EVLA Project Book, Chapter 10

EVLA Monitor and Control System

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2003-Sep-24 Minor revisions based on feedback from the EVLA Advisory Committee
2004-Dec-06 Revisions based on developments over the past year

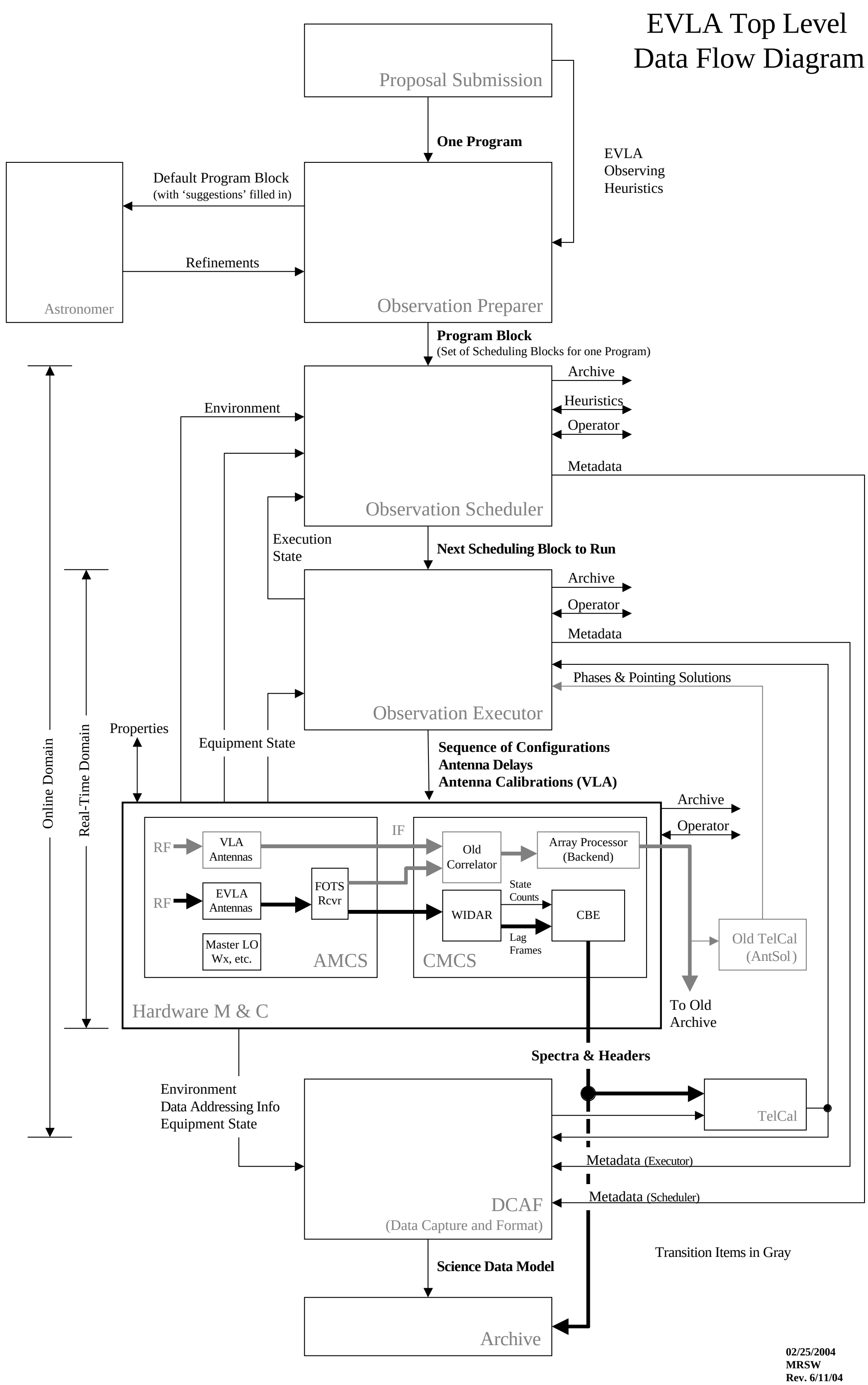
10.1 Introduction

This chapter of the Project Book has been organized by subsystems, with allowances for topics that do not fit within that scheme. Four subsystems have been identified – Antenna Monitor and Control (AMCS), Correlator Monitor and Control (CMCS), the Operational Interface System (OIS), and the EVLA Monitor and Control Network (MCN). The sections covering the four subsystems all have a similar structure:

- 10.a Subsystem Name
  - 10.a.b Subsystem General Description
  - 10.a.c Subsystem Requirements
    - 10.a.c.1 Subsystem Hardware Requirements
    - 10.a.c.2 Subsystem Software Requirements
  - 10.a.d Subsystem Design
    - 10.a.d.1 Subsystem Hardware Design
    - 10.a.d.2 Subsystem Software Design

10.2 EVLA Monitor and Control Software

In June of 2004 a six-month effort to develop a high level design for all EVLA Software was completed. The results of this effort is presented in the document entitled “EVLA High Level Software Design”, which can be found on the Computing Working Documents web page, http://www.aoc.nrao.edu/evla/techdocs/computer/workdocs/index.shtml. It is document # 33. The diagram given below shows the components of the EVLA software system and the major data flows, as identified by the high-level design document.


EVLA Top Level
Data Flow Diagram
Proposal Submission
One Program
EVLA
Observing
Heuristics
Default Program Block
(with 'suggestions' filled in)
Refinements
Astronomer
Observation Preparer
Program Block
(Set of Scheduling Blocks for one Program)
Archive
Heuristics
Operator
Metadata
Environment
Observation Scheduler
Execution
State
Next Scheduling Block to Run
Archive
Operator
Metadata
Phases & Pointing Solutions
Observation Executor
Online Domain
Real-Time Domain
Properties
Equipment State
Sequence of Configurations
Antenna Delays
Antenna Calibrations (VLA)
Archive
Operator
RF
VLA
Antennas
RF
EVLA
Antennas
FOTS
Rcvr
Master LO
Wx, etc.
AMCS
IF
Old
Correlator
Array Processor
(Backend)
State
Counts
WIDAR
CBE
Lag
Frames
CMCS
Old TelCal
(AntSol)
To Old
Archive
Hardware M & C
Spectra & Headers
Environment
Data Addressing Info
Equipment State
TelCal
Metadata (Executor)
Metadata (Scheduler)
DCAF
(Data Capture and Format)
Science Data Model
Transition Items in Gray
Archive
02/25/2004
MRSW
Rev. 6/11/04

That portion of the software identified as being in the "Online Domain" are the components of the software that fall within the EVLA Monitor and Control system, i.e., from some point within the Observation Scheduler into the Data Capture and Format component.

10.2.1 EVLA Software Requirements

The scientific community within NRAO and Array Operations at NRAO has produced a series of requirements documents that represent significant input from the users of the EVLA. The document set is located on the Computing Working Documents web page (http://www.aoc.nrao.edu/evla/techdocs/computer/workdocs/index.shtml), and consists of the following:

- EVLA-SW-001, EVLA e2e Science Software Requirements, April 15, 2003 (#26)
- EVLA-SW-002, EVLA Data Post-Processing Software Requirements, (Draft), July 3, 20003 (#28)
- EVLA-SW-003, EVLA Array Operations Software Requirements, June 6, 2003 (#27)
- EVLA-SW-004, EVLA Engineering Software Requirements, August 8, 2003 (#29)
- EVLA-SW-005, EVLA Science Requirements for the Real-Time Software, November 22, 2004 (#38)

10.2.2 Operations Security

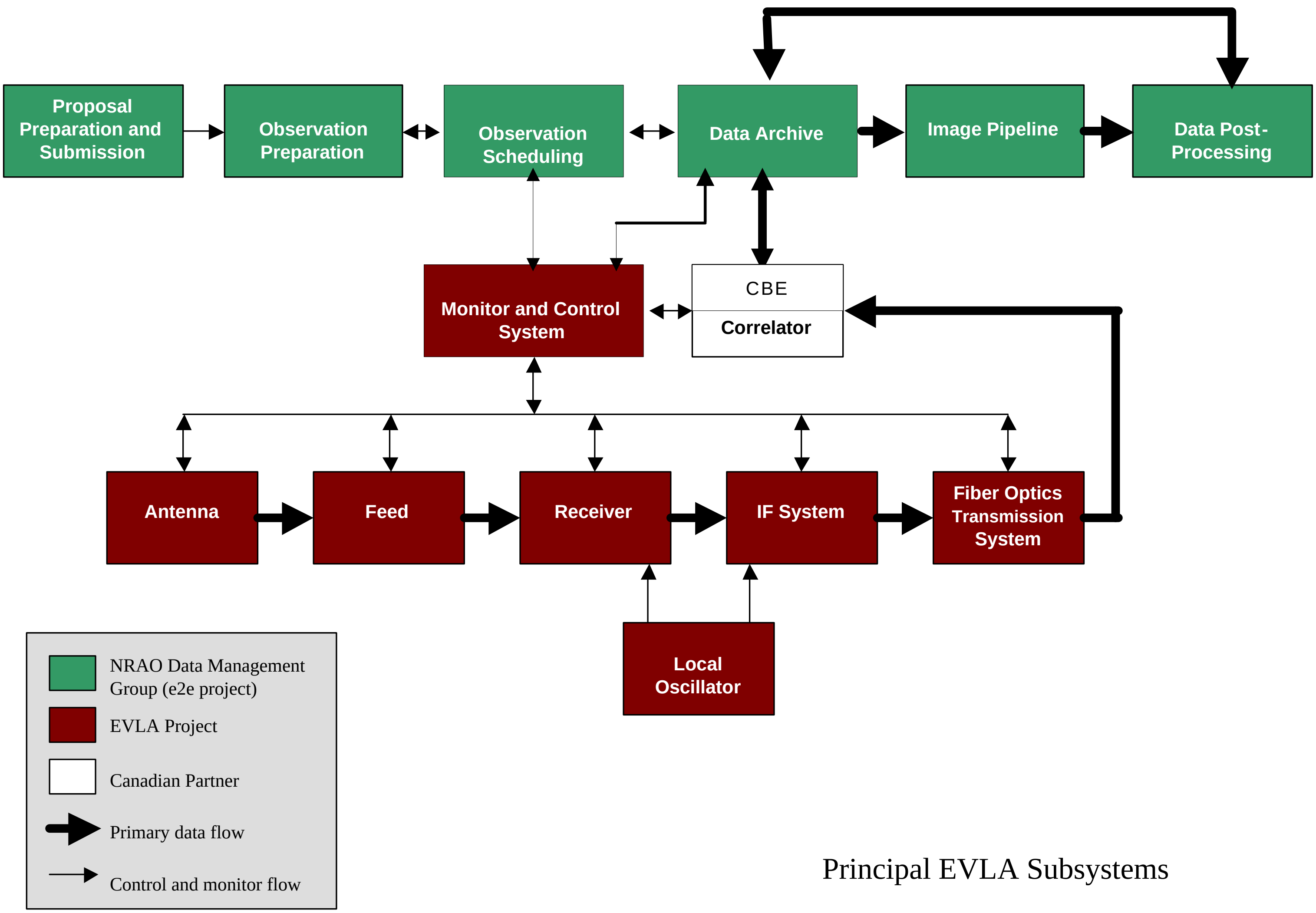
The VLA must be protected 1) from both random and malicious incursions from the Internet outside the NRAO, and 2) from accidental or mistimed interference from within the NRAO. The primary protection from the outside world is via the network routers. The machines of the EVLA reside on a private network that is not routed beyond the NRAO. Within the NRAO (or within the Virtual Private Network that is effectively within NRAO), the usual password protections apply. We shall trust password protection to keep out malicious incursions. Only a modest addition need be provided to guard against accidental interference by technicians with modules actually being used for the current observation. It is planned to implement this safeguard at the module interface board (MIB, see section 10.3.1) level. The observing system will be granted sole command access to those MIBs that it sees as necessary for operation. Only the array operator will be able to release a module for outside command

10.2.3 Software Standards

Software in the MIBs will be written in C and C++. This will be cross-compiled on Windows systems system under the control of the Maven compilation control system. The central Executor system will be written in Java, also compiled under the Maven compilation control system, and documented through the javadoc documentation extraction system. Appropriate documentation should always be included in the code, and indentation should be used to make code maximally readable.

10.3 Antenna Monitor & Control Subsystem (AMCS)

The Antenna Monitor and Control Subsystem is that portion of the EVLA Monitor and Control System responsible for operating the array of antennas, both the new EVLA antennas as they come online and the existing VLA antennas during the transition phase. The AMCS may also be required to operate some of the nearby VLBA antennas and, if Phase II of the VLA Expansion Project occurs, the New Mexico Array (NMA) antennas as well.



Principal EVLA Subsystems

10.3.1 AMCS General Description

The Antenna Monitor and Control Subsystem will consist of processors located throughout the system from the Control Building at the VLA site to within the EVLA antennas themselves. Processors residing in the Control Building will have no limits on size and complexity and will take the form of high reliability desktop and rackmount machines. Processors located within the antennas will be small micro-controller type processor boards with minimal RAM and low clock speeds to help reduce RFI. These micro-controllers will interface the components of the antenna to the rest of the monitor and control system; they are referred to as Module Interface Boards (MIBs).

All AMCS processors, including the MIBs within the antennas will be networked using Ethernet over fiber-optic cable.

10.3.2 AMCS Requirements

10.3.2.1 AMCS Hardware Requirements

10.3.2.1.1 Minimum RFI

The most basic AMCS hardware requirement is low emission of RFI. Minimum emission of RFI is necessary in order to prevent the scientific data from being corrupted by noise from the AMCS. Emissions from all components must meet the requirements specified in EVLA Memo #46 (http://www.aoc.nrao.edu/evla/memolist.shtml).

10.3.2.1.2 Ethernet

The use of Ethernet as the bus is actually an implementation decision. As such it is not a requirement, but this decision has such a widespread impact on such fundamental levels that it has been included in this section. The use of Ethernet allows the entire AMCS to use one bus, to use COTS equipment, guarantees maintainability over a long timespan due to widespread commercial use, allows addressing by slot, and is well suited for object-oriented programming.

10.3.2.1.3 Data Rates

The maximum data rate from an EVLA module is estimated to be 128 Kbits/sec. The majority of the EVLA modules will have a data rate very much less than 128 Kbits/sec. Overall the maximum data rate from an EVLA antenna is expected to be 200 Kbits/sec. It is possible that most of the monitor data from an antenna will be from a single module, where the total power detectors are located.

10.3.2.1.4 Timing

Reconfiguration commands sent by the ACMS must begin not more than 100 μs after the intended implementation time. This requirement will necessitate the queuing of commands at the MIB before the scheduled implementation time.

The monitor and control system must be able to keep absolute time to a resolution of better than 10 ms.

10.3.2.1.5 MIB (Module Interface Board) Requirements

The design of the MIB was largely driven by three main requirements. Additional important design requirements are also necessary for the MIB to perform its duties in a robust manner.

The three main requirements were 1) the choice of TCP/UDP/IP over Ethernet as the communication protocols, 2) low RFI characteristics, and 3) small board size. The RFI emissions requirement limited the choice for the microprocessor and on-board electronics. The small board size is especially important, given space limitations, which are also affected by the low RFI emission requirement.

Additionally, the MIB must utilize both serial and parallel communications to the EVLA devices. It must have the intelligence to implement monitor and control tasks in the modules and devices, and must sometimes be part of control loops. Periodically or on demand, the MIB must be able to send back monitor data to other points on the network. It must be possible to remotely load new software into the MIB. In order to synchronize commands and send monitor data on a periodic basis, the MIB must be able to receive a timing signal and keep track of time. A watchdog timer must be implemented so that the MIB will recover if the processor hangs up. The MIB must be fused. A separate maintenance port that communicates via RS-232 must be included. There must be power indicator LEDs to indicate the presence of each voltage. A test LED must be included to facilitate programming and debugging.

10.3.2.2 AMCS Software Requirements

The current version of the Antenna Monitor and Control Subsystem Requirements document can be found at http://www.aoc.nrao.edu/evla/techdocs/computer/workdocs/index.shtml, under the title "Antenna Monitor & Control Subsystem Preliminary Requirements Specification, V2.0" (document # 17).

This specification was written to address the technical requirements of the AMCS needed for a design that will satisfy the user-related requirements described in section 10.2.2.

While the requirements specification document referenced above contains a detailed description of all of the requirements imposed on the AMCS, it is worth mentioning here the few major requirements that have the most influence in 'shaping' the AMCS software design.

- **Heterogeneous Array.** The EVLA will, from the onset, consist of different types of antennas. During the transition phase this will be the older VLA types as well as the new EVLA types. Eventually VLBA and New Mexico Array (NMA) antennas may be added as well. Because of this, the design of the AMCS must accommodate differences in antenna hardware.

- **Ethernet Based Communications.** The EVLA will be a highly networked system; even the antenna subcomponents will utilize Ethernet with each subcomponent having its own IP address. Ethernet and the associated network communications protocols (IP/TCP/UDP) will require that the AMCS design accommodate this higher level of data communications between the various components of the system.

- **Widespread Operational Interface.** The EVLA will be operated (at various levels) from a potential variety of sources: normal programmed observing from the e2e system, Interactive Observing, control from the AOC and other NRAO entities, subcomponent operation from the technician's workbench and even monitoring from over the Internet at large. The AMCS design must serve a variety of users from a variety of physical locations.

- **Transition Phase Operation**. The transition from the current VLA antennas into the EVLA antennas will take a number of years to complete. The AMCS must be designed so that during this time 1) both antenna types will be operated together under one control system, 2) system down time is minimized and 3) transition specific software (throw-away) code is minimized.

- **Real-Time Requirements.** There are few hard real time requirements imposed on the AMCS but those that do exist most certainly must be accounted for in the AMCS software design. They are:
  - 100 µSec command start latency. This means that a command must be initiated at the hardware within 100 µSec of its scheduled start time.
  - For EVLA antennas, to maintain a sub-arcsecond level of pointing accuracy, the antenna position must be updated every 50 milliseconds.
  - Frequency change within band to be completed within one second.
  - 'Nodding' source switch rate of once per ten seconds.
  - For the most extreme case of OTF mosaicing, the correlator will require new delay polynomials at the rate of 10 per second.
  - The issue of the rate of pointing updates required by the most extreme case of OTF mosaicing has been raised (antenna movement at 10X the sidereal rate). The pointing update rate is set by the servo bandwidth. It does not depend on the rate of motion. For this case, the pointing rate update will be the same as delay polynomial update rate for the correlator – 10Hz.

10.3.3 AMCS Design

The AMCS is being designed with the intent of creating not only a system that is state-of-the-art with today's technology but will also 'scale' with new technology as it comes about. To accomplish this, the choice of technology is biased as much as possible to non-vendor specific, industry standards. For hardware this means computers that will use industry interfaces such as IP/Ethernet for their external communications and, for embedded hardware controllers, standard signal protocols such as SPI and standard mechanical form factor and connectors*. For software it means using commonly available and widely used operating systems and communications 'middleware'. This will allow components of the system to be replaced as technology changes with minimal affect on interoperability with other system components. The ultimate goal of this approach is to create a system that 20 years from now will not be locked into 20-year old technology.

*The MIB does use IP/Ethernet and a SPI interface to hardware but it uses a proprietary form factor and hardware interface connectors.

10.3.3.1 AMCS Hardware

10.3.3.1.1 General Description

The hardware part of the AMCS will consist of a MIB (Module Interface Board) and various other boards to interface the MIB to devices.

10.3.3.1.2 Module Interface Board (MIB)

Every EVLA module or device will contain a Module Interface Board (MIB). The MIB is the interface between the antenna control computer and any module or device electronics in the EVLA. Command and Monitor information will be sent between the MIBs and network computers over 100BaseFX full duplex Ethernet. Communications between the MIB and EVLA devices are primarily carried out via Serial Peripheral Interface (SPI) and General Purpose I/O (GPIO) lines (parallel communications).

The core of the MIB is the Infineon TC11IB microprocessor. This chip incorporates several peripheral functions that often require separate chips. These include the Ethernet controller, 1.5 Megabytes of on-chip memory, a SPI port, and two serial ports. On-chip timers satisfy the timing requirements of the MIB. The TC11IB requires a 12 MHz crystal oscillator that is multiplied, on chip, to create a 96 MHz system clock. It has a watchdog timer to ensure that the program does not hang.

A 64 or 128 Megabit Flash memory chip is used to store the program image(s) for the TC11IB. The MIB can run from the Flash memory, however it is planned that the program will be transferred from Flash to memory on the TC11IB during the boot sequence. It has been shown that RFI is minimized by running from on-chip memory. It will be possible to load new program code into the Flash memory from a network computer via Ethernet. The on-chip memory will also be used to store commands and monitor requests from the antenna computer.

Access is provided to one of the General Purpose Timer Units on the TC11IB chip via connections to 2 timer unit outputs and 2 timer unit inputs. The General Purpose Timer Unit could provide a pulse or a clock to the EVLA module that the MIB is controlling.

The voltage regulator chip on the board includes power management features that reset the TC11IB if the voltages fall below their nominal values. During the power-up sequence, the reset line of this chip keeps the TC11IB in the reset state until all voltages have risen to the correct values. All power supply voltages on the MIB, both input and output, are fused for protection against shorts.

The MIB will receive a 19.2 Hz system heartbeat for timing purposes. A computer on the network will be able to tell the MIB to start keeping absolute time at the arrival of the next system heartbeat. A timer on the TC11IB will then be used to keep time. This will make it possible to queue commands in advance, to be executed by the MIB at a specified time.

The MIB will detect the slot into which it is plugged. This feature eliminates the need to change the module address when the module is moved.

The MIB will not be used to ensure the safety of any EVLA modules or devices. Each module or device must be designed such that it will be protected even in the absence of a MIB.

10.3.3.1.3 Battery Backed Utility

EVLA modules at the antenna and control building, that are powered from the system 48 volt supply, will remain powered for a specified amount of time in the event of a commercial power outage. The specified amount of time will be long enough for the generators to start operating and restore power. In the event that the generators do not start operating, there will be plenty of time for computers in the control building to determine the state of each antenna before the UPS units in the EVLA antennas lose power.

10.3.3.1.4 Voice Communications

Voice communications between an antenna and the outside world will be enabled via VoIP (Voice over IP). The system will carry standard telephone voice communications for an antenna over the Monitor and Control Network link in TCP/IP form. It is predicted that the voice traffic will not hinder antenna control traffic. A spare fiber pair is available if such turns out not to be the case.

The VLA and AOC phone systems are maintained by New Mexico Tech (NMT). Implementing full voice communications between an EVLA antenna and legacy phone systems will require cooperation with New Mexico Tech. NMT is currently implementing a VoIP system. We (NRAO) will be able to tap directly into this system, relieving us of both the need to purchase transition hardware and the need to manage the system. Currently only 100Base-T (twisted pair) IP phones are available. Phones will be connected via a media converter to the antenna switch until fiber based phones are available.

10.3.3.2 AMCS Software

Where feasible, AMCS software is being designed to incorporate open-source Linux operating systems, Web-based tools and common Internet protocols for communications between system components.

Two exceptions exist: the MIB and the low-level, real-time processor in the Interim M & C system for VLA antennas during the transition period. Both of these processors are too resource limited to use a high-level OS such as Linux.

For all but these two exceptions, software will be designed using Object Oriented techniques and written in the Java programming language

10.3.3.2.1 AMCS Software, General Description

This section describes the AMCS software in general terms with loose reference to the major requirements that the design seeks to satisfy.

Ethernet Communications. With no exceptions, all of the processors in the system incorporate operating systems capable of providing TCP and UDP over IP over Ethernet. Data communications between the processors will be non-proprietary using industry standards such as XML, URI and HTTP.

Heterogeneous Hardware. Operating different types of hardware can present difficulties if the controlling process needs to be cognizant of the differences and operate accordingly. These difficulties are lessened in the AMCS by using a distributed processing approach in its design. Implementation differences are encapsulated at appropriate levels throughout the system so that client applications can send commands and receive monitor data of a more generic nature. Using this approach, 'what-to-do' rather than 'how-to-do-it' type information is communicated from client to server.

Variety of Users from a Variety of Locations. AMCS components are designed to be functionally autonomous so that each component can be operated separate from the rest of the system. Components operate together to form the overall functionality of the system for normal observing but each can be operated independently for maintenance and other special uses.

All components are accessible over the Internet so they can be operated from any Internet connected client application within policy restrictions.

Real-Time Considerations. The nature of the communications infrastructure of the AMCS precludes real-time control of hardware from higher-level processes. Rather than attempting real-time function calls between processes over the network, the AMCS is designed so that control instructions are sent ahead of the time of their execution. Once present at the target process, the instructions can be executed at the appropriate time in real-time.

In an attempt to simplify design for application engineers, Remote Procedural Call (RPC) type middleware such as CORBA and Java's RMI attempt to make remote function calls appear as if they are being done locally. In so doing they tend to hide the fallibilities of the network over which they communicate giving a false sense of security that functions and responses are being handled in real-time. The communications mechanism chosen by EVLA engineers exposes the network and its characteristics, such as latency, to the design engineers so they may be dealt with explicitly.

10.3.3.2.2 AMCS Systems Software & Middleware

The AMCS is designed using a client/sever architectural style. Servers represent system entities that are to be controlled and monitored (a piece of hardware, a software function, a property file, etc.); their 'service' is to provide a representation of the entity for manipulation by client applications. Client applications communicate with the servers to 'operate' the system.

Different technologies were investigated for the middleware to be used for communications between the client and server components. The chosen technology would have to operate under the constraints imposed by the requirements described above; additionally, it would be desirable if communications could be consistent among all components of the system including the embedded processes in the MIBs and CMP.

Remote procedural call (RPC) type middleware such as CORBA and SOAP were, in general, ruled out as candidate technologies. Communication in the EVLA will be done by passing messages containing control information ahead of the time of actual execution between controlling client and server. A report giving the analysis and logic supporting the decision to use a message-based approach is in preparation, and is expected to be ready for distribution sometime in January 2005.

Having decided upon a message-based approach, the question then became which message-oriented architecture and technologies would best serve the purposes of the EVLA. Looking to industry, the REST architectural style was studied to see if it could be applied to communications in the EVLA. REST stands for Representational State Transfer and is used to architect the World Wide Web. REST is not a middleware implementation that can be 'used' in a system; it is an architectural style to which a system can be designed in order to use the communications protocols associated with it. The definitive source of information about REST is from its creator, Roy Thomas Fielding. His PhD dissertation, entitled "Architectural Styles and the Design of Network-based Software Architectures", in which the REST architectural style is defined, can be found at: http://www.ics.uci.edu/~fielding/pubs/dissertation/top.htm .

REST was not meant for control systems but the EVLA architecture (of autonomous client/server components distributed over an IP/Ethernet network) is surprisingly close to that of REST. REST uses Hyper-Text Transport Protocol (HTTP) http://www.faqs.org/rfcs/rfc2616.html to communicate information between clients and servers. Every piece of information that can be named is considered to be a resource and Uniform Resource Identifiers (URIs) http://www.faqs.org/rfcs/rfc2396.html are used to uniquely specify these resources. In the EVLA, resources are the entities to be controlled, monitored, or otherwise manipulated such as sub-arrays, antennas, control points, monitor points, configuration files and observe scripts.

The communications middleware must support both human interface (UI's) and process-to-process transactions such as the Executor controlling antenna software objects for an observation; with the use of REST comes a myriad of readily available Web-based tools and applications that supports these requirements. General purpose UI's are possible with standard web browsers while those of a specific nature may be made using Applets and Java Web Start applications. Plain text queries of system resources are possible via the URL input field of a browser. Client processes such as the Executor can send large blocks of configuration information formatted in XML to servers via the message body portion of an HTTP request. Seeing the value of any monitor point in the system can be as simple as typing its URI into a web browser or clicking on a link to it.

Web services tools are available that can be deployed on all processors in the EVLA making communications consistent throughout, including eventually the MIBs.

The software currently being developed for the first phase of the transition to control of a hybrid VLA-EVLA system is exploring the feasibility of applying the REST architectural style to the EVLA Monitor and Control system.

10.3.3.2.3 AMCS Application Software

The AMCS is being built on a layered, client/server architectural style where a client process controls a lower level server that, in turn becomes a client of a still lower level server. With this type of architecture, component interfaces tend to be more general as they move from lower to higher layers, facilitating operation of low-level components without having to know 'how they work'. For example, the Executor will be able to operate both VLA and EVLA antennas without having to know *how* each is controlled internally.

Every physical processor in the system will contain one server process that will present the 'business' logic of that processor to the rest of the system.

MIBs will contain software that *represents* the antenna subcomponent hardware to which they are connected.

Software in more powerful desktop and rack-mounted processors will provide representations of whole antennas by assembling the individual component representations obtained from the MIBs. Details of how subcomponent information is obtained are removed from the antenna object's interface to higher layer clients. For example, the antenna object represents the azimuth and elevation values as simply 'azimuth' and 'elevation' and removes the need for a client to know how that information was obtained.

The Executor, in turn, gathers representations of each of the antennas used in a particular observation and combines them into a (representation of a) sub-array.

During normal observation operation UI's and other client applications will operate the system at the higher, more general layers, but client applications and UI's can move down layers to access more detailed and specific operation for maintenance or other special purposes. Client application interfaces will remain consistent throughout layers.

10.3.3.2.3.1 MIB Software

The MIB software is implemented as a generic framework common to all MIB's plus module specific software. Descriptions of the MIBs module hardware are abstracted to 1) a 'C' language table that defines hardware access parameters, and 2) an XML point configuration file that defines the user view of the hardware. The XML point configuration file can be downloaded to the MIBs flash memory at runtime, and will be activated when the MIB reboots. A detailed description of the MIB Framework can be found in the document titled "MIB Framework Software, Version 1.1.0" on the web page http://www.aoc.nrao.edu/evla/techdocs/computer/workdocs/index.shtml, as document # 36.

The MIB monitors hardware in a periodic polling loop, converts the raw data to engineering units, performs bounds checking (alert detection) and writes the resultant data into a memory resident data base known as 'Logical Points'. All of the data contained in the 'Logical Points' database can be accessed though a command line interface.
The ASCII command interface to the MIB, known as the Service Port, can be accessed over TCP/Telnet, or by UDP. This interface allows one to query the list of available hardware devices and access detailed information on one or more monitor and/or control points. The two primary commands implemented by the Service Port are 'get' and 'set', which are used to read or write data to one or more Monitor or Control points. A detailed specification of the Service Port can be found in the document titled 'MIB Service Port ICD, Version 1.2.0' on the Computing Working Documents web page http://www.aoc.nrao.edu/evla/techdocs/computer/workdocs/index.shtml, as document #34.

Additionally, data is 'pushed' from the MIB over a one-way data channel known as the Data Port. The Data Port is used to multicast monitor data and alerts to any interested clients. Typically monitor data is multicast at a periodic interval and alert messages are multicast when they occur. The protocol specification for the Data Port is contained in the document "MIB Data Port ICD, Version 1.2.0 ", which can be found on the Computing Working Documents web page http://www.aoc.nrao.edu/evla/techdocs/computer/workdocs/index.shtml, as document #35.

The MIB application is time aware and uses a Modified Julian Date formatted time for time stamping monitor data as well as time-deferred command execution. The MIB application initializes its time management facility by way of an NTP server and will scale this time to the nearest 52 mSec Waveguide Cycle, if a 19.2Hz interrupt is present.

The MIB application has the capability of remotely loading code and data over the Ethernet. Code images must be loaded in Motorola S-Record format and data must be formatted as XML Points Configuration files. Additionally, code and data loading progress can be monitored by use of a MIB monitor point.

10.4 Correlator Monitor and Control Subsystem (CMCS)

10.4.1 CMCS General Description

The CMCS will provide Correlator monitor and control through a network of distributed processors and processes. General access to this network will be through a "Virtual Correlator Interface" (VCI) that will provide a unified and flexible means of integrating the Correlator into the overall EVLA system.

Some details of the VCI and scheduling may be found in NRC-EVLA memo #16, "Scheduling and Activating the Configuration Data" by Sonja Vrcic, the recent Software Engineering hire at DRAO in Canada.

http://www.drao-ofr.hia-iha.nrc-cnrc.gc.ca/science/widar/public/NRC_EVLA_memo016.pdf

A separate layer above the VCI will provide extensive diagnostics and control primitives for engineering and technical support. It is the intent of this separate layer to provide the necessary tools for Correlator development during the construction stage.

10.4.2 CMCS Requirements

A more detailed description of CMCS requirements may be found in EVLA Computing memo #15 "EVLA Monitor and Control System, Test Software and Backend Software Requirements and Design Concepts". This document can be found on the VLA Expansion Project Computing Working Documents web page:

http://www.aoc.nrao.edu/evla/techdocs/computer/workdocs/index.shtml

10.4.2.1 CMCS Hardware Requirements

The CMCS shall consist of a network of distributed processors with each processor responsible for managing a single circuit board unit of the Correlator hardware. These Correlator module interface boards (CMIBs) will provide the hard real time control necessary for Correlator operation. There shall be one master Correlator control computer (MCCC) to coordinate and manage the distributed network, host the operational VCI gateway, and centralize Correlator system management. This computer shall be considered a high reliability platform and shall be made fault tolerant through the use of hot standby or other methods to maximize system up time. A separate and similarly equipped computer will manage power monitor and control for the Correlator (CPCC) and will operate independently of the MCCC thereby isolating power control from any faults in the MCCC. The CMIB hardware modules should be of an electrical and mechanical form factor that lends itself to mounting on Correlator hardware devices in a replaceable and standardized fashion.

The CMIB design shall allow for future upgrade with minimal impact on the remaining installed systems. Modules shall provide capability of sufficient non-volatile storage for completely self-contained booting of the operating system, run time code, and Correlator board firmware should that option be deemed necessary at a later date.

The modules shall provide a standardized method of communication with the Correlator monitor and control network and Correlator hardware. Correlator hardware shall be capable of being powered up and initialized into a quiescent state without any external network connections.

Unlike the processor chosen for the AMCS MIBs, the selection of a processor for use as the CMIB is not constrained by RFI considerations. The CMIBs will be located on the Correlator boards, inside a heavily RFI-shielded room.

10.4.2.2 CMCS Software Requirements

The Operating systems used for the MCCC, CPCC, and CMIBs shall provide reliable and maintainable operation for the expected life of the Correlator. CMIB operating systems and run time software shall be capable of responding to a 10 ms interrupt period, provide low level access for Correlator hardware communications, and provide reliable networking with the MCCC. The MCCC operating system and run time software shall provide a reliable and easily managed environment with easy integration into the EVLA MC network. It shall perform predictably under various network loads and fault conditions without operator intervention.

10.4.3 CMCS Design

The CMCS will make extensive use of hardware abstraction such that each functional unit of the correlator will be represented as a black box to higher layers of control software. The details of switch settings, data paths, hardware organization, etc. will be hidden except where this knowledge is needed by higher processes and when accessed through various service ports. Each CMIB will present a unified interface to its methods and control points such that upper level software is decoupled from any changes in CMIB design.

10.4.3.1 CMCS Hardware

It expected that PC-104+ mechanical form factor computer boards will be used for the CMIB hardware. This industry standard lends itself well to creating a piggyback style module for mounting on the Correlator hardware boards.

Communication between the CMIB and Correlator hardware will be over the PC104+ bus (PCI standard). This bus will allow the CMIB to download FPGA personalities and control words to the Correlator hardware as well as extract monitor and ancillary data from the Correlator. It will be desirable to have all FPGA personalities as well as CMIB OS and run time code stored in CMIB flash style memory. This will allow “safe” power up and bench testing of individual Correlator units without any external networking in place. The MCCC and CPCC will most likely be high reliability PCs or VME/CPCI type SBCs with sufficient I/O connectivity to communicate with the Correlator MC network. The network itself will be based on 10/100 Base-T Ethernet using transformer coupled copper connections to reduce potential ground loop problems. The CMIBs, MCCC, and CPCC will need to support communication over this medium and protocol. It is anticipated that much of the MC network between the MCCC and CMIBs (around 300 units) will be routed through switches and hubs to reduce the port requirements on the MCCC. Further details of the topology and networking may be seen in EVLA Computing memo #15.

10.4.3.2 CMCS Software

Due to the need for flexibility and portability on the network side MC code, selection of an OS for the MCCC and CPCC should place connectivity high on the requirements list. Since these computers will not be constrained by memory or CPU speeds, many commercial and public OS choices exist. The preference is to try Linux first since there is already a large installed base within the organization and it has proven to be both reliable and flexible. Selecting the OS for the CMIB is a bit more complex since the system has some modest real time requirements and is more restricted in CPU power and memory (to keep cost down). There exists a wealth of OS choices for these small SBCs among which are the various flavors of real time Linux. Due to the modest interrupt rates and need of good networking connectivity, several of the preempt-able Linux kernels seem like good choices for initial testing. It is expected to divide all run time code into logical processes/threads and assign priorities to best utilize system resources and network bandwidth. Watchdog processes will be used to monitor MC system health and take corrective action when possible.

10.5 Operational Interface Subsystem (OIS)

The Operational Interface Subsystem is one of several major components that constitute the EVLA Monitor and Control System. The primary responsibility of OIS is to provide a suite of software tools that allow the array operators, as well as engineers, technicians, scientists, software developers, and other authorized users to interact with the array in a safe and reliable manner.

10.5.1 OIS General Description

The Operational Interface Subsystem will provide the primary graphical user interface (GUI) tools for the EVLA Monitor and Control System. It is through OIS that users will monitor and command the array. This section will discuss the various components of OIS, the functions OIS must provide, and the users of OIS.

10.5.1.1 Components

- **EVLA Resources.** EVLA resources are components that reside within the EVLA Monitor and Control System. They represent both physical (antennas, weather station) and non-physical (subarray) entities. Each resource will be network addressable and have a common software interface that accepts requests for information and commands.

- **Client-side tools**. OIS is a client-side tool that will allow access to the EVLA system. Parts of OIS will be written as standard Java applications. Other portions will be written as Web-based applications accessible from standard Web browsers. OIS will be accessible from the VLA Control Building, the AOC or any Web-accessible location. Outside access to the EVLA control system must conform to network security guidelines described in the section entitled Monitor and Control Network (MCN) Access.

10.5.1.2 Functions

- **Array Monitoring.** The Operational Interface Subsystem will supply the array operators and other users with high-level and low-level monitoring abilities. High-level screens will provide information on the overall health of the array whereas the low-level screens will give detailed information on specific components within the system. The screens will be composed of textual and graphical components and will use color and audible alerts to inform the user of unexpected events and conditions.

- **Array Control.** Many of the OIS screens will allow authorized users to control all or parts of the array. Control functionality will be built into the screens using graphical user interface (GUI) components (sliders, buttons, combo boxes, etc.) that accept keyboard or mouse input from the user.

- **Reporting/Logging.** The ability to create and manage a variety of reports, including the operator notes pertaining to particular observations (observing log). The Operational Interface will provide a tool that enables authorized users to create and send messages to a message log, presumably a database. This will replace and expand on the functions currently provided by the observing log that is generated by the array operators using Microsoft Excel.

- **User Access Control.** The ability to view and manage users system access and privileges. This is required for security purposes.

- **System Management.** The ability to manage system files and parameters. The Operational Interface will provide a means for operators to update system parameters, such as pointing, delays, baselines, and to maintain a history of parameter changes.

10.5.1.3 Users

- **Array Operators.** The array operators are responsible for the overall success and safety of all observations and will be the primary users of the Operational Interface Subsystem software. They require both monitor and control capabilities of the array and perform their duties from either the VLA Control Building or the AOC.

- **Engineers.** Engineers are responsible for the design, development and testing of the mechanical and electrical components within the system. They require the ability to inspect/control individual system components both remotely and at the antenna during working and non-working hours.

- **Technicians.** Technicians are responsible for the day-to-day monitoring and maintenance of the mechanical and electrical components within the system and are usually the first to be notified in the event of a non-working or malfunctioning component. As with the engineers, technicians require the ability to inspect/control individual system components both remotely and at the antenna during working and non-working hours.

- **Scientists.** Scientists, both NRAO and non-NRAO, are granted time on the array to conduct scientific investigations or tests. Their primary interest lies in the scientific data obtained by the instrument. They require remote access to both monitor data and visibility data to assess progress and to help make decisions during an observation.

- **Programmers.** Programmers are responsible for creating the software that drives the system. They must have access (with control capabilities) to the system, both locally and remotely, for testing and troubleshooting during working and non-working hours.

- **Others.** Access to the system, most likely via a Web browser with read-only access, will be provided to individuals that have an interest in the array and its activities.

10.5.2 OIS Requirements

This section highlights the major requirements of OIS. A detailed description of OIS requirements can be found at http://www.aoc.nrao.edu/evla/techdocs/computer/workdocs/index.shtml in the document titled "EVLA Array Operations Software Requirements" (document #27).

10.5.2.1 OIS Hardware Requirements

OIS will not communicate directly with any hardware. It will, however, communicate directly with the software interface for specific pieces of hardware (e.g., the Antenna Object) that will in turn execute the request on behalf of OIS.

- **Supported Platforms**. The OIS software must be relatively platform independent, as it will run on a wide variety of machines hosting various operating systems. Specifically, the OIS software must be capable of running on commodity PCs hosting Windows and Linux operating systems and Sun Microsystems workstations hosting the Solaris Operating Environment. An optionally supported platform will be the Macintosh/Mac OS.

10.5.2.2 OIS Software Requirements

The software requirements document referenced above contains a detailed description of requirements imposed on OIS; it is worth mentioning here the few major requirements that have the most influence on the design of the OIS software.

- **Remote Observing.** Remote observing will provide users with the ability to run the OIS software from locations other than the VLA control building such as the AOC, other NRAO sites or from any Web-accessible location.

  Several reasons exist as to why remote observing is necessary:

  - Observers can monitor the progress of their observing program and make or request changes during their observation to increase the quality of data.
  - Engineers, technicians and programmers will need the ability to access the system from remote locations during working and non-working hours to do first-order problem solving.
  - Operators may be stationed at the AOC in Socorro in the future.

- **Secure**. The Operational Interface Subsystem will need a robust security mechanism in place so that unauthorized users are not allowed access to parts of the system that may compromise the success of an observation, cause damage to an antenna or jeopardize the safety of personnel in or around an antenna.

  A coarse-grained security mechanism is under consideration that separates users into one of two groups: trusted or non-trusted. Trusted users will have privileged access to the system, namely control capabilities, whereas the non-trusted users will have only monitoring capabilities. Membership in the trusted group will likely be a function of identity and location. Users who would otherwise be trusted may be treated as non-trusted if they are located outside the NRAO or are not part of the NRAO VPN.

- **Easy to Obtain, Install and Update.** Since the OIS software will be geographically dispersed, a simple procedure must exist that allows users to obtain and install the software via the Internet. Several methods exist, including downloading a file (e.g., tar or zip) and running an installation script, accessing the software from a browser using Java applets, or Java Web Start software which is an application deployment mechanism for Java applications. Such methods are currently under consideration, however, Java Web Start is extremely attractive due to the fact that it requires very little interaction on the part of the user and upgrading the software is simple and relatively transparent to the user.

- **Easy to Use.** A feature often overlooked in the design of software for the scientific community is ease-of-use. A goal of the EVLA project is to have graphical user interface tools that are easy to use and intuitive. Besides being intuitive the GUIs must also adhere to a specified set of user interface design guidelines to create consistent interfaces and behavior across the various tools. Software that is easy to use is also often easy to learn which could reduce the three months it currently takes to train an array operator.

- **Robust.** The system must be capable of surviving failures within the system. It should not be affected by network glitches, broken socket connections, or the resetting or rebooting of devices within the system. In the event of such failures, OIS should simply warn the user that a failure has occurred, but it should continue working without incident. For example, if communication to an antenna is lost it should not affect the acquisition of data from all working antennas. And when the antenna is functioning and back online, the system should automatically resume data acquisition as if nothing happened.

10.5.3 OIS Design

The design goal of the Operational Interface Subsystem is to meet the requirements stated in the "EVLA Array Operations Software Requirements" document. At the same time the system must be designed so that parts of the system can be replaced with newer technologies. "Designing for the future" will allow new technologies, both hardware and software, to be "plugged-in" to the system for a gradual upgrade process rather than waiting for the next VLA expansion project.

10.5.3.1 OIS Hardware

OIS will not communicate directly with the hardware. Its only hardware design constraint is that it be relatively platform independent so it can run on many types of computers with little or no changes. This has little impact on the design and more impact on the selection of the implementation language.

10.5.3.2 OIS Software

10.5.3.2.1 General Description

The design of the Operational Interface Subsystem and the EVLA Monitor and Control System as a whole should exhibit the following general characteristics:

Loosely Coupled. Loosely coupled implies that components within the system are not tightly joined at the hip, but instead communicate via a coarse-grained interface that rarely changes. The primary benefit of loose coupling is that changes to one subsystem or subsystem component will not require changes to the subsystem that uses the changed component.

Highly Adaptive. The EVLA as a physical system will change not only through the transition phase and EVLA phase II, but also on a daily basis. During the transition phase VLA antennas will be upgraded to EVLA antennas and eventually NMA antennas will be added to the system. The system should easily adapt to these long-term changes without incident and without specialized code. It should also adapt to short-term changes such as the addition of new modules or monitor points.

Discovery-Based. A discovery-based system allows objects (e.g., subarrays, antennas, antenna subsystems, etc.) to be located at runtime rather than referring to a hard-coded list of known modules. In such a system the client can dynamically locate and manipulate any component within the system as the system dynamically changes beneath it. The more the client can find out about the system at runtime, the more flexible and extensible the system.

Extensible. An extensible system allows new features to be added to the system. The system should be designed so that these new features can be "plugged-in" at a later date with little or no impact on the overall system. Some examples of extensible features are a screen builder that allows users to create their own screens and a system simulator that could be used to test software or train operators.

Scalable. The physical elements of the EVLA will change over time. The number of antennas will increase and hence the number of antenna subsystems. As with most systems, the addition of new elements, in this case antennas, could possibly lead to degradation in performance. The system must be designed such that the addition of new antennas has minimal impact on the overall performance of the system. Likewise, as the number of users increases the overall performance of the system should not degrade.

Lightweight Client. In order to achieve loose coupling, OIS must have little or no knowledge of the implementation of EVLA components. OIS should only be concerned with the presentation of information and the sending and receiving of messages from other subsystems. The less OIS knows about the business logic, the less likely changes to the core system will affect OIS and the more detached the client software can be from the core components.

Use of Standards. The EVLA Monitor and Control System will be designed and implemented as a REST-based system. As such, it will utilize standards such as HTTP, URLs, XML, HTML, etc. (For more information on REST, see Roy Fielding's PhD dissertation, http://www.ics.uci.edu/~fielding/pubs/dissertation/fielding_dissertation.pdf.)

10.6 EVLA Monitor and Control Network (MCN)

The EVLA Monitor and Control Network links all antenna, correlator, and backend devices to the central Monitor and Control systems.

10.6.1 MCN General Description

The MCN, with one minor exception, will be fiber Ethernet. The exception (noted in 10.6.3.1.2) will be twisted pair copper. TCP and UDP packets will carry commands and status information between the control systems and devices. Each antenna will be treated as its own Class C network.

10.6.2 MCN Requirements

The MCN must be able to support expected M & C traffic both in functionality and in load. The MCN must also not hinder instrument performance either through RFI or availability.

10.6.2.1 MCN Hardware Requirements

10.6.2.1.1 MCN Performance requirements

The MCN must be able to sustain an aggregate 200Kb/s per antenna and 4000 packets/s per antenna. (Assumes 1 packet/10ms* 40 MIBs per antenna.)

10.6.2.1.2 MCN RFI requirements

The MCN must meet the RFI requirements defined in section 3.8 of the Project Book, and the requirements given in EVLA memo #46, "RFI Emission Goals for EVLA Electronics" (http://www.aoc.nrao.edu/evla/memolist.shtml).

10.6.2.2 MCN Software Requirements

10.6.2.2.1 MCN Protocol support

The MCN must support both TCP and UDP packets. The MCN must support any protocol such as FTP, HTTP, RPC mandated by the MC software system. The central distribution switch must support both Layer-2 and Layer-3 routing. This switch must have VLAN capabilities on all ports.

10.6.2.2.2 MCN Access requirement

Access to portions of the MCN may be required from remote locations. The exact details of this access will be defined at a later time. Those details should not directly affect the physical design of the network.

10.6.3 MCN Design

10.6.3.1 MCN Hardware in control building

The MCN will be a mixture of 100-1000Mbit single mode and multi mode fiber. Multiport fiber switches will be used to connect all components of the Monitor and Control System (MCS). The switched fiber fabric should meet performance and software requirements as well as mitigating RFI. QoS (quality of service) functionality may be desirable to ensure proper prioritization of traffic. Specifically the QoS capabilities must extent to VoIP traffic.

10.6.3.1.1 MCS Central Hardware

All MCS computers in the control building will be connected with 1Gbit full duplex multi-mode fiber through switches. The link between this cloud and other sections of the MCN will be 1Gbit multi-mode as well though 10Gbit may eventually be required.

10.6.3.1.2 Deformatters

The MCN connection to the deformatter boards will be through 100Mbit twisted pair copper. These devices will be physically located in the (shielded) correlator room. They will be addressed as if they were in their associated antenna.

10.6.3.1.3 LO Tx/Rx and power

These devices will be in the control building but will also be addressed as if they were internal to their antenna via the VLAN capabilities of the central distribution switch.

10.6.3.1.4 Other MCS devices in control building

All other MCS devices in the control building such as the weather station, correlator, and backend cluster will be accessed via multi-mode full duplex fiber. Individual connections will be run at 100Mbit or 1Gbit as required.

10.6.3.1.5 MCS Control building to Antenna link

Each antenna will be connected to the Control building via a 1Gbit full duplex single-mode fiber. All antennas will be connected using attenuated long distance network interfaces that will work over the entire range of distances.

10.6.3.2 MCN Antenna Hardware

10.6.3.2.1 Antenna to MCS Control building link

Each antenna will have a fiber switch with a mate to the control building end of the link. All antennas will be connected using attenuated long distance network interfaces that will work over the entire range of distances.

10.6.3.2.2 MCN antenna network

Each antenna will have a single fiber switch. One port will be connected to the MCS network as described in the previous section, the remaining ports will be directly connected to the MIBs via 100Mbit multi-mode fiber. Additional ports on the switch will be available for transient devices such as laptops or test equipment. These devices will also connect via 100Mbit multi-mode fiber. Until fiber based phones are available the 100Base-T VoIP phones will be connected to the switch via a media converter. The antenna switch should be capable of isolating broadcast between MIBS while allowing direct MIB to MIB communication where needed.

10.6.3.3 MCN addressing

The scale of the MCN requires that device addressing be separated into logical blocks of reasonable size.

10.6.3.3.1 Antenna addressing

Each antenna will be a single Class-C network of the form aaa.bbb.xxx.yyy where xxx defines the antenna and yyy defines the device in the antenna. The aaa.bbb portion will have a fixed value of 10.80. The xxx portion will be the antenna number +100. The yyy portion will be the slot number assigned as per the document "EVLA Hardware Networking Specification (Wayne M. Koski, document #A23010N0003*). As referenced in 10.6.3.1.3 some devices may be addressed as part of an antenna even though they are not physically in the antenna. Two or three of these Class-C networks will be set up in the AOC to facilitate testing. These networks will be addressed as 10.64.x.y.

* The referenced document can be found at:
\\Filehost\evla\techdocs\sysintegrt\system_documentation_standards\A23010N003.pdf (Windows), or
file:///home/evla/techdocs/sysintegrt/system_documentation_standards/A23010N003.pdf (Unix)

10.6.3.3.2 Control building addressing

The MC systems in the control building that include both control computers, switches and AMCS devices will be addressed together as the zero'th antenna.

10.6.3.4 MCN access

Access to the MCN will be restricted and based on the point of origin of the remote connection. Types and levels of access from specific sites have yet to be determined. The selection of the 10.x.y.z network automatically precludes direct access from non-NRAO facilities. We are capable of allowing (or blocking) direct traffic to the EVLA for those links for which we have complete end-to-end management.

10.6.3.4.1 MCN access from VLA systems

Specific access requirements still to be addressed. The VLA network and EVLA network are separated by the site router. Allowing or disallowing traffic flow between the networks can be easily controlled at either router.

10.6.3.4.2 MCN access from AOC systems

Specific access requirements still to be addressed. The AOC and EVLA sites are directly connected by the VLA and AOC routers. Allowing or disallowing traffic flow between the networks can be easily controlled at either router.

10.6.3.4.3 MCN access from NRAO systems

Specific access requirements still to be addressed. All NRAO facilities have direct connections to the AOC router and therefore direct access to the VLA site router and EVLA. Traffic flow can be controlled between the EVLA and any of the sites to meet access requirements. The Mauna Kea and Los Alamos VLBA stations are the lone exceptions. From a network perspective they appear as non-NRAO systems

10.6.3.4.4 MCN access from non-NRAO systems

Because the EVLA is in the 10.x.y.z network, direct traffic flow to the MCN is not possible from non-NRAO systems. By convention packets with this network address are not forwarded by internet routers. Indirect access to the EVLA network from non-NRAO facilities will fall into one of two categories.

Non-NRAO entities at non-NRAO facilities will first connect to a non-EVLA system likely located at the AOC. From there traffic will be limited in the same manner as it is for AOC systems. Since the link from the remote site to the AOC and from the AOC to the EVLA are disjoint, some form of interface or proxy will have to be designed for the AOC end of the system.

NRAO entities at non-NRAO facilities will be supplied with VPN (Virtual Private Network) client software. This will enable them to appear to be physically in the AOC even though they are not. Traffic flow will appear to be direct from the non-NRAO system to the MCN even though it will go through an intermediate system at the AOC. This form of link will not require a separate interface or proxy as the previous style will.

In both cases access can be restricted at the AOC independently of standard AOC traffic if so desired.

10.7 Transition Planning

10.7.1 Overview and Issues

A written plan for the transition from the VLA through a hybrid array to the final form of the EVLA now exists. The document is entitled “VLA/EVLA Transition Observing System Development and Re-engineering Plan”. It was written by Tom Morgan of the EVLA Computing Division, and can be found on the Computing Working Documents web page, http://www.aoc.nrao.edu/evla/techdocs/computer/workdocs/index.shtml (document #37). Briefly, the transition plan outlines seven phases, beginning with multi-antenna EVLA testing, and ending with a fully deployed EVLA. The document is listed as still being in draft status while it awaits further refinement of the later stages of the transition plan. The earlier stages of the plan, through retirement of the Modcomps and the arrival of the prototype correlator, are sufficiently detailed to serve as a basis for planning and organization.

Phases I – III of the plan detail the steps needed to arrive at the point where it is possible to decommission the Modcomp computers currently used to control the VLA. At that point it will be possible to control VLA and EVLA antennas and the existing correlator from an EVLA-hosted control system. The current goal for retiring the Modcomps is December 31, 2005. This goal is considered to be somewhat optimistic. The driver for this date is the arrival of the prototype correlator in Q1-Q2 2006. It is felt that integration of the prototype correlator into the monitor & control system will be simplified if the Modcomps are no longer playing any role in the control system. Phase IV of the transition plan prepares the EVLA Monitor and Control system to handle on-the-sky testing of the prototype WIDAR correlator. Phases V & VI are chiefly devoted to preparing the EVLA system for the production version of the WIDAR correlator. Phase VII is principally concerned with deployment of end-to-end software components.

10.7.2 Requirements

The scientific community stipulated three general requirements for the transition phase:

- The EVLA Monitor and Control must support simultaneous operation of the old VLA antennas and the EVLA antennas during the transition phase,
- Array down time shall be minimized as much as possible during the transition phase,
- Operations using the old VLA shall be possible using the current OBSERVE/JOBSERVE script files (to maintain backward compatibility with VLA antennas while they exist).

10.7.3 Design

10.7.3.1 Transition Hardware Modules

During the transition, EVLA antennas will contain the F14 module that is present in VLA antennas for control of some of the Front Ends. A transition module that enables monitor and control of the F14 module by the EVLA monitor and control system will be designed and constructed.

An interface will be provided between the EVLA M&C system and two VLA antenna subsystems known as the Antenna Control Unit (ACU) and the Focus Rotation Mount (FRM). The ACU controls movement for a VLA antenna, while the FRM establishes the proper positioning of the subreflector for a given band. This transition interface will exist until a replacement ACU and FRM is designed for the EVLA project.

The Digital Transmission System (DTS) deformatter will contain a filter that transforms an EVLA digital IF to an analog IF that is compatible with the current VLA correlator. This module will also match EVLA sidebands to VLA conventions when necessary.

10.7.3.2 Monitor and Control of VLA Antennas

VLA antennas awaiting upgrade to EVLA status will be controlled using the EVLA M&C system through the Interim Control & Monitor Processor (CMP). The CMP interfaces to the VLA antennas through the waveguide via the Serial Line Controller (SLC). The CMP is connected to a second port of the SLC and currently operates (monitor only) in parallel with the Modcomp connected on the first port. Eventually, the Modcomp will be retired and the CMP will take over full control of the VLA antennas.

The CMP is physically two VME Single Board Computers residing in a VME chassis above the SLC in the Control Building at the VLA site. An MVME142 (Motorola 68040) running VxWorks contains the SLC driver software and provides the real-time services timed by waveguide cycle interrupts from the SLC. The second processor is an MVME5100 (Motorola PPC750) running TimeSys Linux that provides the EVLA M&C functionality. The two processors communicate via shared memory over the VME bus.

The CMP will provide VLA Antenna objects similar to the EVLA Antenna objects described earlier to provide consistent operation of the two different antenna types.

10.7.3.3 Monitor and Control of the VLA Correlator

To replace obsolete, unsupportable hardware, and to assist in the transition phase by providing a network accessible controller, a replacement Correlator controller is being built. The new controller is a VME based computer system designed to accept seamlessly the current Modcomp control and data dump formats. The control path is a network connection, which makes it possible to connect the controller to other external systems, including an EVLA monitor and control system. The VME system will consist of a Single Board Computer (SBC) with an Ethernet interface for command/control, a SCSI back end for data storage and/or archiving, and a separate array processor to receive Correlator integrator data and perform final processing. The new system will be installed in the system controller rack of the VLA Correlator.

Currently the system is in the test and deployment stage. Progress continues to be constrained by the limited amount of time available for testing with the array, and by the other duties of the staff working on the project. The new system has been demonstrated to work in line and continuum with all modes and options. Astronomical testing has begun, as have plans for operational deployment. The remaining work is to tie it all together and provide tools for operations. Commissioning is expected in Q2 2005. The system has already been introduced to the operations staff during overnight tests.

10.8 The EVLA Test Antennas

10.8.1 EVLA Tests with Antenna 13

An incomplete set of the EVLA hardware has been installed on one antenna, antenna 13, and additional antennas are currently being fitted with the hardware. The primary uses of the test antenna so far have been to test and refine the hardware designs, and to provide a test bed for the software being developed for the eventual complete system. As each hardware module is brought up, the software to operate it is developed and installed in the MIBs that control it, and, usually, additional software from the overall script interpreter is effectuated to automatically set up and control the device. Eventually, more sophisticated tests will be done with the test antenna in conjunction with the rest of the VLA, and, in 2006, the test array of converted antennas will be used to test the WIDAR prototype correlator.

10.8.2 Software Requirements During the Testing Phase

To support development and debug efforts at the antenna, the EVLA Monitor and Control group must, at a minimum

- supply software for the MIBs that allows monitor data to be viewed in real-time, and accepts device commands;
- provide a central control program which can interpret a human readable script to control the operation of an antenna or antennas for test observing;
- provide a means of archiving the test antenna monitor data.

All three items are reasonably well in-hand. As of 11/01/2004 we have reasonable control software for the Antenna Control unit (ACU), the Subreflector Control Unit (FRM), both local oscillator modules (L301 and L302), the Baseband Converter module (T304), the Digital Data Transmitter (D30x), and the Digital Data Deformatter (D352). Only the bandswitching module (M301) needs to be done to provide sufficient control of the antenna hardware for simple observing.

The executive script interpreter module is operational, and has been used to control the test antenna in conjunction with the VLA, getting fringes via the VLA correlator.

A monitor data archive is in operation, and stores monitor data from the modules installed in the test antenna. Test antenna monitor data is stored in an Oracle database. It is expected that this scheme will suffice to archive monitor data for the operational EVLA. Various tools have been provided for data retrieval, listing, plotting, and analysis of the monitor data being collected.

10.8.3 Hardware Requirements during the testing phase

Software is being developed which runs on MIBs in the modules, in the correlator equivalent of MIBs (called CMIBs), and in a general purpose Linux computer system that provides the overall control of the array. The MIBs are planned to be the eventual array hardware; there is no expectation of any need to replace the MIB in any module; they should have the lifetime of the module. CMIBs, since they will be operated in shielded environments, are commercially available single board computers, and are thus considerably more capable than the MIBs. But again, it is likely that they will last the lifetime of their associated hardware. The Linux systems upon which the array control software is being developed, on the other hand will almost certainly need replacement. The existing system cannot provide the computing needed for fast mosaicing requirements of the system. This system will need replacement with one or more newer, faster systems late in the project. It is, however, adequate to operate within the bounds accessible with the current VLA, and we do not expect the system to be stressed for several years.