Monitor and Control

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Revision History:
2000-2-15: Fixed some typos and removed task diagram from Section 10.4
2000-2-14: Altered heading numbers for new project book
2000-2-4: Revised to include design decisions and implementation information for test interferometer
1999-4-8: Add in new detail on M&C data sizes and rates; minor changes to discussion points
1998-11-16: Combine previous contributions – favor distributed computing model

10.1 Summary

This section describes hardware and communications considerations and design decisions for the Monitor and Control (M&C) system, and some consideration of task structure. Other software considerations are described in Chapter 11.

Data rates for the M&C system are modest in most situations, ~4000 Bytes/second/antenna. Sampling of total power data, video data from an optical telescope, and FPGA downloads are some of the possible situations where the data load is significantly larger. An architecture in which as-dumb-as-possible devices communicate via a field bus, mastered by M&C computers at each antenna, is described. Separate, dedicated communications media will be required for the higher throughput subsystems.

Table 10.1.1 Principal M&C milestones, D&D phase

Standard bus interface circuit prototype	2000/02/25
M&C draft interface specifications	2000/03/25
Critical design review (M&C)	2000/06/31
Deliver single dish antenna test system	2001/09/01

10.2 Design Considerations

This is a list of high-level issues that have affected the choice of communication hardware and protocols; the type and distribution of computers; and the design of real-time control software.

1. The principle guiding the design of individual devices is to limit their intelligence. It is proposed that individual subsystems contain micro-controllers at least for maintaining communications with the computing system. These local processors may be required to perform some local hardware control, but in general will be mere input/output processors. Accordingly they should not be required to run an operating system or require large amounts of memory or rotating disk media.
2. Data rates at each device should be modest, and large amounts of data should not require tight timing constraints. The worst case latency for any M&C message should be no

greater than 1 ms. This requirement is intended to give sufficient scan time to sample several M&C points on the bus for presentation in a "virtual oscilloscope" fashion. The M&C medium should be deterministic such that priorities may be assigned to ensure that certain M&C values reach their destination within a timing tolerance of 1 ms.

3. The proposed allocation of "intelligence" is that each device at an antenna subsystem be considered as quite dumb. Control tasks requiring sub-millisecond timing should be handled within the subsystem. A field bus linking these subsystems and mastered by a real-time computer at each antenna will attend to control tasks above the sub-millisecond level.
4. The M&C communication system should support development and maintenance in the absence of the complete monitor and control system. Control signals must be provided and monitor signals recorded and displayed not only during normal operation of the array but also during development and testing. An individual device must be testable in the laboratory without the master computer or any subordinate computer of the M&C system. A collection of devices forming a subsystem, or a complete antenna's hardware, should be separately testable without support from the master computer (which might be busy with software tests or otherwise unavailable). It is intended to use LabView to support laboratory access to the M&C communication medium.
5. The current proposal is for a master computer housed in a control building of some sort. There will be a separate communications path from there to each antenna (a star configuration) run via optical fiber. A possible protocol for use here is ATM, providing a mix of dedicated real-time bandwidth and general purpose TCP/IP connections. A bus master, comprising a real-time computer, will be situated at each antenna and provides access to individual devices via a field bus. This topology assumes that devices on one antenna do not need to communicate with devices at another antenna.
6. The M&C system should make use of commercially available solutions wherever possible. Distributed control systems are common in the industrial process control and factory automation industries. In the past, NRAO has developed communications protocols and interfaces itself. Commercial products offer advantages in terms of cost, development time and fault tolerance.

10.3 Data Rates

The rate at which devices will have to be monitored or controlled is known to first order at this time. Current estimates follow. The first table, Table 10.3.1, summarizes the average and peak data rates at each antenna, according to information at the time of writing.

Table 10.3.1 Average and Peak Data Rates at Each Antenna

Mode	Average Data Rate (kB/s)	Peak Data Rate (kB/s)
Normal Observing	4.1	8.3
Total Power OTF	16.0	32.0
Video Data	4 200	4 200
Holography	4.3	8.3

Note that the net data rates are low (excluding science data of course) if we exclude the possibility of video data and total power, both of which should not be considered as monitor data. Sporadic data such as FPGA downloads may be quite large (20 Mbytes) but require only soft delivery deadlines; these account for the peak rates.

In Table 10.3.2, each subsystem at an antenna is listed with the numbers of M&C points allocated to each. The total shows that 75% of M&C traffic will be monitor data.

Table 10.3.2 Total Monitor and Control Points for devices at each antenna

Item	Control Points	Monitor Points
ACU	45	60
Metrology	4	10
Subreflector	4	4
Cryogenics	4	19
Dewar	1	8
HFET Receivers (3)	14	52
SIS Receivers (7)	14	52
Optical Telescope	8	8
Local Oscillator	4	18
IF System	14	8
Fiber Optics	8	12
Samplers and Filters	10	20
Other (environmental, safety, etc).		32
Totals	242	719

In Table 10.3.3, the most time critical M&C points for each subsystem are listed with their typical access intervals. The shortest interval is that of the Antenna Control Unit, requiring trajectory commands and position data to be transferred once every 50 ms.

Table 10.3.3 Time critical monitor and control points for devices at each antenna

Item	Control		Monitor	
	Size (B)	Time (s)	Size (B)	Time (s)
ACU mount positions	16	0.05[1]	20	0.05
Metrology	2	Rare	10	0.5
Subreflector nutation control	6	0.1	6	0.1
Cryogenics	10	Rare	100	600
Dewar	2	Rare	30	600
HFET Receivers (3)	10	Rare	180	60
SIS Receivers (7)	10	Rare	180	60
Optical Telescope	8	Rare	8	Rare
Local Oscillator	2	0.1	10	1
IF System	10	10		
Fiber Optics			12	10
Samplers and Filters	10	1	10	10
Other (environmental, safety, etc).			32	600

In Tables 10.3.4 and 10.3.5, the numbers of M&C points located in the central control building are broken down by subsystem. Note that in the case of the correlator, many of the M&C points may be broadcast

[1] This rate is an update for position and velocity commands. The actual servo period will be much shorter.

Table 10.3.4 Total monitor and control points for common devices, at central building

Item	Control Points	Monitor Points
Timing standard	10	60
LO System	10	10
Optical Transmitters	10	10
Reference signal generation	10	20
Weather instruments	1	8
Totals	41	108

Table 10.3.5 Total monitor and control points for correlator related subsystems

Item	Control Points	Monitor Points
Input configuration	200	20
Delay tracking	200	20
Output configuration	200	20
Totals	600	60

10.4 Conceptual Design

The design presented here is currently under review.

- **Device Complexity.** Devices are allowed to have a wide range of complexity and built-in "intelligence". There is no requirement for some minimum processing capability, and most devices may be completely "dumb". A dumb device is one that sets its state to that given in a coded instruction immediately upon receipt of the instruction, without further processing. A somewhat intelligent device might execute instructions at specified future times, or interpolate between instructions, or derive its new internal state from a combination of the present instruction and its current state. In all cases, device intelligence is considered "embedded" - part of the hardware - and therefore not part of the monitor/control system.
- **Overall Communication**. The correlator and all antennas are joined at the master computer by a fiber network, arranged in a star topology. A standard networking protocol, most probably ATM, will be used to implement this communication. Many recent telescope control systems have used commodity networking to good effect.
- **Distribution of Intelligence.** Besides the master computer and embedded processors, there will be a separate computer for the control of the correlator, and a computer at each antenna. The role of this antenna computer is twofold: to organize communications between devices at the antenna and the central computer, and to implement tasks that can most profitably be executed locally.
- **Intra-antenna Communication.** At each antenna there shall be one or more local buses which interface the devices situated at the antenna to the antenna computer, which in turn organizes communication with the master computer over the fiber network. These buses will be commercial systems based on the CAN network, ISO 11898. In addition, a non-standard higher layer protocol will be developed to provide application level services. A separate communications path would be provided to carry the video signal from the optical telescope to a computer with a frame grabber and to collect total power samples.

- **Real Time Boundary.** Any loop requiring a response to an event with a hard deadline of less than 1 millisecond should close the control loop within the local device. Closed loop systems with looser deadlines may be closed by the “bus master”.
- **Time.** All M&C computers shall know the time to an accuracy of least 0.1ms, and shall be capable of delivering a periodic signal with a jitter of less than 0.05ms (these values are subject to revision during detailed design). Low-speed devices thus do not need any knowledge of time; the M&C computer can time them appropriately. A 50 Hz period, sub-microsecond jitter distributed time signal will be required for other purposes in ALMA. It is anticipated that the M&C system will tap into this system for time synchronization.

This design essentially uses a computer to couple a local intra-antenna bus to a wider ALMA network. The aggregate computing power at each antenna exceeds that which is required for its coordination role. On the other hand this design allows for much flexibility in handling antennas with special instrumentation, implementing high-speed sampling for debugging devices at the antenna remotely (“virtual oscilloscope”), and other requirements which are unknown now but will inevitably become important later.

Testing outside of the M&C system can be accomplished in two ways. First, the entire antenna may be unplugged from the M&C system and into another computer (*e.g.*, a technician’s laptop or a computer on the antenna transporter). Similarly, a particular device may be plugged into a local bus that is attached to some other computer. This allows for testing during development when a full M&C software system is not available. For example, a PC with a commercial CAN bus interface card will be used to act as a bus master in the lab. National Instruments LabView is the defacto standard for test software in this phase.

10.5 Implementation Details

The current state of M&C implementation is summarized as follows:

- Slave node software has been developed supporting the CAN bus and the non-standard higher layer protocol. This software is written in C and is available for Siemens C167 and Microchip PIC16C74 micro-controllers.
- A prototype standard M&C interface circuit is currently being fabricated and will be tested shortly. This standard circuit is based on the Siemens C167 micro-controller and includes flexible digital and analog I/O options.
- A prototype M&C interface has been tested for the Fiber Optic laser temperature/current controller making use of the PIC16C74 micro-controller.
- Bus master Virtual Instruments have been developed for use in LabView and have been tested with the prototype slave nodes available. This software has been tested on a standard PC running Windows NT and using the National Instruments PCI CAN board.
- Bus master software has been written for use in VxWorks PowerPC systems. A test system using an MVME1603 motherboard and an SBS Greenspring PMC-ECAN-1 CAN interface board has been tested with the prototype slave nodes available. This software was written in C and makes use of a VxWorks device driver supplied by SBS Greenspring.

10.6 Reference Documents

[1] ALMA-US Computing Memo #1 Monitor and Control Points for the MMA, F. Stauffer, 1999-May-11

[2] ALMA-US Computing Memo #5 ALMA Monitor and Control Bus Requirements, M. Brooks, 1999-Jun-02

[3] ALMA-US Computing Memo #6 ALMA Monitor and Control System, M. Brooks, 1999-Jun-07

[4] ALMA-US Computing Memo #7 ALMA Monitor and Control Bus Draft Specifications, M. Brooks, 1999-December-09

[5] "CAN System Engineering", Wolfhard Lawrenz, Springer-Verlag, 1997

[6] ISO 11898:1993 Road vehicles - Interchange of digital information - Controller area network (CAN) for high-speed communication