)



b.)

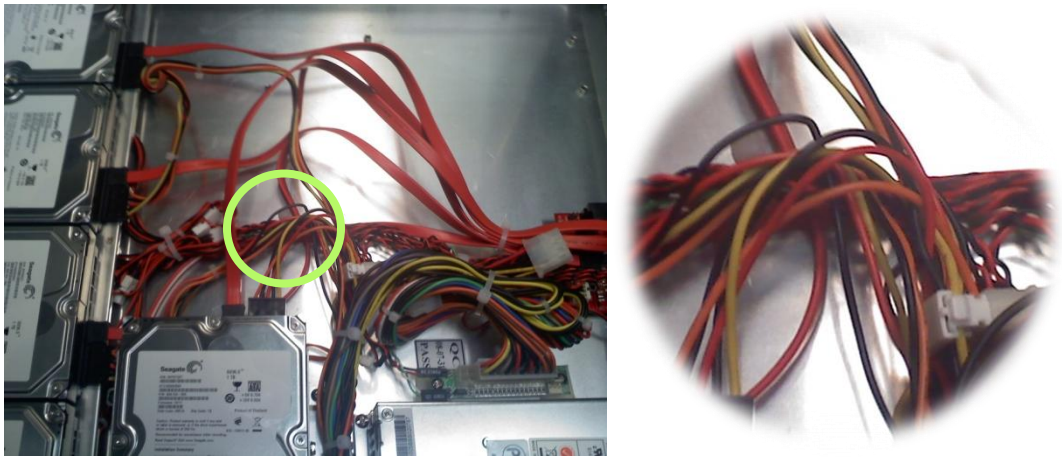


Figure 6. Cable connection order and notes.

It is advisable but not necessary to attach the drives in a consistent ordering in the event that data needs to be recovered or a drive replaced. In figure 6.a, the circled SATA cable bundle shows the desirable drive numbering used. The manufacturer may not guarantee that the cables will always be thus bundled, though you may use these images to trace the SATA cables to their connection point on the port-multiplier board and use the same numbering scheme.

As shipped, the cables in the enclosure were zip-tied in way that made connecting the drives difficult. It may be necessary to cut a zip-tie or two near the area highlighted (shown with zip-tie already removed).

Figure 7. The enclosure with 5 mounted drives.

All that remains now is to replace the lid with its 3 retaining screws. The preferred drive numbering is indicated in green.

4 APPENDIX A: ENCLOSURE VENDOR WEBSITE

http://www.cwol.com/serial-ata/sata-port-multiplier-encl-rack-mount.htm

Not a do-it yourselfer?
Buy this enclosure with up to 10TB of installed and tested storage!

5 Drive SATA Rack Mount Port Multiplier Enclosure. Mounts in 1U rack space or stacks on desktop

Team Up this eSATA Rack Mount Enclosure with:
Hi Performance x8 PCI-e eSATA card
CalDigit FASTA Hi-Performance Cards
Sonnet Tempo SATA Host Controllers
eSATA 4 Port SATA II PCI-X RAID Controller
Hitachi SATA II Hard Drives
Seagate Serial ATA 3Gb/s Hard Drives

SATA Rack Mount Enclosure, 5 Drive
Retail Value: $499.00

As Low As:

$359.50
In Qty.

IN STOCK

Enter quantities of items you wish to purchase then "Add" to cart

1 Add **5 Drive SATA Rackmount Port Multiplier Encl.**

Retail	1 ea	2 ea	3-4	5+
~~$499.00~~	$374.50	$367.50	$364.50	$359.50

Buy hard drives with this enclosure and SAVE!

2 Add **500GB WD RE3 RAID Edition SATA II HDD**

Retail	2-4	5-9	10+
~~$179.00~~	$93.00	$91.00	$89.00

2 Add **750GB Seagate 32MB, SATA II 7200.12 HDD**

Retail	2-4	5-9	10+
~~$369.00~~	$83.25	$81.25	$79.25

2 Add **1TB Seagate 32MB, SATA II 7200.12 HDD**

Retail	2-4	5-9	10+
~~$449.00~~	$89.00	$87.00	$86.00

2 Add **1.5TB Seagate 32MB, SATA II 7200.11 HDD**

Retail	2-4	5-9	10+
~~$599.00~~	$135.75	$133.75	$131.75

2 Add 2TB 64 MB Cache WD RE4 RAID SATA II HDD

Retail	2-4	5-9	10+
~~$699.00~~	$310.50	$308.50	$307.50

View / Checkout

5-Drive SATA Port Multiplier Rack Mount Enclosure

Super High Density Near Line Storage! Up to 10 Terabytes in a single 1U rack space!

This sleek 1U rack mount enclosure features the latest Silicon Image SiI-3726 SATA Port Multiplier technology and houses five (5) high capacity SATA I or SATA II disks in a single enclosure while connecting to the host system via a single external eSATA cable. Depending upon SATA host controller capabilities, configure as hardware or/and software RAID including: RAID 0, RAID 1, RAID 5, RAID 1+0 or JBOD!

The perfect solution for large storage libraries, digital video & digital audio files and backups, with the flexibility to grow with your storage needs. Using four of the enclosures, in only a 4U rack mount space mount TWENTY (20) SATA drives! Using 2TB hard drives, that's up to Forty (40) Terabytes of near line storage in a 4U space!

Incorporating DirectAir™ technology, the enclosure design includes multiple drive cooling fans to insure that hard drive temperatures stay within eight (8) degrees Celsius of the ambient room temperature, increasing performance reliability and extending hard drive life.

Multiple fans keep your drives running cool, increasing performance and reliability

Features:

- 5 SATA hard drive 1U rack mount enclosure
- Built-in SATA Port Multiplier with eSATA 3.0Gb/s interface
- Compatible with all 3.5" SATA I (Serial ATA 1.5Gb/s) and SATA II (Serial ATA 3Gb/s) Hard Drives
- Auto negotiation for SATA 3 Gb/s and SATA 1.5 Gb/s drives
- Built-in universal power supply with ON/OFF switch
- Drive activity and drive power LEDs

- Platform independent—works with any Mac, Windows or Linux system with compatible SATA Host controller

Specifications:

- **Connectors:** One eSATA connector
- **Cooling:** DirectAir technology
- **Performance:** Up to 3.0Gb/s (300 MB/s)
- **Compatibility:** Compatible with all 3.5" SATA I (Serial ATA 1.5Gb/s) and SATA II (Serial ATA 3Gb/s) Hard Drives
- **Dimensions:** 1U rackmount (W x D x H):19.0"x 20.8"x 1.75"
- **Weight:** 9 lbs / 4.5 kg (without hard drives)
- **Switches:** 1 - Power ON/OFF
- **Power:** Universal AC Voltage (115/230 VAC auto switching) 200W power supply
- **LED Indicators:** 5 - Hard Drive Power, 5 - Hard Drive Activity

Includes:

- 1 - 5 Drive 1U rack mount enclosure
- 1 - eSATA cable
- 1 - AC power cable
- 1 - Drive mounting screw set
- 1 - User manual
- 4 - non-mar rubber feet (protect desktop, and allow multiple units to be "stacked" if not rack mounting)

System Requirements:

- eSATA controller that supports SATA Port Multipliers

4 APPENDIX A: HARD DRIVE VENDOR WEBSITE

http://www.pcconnection.com/IPA/Shop/Product/Detail.htm?sku=9876607

Interface Control Document for Monitor and Control System Data Recorder (MCS-DR)

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October 10, 2009

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1 Description

1.1 Purpose

The purpose of this document is to define the interface between Monitor and Control System Data Recorder (MCS-DR) and other Long Wavelength Array (LWA) station subsystems. The MCS-DR subsystem records output of the Digital Processing (DP) subsystem and is controlled by the Monitor and Control System (MCS). Whereas station architecture and subsystem ICDs may refer to the MCS-DR as a whole, this ICD applies to a single MCS-DR PC.

1.2 Scope

This ICD shall describe the MCS-DR's physical and electrical connections, software interfacing and control methods.

1.3 Related Documents and Drawings

LWA Station Architecture [1]
MCS Architecture [2]
MCS Subsystem Definition [3]
MCS Common ICD [4]
DP ICD [5]
MCS - Data Recorder Preliminary Design & Verification [6]
MCS-DR Storage Unit [7]

2 Document Conventions

2.1 Abbreviations and Acronyms

DP	Digital Signal Processing
DRX	Digital Receiver
LWA	Long Wavelength Array
MIB	Management Information Base
MCS	Monitor and Control System
MCS-DR	Monitor and Control System - Data Recorder
TBN	Transient Narrowband Buffer
TBW	Transient Wideband Buffer
U	Rack Units (1.75 inches)

2.2 Command Parameter Types

uint8	unsigned integer, 8 bits
ASCII-XXX-#	An ASCII string exactly XXX characters in length which is interpreted as a number. Valid characters are numbers and right-padding spaces only.
ASCII-XXX-A	An ASCII string exactly XXX characters in length which is interpreted as a text string. Unless otherwise noted, valid characters are letters, numbers, the underscore character, and periods.

2.3 Mark-up Conventions

Symbol/Mark-up	Meaning	Example
italics	Italics indicate a variable, parameter, or response element name.	*Start MPM*
`Bold Fixed-width`	Text in this font indicates a particular parameter or response format. A single quote character appearing in a literal format should be interpreted as a space.	"`AB'_`" would indicate a literal "A" followed by a literal "B", followed by a space, followed by a literal "_".
`<...>`	Text appearing in these brackets indicates a parameter or variable substitution to a format specification. The brackets themselves are omitted from the format.	"`A<B>_`" would indicate a literal "A" followed by the variable *B*, followed by a literal "_".

2.4 Numeric Representation Convention

Numbers, units, and their associated prefixes and suffixes conform to the standard of IEC 60027-2 [8]. Specifically, the prefixes Ki, Mi, Gi, and Ti refer to 2^{10}, 2^{20}, 2^{30}, and 2^{40}, respectively. Likewise, the prefixes K, M, G, and T refer to 10^3, 10^6, 10^9, and 10^{12}, respectively. If a unit specifies a binary size or rate, an uppercase B represents a byte, whereas a lowercase b indicates an individual bit (i.e. MB = Megabyte, or 1,000,000 bytes, and Kb = kibibit or 1,024 bits).

3 Physical System Interfaces

3.1 Mechanical Interface

Figure 1 shows the MCS-DR mounted in one possible configuration. The MCS-DR consists of a PC and a RAID storage unit. The PC is mounted in a 6U EIA 19" shelf rack, and the storage unit requires 1U of rack space. The PC and storage unit may be mounted anywhere within the shelter so long as they are within cable's reach of each other (approx. 1 m). For more details on the 1U storage unit, see "MCS-DR Storage Unit" ([7]).

Figure 1: An MCS-DR PC and storage unit mounted on a 19" rack

3.2 Electrical and Electronic Interfaces

The PC will be powered by a 3-prong, grounded, 110 Volts RMS outlet, and power usage will not exceed 500 Watts. The storage unit will be powered by a 3-prong, grounded, 110 Volts RMS outlet, and power usage will not exceed 250W.

3.3 Electronic Interface

Figure 2 illustrates the electrical and electronic connections between the MCS-DR PC, MCS-DR storage unit, station power, and station subsystems. The insets of Figure 2 show expanded rear views of the MCS-DR PC and storage unit.

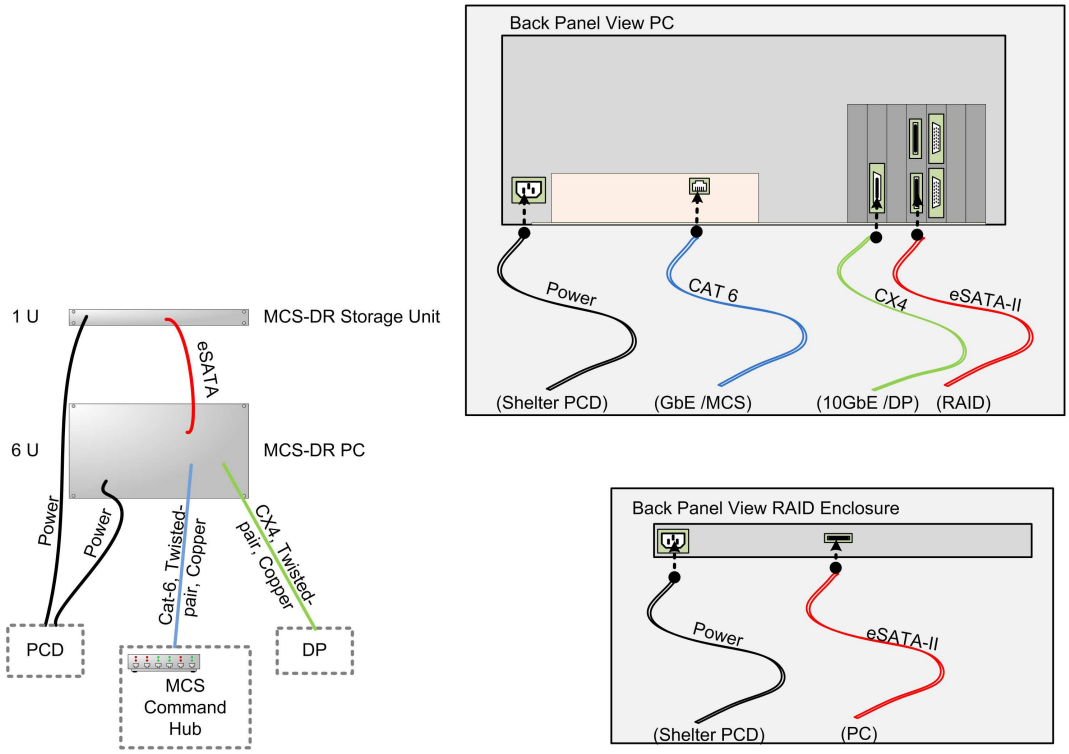


Figure 2: Diagram of electrical connections

4 Monitor and Control Interface

4.1 Overview

Control and monitoring of the MCS-DR is performed by the exchange of two different classes of messages. The first class of messages are monitoring messages which request system status information from the MCS-DR, while the second class of messages – command messages – request that the MCS-DR execute some action. The format of monitoring messages are all the same, while command messages may have formats that differ with respect to the specific command. Each monitoring message requests some part of the MCS-DR's Management Information Base (MIB). The following sections describe in detail each of the MIB entries and command actions that the MCS-DR supports, as well as the format of the response that the MCS-DR will return. If the MCS-DR cannot comply with the request, then a rejection response will be sent with an error message as defined in section 4.7.

4.2 Timing Restrictions

The MCS-DR supports up to 100 commands per second. Commands which schedule recording must allow at least 5 seconds between the receipt of the command, and the start of recording. Additionally, recordings may not be scheduled to begin within 5 seconds of the termination of a prior recording session.

4.3 MIB

Index	Label	Description	Section
2	CURRENT-OPERATION		
2.1	OP-TYPE	Type of operation currently being performed by the MCS-DR.	4.4.1
2.2	OP-SCHEDULE		
2.2.1	OP-START	Start time of the current operation.	4.4.2
2.2.2	OP-STOP	Scheduled stop time of the current operation.	4.4.3
2.3	OP-REFERENCE	MCS-assigned reference number of the command message which initiated the current operation.	4.4.4
2.4	OP-ERRORS	Number of errors and warnings generated during the current operation.	4.4.5
2.5	OP-FILEINFO-INTERNAL		
2.5.1	OP-TAG	Internal storage tag uniquely identifying the file in use by the current operation.	4.4.6
2.5.2	OP-FORMAT	Data format of the file in use by the current operation.	4.4.7
2.5.3	OP-POSITION	File position information of the internal file in use by the current operation.	4.4.8
2.6	OP-FILEINFO-EXTERNAL		
2.6.1	OP-FILENAME	File name and device id of the external storage file in use by the current operation.	4.4.9
2.6.2	OP-FILEINDEX	Indicates which file of a external storage file series is currently being written to.	4.4.10
3	SCHEDULE		
3.1	SCHEDULE-COUNT	A count of all scheduled recordings.	4.4.11
3.2	SCHEDULE-ENTRIES		
3.2.X	SCHEDULE-ENTRY-X	The X^{th} entry in the schedule of recordings with start time, durations, and data formats.	4.4.12
4	DIRECTORY		
4.1	DIRECTORY-COUNT	A count of recordings stored on internal storage.	4.4.13
4.2	DIRECTORY-ENTRIES		
4.2.X	DIRECTORY-ENTRY-X	The X^{th} entry in the list of recordings with pertinent data.	4.4.14
5	STORAGE-INFO		
5.1	TOTAL-STORAGE	Total storage capacity in bytes	4.4.15
5.2	REMAINING-STORAGE	Available storage capacity in bytes	4.4.16

Table 1: MCS-DR MIB structure

Index	Label	Description	Section
6	REMOVABLE-DEVICES		
6.1	DEVICE-COUNT	The number of additional storage devices which may be used in conjunction with commands to retrieve a recordings' contents.	4.4.17
6.2	DEVICE-IDS		
6.2.X	DEVICE-ID-X	The device id of the X^{th} discovered removable device.	4.4.18
6.3	DEVICE-STORAGES		
6.3.X	DEVICE-STORAGE-X	The remaining storage space on the X^{th} discovered removable device.	4.4.19
7	CPU-INFO		
7.1	CPU-COUNT	Number of CPU cores	4.4.20
7.2	CPUTEMPS		
7.2.X	CPU-TEMP-X	Temperature in degrees Celsius of CPU core X.	4.4.21
8	HDD-INFO		
8.1	HDD-COUNT	Number of hard drives comprising internal storage	4.4.22
8.2	HDD-TEMPS		
8.2.X	HDD-TEMP-X	Temperature in degrees Celsius of HDD X.	4.4.23
9	DATA-FORMATS		
9.1	FORMATS-COUNT	Count of available, configured data recording modes.	4.4.24
9.2	FORMAT-NAMES		
9.2.X	FORMAT-NAME-X	Name of the X^{th} data recording mode.	4.4.25
9.3	FORMAT-PAYLOADS		
9.3.X	FORMAT-PAYLOAD-X	UDP Payload Size of the X^{th} data recording mode.	4.4.26
9.4	FORMAT-RATES		
9.4.X	FORMAT-RATE-X	Rate of the X^{th} data recording mode.	4.4.27
9.5	FORMAT-SPECS		
9.5.X	FORMAT-SPEC-X	Format specification of the X^{th} data recording mode.	4.4.28
10	LOG		
10.1	LOG-COUNT	The number of entries in the system log.	4.4.29
10.2	LOG-ENTRIES		
10.2.X	LOG-ENTRY-X	The X^{th} entry in the system log.	4.4.30

Table 2: MCS-DR MIB structure *(Continued)*

4.4 MIB Entries in Detail

4.4.1 OP-TYPE

MIB Entry:	Operation Type
Index:	2.1
Label:	OP-TYPE
Description:	OP-TYPE reports the current operation type. If no operation is in progress, it indicates the idle state.
Response Format:	`<Operation Type>`

Response Element	Type and Size	Description
Operation Type	(ASCII-11-A)	One of "Idle", "Initialize", "Record", "Copy", "Dump", "Down", "Synchronize".

Operation Type	Meaning
"Idle"	The system is not currently performing any operation.
"Initialize"	The system is currently being initialized.
"Record"	The system is currently recording data.
"Copy"	The system is currently offloading a single region of recorded data to external storage.
"Dump"	The system is currently offloading blocks of recorded data to external storage.
"Down"	Internal storage is currently offline due to a DWN command having been issued.
"Synchronize"	The system is currently synchronizing time with station NTP server time.

4.4.2 OP-START

MIB Entry:	Current Operation Start-time
Index:	2.2.1
Label:	OP-START
Description:	OP-START reports the time at which the current operation began. This MIB entry is not valid if the current operation (as reported by MIB 2.1 *Operation Type*) is "Idle", or "Down".
Response Format:	`<Start MJD>'<Start MPM>`

Response Element	Type and Size	Description
Start MJD	(ASCII-6-#)	MJD at which the operation began.
Start MPM	(ASCII-9-#)	MPM at which the operation began.

4.4.3 OP-STOP

MIB Entry: Current Operation Expected Stop-time
Index: 2.2.2
Label: OP-STOP
Description: OP-STOP reports the scheduled or expected end-time of the current operation. This MIB entry is not valid if the current operation (as reported by MIB 2.1 *Operation Type*) is "Idle", or "Down". If *Operation Type* is "Copy", or "Dump", this entry will represent an estimation of completion time, and as such may not be accurate until average transfer rates have been determined.
Response Format: `<Stop MJD>'<Stop MPM>`

Response Element	Type and Size	Description
Stop MJD	(ASCII-6-#)	MJD at which the operation will end.
Stop MPM	(ASCII-9-#)	MPM at which the operation will end.

4.4.4 OP-REFERENCE

MIB Entry: Current Operation Reference Number
Index: 2.3
Label: OP-REFERENCE
Description: OP-REFERENCE reports the reference number of the command message which initiated or scheduled the current operation. This MIB entry is not valid if the current operation (as reported by MIB 2.1 *Operation Type*) is "Idle".
Response Format: `<Reference Number>`

Response Element	Type and Size	Description
Reference Number	(ASCII-9-#)	Reference number of the command message which initiated or scheduled the current operation.

4.4.5 OP-ERRORS

MIB Entry: Current Operation Error Count
Index: 2.4
Label: OP-ERRORS
Description: OP-ERRORS reports the number of errors and warnings generated during the current operation. This is valid if the current operation (as reported by MIB 2.1 *Operation Type*) is "Copy", "Dump", or "Synchronize".
Response Format: `<Errors>'<Warnings>`

Response Element	Type and Size	Description
Errors	(ASCII-15-#)	Number of errors detected in the current operation.
Warnings	(ASCII-15-#)	Number of warnings detected in the current operation.

4.4.6 OP-TAG

MIB Entry: Current Operation File Tag
Index: 2.5.1
Label: OP-TAG
Description: OP-TAG reports the tag value used to identify the file in use by current operation. The file may be in read or write mode, depending on whether the current operation (as reported by MIB 2.1 *Operation Type*) is "Record", "Copy", or "Dump". This MIB entry is not valid if the current operation is "Idle", "Initialize", "Down", or "Synchronize".
Response Format: `<Tag>`

Response Element	Type and Size	Description
Tag	(ASCII-16-A)	Filename tag in use by the current operation; They are `<MJD>_<Reference Number>`–including the literal underscore.

4.4.7 OP-FORMAT

MIB Entry: Current Operation File Data Format
Index: 2.5.2
Label: OP-FORMAT
Description: OP-FORMAT reports the data format in use current operation. If the operation type as reported by MIB 2.1 *Operation Type* is "Record", then *Data Format* is the format which the MCS-DR is currently recording. If the operation type is "Copy", "Dump", then this MIB entry is the data format specified by the "REC" command which initiated or scheduled the recording. For all other operation types, this entry is invalid.
Response Format: `<Data Format>`

Response Element	Type and Size	Description
Data Format	(ASCII-32-A)	Data format in use. See the "REC" control command for more information on data formats.

4.4.8 OP-FILEPOSITION

MIB Entry: Current Operation File Position Information
Index: 2.5.3
Label: OP-FILEPOSITION
Description: OP-FILEPOSITION reports the start position, length, and current position of reading or writing with respect to the file in use by current operation (as reported by MIB 2.1 *Operation Type*). The *Current Position* value is always an offset relative to *Start Position*. This MIB entry is only valid if the current operation (as reported by MIB 2.1 *Operation Type*) is "Record", "Copy", or "Dump".
Response Format: `<Start Position>'<Length>'<Current Position>`

Response Element	Type and Size	Description
Start Position	(ASCII-15-#)	The position of the first byte to be copied or dumped to external storage; is always 0 for Recording operations.
Length	(ASCII-15-#)	Copy: The number of bytes to copy; Dump: Size of each file chunk. Record: The expected size of the file.
Current Position	(ASCII-15-#)	The position of the most recent byte to be copied, dumped, or recorded.

4.4.9 OP-FILENAME

MIB Entry: Current Operation External File Information
Index: 2.6.1
Label: OP-FILENAME
Description: OP-FILENAME reports the file name and external storage device id in use by current operation. This MIB entry is only valid if the current operation (as reported by MIB 2.1 *Operation Type*) is "Copy" or "Dump". If the operation is "Dump", the returned file name is the name of the series, and individual files will be named as specified in the "DMP" command.
Response Format: `<Storage ID>'<Filename>`

Response Element	Type and Size	Description
Storage ID	(ASCII-64-A)	Linux partition (e.g. /dev/sdf1) of an attached external storage device. The device/partition must be formatted with the ext2 file system to be properly recognized and usable.
Filename	(ASCII-128-A)	The name of a file or file series in use by the current operation. If the current operation is using a file series, then each file, including the first, will be named `<Filename>.X`, where X is a zero-padded serial identifier. The width – in characters – of X will be determined by the number of digits required to represent the largest id generated, and subject to the name length restriction of 128 characters.

4.4.10 OP-FILEINDEX

MIB Entry:	Current Operation
Index:	2.6.2
Label:	OP-FILEINDEX
Description:	OP-FILEINDEX reports the which file of the file series is being written to. This MIB entry is only valid if the current operation (as reported by MIB 2.1 *Operation Type*) is "Dump".
Response Format:	`<Storage ID>'<Filename>`

Response Element	Type and Size	Description
File index	(ASCII-9-#)	Indicates which file of the series is being dumped to.

4.4.11 SCHEDULE-COUNT

MIB Entry:	Schedule Count
Index:	3.1
Label:	SCHEDULE-COUNT
Description:	SCHEDULE-COUNT reports a count of all scheduled operations, including the current operation if one is in progress.
Response Format:	The output format is a comma separated list of: `<Count>`

Response Element	Type and Size	Description
Count	(ASCII-6-#)	The number of scheduled recordings.

4.4.12 SCHEDULE-ENTRY-X

MIB Entry:	Schedule Entry X
Index:	3.2.X
Label:	SCHEDULE-ENTRY-X
Description:	SCHEDULE-ENTRY-X reports relevant information for the X^{th} scheduled operation.
Response Format:	`<Reference Number><Start MJD>'<Start MPM>'<Stop MJD>' <Stop MPM>'<Data Format>`

Response Element	Type and Size	Description
Reference Number	(ASCII-9-#)	Reference number of the command which scheduled the recording.
Start MJD	(ASCII-6-#)	MJD at which the recording will begin.
Start MPM	(ASCII-9-#)	MPM at which the recording will begin.
Stop MJD	(ASCII-6-#)	MJD at which the recording will end.
Stop MPM	(ASCII-9-#)	MPM at which the recording will end.
Format Name	(ASCII-32-A)	The data format of the scheduled operation. Must include only numbers, letters, and the underscore character.

4.4.13 DIRECTORY-COUNT

MIB Entry:	Directory File Count
Index:	4.1
Label:	DIRECTORY-COUNT
Description:	DIRECTORY-COUNT reports the number of recordings contained on internal storage.
Response Format:	`<Count>`

Response Element	Type and Size	Description
Count	(ASCII-6-#)	The number of recordings.

4.4.14 DIRECTORY-ENTRY-X

MIB Entry:	Directory Entry X
Index:	4.2.X
Label:	DIRECTORY-ENTRY-X
Description:	DIRECTORY-ENTRY-X reports pertinent information for the th recording contained on internal storage.
Response Format:	`<Tag>'<Start_MPM>'<Stop_MJD>'<Stop_MPM>'<Data Format>' <Size>'<Disk Usage>'<Complete>`

Response Element	Type and Size	Description
Tag	(ASCII-16-A)	Filename tag which uniquely identifies the file; They are of the form "`<MJD>_<Reference Number>`" – including the literal underscore, where MJD is the MJD when the recording began, and Reference Number is the Reference Number of the REC command which initiated/scheduled the recording.
Start MPM	(ASCII-9-#)	MPM at which the recording was started.
Stop MJD	(ASCII-6-#)	MJD at which the recording was stopped.
Stop MPM	(ASCII-9-#)	MPM at which the recording was stopped.
Data Format	(ASCII-32-A)	Data format which was used when the file was recorded. See the "REC" and "DFD" control commands for more information.
Size	(ASCII-15-#)	Size of the recording in bytes. This number reflects the actual number of bytes written to disk, but not the amount of space used by the file.
Disk Usage	(ASCII-15-#)	The total number of bytes occupied by the file on disk. Incomplete recordings will occupy an amount of space determined by the scheduled recording operation and data format. Bytes allocated in such a fashion will not be freed until the file is deleted.
Complete	(ASCII-3-A)	Either "YES" or "NO " depending on whether the recording completed without being interrupted or aborted.

4.4.15 TOTAL-STORAGE

MIB Entry: Total Storage
Index: 5.1
Label: TOTAL-STORAGE
Description: TOTAL-STORAGE reports the total storage capacity of internal storage in bytes.
Response Format: `<Size>`

Response Element	Type and Size	Description
Size	(ASCII-15#)	Total size of internal storage in bytes. This number does not reflect the number of bytes unavailable due to formatting and file system usage. This will be 0 when internal storage has been taken offline, or if a problem prevents the internal storage from being used.

4.4.16 REMAINING-STORAGE

MIB Entry: Remaining Storage
Index: 5.2
Label: REMAINING-STORAGE
Description: REMAINING-STORAGE reports the number of available bytes on internal storage.
Response Format: `<Available>`

Response Element	Type and Size	Description
Available	(ASCII-15#)	Total size of unused portion of internal storage in bytes. This number does not reflect the number of bytes unavailable due to formatting and file system usage. Each recording requires 4096 bytes in the file table, 512 kB of start and stop tags, and 256 kB of header information in addition to the actual file size, which is rounded up in units of 256 kB.

4.4.17 DEVICE-COUNT

MIB Entry: Removable Device Count
Index: 6.1
Label: DEVICE-COUNT
Description: DEVICE-COUNT reports a the number of available external storage devices.
Response Format: `<Count>`

Response Element	Type and Size	Description
Count	(ASCII-6-#)	The number of devices detected.

4.4.18 DEVICE-ID-X

MIB Entry: Removable Device ID X
Index: 6.2.X
Label: DEVICE-ID-X
Description: DEVICE-ID-X reports the device id of the Xth external storage device.
Response Format: `<Storage ID>`

Response Element	Type and Size	Description
Storage ID	(ASCII-64-A)	Linux partition (e.g. /dev/sdf1) of detected storage device. The device/partition must be formatted with the ext2 file system to be properly recognized and usable.

4.4.19 DEVICE-STORAGE-X

MIB Entry: Removable Device X Remaining Storage
Index: 6.3.X
Label: DEVICE-STORAGE-X
Description: DEVICE-STORAGE-X reports the free storage space on the Xth external storage device.
Response Format: `<Available>`

Response Element	Type and Size	Description
Available	(ASCII-15-#)	Total size of unused portion in bytes of external storage specified by *Storage ID* in MIB entry 6.2.X. This number does not reflect the number of bytes unavailable due to formatting and file system usage. If this number is 0, it indicates that a removable device was detected, but is not formatted properly, or contains an unsupported file system.

4.4.20 CPU-COUNT

MIB Entry: CPU Count
Index: 7.1
Label: CPU-COUNT
Description: CPU-COUNT reports the number of CPU cores present in the MCS DR. Typically this value will be 8, but to support the possibility of future hardware changes, this MIB entry is included.
Response Format: `<Count>`

Response Element	Type and Size	Description
Count	(ASCII-3-#)	The number of CPU cores.

4.4.21 CPU-TEMP-X

MIB Entry: CPU Temperatures
Index: 7.2.X
Label: CPU-TEMP-X
Description: CPU-TEMP-X reports temperature of the of core X.
Response Format: `<Core X Temp>`

Response Element	Type and Size	Description
Core X Temp	(ASCII-3-#)	Temperature in degrees Celsius of core X.

4.4.22 HDD-COUNT

MIB Entry: HDD Count
Index: 8.1
Label: HDD-COUNT
Description: HDD-COUNT reports the number of hard drives comprising internal storage. Typically this value will be 5, but to support the possibility of future hardware changes, this MIB entry is included.
Response Format: `<Count>`

Response Element	Type and Size	Description
Count	(ASCII-3-#)	The number of hard disk drives.

4.4.23 HDD-TEMP-X

MIB Entry: Hard Disk Drive Temperatures
Index: 8.X
Label: HDD-TEMP-X
Description: HDD-TEMP-X reports temperature of the X^{th} hard drive in the internal storage RAID array.
Response Format: `<HDD X Temp>`

Response Element	Type and Size	Description
HDD X Temp	(ASCII-3-#)	Temperature in degrees Celsius of drive X in the array.

4.4.24 FORMAT-COUNT

MIB Entry: Data Formats Count
Index: 9.1
Label: FORMAT-COUNT
Description: FORMAT-COUNT returns the number of recording formats supported.

Response Element	Type and Size	Description
Count	(ASCII-6-#)	The number of formats supported.

4.4.25 FORMAT-NAME-X

MIB Entry: Data Format X Name
Index: 9.2.X
Label: FORMAT-NAME-X
Description: FORMAT-NAME-X returns the name of the X^{th} recording format.

Response Element	Type and Size	Description
Format Name	(ASCII-32-A)	The name assigned to the format. Must include only numbers, letters, and the underscore character. Data formats should be named appropriately. e.g.: TBN_1024_112 for a TBN packet of 1024 bytes at a rate of 112 MiB/s.

4.4.26 FORMAT-PAYLOAD-X

MIB Entry: Data Format X UDP Packet Payload Size
Index: 9.3.X
Label: FORMAT-PAYLOAD-X
Description: FORMAT-PAYLOAD-X returns the UDP Packet Payload Size of the X^{th} recording format.

Response Element	Type and Size	Description
UDP Payload Size	(ASCII-4-#)	The size in bytes of the payload portion of UDP packets for this format. Typically this will be 1024 for TBN, 1224 for TBW, or 4128 for DRX. See the DP Common ICD ([5]) for more information.

4.4.27 FORMAT-RATE-X

MIB Entry: Data Format X Rate
Index: 9.4.X
Label: FORMAT-RATE-X
Description: FORMAT-RATE-X returns the data rate of the X^{th} recording format.

Response Element	Type and Size	Description
Rate	(ASCII-9-#)	Overall data rate once formatting has been taken into consideration. Specifically, this is the rate used in calculating the amount of space a recording will require on disk. If the entire UDP payload is recorded to disk, then this rate will equal the transmission rate. Likewise, if the format requires that portions of the payload will be discarded, then this number will be less than the actual transfer rate. Note that the MAC and UDP packet headers should not be considered in this rate as they are discarded automatically.

4.4.28 FORMAT-SPEC-X

MIB Entry: Data Format X specification
Index: 9.5.X
Label: FORMAT-SPEC-X
Description: FORMAT-SPEC-X returns the specification of the X^{th} recording format. This specification is an ordered list of Keep or Drop operations to be performed on portions of the received data packet. This feature's primary use is in conserving storage space by discarding portions of a packet that may not be needed before the packet is written to disk.

Response Element	Type and Size	Description
Format	(ASCII-256-A)	The format is defined as an ordered list of terms Kxxxx or Dyyyy where Kxxx means that xxxx bytes should be kept, and Dyyyy means that yyyy bytes should be dropped. For instance, the pattern "D0024K0512D0488" reads as "Drop the first 24 bytes, keep the next 512, and drop the 488 subsequent bytes. All xxxx and yyyy will add up to the specified UDP packet payload size, so for the example shown, the UDP packet payload size is 1024. These formats are predefined based on data formats specified in the DP ICD.

4.4.29 LOG-COUNT

MIB Entry: System Log Length
Index: 10.1
Label: LOG-COUNT
Description: LOG-COUNT reports the number of system log entries.
Response Format: `<Count>`

Response Element	Type and Size	Description
Count	(ASCII-6-#)	The number of entries in the system log.

4.4.30 LOG-ENTRY-X

MIB Entry: System Log Entry X
Index: 10.2.X
Label: LOG-ENTRY-X
Description: LOG-ENTRY-X reports the X^{th} entry in the system log.
Response Format: `<MJD>'<MPM>'<Message Class>'<Message>`

Response Element	Type and Size	Description
MJD	(ASCII-6-#)	MJD when the entry was logged.
MPM	(ASCII-9-#)	MPM when the entry was logged.
Message Class	(ASCII-7-A)	One of: "info...", "warning", or "error.." (periods indicate padding spaces)
Status	(ASCII-234-A)	A human readable string of at most 234 characters, padded with spaces, describing an event of interest.

4.5 Control Commands

Command Name	Description	Section
INI	Initialize or restore the MCS-DR to its initial boot-up state.	4.6.1
REC	Schedule a recording operation with the start-time, duration, and data format specified.	4.6.2
DEL	Delete existing recording specified by a supplied tag-value	4.6.3
STP	Stop the recording specified by a supplied tag-value, halting if in-progress, and canceling if not yet begun.	4.6.4
GET	Retrieve a portion of the recording specified by a supplied tag-value, a byte-offset, and number of bytes.	4.6.5
CPY	Copy a portion of the recording specified by a supplied tag-value, a byte-offset, and number of bytes to a file on a removable storage device.	4.6.6
DMP	Dump a portion of the recording specified by a supplied tag-value, a byte-offset, and number of bytes to a series of files on a removable storage device.	4.6.7
FMT	Format internal or external storage device.	4.6.8
DWN	Bring internal storage to an offline state suitable for removal/replacement.	4.6.9
UP	Scan for internal storage and bring to an online state if possible.	4.6.10
EJT	Unmount external storage device and bring to a state suitable for removal	4.6.11
SYN	Synchronize MCS-DR with NTP server time.	4.6.12
TST	Perform a system self-test.	4.6.13

Table 3: MCS-DR Commands

4.6 Control Commands in Detail

Each of the following commands specifies a list of arguments and their meanings, the response format returned if the command can be successfully executed. If the specification does not include a list of arguments, then none are required. If a description of the response format is not included, then the "R-COMMENT" field of the response shall be empty upon successful execution. In all commands below, the response format assumes the "R-RESPONSE" and "R-SUMMARY" as defined in the MCS Common ICD [4]. The response format listed for each command describes the contents of "R-COMMENT". Commands which cannot be executed will return a "R" in "R-RESPONSE", and "R-COMMENT" will be set to the corresponding error message. No commands will be rejected without returning a human-readable description of the reason in the "R-COMMENT" field. Possible error messages and their meanings are listed in section 4.7.

4.6.1 INI

Command: Initialize
Description: Initialize restores the MCS-DR to the initial boot-up state in all regards except for the system log and the contents of internal storage.
Argument Format: `<Flags>`

Argument	Type and Size	Description
Flags	(ASCII-256-A)	To force re-initialization of the system log, specify the flag "`--flush-log`" or "`-L`". To force re-initialization of internal RAID storage, specify the flag "`--flush-data`" or "`-D`". Field need not be padded with spaces, and order of flags appearance does not matter.

4.6.2 REC

Command: Record
Description: This command schedules or initiates a recording of output from the DP subsystem. Upon successful execution of the REC command, a tag value will be returned which will uniquely identify the file. A file will have been created on the file-system which is large enough to accommodate the recording. If an operation is in progress which prohibits writing to the disk, the file creation will only exist in memory until the disk is available for writing. A request to shutdown with the SCRAM option before such a file has been written to the drive will discard the file.
Argument Format: `<Start MJD>'<Start MPM>'<Length>'<Data Format>`
Response Format: `<Tag>`

Argument	Type and Size	Description
Start MJD	(ASCII-6-#)	Modified Julian Day to begin the recording. Must not be more than 24 hours into the future.
Start MPM	(ASCII-9-#)	Milliseconds Past Midnight to begin the recording. Must not be within 5 seconds of the termination of another operation.
Length	(ASCII-9-#)	The number of milliseconds to record. Must not terminate within 5 seconds of another scheduled operation, nor can any portion of the time period overlap any other scheduled operation. Note that the recording remains active for a short time afterwards to accommodate packets which have not been delivered yet. Consequently, additional data may be included past the end of the specified period. The length of this grace period is TBD.
Data Format	(ASCII-32-A)	The name of the pre-configured data format to use. See section 4.4.28 for details regarding data formats.

Response Element	Type and Size	Description
Tag	(ASCII-16-A)	A file name of the form `<MJD>_<Reference Number>`, where MJD is the MJD on which recording is scheduled to begin, and Reference number is the reference number of the command message which scheduled the recording.

4.6.3 DEL

Command: Delete
Description: This command deletes a recording from internal storage.
Argument Format: `<Tag>`

Argument	Type and Size	Description
Tag	(ASCII-16-A)	A file name of the form `<MJD>_<Reference Number>`. See section 4.6.2 for more information.

4.6.4 STP

Command: Stop
Description: This command halts or prevents the specified recording. If the recording is scheduled but not in-progress, it is deleted from the schedule and the corresponding hard drive space is freed. If the recording is in progress, it is halted and the corresponding file is closed, but not deleted.
Argument Format: `<Tag>`

Argument	Type and Size	Description
Tag	(ASCII-16-A)	A file name of the form `<MJD>_<Reference Number>`. See section 4.6.2 for more information.

4.6.5 GET

Command: Get
Description: The Get command retrieves a portion of a specified recording.
Argument Format: `<Tag>'<Start Byte>'<Length>`
Response Format: `<Data>`

Argument	Type and Size	Description
Tag	(ASCII-16-A)	A file name of the form `<MJD>_<Reference Number>`. See section 4.6.2 for more information.
Start Byte	(ASCII-15-#)	The byte offset within the file to start retrieval at.
Length	(ASCII-15-#)	The number of bytes to return. This is limited to the maximum size of a R-COMMENT field in a command response, or 8146 bytes.

Response Element	Type and Size	Description
Data	(uint8)x*Length*	On success, this field will contain *Length* bytes of data from the specified position in the file.

4.6.6 CPY

Command: Copy

Description: The Copy command copies portions of a recording to a file an external storage device. If the file already exists, it will be overwritten without warning or notification. The Copy and Dump commands are not available if there are any recordings scheduled.

Argument Format: `<Tag>'<Start Byte>'<Length>'<Device ID>'<Filename>`

Argument	Type and Size	Description
Tag	(ASCII-16-A)	A file name of the form `<MJD>_<Reference Number>`. See section 4.6.2 for more information.
Start Byte	(ASCII-15-#)	The byte offset within the file to start retrieval at.
Length	(ASCII-15-#)	The number of bytes to copy. This is limited to the free space on the target removable storage device.
Storage ID	(ASCII-64-A)	Linux partition (e.g. /dev/sdf1) of an attached external storage device. The device/partition must be formatted with the ext2 file system to be properly recognized and usable.
Filename	(ASCII-128-A)	The name of a file to create. Acceptable characters are letters, numbers, the underscore and period.

4.6.7 DMP

Command: Dump

Description: The Dump command copies blocks of data from a recording to a series of files on an external storage device. If any of the files already exist, they will be overwritten without warning or notification. The Copy and Dump commands are not available if there are any recordings scheduled.

Argument Format: `<Tag>'<Start Byte>'<Length>'<Block Size>'<Device ID>'<Filename>`

Argument	Type and Size	Description
Tag	(ASCII-16-A)	A file name of the form `<MJD>_<Reference Number>`. See section 4.6.2 for more information.
Start Byte	(ASCII-15-#)	The byte offset within the file to start retrieval at.
Length	(ASCII-15-#)	The number of bytes to copy. This is limited to the free space on the target removable storage device.
Block Size	(ASCII-15-#)	The number of bytes to copy before moving on to the next file. The files created by this command will be exactly Block Size bytes with the exception of the last, which will be determined by the *Length* specified.
Storage ID	(ASCII-64-A)	Linux partition (e.g. /dev/sdf1) of an attached external storage device. The device/partition must be formatted with the ext2 file system to be properly recognized and usable.
Filename	(ASCII-128-A)	The name of a file series to create. Acceptable characters are letters, numbers, the underscore and period. Each file, including the first, will be named `<Filename>.X`, where X is a zero-padded serial identifier. The width – in characters – of X will be determined by the number of digits required to represent the largest id generated, and subject to the name length restriction of 128 characters.

4.6.8 FMT

Command: Format

Description: This command formats either internal storage, or an attached external storage device. When formatting an external device, the operation can require a substantial amount of time, proportional to the size of the device. To determine whether a format command completed, poll the OP-INFO MIB entry until it no longer indicates that an operation is in progress, and then request the REMOVABLE-DEVICES MIB entry. If the command was successful, the available space on the device will reflect the formatted size. If unsuccessful, the reported size will be 0.

Argument Format: `<Storage ID>`*optional*

Argument	Type and Size	Description
Storage ID	(ASCII-64-A)	Optional argument specifying an external storage device's partition. If omitted, the command will format internal storage. In both cases, it is a destructive operation and all data on the target is erased. Formatting unpartitioned devices is not supported, though it may be in the future.

4.6.9 DWN

Command: Down (internal storage)

Description: This command prepares the MCS-DR's internal storage for removal/replacement. The command is executed immediately, but requires as much as 120 seconds to complete. Storage device must not be disconnected until a TOTAL-STORAGE request returns 0 as data may be lost.

4.6.10 UP

Command: Up (internal storage)

Description: This command brings internal storage back online, and reports the amount of free space if successful. If the MCS-DR cannot determine necessary file system information, no destructive changes will be made. To override this behavior and force a drive initialization, specify "-F" as an argument. Otherwise, this command has no arguments.

Response Format: `<Available>`

Response Element	Type and Size	Description
Available	(ASCII-15-#)	Total size of unused portion of internal storage in bytes. This number does not reflect the number of bytes unavailable due to formatting and file system usage.

4.6.11 EJT

Command: Eject
Description: Eject un-mounts an external storage device in preparation for removal.
Argument Format: `<Storage ID>`

Argument	Type and Size	Description
Storage ID	(ASCII-64-A)	Linux partition (e.g. /dev/sdf1) of an attached external storage device. The device/partition must be formatted with the ext2 file system to be properly recognized and usable.

4.6.12 SYN

Command: Synchronize
Description: This command explicitly synchronizes the MCS-DR with the station NTP time server. Executing this command while operations are scheduled or in progress may result in recording more or less data than desired, as well as shifting the times at which they occur. Such deviations should be minor, but no guarantees are made to that effect.

4.6.13 TST

Command: Self Test
Description: Perform a system self-test. This command is used solely for development purposes and is not supported by this ICD. This command will be removed from release systems.
Argument Format: `N/A`
Response Format: `N/A`

4.7 Error Messages

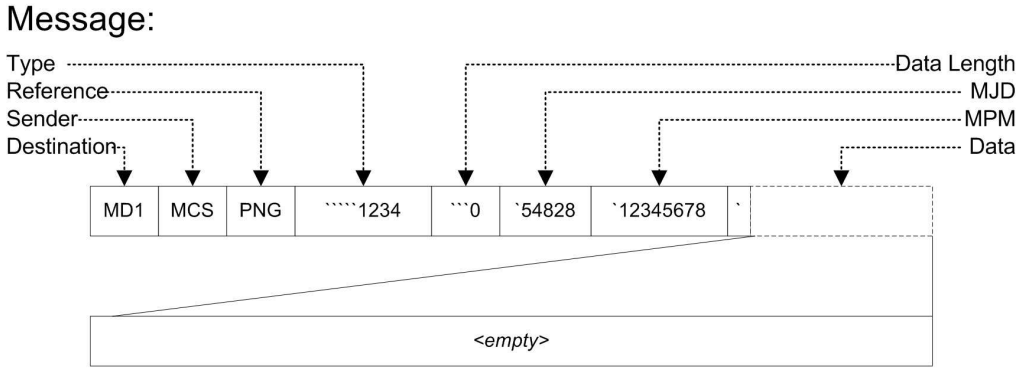
Error Message	Error Description
Operation not permitted	Operations scheduled or in progress prevent the execution of this command.
Invalid Name	The specified *Format Name* contains illegal characters.
Format Already Defined	The specified *Format Name* is already in use.
Invalid Size	Specified *UDP Packet Payload Size* exceeds the maximum allowable size–determined by the Ethernet Jumbo Frames MTU less MAC, IP, and UDP header data. Specified limit is 8192 bytes.
Invalid Rate	The *Rate* specified exceeds the capabilities of the system, or the calculated actual rate exceeds the capabilities of the system. Currently this threshold is set at 120 MiB/s, and rates above 115 MiB/s are not supported and can not guarantee data will be recorded successfully.
Already Up	Internal storage is already online.
Not Detected	Internal storage was not detected.
Cannot Start	File system information was not detected on the device.
Already Down	Internal storage is already offline.
Invalid Storage ID	The *Storage ID* specified does not exist in the system.
File not found	The *Tag* value supplied does not refer to any file on internal storage.
Invalid Filename	The *Filename* specified contains illegal characters.
Invalid Position	The requested *Start Byte* and *Length* exceeds the size of the file.
Invalid Range	The requested *Length* exceeds response size limitations.
Not Scheduled	The specified *Tag* neither refers to any scheduled recording, nor to any existing recordings.
Already Stopped	The *Tag* value refers to a recording which has already completed.
Invalid Time	The requested time frame is either in the past or too far into the future.
Time Conflict: `<Operation>`	The requested time frame overlaps a scheduled operation. *Operation* lists the first scheduled operation which causes a conflict, and is formatted as with the SCHEDULE-ENTRY-X MIB entry (see section 4.4.12).
Unknown Format: `<Format>`	The specified *Format* has not been defined and cannot be used.
Insufficient Drive Space	The amount of storage space required for the requested recording exceeds the remaining space on internal storage, or it exceeds the amount of the largest contiguous block of free-space.
Component Not Available: `<X>`	Some internal component *X* of the MCS-DR is unavailable, unusable, or malfunctioning.

5 Control and Monitoring Session Examples

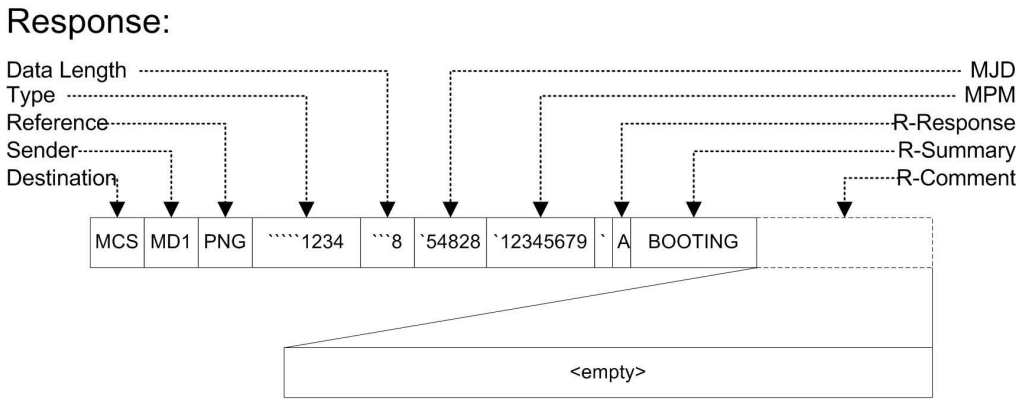
The following examples walk through a usage scenario and demonstrate the types of command and monitor messages needed to operate the MCS-DR as well as the responses and error messages that might be generated. It should be noted that the error conditions in the scenario are atypical, and are included for the sake of demonstrating the interface. In the following examples, a single quote is used to denote spaces appearing in arguments and responses. Subsystem ID is assumed to be "MD1" in these examples.

The example starts by checking system status to which the MCS-DR responds that it is booting. MCS then requests initialization but MCS-DR discovers that internal storage is missing and responds to that effect. MCS issues an UP command to bring storage online, and the MCS-DR is able to comply and fix the problem. MCS then schedules a recording and checks to verify that the recording was scheduled. Once the recording begins, the MCS checks the status of the operation. Once the operation is complete, MCS requests that the MCS-DR copy a portion of the new recording to an external storage device.

5.1 Checking System Status



Description: MCS sends a “PNG” request to MCS-DR PC #1 with reference designator “MD1”. The data field is empty and consequently, the Data Length field is set to 0.

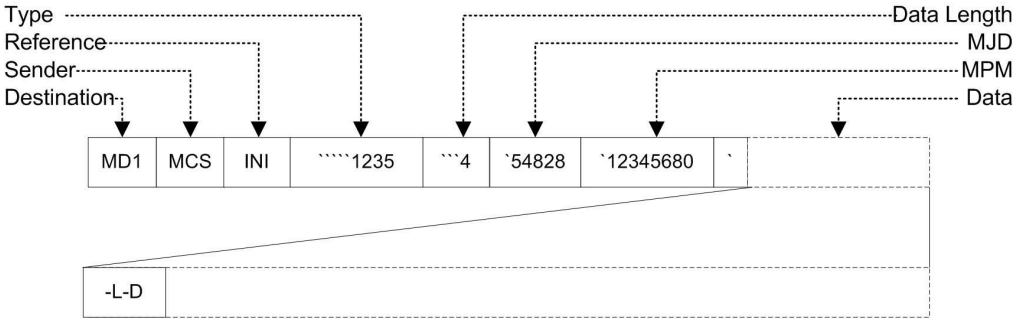


Description: MCS-DR PC #1 responds, acknowledging acceptance of the message, and with the status of “BOOTING”. R-Comment is empty, and thus the Data Length returned is 1+7, or 8.

Figure 3: Example of checking system status

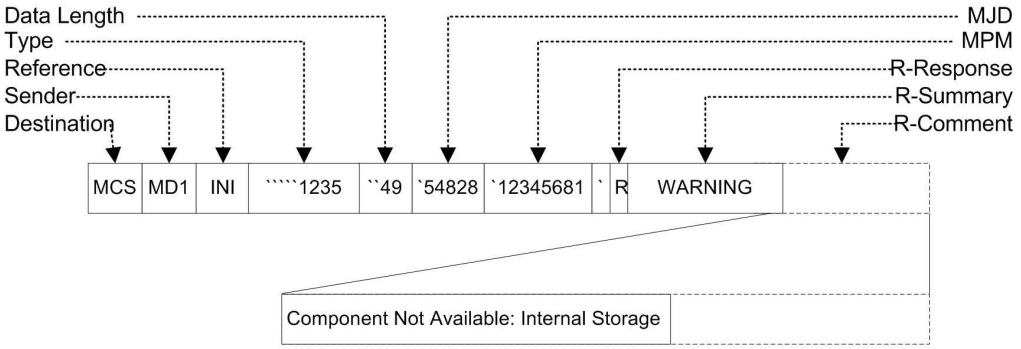
5.2 Requesting Initialization (w/ Error Response)

Message:



Description: MCS requests initialization of the system with the “-L” and “-D” options. The options specified request that the MCS-DR clear its internal log and any previously recorded data.

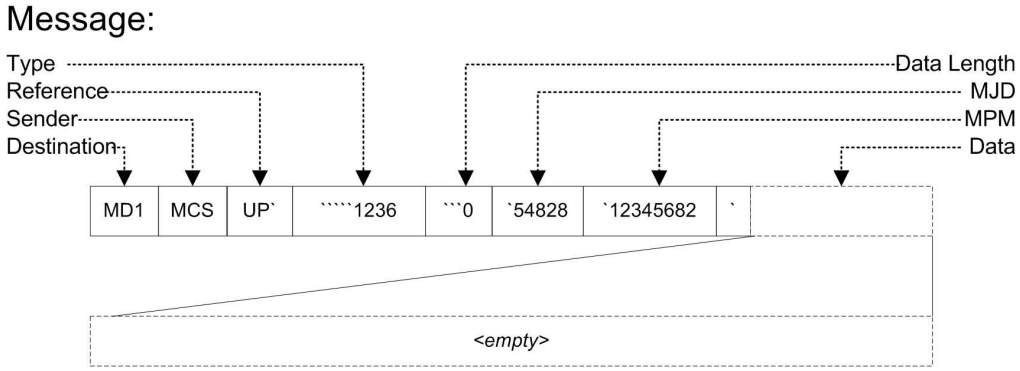
Response:



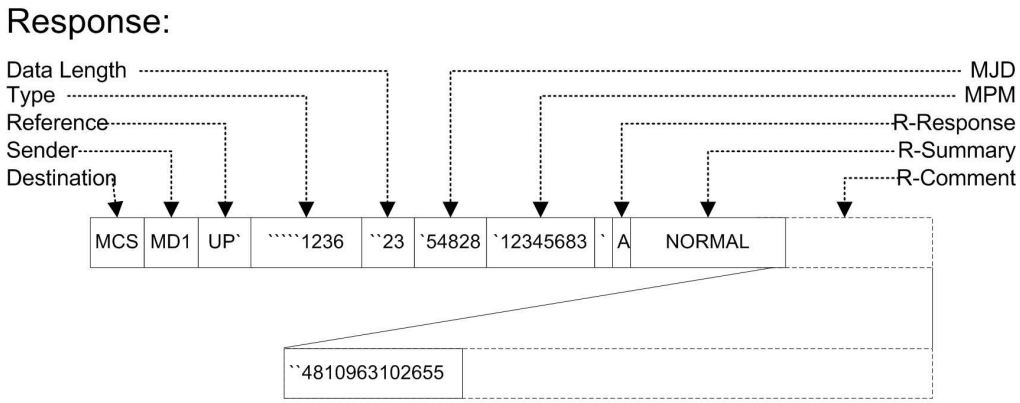
Description: The MCS-DR is not able to comply with the request, and a rejection response is sent. In this scenario, previous commands had taken the internal storage offline for replacement. The storage had since been replaced, but no request to “UP” the storage had been made.

Figure 4: Example of requesting initialization (w/ Error Response)

5.3 Up-ing Internal Storage



Description: MCS is requesting that the MCS-DR bring the internal storage online with this message.



Description: MCS-DR responds with an acceptance message, and internal storage is brought online. The R-Comment field contains the amount of storage space available in bytes—in this case, just under 5 TB.

Figure 5: Example of bringing internal storage online

5.4 Requesting Initialization

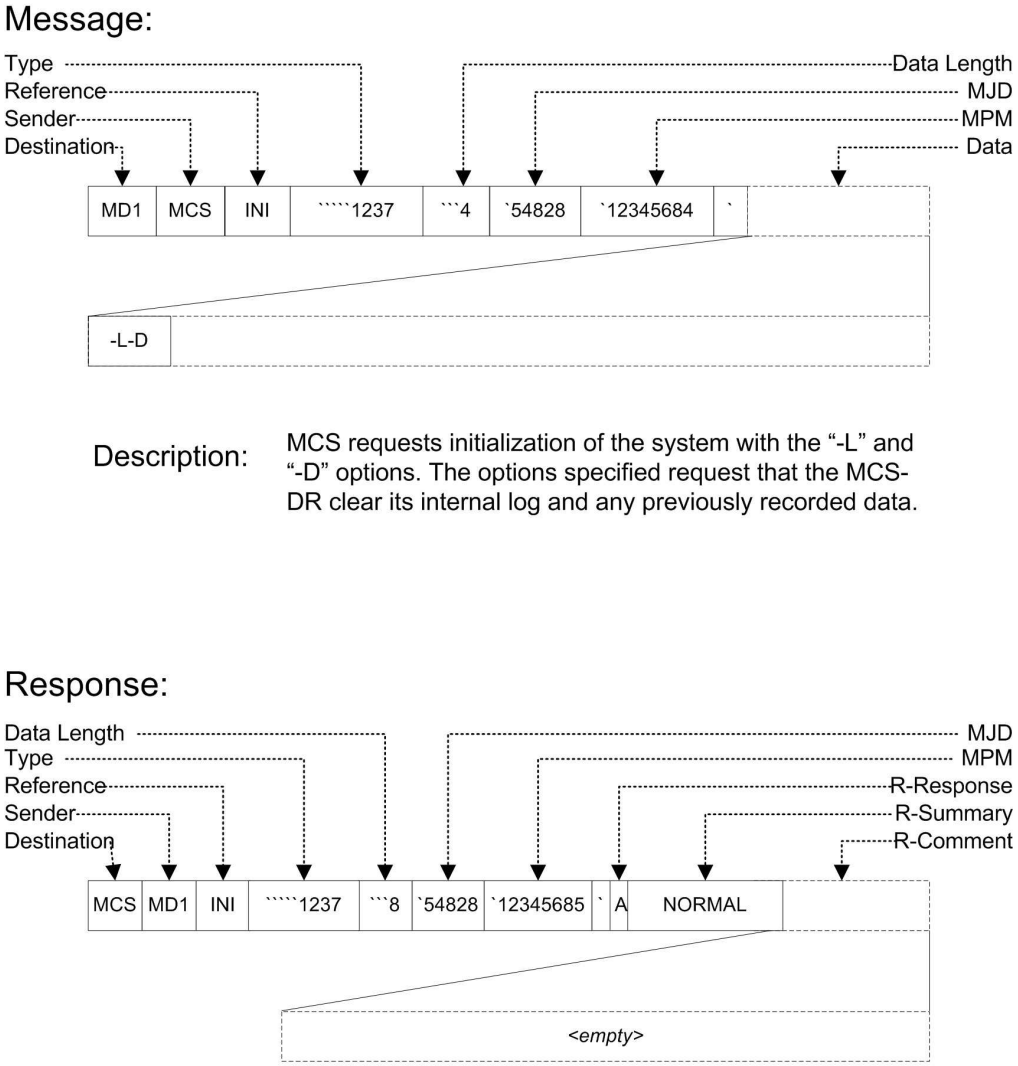


Figure 6: Example of requesting initialization

5.5 Scheduling a Recording

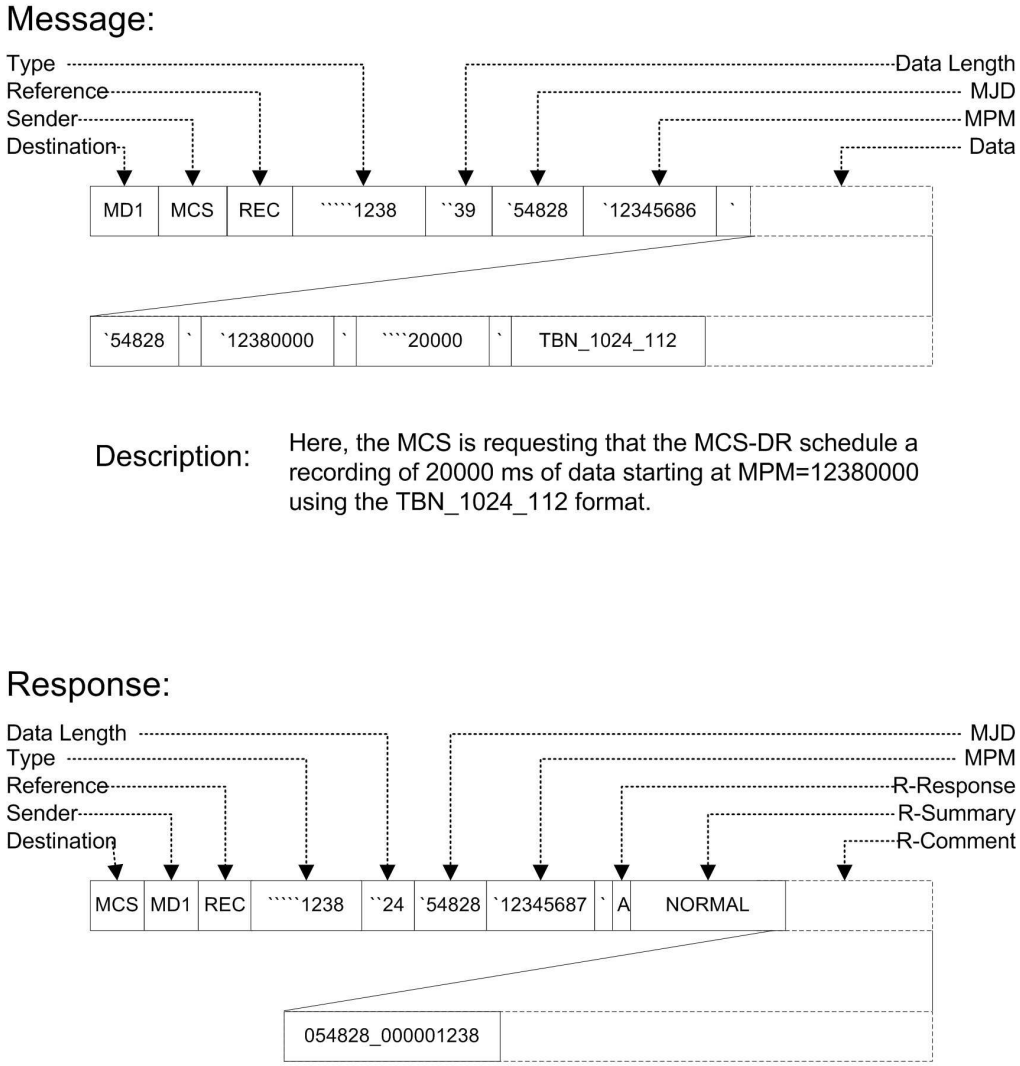
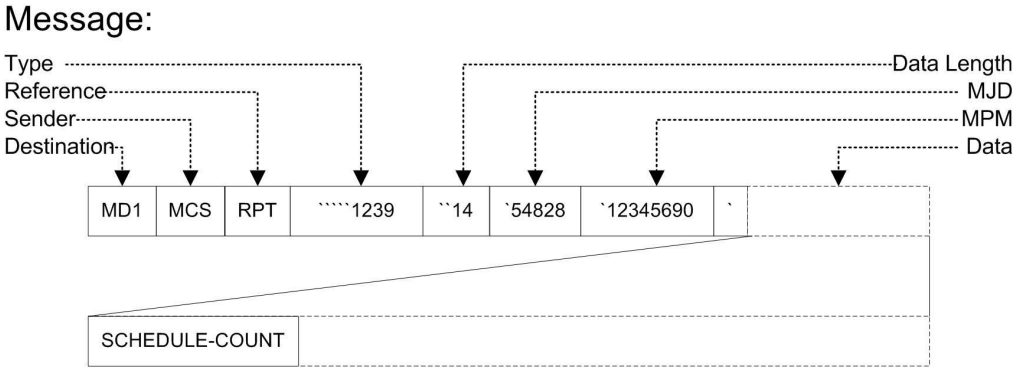
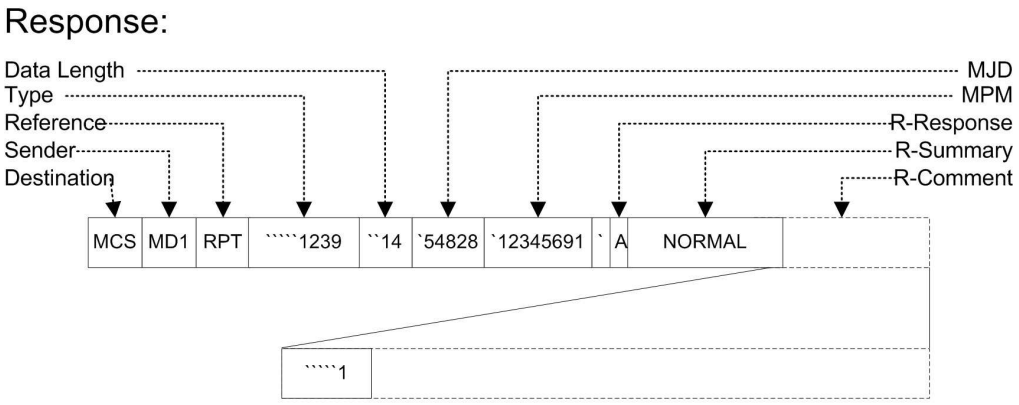


Figure 7: Example of scheduling a recording

5.6 Checking Scheduled Operations



Description: Here, the MCS is making sure the recording is scheduled by checking the number of scheduled recordings (MIB entry 3.1).



Description: MCS-DR reports that there are 1 operations scheduled. Requesting additional MIB entries under the SCHEDULE branch will provide details of the specific operation, but that is not demonstrated in this scenario.

Figure 8: Example of checking the recording schedule

5.7 Checking An Operation's Progress

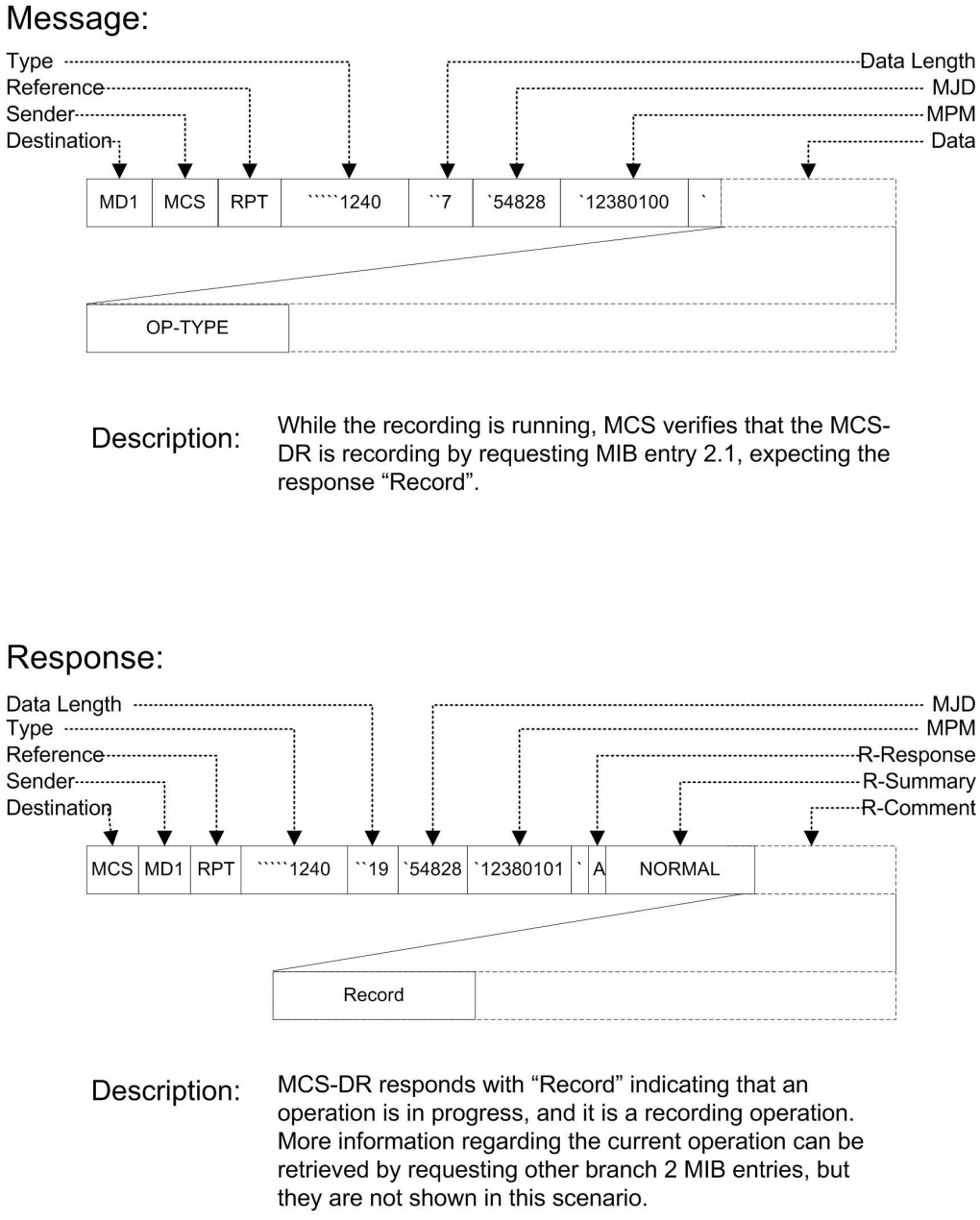
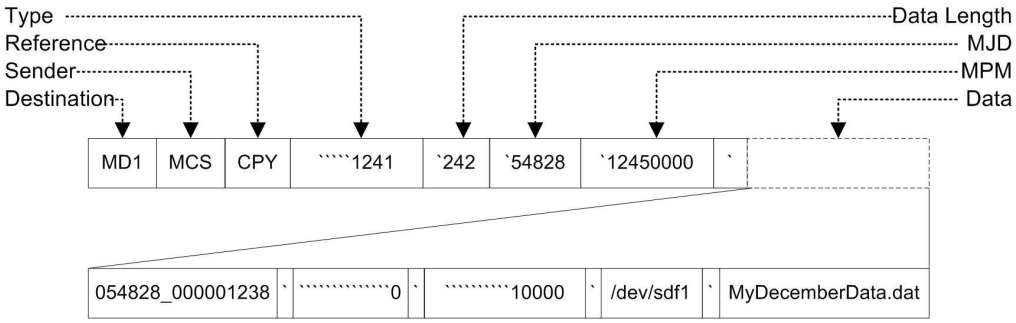


Figure 9: Example of checking that an operation is in progress as scheduled

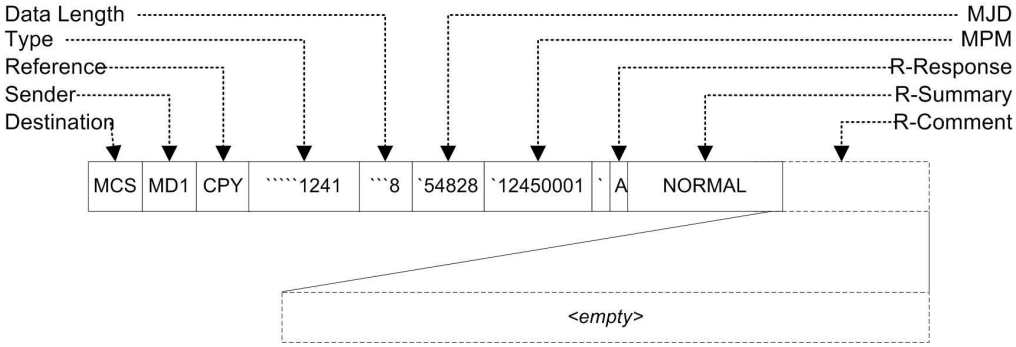
5.8 Retrieving Recorded Data

Message:



Description: Here, the MCS is requesting that data be copied from recording 054828_000001238 to "/dev/sdf1/ MyDecemberData.dat" starting with the first byte and continuing for 10000 bytes. *Note that padding spaces are not shown for Storage ID and Filename, but either left or right padding spaces are fine.* Spaces contained between the first and last non-space character are interpreted as part of the filename or storage id. Rules and semantics concerning such spaces are defined by the Ubuntu Linux operating system.

Response:



Description: The MCS-DR returns an acceptance response and begins copying the data.

Figure 10: Example of using the copy command to retrieve data

6 Change Record

Version	Date	Affected Section(s)	Reason/Description
0.4	2009-10-10	All	Fourth draft of document, removed image matte, removed references to development-stage diagnostics except "TST", revised electrical connections view to not imply a specific mounting requirement, updated argument and response formats to separate all parameters with spaces, updated use-case example to reflect new formats, rewrote FORMAT-SPEC-X description to remove ambiguity.
0.3	2009-10-04	All	Third draft of document, restructured MIB to remove the "MORE" entry. Removed the "DFD" command. Added mechanical and electrical figures and use-case scenario examples.
0.2	2009-09-24	All	Second draft of document, corrected typos and removed extraneous material.
0.1	2009-09-12	All	Initial draft of document.

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MCS-DR Operating Software
Version 0.8
C.N. Wolfe
Nov. 9, 2009

Introduction

This archive contains the MCS-DR Operating Software (MCS-DROS or DROS). DROS is designed to accept commands from MCS to record and later retrieve data provided by DP. In this tarball exists all of the souce for the executable, as well as make files needed to build it.

The application is developed in C and is mostly ANSI C compliant barring the occasional mixing of declarations and code. The final release version will be 100% ANSI C compliant. The application is developed under Eclipse 3.4 (Ganymede), and this archive includes the .project and .cproject files required to import the project back into eclipse.

DROS is designed exclusively for 64-bit linux architectures, and will not compile for 32-bit targets. This design is targeted for Ubuntu Linux 9.04 x86_64, Desktop, and no other targets have been tested. Although the software should build for any 64-bit linux target, this is not guaranteed.

DROS requires two libraries to be installed to build: libgdbm and librt. libgdbm provides basic database-like capabilities and fast hashed lookup of associative key-value pairs, and librt provides asynchronous disk access. Under Ubuntu, "apt-get install libgdbm3 libgdbm-dev" installs the required libgdbm, and librt is installed by default.

The DROS contained in this tarball is not the same as the code used to test & verify in LWA memo 165. This software differs in that a good portion of the ICD has been implemented on top of the existing data and message processing mechanisms. Further, the software has been cleaned to remove portions only useful in testing and development.

Limitations

DROS is currently under development, and the version provided here is 'pre-alpha'. The main thrust of the current release aims at implementing the MCS-DR ICD (Engineering Memo MCS0020). However, several key features defined in the MCS-DR ICD are not yet implemented, or only partially implemented. What follows is a list of deviations from the ICD that can be expected:

1) Interlocks Commands which would normally be rejected with the error message "Operation Not Permitted" may be executed, likely causing the system to crash or corrupting recorded data or deleting it altogether. To aviod this type of situation, do not issue commands while a recording is in progress, or any other operation which explicitly interacts with internal storage (CPY,REC,DMP,FMT,DEL, etc.)

2) MIB several MIB entries are not implemented. specifically,
* Branch 4 (Directory): 4.1 (count) works, but 4.2.x will return an empty string
* Branch 5-8 (storage info, removable devices, cpu info, and hdd info) : not implemented
* Branch 10 (log) : not implemented

3) Commands The following list describes the functionality and limitations of the DROS's command set as of 0.8 pre-alpha release;
* DMP ,FMT, DWN, UP, EJT, DEL not implemented
* CPY command is partially implemented. no data will be copied, but command message will be parsed and response generated as if it would be. entry will be added to the schedule. When the scheduled time is reached, the command will fail, and will be removed form the schedule

The execution of any command not fully implemented may result in crashing the system, and is not advised. Further, sending binary data in the data field of any message may also

crash the system. Safeguards against such possibilities are developed for future releases,
but not included with this release.

Additional Files required

DROS expects to be installed to a specific path, and expects to find additional support files
at specified loactions.

```
/LWA/scripts            Contains the launch.sh host script. see sec. "Host Script"
/LWA/config             Conatins defaults.cfg, and formats.cfg
/LWA/bin                Contains the DROS binary "WAVE_Y"
/LWA/database           Folder to hold runtime information such as log and scheduling databases.
                        Runtime fiules are created automatically if missing.
```

defaults.cfg

This file is used to configure the MCS-DROS on first boot and/or at the issuance of an INI command
The following is a sample config file. Note that the values are those used in development,
and not suitable for the LWA shelter network environment.

```
# system IP
SelfIP          192.168.1.20

# system reference Identifier
MyReferenceDesignator   MD1

# udp port to listen for messages
MessageInPort           5001

# udp port to send responses to (presumable MCS)
MessageOutPort          5000

# URL to send responses to (presumably MCS)
MessageOutURL           192.168.1.20

# udp port to listen for data
DataInPort              6002

# ntp time server ip address or URL
TimeAuthority           ntp.ubuntu.com
```

formats.cfg

This file is used to describe the supported data formats of the MCS-DROS on first boot and/or
at the issuance of an INI command. The following is a sample config file. Note that the values
are those used in development, and not necessarily the final values. (i.e., this is to demonstrate
the format, not specify content)

```
# number of formats
FORMAT-COUNT            3

# format 0: default full TBN
FORMAT-NAME-0           DEFAULT_TBN
FORMAT-RATE-0           117440512
FORMAT-SPEC-0           K1024
FORMAT-PAYLOAD-0        1024

# format 1: default full TBW
FORMAT-NAME-1           DEFAULT_TBW
FORMAT-RATE-1           104857600
FORMAT-SPEC-1           K1224
FORMAT-PAYLOAD-1        1224

# format 2: debugging format spec rules TBN
```

```
    | FORMAT-NAME-2           TEST_TBN                                                |
    | FORMAT-RATE-2           117440512                                               |
    | FORMAT-SPEC-2           K100D100K100D724                                        |
    | FORMAT-PAYLOAD-2        1024                                                    |
    |                                                                                 |
    \---------------------------------------------------------------------------------/
```

Host Script
===========

The DROS executable is launched from within a simple bash shell script which facilitates the SHT and INI commands. Without this script, those commands will not function as expected. The script should be launched as a startup task, with root permissions. The script is as follows:

```
    /---------------------------------------------------------------------------------\
    |                                                                                 |
    | #!/bin/bash                                                                     |
    | CF=/LWA/config/LAUNCHOPTIONS                                                    |
    | while [ 1 ]                                                                     |
    | do                                                                              |
    |         OPTIONS=$(cat $CF)                                                      |
    |         cd /LWA; /LWA/bin/WAVE_Y $OPTIONS                                       |
    |         RESULT=$?                                                               |
    |         let "FFD = ($RESULT & 0x01) == 0x01"                                    |
    |         let "FFC = ($RESULT & 0x02) == 0x02"                                    |
    |         let "FFS = ($RESULT & 0x04) == 0x04"                                    |
    |         let "FFL = ($RESULT & 0x08) == 0x08"                                    |
    |         let "SHT = ($RESULT & 0x10) == 0x10"                                    |
    |         let "RST = ($RESULT & 0x20) == 0x20"                                    |
    |                                                                                 |
    |         echo "" > $CF                                                           |
    |         if [ $FFD = 1 ]; then echo " -flushData" >> $CF; fi                     |
    |         if [ $FFC = 1 ]; then echo " -flushConfig" >> $CF; fi                   |
    |         if [ $FFS = 1 ]; then echo " -flushSchedule" >> $CF; fi                 |
    |         if [ $FFL = 1 ]; then echo " -flushLog" >> $CF; fi                      |
    |         if [ $SHT = 1 ]; then                                                   |
    |                 if [ $RST = 1 ]; then                                           |
    |                         shutdown -r 0;                                          |
    |                 else                                                            |
    |                         shutdown -h 0;                                          |
    |                 fi                                                              |
    |         fi                                                                      |
    | done                                                                            |
    |                                                                                 |
    \---------------------------------------------------------------------------------/
```

Build instructions
==================

The DROS executable may be built by untarring, entering the Release folder, and issuing make:

```
  tar -xvf ./precdr.tar.gz
  cd WAVE_Y/Release/
  touch ../*
  make
```

The DROS executable may be also be built by untarring, importing the project into Eclipse (Ganymede), and choosing "Build Project" from eclipse's menu system.

File Inventory
==============

readme.txt	This file.
.project	Eclipse-specific project settings file
.cproject	Eclipse-specific project settings file
/Release/makefile	makefile
/Release/objects.mk	file included by makefile during make
/Release/sources.mk	file included by makefile during make
/Release/subdir.mk	file included by makefile during make

Main.c	performs initialization, main loop, message rx/tx loop, shutdown
Defines.h	defines several constants and macros used throughout
Globals.h	defines several globals which are frequently required
Message.c	Wrapper functions and data structure definitions
MessageQueue.c	for POSIX features and data buffering mechanisms
Socket.c	
RingQueue.c	
Message.h	
MessageQueue.h	
RingQueue.h	
Socket.h	
Persistence.c	Wrappers for libgdbm interface for associative arrays
Persistence.h	and persistent data
DataFormats.h	persistent data formats records
DataFormats.c	
Log.h	persistent system log
Log.c	
Config.h	persistent configuration data
Config.c	
Schedule.h	persistent scheduling, and schedule processing
Schedule.c	
Commands.c	command message processing (includes RPT, which is passed to MIB.c)
Commands.h	
Operations.c	handles the execution of commands which must be scheduled or
Operations.h	can't be executed in the 3 seconds allotted to message-response time. (REC,CPY,DMP,TST,SYN,FMT, etc.)
MIB.c	monitor and control points (MIB) processing
MIB.h	
Disk.c	partition recognition, formatting, mounting
Disk.h	
FileSystem.c	internal storage file system and file functions
FileSystem.h	
Time.c	functions for dealing with and calculating MJD and MPM from system time,
Time.h	as well as various timing mechanisms and utility functions.
HostInterface.h	funcitons for interacting with the host operating system via
HostInterface.c	child process execution

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Dell Precision Workstation R5400: Quad Core Intel® Xeon® Processor E5405 (2.0GHz,2X6M L2,1333)	R520N	1	[223-9631]	1
Operating System: Red Hat Enterprise Linux WS v5 for EM64T 64bit system w/ 1 YR RHN, w/ Media	RH6451Y	1	[420-7036]	11
Hardware Support Services: 3 Year Basic Limited Warranty and 3 Year NBD On-Site Service	Q3YOS	1	[989-0042] [989-3150] [991-2187] [991-2188] [991-2878]	29
Graphic Cards: 256MB PCIe x16 nVidia NVS 290, Dual Monitor DVI Capable	NV290	1	[320-6958]	6
Memory: 4GB, DDR2 SDRAM FBD Memory, 667MHz, ECC (2 DIMMS)	4G2E6	1	[311-8935]	3

Removable Media Storage Device: 8X DVD-ROM, Data Only	DVD8O	1	[313-6619]	16
Hard Drive Configuration: C1 All SATA drives, Non-RAID, 1 drive total configuration	SATA1	1	[341-7029]	9
Boot Hard Drive: 250GB SATA 3.0Gb/s,7200 RPM Hard Drive with 8MB DataBurst Cache™	250ST	1	[341-7553]	8
Riser with 2 slots: Riser with PCIe x16 wired as x8 (1), PCI-X (1)	PCIER	1	[430-3122]	24
Monitors: No Monitor Option	NMN	1	[320-3316]	5
Remote Access Host Card: No Remote access host card for FX100 Remote Access Device	NORAD	1	[330-1085]	19
Rack Rails & Cable Management Arm: Sliding Rapid/Versa Rails and Cable Management Arm,Universal	RAILS	1	[330-0918]	27
Resource DVD: Resource DVD - Contains Diagnostics and Drivers	RDVD	1	[330-0924]	21
Speakers: No Speaker option	NSPKR	1	[313-2663]	18
Keyboard: USB Entry Quietkey, No Hot Keys	U	1	[330-1086]	4
Mouse: New Dell USB Optical Mouse with scroll, All Black Design	LOB	1	[330-1552]	12
Installation Services: No Onsite System Setup	NOINSTL	1	[900-9987]	32

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Processors	Dual-Core (6MB L2 cache) & Quad-Core (2X 6MB L2 cache) Intel® Xeon® Processors.
Operating Systems	Genuine Windows Vista® Ultimate 32Bit; Genuine Windows Vista® Ultimate 64Bit; Genuine Windows Vista® Business 32Bit; Genuine Windows Vista® Business 64Bit; Genuine Windows Vista® Ultimate Downgrade, XP Professional; Genuine Windows Vista® Ultimate Downgrade, XP Professional x64 Edition; Red Hat® Enterprise Linux WS v.5 EM64T. (Also certified to run Red Hat Enterprise Linux Version 4 64-bit.)
Chipset	Intel® 5400 chipset, which supports the latest generation of multi-core Intel® Xeon® Processors, advanced ECC memory, and scalable industry standard graphics and storage options.
Memory	Up to 32GB[1] quad-channel[2] architecture Fully Buffered DIMM 667MHz ECC memory; in 4 DIMM slots (when available).
Flash BIOS	BIOS 8MB flash memory for system BIOS; SMBIOS 2.5 support.
Graphics	Support for 2 PCI Express x16 graphics cards up to 150 watts including: NVIDIA® Quadro® FX 4600; Quadro FX 3700; Quadro FX 1700; NVIDIA Quadro FX570; NVIDIA Quadro NVS 290. All graphics cards support dual monitor configurations.
Hard Drives	The Dell Precision R5400 can be ordered with up to 2 SATA hard drives, with a potential capacity of 2.0TB[2]. And with RAID 0 or 1 options, you can configure your storage to meet your needs for storing extremely large files or helping improve performance with data-striping. SATA 3.0Gb/s 7200 RPM with 16MB DataBurst Cache up to 1.0TB[2]; SATA 3.0Gb/s 7200RPM with 8MB DataBurst Cache™ up to 320GB2; SATA 3.0Gb/s 10K RPM with 16MB DataBurst Cache up to 160GB[2] (when available).
Hard Drive Controller	The R5400 uses an Integrated SATA 3.0Gb/s controller that supports host-based (software) RAID 0, 1.
Network Controller	Dual Broadcom® NetXtreme 10/100/1000 Gigabit Ethernet controllers.
Audio Controller	Integrated High Definition Audio (Rev 1.0 Specification) with Sigmatel STAC9200 High Definition Audio CODEC and Intel ESB2's integrated AC97/ High Definition digital controller.
Standard I/O Ports	Six USB 2.0: two on front panel, three on back panel, and one internal; Two serial; Two PS/2; Two RJ-45; Stereo line-in and line-out on back panel.
Bays	2 internal 3.5" hard disk drive bays; 1 external 5.25" slim-line optical bay.
Slots	All full height and full length accommodated in two risers: Riser 1: Two standard PCIe x16 Gen 1 full length graphics slots each with 150W (300W total) Riser 2: Either: (1) PCIX 64-bit @ 100MHz; (1) PCIe x16, wired as x8 (default) Or: (1) PCIX 64-bit @ 100MHz; (1) PCI 32-bit; 5V
Chassis (2U Rack)	
Dimensions	27" (68.5cm) D x 17.5" (44.4cm) W x 3.4" (8.6cm) H without bezel attached.
Peripherals	
Monitors	Performance flat-panel displays, Dell UltraSharp™ widescreen and standard flat panel displays from 17" viewable to 30" viewable.
Keyboard	Dell Enhanced QuietKey USB. Enhanced Multimedia USB; Smart Card keyboard USB.
Mouse	Dell USB two-button mouse and Dell USB optical two-button scroll mouse.
Optional Speakers	Internal chassis speaker; Dell two- and three-piece stereo system; Dell sound bar for all flat-panel displays.
Storage Devices	
Optional Removable Storage	CD-RW/DVD Combo, DVD-ROM, DVD+/-RW, USB external Floppy Drive.
Optional Connectivity	IEEE 1394a card; Broadcom® NetXtreme 10/100/1000 Gigabit Ethernet controller PCI Express card.
Security	
Software	Trusted Platform Module 1.2 (TPM 1.2); Chassis intrusion switch; Setup/BIOS Password; I/O Interface Security.
Hardware	Front bezel key lock, top chassis cover lock
Environmental & Regulatory	
	You can find additional Safety Best Practices information on the Regulatory Compliance Homepage on www.dell.com at the following location: www.dell.com/regulatory_compliance.
Service & Support	
Base	3-Year Limited Warranty[3] with 3 years standard Next Business Day (NBD) on-site[4] parts replacement and 3 years NBD On-Site Service[4].
Recommended	Dell ProSupport is designed to rapidly respond to your business' needs, protect your investment and sensitive data, and provide enhanced proactive support services to help reduce risk and complexity within your IT environment.

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Dell PCs use Genuine Microsoft® Windows.
1. Up to 1GB may not be available with 32-bit operating systems due to system resource requirements.
2. GB means 1 billion bytes and TB equals 1 trillion bytes; actual capacity varies with preloaded material and operating environment and will be less.
3. For a complete copy of our guarantees and limited warranties, please write Dell U.S.A. L.P., Attention: Warranties, One Dell Way, Round Rock, TX 78682.
For more information, visit . www.dell.com/warranty
4. May be provided by third-party. Technician dispatched, if necessary, following phone-based troubleshooting. Availability varies. See dell.com/servicecontracts for details.

PowerConnect 6224 Details

Advanced Layer 3 Switching 24 Port Stackable Switch

The PowerConnect™ 6224 is a high performance switch offering with advanced core switching capabilities for the small to medium enterprise.

- 24-port Gigabit Ethernet Layer 3 switch
- Stacking for up to twelve systems
- Supports 10GBase T and SFP+ 10GE Modules

Resources

- PowerConnect 6200 Series specsheet
- The Tolly Group - PowerConnect 6224/6248 Throughput Evaluation
- Dell PowerConnect™ switches help build a high performance computing (HPC) cluster at Stanford University
- Featured Case Study: Hosted Solutions

PowerConnect 6224

Starting Price	$1,798
Instant Savings	$270
Subtotal	**$1,528**

Lease from **$41**/mo. (48 pmts)[1]

Collapse

PowerConnect 6224
PowerConnect 6224, 24 GbE Ports, Managed Switch, 10GbE and Stacking Capable

Hardware Support Services
3Yr Basic Hardware Warranty[2] Repair: 5x10 HW-Only, 5x10 NBD Parts

Offers subject to change. Taxes, shipping, handling and other fees apply. U.S. Dell Small Business new purchases only. LIMIT 5 DISCOUNTED OR PROMOTIONAL ITEMS PER CUSTOMER. LIMIT 5 VOSTRO UNITS PER CUSTOMER. Dell reserves right to cancel orders arising from pricing or other errors.

DELL™ POWERCONNECT™ 6200 SERIES SWITCHES

The PowerConnect 6200 series is Dell's most advanced switching product line, offering advanced switching capabilities including high-density, high-performance stacking and 10 Gigabit Ethernet capabilities scalable from the small business to the Enterprise Edge.

HIGH DENSITY

The PowerConnect 6200 series offers versions with 24 and 48 ports of 10/100/1000BASE-T Gigabit Ethernet. The PowerConnect 6248 and 6224 series switches support up to four 10 Gigabit Ethernet uplinks for connectivity directly to 10GE routers, servers, enterprise backbones and data centers. Delivering significant rack density, the PowerConnect 6200 gives users the flexibility to maximize server and workstation connectivity in a 1U form factor. Up to 576 servers and/or clients can be connected in a stack of 6200 series switches to help provide the maximum density, flexibility and manageability.

HIGH-PERFORMANCE STACKING

The PowerConnect 6200 series supports high-performance resilient stacking for up to twelve systems, which allows increased throughput to be added as needed without affecting network performance. With each switch supporting up to 184 Gbps in switch capacity, the customer can have almost 2 Terabits of capacity in a single stack!

10 GIGABIT ETHERNET

The PowerConnect 6200 series switches support up to four 10 Gigabit Ethernet uplinks for connectivity directly to 10GE routers, servers, enterprise backbones and data centers.

GIGABIT FIBER CONNECTIVITY

The PowerConnect 6224F offers up to 24 Fiber GbE ports for the small to medium enterprise network backbone or long-haul connectivity.

ADVANCED LAYER 3 CAPABILITIES

The PowerConnect 6200 series supports advanced Layer 3 routing and multicast protocols to help reduce congestion and manage traffic in the network. The PowerConnect 6200 series supports frequently used LAN routing protocols such as RIPv1/v2, OSPFv2/v3, VRRP, IGMP, DVMRP, PIM and LLDP-MED.

ADVANCED QoS

The PowerConnect 6200 offers flexibility in Quality of Service (QoS) by giving network administrators the ability to prioritize time-critical network traffic based on a variety of user-defined criteria. Administrators can expedite traffic based on L2 or L3 information to provide greater control over traffic flow within the network.

ADVANCED SECURITY

Support for L2-L4 Access Control Lists (ACLs) on the switch allows the user to perform deep packet inspection. 802.1x port authentication offers both single and multiple host access. Further security is provided through Denial of Service (DoS) Attack Prevention, whereby the switch can protect against common network attacks, such as Blat, Land, Smurf, Ping of Death, Xmascan, Nullscan, Scan SYNFIN, in addition to CPU attacks, such as VLAN flooding, TCP SIM, TCP port scan, IP address spoofing and MAC address spoofing.

IPv6 READY

IPv6 is version six of the "Internet Protocol" that has been in development for over 20 years. IPv6 has been designed to address IP address limitations of previous version of the Internet Protocol, enabling an increased number of unique IP addresses for broader scalability worldwide now and in the future.

VALUE AND FLEXIBILITY

The PowerConnect™ 6200 series offers additional value because the unique modular design allows you to upgrade to advanced stacking or 10 Gigabit Ethernet only when you need it. Plus the 6200 series offers further flexibility and value with optional modules that allow for either 10 Gigabit optical or CX-4 copper interfaces, or both, based on your needs.

INTRODUCING DELL PROSUPPORT

Designed to address the technology challenges you face today. Designed for IT professionals like you, Dell ProSupport for IT provides 7x24 direct access to Dell Expert Centers, fast-track dispatch of parts and labor without phone troubleshooting when desired for Dell-certified technicians, and escalation management through Dell's Global Command Centers. In addition, Dell ProSupport optional services align with the way you use technology by providing rapid response to your needs, helping to protect your investment, productivity and sensitive data, and enhancing proactive support services to help reduce the risk and complexity of managing your infrastructure.

Speed of Response

With the Mission Critical[1] option you get priority response for server and storage environments when avoiding unplanned downtime and reducing recovery time are critical. Includes priority 4-hr onsite[1] service or optional 2-hr response[1] with 6-hr hardware repair,[1] Dell's proven Critical Situation process, and emergency dispatch.

Protection

With the Keep your Hard Drive[2] option you retain control of your sensitive data and comply with data privacy regulations (to help mitigate regulatory and civil liability risks) by keeping your hard drive.

Premium Proactive

With the Enterprise-Wide Contract option, you get enhanced, proactive capabilities via a designated Service Delivery Manager, performance benchmarking and custom reporting, and planning and assessments. Our Proactive Maintenance option is designed to proactively maximize the availability and stability of your infrastructure. Includes a detailed system assessment and implementation of driver or firmware updates and upgrades for your server or storage systems. Remote Advisory option provides telephone and Internet access to technical expertise for specialized applications and solutions such as Microsoft Exchange, Virtualization, and more.

ADDITIONAL SERVICE OFFERINGS

Comprehensive Storage Training and Certification

Provides expertise for integrating Dell storage into an existing IT infrastructure. For company compliance, an advanced certification path is available for validating or maintaining skill sets.

Backup and Recovery

Solutions that help ensure adequate procedures are in place to minimize or avoid data loss.

Storage Consolidation

Our storage experts can analyze your existing infrastructure, operational practices and technical readiness, and develop a detailed consolidation deployment plan that includes a validated and refined solution design.

To help you get the most from your Dell systems, visit www.dell.com/services

Services vary by region.

[1] For terms of service, please visit www.dell.com/servicecontracts
[2] The defective hard drive must still be covered by the hardware limited warranty.

FEATURES	DELL™ POWERCONNECT™ 6248	DELL™ POWERCONNECT™ 6224	DELL™ POWERCONNECT™ 6224F High Performance all-Fiber Gigabit Ethernet Switch. Enhanced Fiber capabilities provides for distances up to 2 km
Port Attributes	48 10/100/1000BASE-T auto-sensing Gigabit Ethernet switching ports; 4 SFP combo ports for fiber media support; 10 Gigabit Ethernet uplink modules (optional); Resilient stacking up to 12 systems (with optional module); Auto-negotiation for speed, duplex mode and flow control; Auto MDI/MDIX; Port mirroring; Flow-based port mirroring; Broadcast storm control	24 10/100/1000BASE-T auto-sensing Gigabit Ethernet switching ports; 4 SFP combo ports for fiber media support; 10 Gigabit Ethernet uplink modules (optional); Resilient stacking up to 12 systems (with optional module); Auto-negotiation for speed, duplex mode and flow control; Auto MDI/MDIX; Port mirroring; Flow-based port mirroring; Broadcast storm control	24 1000-SX or 1000-LX Gigabit Ethernet ports; 4 Combo (SFP or 10/100/1000) Gigabit Ethernet ports; Up to 4 10-Gigabit Ethernet Ports; Resilient Stacking up to 12 systems (with optional module); Distances: 1000BASE-SX : Up to 500 m 1000BASE-LX : Up to 2 km; Auto-negotiation for speed, duplex mode and flow control; Auto MDI/MDIX; Port mirroring; Flow-based port mirroring; Broadcast storm control
Performance	Switch Fabric Capacity 184 Gb/s Forwarding Rate 131 Mpps Up to 8,000 MAC Addresses 256MB of CPU SDRAM 32MB of Flash Memory	Switch Fabric Capacity 136 Gb/s Forwarding Rate 95 Mpps Up to 8,000 MAC Addresses 256MB of CPU SDRAM 32MB of Flash Memory	Switch Fabric Capacity 136 Gb/s Forwarding Rate 95 Mpps Up to 8,000 MAC Addresses 256MB of CPU SDRAM 32MB of Flash Memory
Availability	Spanning Tree (IEEE 802.1D) and Rapid Spanning Tree (IEEE 802.1w) with Fast Link Support; Multiple spanning trees (IEEE 802.1s); Supports Virtual Redundant Routing Protocol (VRRP); External redundant power support with PowerConnect RPS-600 (sold separately); Cable diagnostics; SFP transceiver diagnostics		
Layer 3 Routing Protocols	Static Routes; Routing Information Protocol (RIP) v1/v2; Open Shortest Path First (OSPF) v1/v2/v3; Classless Inter-Domain Routing (CIDR); Internet Control Message Protocol (ICMP); ICMP Router Discover Protocol (IRDP); Virtual Redundant Routing Protocol (VRRP); Address Resolution Protocol (ARP); Internet Group Management Protocol (IGMP) v2; Distance-Vector Multicast Routing Protocol (DVMRP)		
VLAN	VLAN support for tagging and port-based as per IEEE 802.1Q; Double VLAN tagging (QinQ); Up to 4093 VLANs supported; Dynamic VLAN with GVRP support		
Quality of Service	Layer 2 Trusted Mode (IEEE 802.1p tagging); Layer 3 Trusted Mode (DSCP); Layer 4 Trusted Mode (TCP/UDP); Advanced Mode using Layer 2/3/4 flow-based Policies, including metering/rate limiting, marking and bandwidth guarantees; up to 100 ACLs can be used for QoS flow identification via Class-maps; 8 Priority Queues per Port; Adjustable Weighted-Round-Robin (WRR) and Strict Queue Scheduling; Port-based QoS Services Mode; Flow-based QoS Services Mode		
Layer 2 Multicast	Static IP Multicast; Dynamic Multicast Support – 256 Multicast groups supported in IGMP Snooping; IGMP snooping for IP multicast support; IGMP Querier; Protocol Independent Multicast (PIM-DM, PIM-SM)		
Security	IEEE 802.1x-based edge authentication; Switch access password protection; User-definable settings for enabling or disabling Web, SSH, Telnet, SSL management access; Port-based MAC Address alert and lock-down LLDP-MED; IP Address filtering for management access via Telnet, HTTP, HTTPS/SSL, SSH and SNMP; RADIUS and TACACS+ remote authentication for switch management access; Up to 100 Access Control Lists (ACLs) supported; up to 12 Access Control Entries (ACEs) per ACL; SSLv3 and SSHv2 encryption for switch management traffic; Management access filtering via Management Access Profiles		
Other Switching Features	Link Aggregation with support for up to 8 aggregated links per switch and up to 8 member ports per aggregated link (IEEE 802.3ad); LACP support (IEEE 802.3ad) Link Layer Discovery Protocol supported (IEEE 802.1AB)		
Management	Web-based management interface; Industry-standard CLI accessible via Telnet or Local Serial Port; SNMPv1, SNMPv2c and SNMPv3 supported; four RMON groups supported (history, statistics, alarms and events); TFTP transfers of firmware and configuration files; Dual firmware images on-board; Multiple configuration file upload/download supported; Statistics for error monitoring and performance optimization including port summary tables; BootP/DHCP IP address management supported; Syslog remote logging capabilities; Temperature sensors for environmental monitoring		
Chassis	Approximate weight (without modules): 13.4 lbs, 6.06 kg Approximate weight (with modules): 13.7 lbs, 6.20 kg 440 x 387 x 43.2 mm (W x D x H); 17.3" x 15.2" x 1.7"; 1U, rack-mounting kit included	Approximate weight (without modules): 12.2 lbs, 5.54 kg Approximate weight (with modules): 12.6 lbs, 5.70 kg 440 x 387 x 43.2 mm (W x D x H); 1U, rack-mounting kit included	Approximate weight (without modules): 12.2l bs, 5.54 kg Approximate weight (with modules): 12.6 lbs, 5.70 kg 440 x 387 x 43.2 mm (W x D x H); 1U, rack-mounting kit included
Optional Peripheral Products	RPS-600 Redundant Power Supply EPS 470 Redundant Power Supply for POE models SFP Optical Transceivers, 1000BASE-SX, LC Connector SFP Optical Transceiver, 1000BASE-LX, LC Connector CX-4 Module	XFP Module 10GBase-T Module Stacking Module with 1 Meter Dell stacking cable 3 meter stacking cable	

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Processors

- ☐ Intel® Core™ i7-920 Processor(8MB L2 Cache, 2.66GHz) [subtract $470]
- ☑ Intel® Core™ i7-940 Processor(8MB L2 Cache, 2.93GHz) [Included in Price]

Hardware Support Services

- ☐ 4Yr Ltd Hardware Warranty, InHome Service after Remote Diagnosis [add $299 or $9/month[1]]
- ☐ 4 yr In-home Service after remote diagnosis + Complete Care [add $368 or $12/month[1]]
- ☐ 4 yr In-home Service after remote diagnosis + Complete Care, FL [add $368 or $12/month[1]]
- ☐ 4 yr In-home Service after remote diagnosis + Your Tech Team [add $528 or $16/month[1]]
- ☐ 4 yr In-home Service after remote diagnosis + Your Tech Team, FL [add $528 or $16/month[1]]
- ☐ 4 yr In-home Service after remote diagnosis+Your Tech Team+Complete Care [add $597 or $18/month[1]]
- ☐ 4 yr In-home Svc after remote diagnosis+Your Tech Team+Complete Care, FL [add $597 or $18/month[1]]
- ☐ 3Yr Ltd Hardware Warranty, InHome Service after Remote Diagnosis [add $249 or $8/month[1]]
- ☐ 3Yr Ltd Hardware Warranty, InHome Service after Remote Diagnosis,Florida [add $249 or $8/month[1]]

- [ ] 3 yr In-home Service after remote diagnosis + Complete Care [add $318 or $10/month[1]]
- [ ] 3 yr In-home Service after remote diagnosis + Complete Care, FL [add $318 or $10/month[1]]
- [ ] 3 yr In-home Service after remote diagnosis + Your Tech Team [add $438 or $14/month[1]]
- [ ] 3 yr In-home Service after remote diagnosis + Your Tech Team, FL [add $438 or $14/month[1]]
- [ ] 3 yr In-home Service after remote diagnosis+Your Tech Team+Complete Care [add $507 or $16/month[1]]
- [ ] 3 yr In-home Svc after remote diagnosis+Your Tech Team+Complete Care, FL [add $507 or $16/month[1]]
- [ ] 2Yr Ltd Hardware Warranty, InHome Service after Remote Diagnosis [add $149 or $5/month[1]]
- [ ] 2Yr Ltd Hardware Warranty, InHome Service after Remote Diagnosis,Florida [add $149 or $5/month[1]]
- [ ] 2 yr In-home Service after remote diagnosis + Complete Care [add $218 or $7/month[1]]
- [ ] 2 yr In-home Service after remote diagnosis + Complete Care, FL [add $218 or $7/month[1]]
- [ ] 2 yr In-home Service after remote diagnosis + Your Tech Team [add $298 or $9/month[1]]
- [ ] 2 yr In-home Service after remote diagnosis + Your Tech Team, FL [add $298 or $9/month[1]]
- [ ] 2 yr In-home Service after remote diagnosis+Your Tech Team+Complete Care [add $367 or $11/month[1]]
- [ ] 2 yr In-home Svc after remote diagnosis+Your Tech Team+Complete Care, FL [add $367 or $11/month[1]]
- [x] 1Yr Ltd Hardware Warranty, InHome Service after Remote Diagnosis [Included in Price]
- [ ] 1Yr Ltd Hardware Warranty, InHome Service after Remote Diagnosis,Florida add $0
- [ ] 1 yr In-home Service after remote diagnosis + Complete Care [add $69 or $3/month[1]]
- [ ] 1 yr In-home Service after remote diagnosis + Complete Care, FL [add $69 or $3/month[1]]
- [ ] 1 yr In-home Service after remote diagnosis + Your Tech Team [add $99 or $3/month[1]]
- [ ] 1 yr In-home Service after remote diagnosis + Your Tech Team, FL [add $99 or $3/month[1]]
- [ ] 1 yr In-home Service after remote diagnosis+Your Tech Team+Complete Care [add $168 or $6/month[1]]
- [ ] 1 yr In-home Svc after remote diagnosis+Your Tech Team+Complete Care, FL [add $168 or $6/month[1]]

Operating System

- [x] Genuine Windows Vista® Home Premium Edition SP1, 64-Bit [Included in Price]
- [ ] Genuine Windows Vista® Ultimate SP1 64-bit [add $150 or $5/month[1]]

Office Productivity Software (Pre-Installed)

- [ ] Microsoft® Office Home and Student 2007 [add $149 or $5/month[1]]
- [ ] Microsoft® Office Small Business 2007 [add $279 or $9/month[1]]
- [ ] Microsoft® Office Home and Student 2007 + Adobe® Acrobat ® 9 [add $179 or $6/month[1]]
- [ ] Microsoft® Office Professional 2007 [add $399 or $12/month[1]]
- [ ] Microsoft® Works Plus 2008 [add $79 or $3/month[1]]
- [x] Microsoft Works 9 [Included in Price]

Memory

- [ ] 3GB DDR3 Tri-Channel SDRAM at 1066MHz - 3 DIMMs [subtract $150]
- [ ] 4GB Dual Channel DDR3 SDRAM at 1066MHz - 4 DIMMs [subtract $100]
- [x] 6GB Tri-Channel DDR3 SDRAM at 1066MHz - 6 DIMMs [Included in Price]
- [ ] 8GB Dual Channel DDR3 SDRAM at 1066MHz - 6 DIMMs [add $100 or $3/month[1]]
- [ ] 12GB Tri-Channel DDR3 SDRAM at 1066MHz - 6 DIMMs [add $300 or $9/month[1]]

Hard Drives

- [ ] 500GB - 7200RPM, SATA 3.0Gb/s, 16MB Cache [subtract $200]
- [ ] 750GB - 7200RPM, SATA 3.0Gb/s, 16MB Cache [subtract $100]
- [x] 1TB - 7200RPM, SATA 3.0Gb/s, 16MB Cache [Included in Price]
- [ ] 640GB Performance RAID 0 (2 x 320GB SATA 3Gb/s 7200 RPM HDDs) [subtract $100]
- [ ] 1TB Performance RAID 0 (2 x 500GB SATA 3Gb/s 7200 RPM HDDs) [subtract $50]
- [ ] 1.28 TB Performance RAID 0 (2 x 640GB SATA 3Gb/s 7200 RPM HDDs) [subtract $25]

- [ ] 500GB Data Security RAID 1 (2 x 500GB SATA 3Gb/s 7200 RPM HDDs) [subtract $50]
- [ ] 640GB Data Security RAID 1 (2 x 640GB SATA 3Gb/s 7200 RPM HDDs) [subtract $25]

Optical Drives

- [x] Single Drive: 16X CD/DVD burner (DVD+/-RW) w/double layer write capability [Included in Price]
- [ ] Single Drive: Internal Qflix-enabled DVD Burner [add $20 or $1/month[1]]
- [ ] Dual Drives: 16x DVD-ROM Drive + 16x DVD+/-RW w/ dbl layer write capability [add $30 or $1/month[1]]
- [ ] Dual Drives: Internal Qflix-enabled DVD Burner and DVD-ROM [add $50 or $2/month[1]]
- [ ] Single Drive: Blu-ray Disc (BD) Combo (Reads BD and Writes to DVD/CD) [add $120 or $4/month[1]]
- [ ] Dual Drives: Blu-ray Disc (BD) Combo (BD-ROM; DVD/CD Burner) and DVD+/-RW [add $150 or $5/month[1]]
- [ ] Single Drive: Blu-ray Disc (BD) Burner (Writes to DVD/CD/BD) [add $200 or $6/month[1]]
- [ ] Dual Drives: Blu-ray Disc (BD) Burner (Writes to DVD/CD/BD) and DVD+/-RW [add $230 or $7/month[1]]

Monitor

- [x] Dell S1909WX 19 inch Widescreen Flat Panel Monitor [Included in Price]
- [ ] No Monitor [subtract $180]
- [ ] 21.5 inch Dell S2209W Full HD Widescreen Monitor [add $50 or $2/month[1]]
- [ ] Dell 23 inch Consumer™ S2309W Flat Panel, Adjustable Stand [add $70 or $3/month[1]]
- [ ] Dell 24 inch Consumer™ S2409W Flat Panel, Adjustable Stand [add $160 or $5/month[1]]
- [ ] 20” Dell SP2009W Widescreen LCD with 2.0 Megapixel Webcam, Dual Microphones [add $70 or $3/month[1]]
- [ ] 20 inch UltraSharp™ 2009WFP Widescreen Digital Flat Panel [add $20 or $1/month[1]]
- [ ] 24 inch Ultrasharp™ 2408WFP Digital Flat Panel [add $490 or $15/month[1]]

Large Displays

- [ ] Dell Ultrasharp 2709WFP 27-inch Widescreen Flat Panel LCD Monitor [$849 or $26/month[1]]
- [ ] Dell Ultrasharp 3007WFP-HC 30-inch Widescreen Flat Panel LCD Monitor [~~**$1,299**~~ $1,099 or $33/month[1]]

- [ ] Dell Ultrasharp 3008WFP 30-inch Widescreen Flat Panel LCD Monitor [$1,699 or $51/month[1]]

Video Card

- [x] ATI Radeon HD 3450 256MB [Included in Price]
- [ ] ATI Radeon HD 3650 256MB [add $50 or $2/month[1]]
- [ ] ATI Radeon HD 4670 512MB [add ~~$100~~ $70 or $3/month[1]]
- [ ] ATI Radeon HD 4850 512MB [add $200 or $6/month[1]]

Sound Card

- [x] Integrated 7.1 Channel Audio [Included in Price]
- [ ] Soundblaster X-Fi Hi Def Audio - Software Enabled [add $25 or $1/month[1]]
- [ ] Soundblaster X-Fi Xtreme Audio [add $70 or $3/month[1]]

Speaker

- [x] No speakers (Speakers are required to hear audio from your system) [Included in Price]
- [ ] Dell A525 30 Watt 2.1 Stereo Speakers with Subwoofer [add $50 or $2/month[1]]
- [ ] Dell AX510PA 10W Attached Speaker for Dell Flat Panel Monitors [add $10 or $1/month[1]]
- [ ] Bose Companion 2 Series II Multimedia Speaker System [add $110 or $4/month[1]]
- [ ] Bose Companion 3 Series II Multimedia Speaker System [add $270 or $9/month[1]]

TV Tuner

- [x] None
- [ ] Hauppauge Computer Win TV-HVR-950Q Hybrid Video Recorder – Watch/Record TV on your PC [add $83 or $3/month[1]]

Keyboard

- [ ] Logitech Cordless Desktop S 510 Keyboard and Mouse - Arctic Silver [add $31 or $1/month[1]]
- [ ] Logitech Illuminated Keyboard [add $51 or $2/month[1]]
- [ ] Logitech G15 Gaming Keyboard [add $75 or $3/month[1]]
- [ ] Logitech Cordless Desktop MX 5500 Revolution [add $135 or $5/month[1]]

- [x] Dell USB Consumer Multimedia Keyboard [Included in Price]
- [ ] Keyboard included in Dell Bluetooth Package [subtract $25]

Mouse

- [ ] Microsoft Arc Mouse Black [add $40 or $2/month[1]]
- [ ] Logitech VX Revolution [add $70 or $3/month[1]]
- [ ] Logitech G9 Laser Gaming Mouse [add $80 or $3/month[1]]
- [ ] Logitech MX Revolution Mouse [add $90 or $3/month[1]]
- [x] Dell Premium Laser Mouse [Included in Price]
- [ ] Mouse included in Dell Bluetooth Package [subtract $10]

Bluetooth Options

- [x] None
- [ ] Dell Bluetooth Wireless Media Hub + VOIP Stereo Headset [add $90 or $3/month[1]]
- [ ] Dell Bluetooth Wireless Media Hub + Keyboard/Mouse [add $100 or $3/month[1]]
- [ ] Dell Bluetooth Wireless Media Hub + Keyboard/Mouse + VOIP Stereo Headset [add $150 or $5/month[1]]
- [ ] Dell 19 in 1 Media Reader with Bluetooth [add $40 or $2/month[1]]
- [ ] 19 in 1 Media Card Reader [add $20 or $1/month[1]]

Floppy Drive or Media Card Reader

- [x] No Floppy Drive or Media Reader Included [Included in Price]
- [ ] Dell Media Card Reader included in Dell Bluetooth Package add $0

Network

- [x] None
- [ ] Dell 1505 WLAN PCIe card with11n mini-Card & external antenna [add $70 or $3/month[1]]

Environmental Options

- [x] None
- [ ] Recycle my old system with Dell (FREE) add $0
- [ ] Support Reforestation: Plant a Tree for Me [add $6 or $1/month[1]]
- [ ] Recycling Kit and Plant a Tree for Me [add $6 or $1/month[1]]

Accessories

- [ ] Logitech VX Nano Mouse [$70 or $3/month[1]]
- [ ] Belkin Surge Protector Bundle [$33 or $1/month[1]]
- [ ] Logitech Z-4 Multimedia Speaker System [$80 or $3/month[1]]

Adobe Software

- [x] Adobe® Acrobat® Reader 9.0 Multi-Language [Included in Price]

Direct Line

- [x] None
- [ ] Your Tech Team Unlimited 1 YR [add $99 or $3/month[1]]

Dell Printers

- [ ] Dell V305 All In One Printer [$99 or $3/month[1]]
- [ ] Dell V305w All In One WiFi Printer [$129 or $4/month[1]]
- [ ] Dell P703w All-In One Printer [$199 or $6/month[1]]
- [ ] 968w All In One Wireless Printer [$219 or $7/month[1]]
- [ ] Dell V505w All In One (PRODUCT)RED™ Printer [$169 or $6/month[1]]

Security Software

- [ ] McAfee SecurityCenter with anti-virus, anti-spyware, firewall, 15-months add $0
- [ ] McAfee SecurityCenter with anti-virus, anti-spyware, firewall, 24-months [add $19 or $1/month[1]]
- [ ] McAfee SecurityCenter with anti-virus, anti-spyware, firewall, 36-months [add $39 or $2/month[1]]
- [ ] Trend Micro Internet Security with AntiVirus and Spyware removal 15-months add $0

- [x] No Security software pre-installed [Included in Price]

Entertainment and Editing Software

- [ ] Adobe® Photoshop® Elements [$79 or $3/month[1]]
- [ ] Adobe® Premier® Elements [$79 or $3/month[1]]
- [ ] Adobe® Photoshop® Elements + Adobe® Premiere® Elements [$99 or $3/month[1]]

Gaming Software

- [ ] Need For Speed: Undercover [$40 or $2/month[1]]
- [ ] High School Musical 3: Senior Year Dance! [$30 or $1/month[1]]
- [ ] Call of Duty: World at War [$50 or $2/month[1]]
- [ ] World of Warcraft: Wrath of the Lich King - Expansion Pack [$40 or $2/month[1]]
- [ ] Far Cry 2 [$50 or $2/month[1]]
- [ ] Crysis Warhead [$30 or $1/month[1]]

Gaming Accessories

- [ ] Logitech Rumblepad 2 [$30 or $1/month[1]]
- [ ] Razer Barracuda HP-1 [$116 or $4/month[1]]
- [ ] Astro Gaming A40 Audio System – Black [$250 or $8/month[1]]
- [ ] Logitech Force 3D Pro [$56 or $2/month[1]]
- [ ] Logitech MOMO Racing Force Feedback Wheel & Pedals [$90 or $3/month[1]]
- [ ] Saitek X52 Pro Flight Control [$150 or $5/month[1]]

Top Selling Software

- [ ] Quicken Home and Business 2009 [~~**$100**~~ $55 or $2/month[1]]
- [ ] Sony Imagination Studio Suite [~~**$200**~~ $100 or $3/month[1]]
- [ ] Norton 360 3.0 - Complete Package [~~**$80**~~ $68 or $3/month[1]]

- [ ] McAfee Total Protection 2009 – 3 Users [~~$68~~ $38 or $2/month[1]]
- [ ] Webroot Internet Security with SpySweeper - up to 3 PCs [~~$60~~ $30 or $1/month[1]]
- [ ] Laplink PCmover – moves everything to your new PC [~~$50~~ Free!]
- [ ] Corel Paint Shop Pro Photo X2 [$76 or $3/month[1]]
- [ ] Quickbooks Accounting Pro 2009 [~~$200~~ $130 or $4/month[1]]
- [ ] Digital Scrapbook Artist [~~$40~~ $30 or $1/month[1]]

Networking Options

- [ ] Netgear WNR2000 Wireless-N Broadband Router [$80 or $3/month[1]]
- [ ] Linksys WRT160N Wireless-N Home Router [~~$80~~ $70 or $3/month[1]]
- [ ] Netgear WNDR3300 RangeMax Dual Band Wireless-N Router [$100 or $3/month[1]]
- [ ] Linksys WRT610N Wireless N Simultaneous Dual band Entertainment Router with 4 Gigabit port switch [$170 or $6/month[1]]
- [ ] XCAT6 Snagless Molded Blue Cable – 10 ft [$22 or $1/month[1]]
- [ ] Netgear 500 GB ReadyNAS Duo Network Attach Storage (1 Drive & Upgradable) [$400 or $12/month[1]]
- [ ] Linksys WRT310N Wireless-N Gigabit Router [$110 or $4/month[1]]

Power Protection

- [ ] Belkin 7-Outlet Small Conceal Surge Protector [$23 or $1/month[1]]

Storage Backup

- [ ] 8GB Cruzer Micro USB Flash Drive [$27 or $1/month[1]]
- [ ] WD 500GB My Book Essential External Storage [$90 or $3/month[1]]
- [ ] WD 1TB My Book Essential External Storage [$130 or $4/month[1]]
- [ ] Seagate 1.5TB FreeAgent External Storage [~~$150~~ $136 or $5/month[1]]
- [ ] 1TB My Book World Network Storage [$200 or $6/month[1]]

Hot Deals

- [ ] McAfee Total Protection [$50 or $2/month[1]]
- [ ] 400GB My Passport Essential Cherry Red [~~$110~~ $90 or $3/month[1]]
- [ ] TomTom XL 330 GPS [~~$180~~ $144 or $5/month[1]]

Movie Bundles

- [ ] The Best of Monty Python [$19 or $1/month[1]]
- [ ] The Will Smith A-List Collection [$29 or $1/month[1]]
- [ ] Spider-Man Trilogy [$20 or $1/month[1]]
- [ ] Bust A Gut Comedy Collection [$25 or $1/month[1]]
- [ ] Batman Begins & Dark Knight w/ Bonus Content [$25 or $1/month[1]]
- [ ] Godfather Trilogy movie bundle [$30 or $1/month[1]]
- [ ] Romantic Comedy bundle 2 [$27 or $1/month[1]]
- [ ] The Fast & Furious 3-movie collection [$25 or $1/month[1]]
- [ ] Iron Man movie with bonus content [$20 or $1/month[1]]
- [ ] The Matrix Trilogy and Animatrix [$25 or $1/month[1]]
- [ ] Nickelodeon Collection [$25 or $1/month[1]]

Music Bundles

- [ ] #1 Songs 50 MP3 Songs [$25 or $1/month[1]]
- [ ] #1 Songs 100 MP3 Songs [$45 or $2/month[1]]
- [ ] #1 Songs 200 MP3 Songs [$75 or $3/month[1]]
- [ ] Afternoon Delight 50 MP3 Songs [$25 or $1/month[1]]
- [ ] Afternoon Delight 100 MP3 Songs [$45 or $2/month[1]]
- [ ] Blues Masters 50 MP3 Songs [$25 or $1/month[1]]

- [ ] Blues Masters 100 MP3 Songs [$45 or $2/month[1]]
- [ ] The Classics 100 MP3 Songs [$45 or $2/month[1]]
- [ ] Freshmen 50 MP3 Songs [$25 or $1/month[1]]
- [ ] Freshmen 100 MP3 Songs [$45 or $2/month[1]]
- [ ] Rock Titans 50 MP3 Songs [$25 or $1/month[1]]
- [ ] Rock Titans 100 MP3 Songs [$45 or $2/month[1]]
- [ ] Rock Titans 200 MP3 Songs [$75 or $3/month[1]]
- [ ] Sweatbands & Leotards 50 MP3 Songs [$25 or $1/month[1]]
- [ ] Sweatbands and Leotards 100 MP3 Songs [$45 or $2/month[1]]

Dell Remote Access

- [x] Dell Remote Access, free basic service [Included in Price]
- [ ] Dell Remote Access, 1Yr Subscription [add $99 or $3/month[1]]

Extended Service

- [x] None
- [ ] On Call Services 30 days [add $49 or $2/month[1]]
- [ ] On Call Services 13 months [add $149 or $5/month[1]]

Service 1

- [ ] None
- [ ] Dell Online Backup 100GB for 1 year [add $59 or $2/month[1]]
- [ ] Dell Online Backup 50GB for 1 year [add $49 or $2/month[1]]
- [ ] Dell Online Backup 30GB for 1 year [add $39 or $2/month[1]]
- [ ] Dell Online Backup 10GB for 1 year [add $29 or $1/month[1]]
- [ ] Dell Online Backup 5GB for 1 year [add $10 or $1/month[1]]

Dell Online Backup 2GB for 1 year [Included in Price]

PC Tune Up

None

1 Year Automated PC Tune Up 2.0 [add $29 or $1/month[1]]

3 Year Automated PC Tune Up 2.0 [add $49 or $2/month[1]]

Installation

None

In-Home System Setup [add $149 or $5/month[1]]

In-Home System and Wireless Network Setup [add $229 or $7/month[1]]

In-Home System Setup with Data Transfer [add $229 or $7/month[1]]

Print

How to Contact Dell

Phone	Fax
800-915-3355	800-317-3355

Address

Dell Inc.

One Dell Way

Round Rock, Texas 78682

Offers subject to change, not combinable with all other offers. Taxes, shipping, handling and other fees apply. Dell reserves the right to cancel orders arising from pricing or other errors. Limit of 5 systems per customer please.

[1] DELL PREFERRED ACCOUNT (DPA) - Offered to U.S. residents by CIT Bank, who determines qualifications for and terms of credit. Promotion eligibility varies and is determined by CIT Bank. Qualifying for DPA does not guarantee promotion. Taxes, shipping, and other charges are extra and vary. Minimum monthly payments are the greater of $15 or 3% of account balance.

Print Summary

Precision T1500 64 bit

Starting Price **$1,989**

Quickly create your own professional-looking custom forms, such as customer estimates, invoices and reports by using any of the over 100 included templates. Upgrade to Quickbooks Software Now!

Lease from **$53**/mo. (48 pmts)[1]

Dell Business Credit | Apply

Preliminary Ship Date: **11/18/2009**

My Selections **All Options**

- **Precision T1500 64 bit**

Date	10/21/2009 10:31:59 AM Central Standard Time
Catalog Number	4 Retail 04

Catalog Number / Description	Product Code	Qty	SKU	Id
Dell Precision T1500: Dell Precision T1500, Minitower	T1500	1	[224-6803]	1
Processor: Quad Core Processor Core i7-870,2.93GHz,8MB	I7870	1	[317-2380]	2
Operating System: Genuine Windows® 7 Professional, with Media, 64-bit, English	W7P6E	1	[330-6228] [421-1485]	11
Memory: 8GB, DDR3 Non-ECC SDRAM Memory,1333MHz, 4X2GB	8G3N34	1	[317-2386]	3
Hardware Support Services: 3 Year Basic Limited Warranty and 3 Year NBD On-Site Service	Q3YOS	1	[905-0272] [905-1717] [905-3458] [905-7800]	29
Graphics: 256MB NVIDIA® Quadro® NVS 295, 2MON, 2 DP w/ 1 DP to DVI Adapter	NVS2951	1	[320-1196] [330-4085]	6
1394 Controller: No 1394	MT	1	[311-7463]	15
Hard Drive Configuration: C1 All SATA Hard Drives ,Non- RAID for 1 Hard Drive	SATA1	1	[341-1256]	9
Boot Hard Drive: 80GB SATA 3.0Gb/s,7200 RPM Hard Drive with 8MB DataBurst Cache™	80GB	1	[341-1255]	8
DVD and Read-Write Devices: 16X DVD-ROM with Cyberlink Power DVD™	DVD16	1	[313-9193] [330-6758] [421-0536]	16
Monitor: No Monitor	NMN	1	[320-3316]	5
Media Card Reader: No Media Card Reader	NOMCR	1	[330-5783]	10
Resource DVD: Resource DVD	RDVD	1	[330-5526]	27
Quick Reference Guide: Quick Reference Guide, English	REFE	1	[330-5528]	39
Shipping Packaging Options: Shipping Material for System	SHIP	1	[330-6760]	40
Sound Card: Integrated 5.1 Channel Audio	INAUDIO	1	[313-8764]	17
Speakers: No Speaker option	NSPKR	1	[313-2663]	18
Keyboard: Dell QuietKey Keyboard	QUSB	1	[330-5522]	4

Mouse: Dell Optical USB Mouse	OMSSCRL	1	[330-5524]	12
Network Adapter: Intergrated PCIE 10/100/1000	INT	1	[430-3246]	13
Documentation: Documentation, English, with 125V Power Cord	DOCENG	1	[330-3156] [330-3157]	21
Installation Services: No Onsite System Setup	NOINSTL	1	[900-9987]	32

Print

*Offers subject to change. Taxes, shipping, handling and other fees apply. U.S. Dell Small Business new purchases only. LIMIT 5 DISCOUNTED OR PROMOTIONAL ITEMS PER CUSTOMER. LIMIT 5 VOSTRO UNITS PER CUSTOMER. Dell reserves right to cancel orders arising from pricing or other errors.

snCFG2

DELL PRECISION™ T1500

WORKSTATION PERFORMANCE, DESKTOP VALUE

Looking for a cost-effective system to drive your Computer Aided Design productivity? Look no further. The Dell Precision T1500 is an excellent system providing advanced performance for workstation applications like AutoCAD®. It boasts workstation-class professional graphics card options, yet offers a cost-effective combination of technologies designed to help make the most of ever tightening budgets.

PEACE OF MIND

Now you can have the reassurance of a workstation tested and certified to run popular CAD applications but with the value of a mainstream business desktop. Professional graphics card options from AMD® and NVIDIA® are designed to deliver accurate 3D CAD model views and accelerated OpenGL® performance, and are tested in Dell Precision workstations for use with leading applications unlike their consumer counterparts. The Dell Precision T1500 offers a choice of AMD ATI® FirePro® and NVIDIA Quadro® cards and, with it, peace of mind when running popular CAD applications on a complete, tested system.

TECHNOLOGY

Lightning fast application performance and excellent productivity for users of demanding applications comes from the Intel® Core®i7 processors and chipset technology linked with fast 1333MHz DDR3 memory. Interactive and responsive work comes from the professional graphics cards that take advantage of amazing bandwidth of the PCI Express Generation 2 graphics slot. Important data files can be loaded and stored rapidly, or backed up locally, using RAID options when more than one hard drive is installed.

COMPACT AND QUIET

The T1500 offers a compact µATX chassis design that delivers on performance while operating quietly. This unobtrusive tower workstation is easy to position in an office and delivers the compute performance required. Its quiet operation helps provide an environment where creativity and interactivity can thrive.

FEATURES	Dell Precision™ T1500
Processors	Quad-core Intel® Core® i7 and i5 processors All processors are 64-bit, select CPUs support Turbo Mode and HyperThreading technology
Operating Systems	Microsoft® Windows 7® Business and Ultimate Microsoft® Windows Vista® Business and Vista® Ultimate, Microsoft® Windows Vista® Business and Vista® Ultimate 64-bit Microsoft® Windows® XP Professional via Vista downgrade Ubuntu 9.04 Linux 32-bit
Chipset	Intel P55
Memory[2]	Up to 16GB[1] 1066MHz and 1333MHz non-ECC memory in 4 DIMM slots
Flash BIOS	BIOS 8MB flash memory for system BIOS; SMBIOS 2.5 support
Graphics[2]	Support for one PCI Express x16 Gen 2 graphics card up to 150W including: ATI FirePro V3750; NVIDIA Quadro FX580; NVIDIA Quadro NVS 295
Hard Drives[3]	SATA 3.0Gb/s: 7200RPM with 8MB DataBurst Cache™ up to 1.0TB Chassis supports up to two internal SATA drives (2.0TB storage maximum)
Networking	Integrated Broadcom® 57780 Gigabit Ethernet controller
Audio Controller	Integrated High Definition Audio (Rev 1.0 Specification) implemented with a two-chip audio solution comprised of the ADI 1984a High Definition Audio CODEC and the ICH10's integrated AC97/High Definition digital controller.
Standard I/O Ports	Twelve USB 2.0: four on front panel, six on back panel, two internal (UDOC) on motherboard; one serial; two PS/2; one RJ-45; stereo line-in and headphone line-out on back panel; microphone and headphone connector on front; IEEE 1394a ports are provided with optional 1394 PCIe card
MINI TOWER CHASSIS	
Dimensions	Mini-tower orientation: (HxWxD) 14.58" x 6.69" x 17.08"; 37.04 cm x 17.0 cm x 43.38 cm
Slots and Bays	**Bays:** Two internal 3.5" HDD bays; two external 5.25" optical bays. **Slots:** One PCIe x1 slot; one PCIe x16 Gen 2 graphics slot; two PCI slots
Power Supply[4]	350W Power Factor Correcting (PFC) power supply
Monitor Compatibility	Compatible with performance flat-panel displays, Dell UltraSharp™ widescreen and standard flat-panel displays from 17" viewable to 30" viewable; analog flat-panel displays also available
Keyboard	Dell Enhanced QuietKey USB or optional: Enhanced Multimedia USB or Smart Card keyboard USB
Mouse	Dell USB two-button mouse or optional Dell USB optical two-button scroll mouse
Optional Speakers	Optional Speakers Internal chassis speaker; Dell two- and three-piece stereo system; Dell sound bar for all flat-panel displays
Storage Devices	**Optional Removable Storage:** CD-RW/DVD Combo, DVD-ROM, DVD+/-RW, Blu-ray Disc™, USB Floppy Drive, USB media card reader
Security	**Software:** Setup/BIOS Password; I/O Interface Security **Hardware:** Kensington® Lock slot and padlock ring
Environmental and Regulatory	Please refer to Safety Best Practices information on the Regulatory Compliance Homepage on www.dell.com at the following location: www.dell.com/regulatory_compliance
Service and Support	**Base:** 1-Year Limited Warranty[5] with 1 year standard Next Business Day (NBD) On-Site[6] parts replacement and 1 years NBD On-Site Service[6] **Optional:** 3-Year Limited Warranty[5] with 3 year standard Next Business Day (NBD) On-Site[6] parts replacement and 3 years NBD On-Site Service[6] **Recommended:** Dell ProSupport[7] is designed to rapidly respond to your business's needs, help protect your investment and sensitive data, and provide enhanced proactive support services to help reduce risk and complexity within your IT environment

[1] A 64-bit operating system is required to support 4GB or more of system memory.

[2] Significant system memory may be used to support graphics, depending on system memory size and other factors.

[3] GB means 1 billion bytes and TB equals 1 trillion bytes; actual capacity varies with preloaded material and operating environment and will be less

[4] For copy of Ltd Hardware Warranty, write Dell USA LP, Attn: Warranties, One Dell Way, Round Rock, TX 78682 or see www.dell.com/warranty

[5] May be provided by third-party. Technician dispatched, if necessary, following phone-based troubleshooting. Availability varies. See www.dell.com/servicecontracts for details. Remote Diagnosis is determination by online/phone technician of cause of issue; may involve customer access to inside of system and multiple or extended sessions. If issue is covered by Limited Hardware Warranty www.dell.com/warranty and not resolved remotely, technician and/or part will be dispatched, usually within 1 business day following completion of Remote Diagnosis. Availability varies. Other conditions apply

[6] Availability and terms of Dell Services vary by region. For more information, visit www.dell.com/servicedescriptions.

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