VLBA ACQUISITION MEMO # 238*

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

HAYSTACK OBSERVATORY

WESTFORD, MASSACHUSETTS 01886

(24 January 1991)
**REVISED 22 May 1992*

Telephone: 508-692-4764
Fax: 617-981-0590

To: VLBA Tape Drive Users

From: Roger Cappallo

Subject: Recorder Controller Commands (ReCon v. 6.0)

Date: May 22, 1992

The VLBA tape drive is controlled via 16 bit command words through the Monitor and Control Bus (MCB), or equivalently, via an RS-232 emulation of the MCB. I have listed the commands in tabular form in VLBA Acquisition Memo number 71, dated 86.10.16, which was most recently updated on 92.5.22. Since the original protocol document was not intended to provide sufficient information to operate the drive, there has been some confusion about some of the commands. In this document I intend to supply enough detail about the workings of each command to allow the user to control the drive in a sensible manner. The reader will probably find it useful to refer to the protocol document to place this information in perspective. I will list the commands in MCB-address order, with the monitor output address space (00-7F) coming first.

Monitor words

Monitor data generally reflect the current state of the machine, and are developed, whenever possible, by reading the outputs of latches, etc. There will be a delay of a few tens of milliseconds between issuance of a command, and a change in state of the corresponding monitor variables.

Write Module

- **00 - 09:** The signal-switching capabilities of the Digital Write Module are exercised through the commands residing at addresses 80 - 89. These corresponding monitor addresses allow the user to *read* the outputs of the PPI chips that are used to implement the switching functions. This is useful for hardware maintenance, and under normal operation the values at locations 00 - 09 will be identical to those at 80 - 89.

Monitor Module

- **10 - 1D:** As was the case with the Write board, the Digital Monitor Module has switching functions that are implemented by commands 90 - 9D, but which can be monitored at locations **10** - **1D**. Once again, the values read on the command side and monitor side will not differ (save for slight delays as the commands are implemented) when the hardware is properly working.

- **1E** - **1F**: When data is extracted (see **9D**) the 32 bits are placed here. The MSB (bit 31) corresponds to bit 15 of **1E**, while the LSB (bit 0) corresponds to bit 0 of **1F**. Bit 31 is the *earliest* bit to be received.

- **20**: The frequency search range for the clock extraction (see **A8**) is read back from the AT&T T7033 clock recovery chip and displayed here.

Transport Module

- **30**: The current reading of the footage counter can be read at this location. It is calculated by counting capstan tachometer pulses, and dividing by a constant appropriate to the size of the capstan on this machine. See also commands **B8** and **B9**.

- **31**: The recorder controller hardware contains a feature that allows one to estimate the number of feet of tape remaining on each of the reels. This feat of legerdemain is accomplished by counting capstan tach pulses for each rotation of the reel motors (which have mercury switches in them). The count allows one to determine the ratio of the capstan diameter to the diameter of the current state of the reel. The reel diameter, in conjunction with an estimate of the tape thickness (see command **BD**), allows one to estimate the number of feet of tape currently on the reel. The estimate is good to perhaps 50 feet or so. The usefullness of this feature lies in the ability to reset the footage counter (command **B8**) in the event of power outage, or CPU reset, somewhere in the middle of the tape. This location contains the current estimate for the supply (upper) reel.

- **32**: The equivalent of location **31** for the take-up (lower) reel.

- **33**: The motion of the reels will normally be halted a short distance ($\approx$ 50 ft) from the end of the tape. This is accomplished with the same hardware as the reel-pack detector. When the lowtape condition is sensed, regardless of whether or not the tape motion is stopped (see command **B6**), this location will be set to 1.

- **34**: The length of the last successful bar code reading is stored here in units of characters. This length will include, for example, the space and check characters found at the end of a Mark 3 bar code.

- **35** - **3A**: The actual bar code last read is stored in these locations. It is left-justified, i. e. the first character is in bits 15–8 of location **35**. If the code was less than 12 characters, it is right-padded with blanks. Otherwise, the first 12 characters are displayed in these locations. When a checksum character is employed (see **BE**), it will be displayed here, so long as it isn't the 13th or greater character. Normally, for Mark 3, one is expected to use the first 8 characters and ignore the rest.

Head Positioner

- **40**: This location will always contain the value of the headblock parameter pointed to by locations **C3** and **C4**. There will be a 2 or 3 ms delay after these pointers are modified before the effect will appear at location **40**. This is due to the finite time required by RECON (the recorder controller program) to access the requested parameters.

- **41:** The total position commanded is expressed in units of kilo-Angstroms (kÅ), or equivalently, in tenths of microns. This value was used for the last head positioning command that was issued.
- **42:** The actual position is also given in kÅ. Whenever the headstack is moved an internal command to measure head position (**CE**) is executed. This quantity can also be updated as a result of the user issuing a **CE**.
- **43:** For some users it is convenient to know directly what the reading in millivolts was the last time that the LVDT was sampled. If, instead, one were to simply read the current raw A/D values for the LVDT output, the answer would be useless, since the LVDT oscillator is no longer activated.

A/D Board

- **50 - 5F:** The XYCOM A/D board has 16 input channels in the differential input mode. The board is further configured to measure voltages in the range -10V to 10V, and converts the analog voltage to a 12 bit 2's complement number. Thus -10V will be converted to -2048, and +10V will show up as +2047. The resolution is about 4.883 mV per bit. The RECON task responsible for sampling the analog inputs will update all 16 channels in about 800μs, and does so at 30 ms intervals. The mapping of signals to A/D channels can be found in ATOD.HH.
- **60 - 61:** The total power for each of two possible headstacks is determined by applying the equalized output of a selected track to a square-law detector, and measuring the resultant voltage using the A/D converter. The units presented here are 0.01 volts, and are totally arbitrary. No attempt has been made to calibrate the power scale such that one can tell what the real amount of received power is. The track selection is accomplished by commands **90** and **92**.
- **62 - 63:** The temperature of each head is sensed by a transducer embedded in the head block. A voltage proportional to the temperature, over the range 0–100 C is produced. The voltage is then measured in the A/D board, and the implied temperature, in units of 0.1 deg C, is reported here. The calibration of the transducers is done within the Analog Conditioning module.
- **64:** The vacuum level in the vacuum column is sensed by a pressure transducer which produces a voltage that is proportional to the pressure difference between the vacuum column and the ambient air. However, the constant of proportionality and the y-intercept seem to vary from transport to transport. Therefore, in revision 5 of RECON there is the capability for the user to set these calibration constants, as determined by comparison with the (hopefully) more reliable analog pressure gauge supplied by Honeywell. The units given are in 0.1 inches of water pressure. Optimal operating pressure depends on the thickness of tape being used, as well as the intended speed of operation of the transport. As the vacuum increases,so does head wear. At lower pressures and higher speeds, one starts to experience head-tape contact problems ("flying"). The canonical value being used in early 1990 is about 9 inches of water.

Mark 3A Clock Recovery Module

- **68:** The frequency search range for the clock extraction (see **D8**) is read back from the AT&T T7033 clock recovery chip and displayed here.
- **69:** The current track assignment is read back from the SC11320 cross-point array chip and displayed here. An input track from (-1 – 30) is returned, and corresponds to the source of the signal for the output track (1 – 32) currently selected by word **DA**.

CPU Board

- **70:** This location provides a window into the RAM/ROM/Memory-mapped-devices memory space. It contains the current contents of the 16 bit word pointed to by the 24 bit address in locations **E0** and **E1**, and is updated every $\sim$ 100 ms. This function is analogous to a BASIC PEEK, and is useful for program development and hardware debugging.
- **71:** The current revision number of RECON, which is contained in ROM, is also copied to this address. This is useful for configuration control.
- **72:** The transport chassis, proper, has no provision for a hardware, machine-readable serial number. Thus we use the 8-bit "piano" switch on the front of the MVME117 CPU board to supply this function. The intent is to set these switches with consecutive numbers as the units are built. One must be careful to reconfigure the switch upon CPU board transplant, however, since the serial number is to be associated with the transport itself, and not with the CPU. The state of the piano switch is read once, when RECON is first initiated.
- **73:** The general status word contains many bits describing the current health and happiness of the machine.

  Bit 0 – In order to keep normal communications to a minimum, this is a single bit which denotes whether or not one or more error conditions exist. If this bit is set, one must read the error flags in word **74** to ascertain which errors have been detected. The act of reading the error flag word will reset Bit 0.

  Bit 1 – There is actually a small circuit in hardware which detects whether or not the capstan is moving, by measuring the time between tach pulses. This bit reflects the instantaneous state of the capstan, and would, for example, be true even if the capstan is being rotated by hand.

  Bit 2 – There is also digital logic to detect when the inchworm device is being pulsed, thus this bit reflects the current state of motion of the active headstack.

  Bit 3 – The digital ramp generator is used to accelerate and decelerate the capstan. It accomplished this by either incrementing or decrementing a frequency register, which in turn drives the capstan. When the frequency register matches the target frequency (speed), the value is frozen. Bit 3 is true whenever the frequency register's value is up or down-counting.

  Bit 4 – Head positioning is an iterative process. First, RECON measures the current head position and calculates the distance to move. The inchworm is then moved at either fast or slow speed (depending on the distance to go), for an appropriate amount of time (which gets loaded into a head-control timer that gates the oscillator output). When the timer times out, the current position is measured, and if we are within an acceptable distance (currently 5 kÅ), the process is halted. Otherwise, the new position error is used for a second round of head motion, as above, and so on. Eventually the head either reaches the desired position, or times out (see **74** bit 3). From the time of first measurement to final measurement Bit 4 is true, whether or not the headstack is physically in motion (see Bit 2).

Bit 5 – Tape positioning is also an (potentially) iterative task (see **B7**). Bit 5 is true from receipt of a positioning command until the tape comes to rest at the desired footage.

Bit 6 – In addition to both the analog vacuum gauge on the Honeywell transport, and the machine-readable pressure transducer (see **64**), there is a "go - no go" style vacuum sensor. This sensor is used by the hardware as a safety interlock, to prevent potentially damaging motion in the event of vacuum failure, or when the tape is improperly loaded. Bit 6 reflects the current state of this sensor.

Bit 7 – The transport uses a 5 MHz signal for a number of vital functions. This 5 MHz can either be externally supplied, or generated with an internal oscillator. There is circuitry which detects whether or not an external 5 MHz signal is connected, and if not the machine will switch to its internal standard. Bit 7 will be true when the external 5 MHz is present.

Bit 8 – In order to ensure future flexibility, the digital control logic was designed with synchronicity to external timing signals in mind. To this end, a 1 pps input to the transport is supplied, and this signal is distributed internally to several counters and timers. If so desired, RECON could be modified to make use of these signals for motion and data capture and time tagging. If 1 pps is present, then Bit 8 will be set.

Bit 9 – Since the peak (once) command, see **C9**, takes a while to execute, this bit is supplied so that the user can tell when the operation is complete, namely, when the bit is cleared.

Bit 10 – When this bit is true, the automatic head tracking feature is enabled (active). See command **CA**.

Bit 11 – This bit is true whenever the capstan is currently enabled to go in the *forward* direction. The direction indicated here is more immediate than, for example, that of command **B1**: If the transport is moving in the forward direction, and a move-in-reverse command is given (**B1** = 0), it will take several seconds for the transport to come to a stop, and set off in reverse, at which point bit 11 would change from 1 to 0.

Bit 12 – is true whenever the bar code starting at location **35** is valid. It is cleared upon unloads (**B4**), unsuccessful reads (**BE**), or by issuing **BE** with bit 0 = 0.

Bit 13 – is true whenever the tape drive is slewing (see **BB**).

- **74:** The various error conditions that can arise during the operation of the transport are tabulated here. Normally, all bits are zero. Whenever this word is read, the bits are all reset to zero.

Bit 0 – This is a generic data-out-of-range indicator defined at the request of the Penny & Giles folks, to support their implementation of a reproduce transport.

Bit 2 – When the transport is unable to achieve a sufficient vacuum in response to a load command (**B3**), this bit is set.

Bit 3 – If set, a request to change the active head (command **C3**) has failed. One possibility is that the currently active head is indeed actively engaged in positioning. (The hardware can only manipulate one head at a time). The other possibility is that the requested active head is out of range. The current (version 5) software only supports two heads, numbers 1 and 2.

Bit 4 – When set, the index number specified by command **C0** was out of range. In version 5 the allowable indices are 1 – 32.

Bit 5 – The allowable head block parameter numbers are 0 – 11. Any other value being issued by **C4** will cause this bit to be set.

Bit 6 – The XYCOM A/D board will perform one dual-ended conversion in a nominal $50\mu s$. If the board has not completed a conversion after $\approx 200\mu s$ this bit gets posted. It almost certainly indicates an I/O board failure.

Bit 7 – The lower half (00 – 7F) of the MCB address space is reserved for (read-only) monitor data. If bit 7 is set, a request was made to write to one of these locations.

Bit 8 – Before the transport can move tape, the drive must be in the loaded state, i.e. - a successful **B3** command must have been executed. If not, and a request for motion is made (**B1, B2, B4, B7**), the request will be rejected, and bit 8 will be set.

Bit 9 – The head positioning mechanism is not fully reliable, and occasionally a head movement request (**C6, C7, C8**) will fail. If the headstack does not reach the desired location within a preset amount of time (15 s in version 4 of RECON), the movement is aborted, and bit 9 is posted.

Bit 10 – Whenever an attempt to read the bar code fails, this bit is set. Possible causes are: tape was not loaded when the read command was issued, the tape was moving (so that the request was rejected), or the software was unable to successfully read the label and timed out.

Bit 14 – The internal task dispatcher intercepts all interrupts that may conceivably be acknowledged by the 68010 CPU. Since only a small fraction are actually used, any others are ignored. This bit, when set, implies that an unexpected interrupt has occurred (see **76**).

Bit 15 – This flag, when set, indicates that there is a further software error code to be found in location **75**. When the contents of **75** are read, then this bit is cleared.

- **75:** The software error codes report various low-level problems that might occur within RECON. They are listed in the include file mcbus.h, and should be attended to by a cognizant programmer.
- **76:** When an unbidden interrupt does occur (see word **74**, bit 14), the interrupt vector (address) is reported in this location.

Commands

Write Module

- **80:** The recorder has the capability to receive 36 parallel signals from each of two independent formatters, designated as FMTR1 and FMTR2. The recorder can also be routinely outfitted with two headstacks. Each output group of 9 tracks for each headstack (8 groups in all, for a total of 72 tracks) can independently be directed to select the corresponding input group from FMTR1 or FMTR2.

- **81:** Each of the four output groups in each of the two headstacks can have its recording current enabled/disabled by the low-order 8 bits of this command.
- **82 - 89:** There are four so-called system tracks on each of the two headstacks, residing at track numbers 0, 1, 34, and 35. For each headstack, each one of the four system tracks (eight in all) can get as its input any one of the available 36 formatter output tracks as selected by command **80** above.

Monitor Module

- **90 - 93:** The analog read module has the capability to select 2 tracks, from among its 36 input tracks, to return back to the monitor module for analysis. These outputs are called A and B. If there are 2 headstacks, one needs to specify 4 6-bit numbers.
- **94 - 97:** In each of the analog read modules there are 2 equalizers, which receive the channel A and B outputs. To allow for experimentation there are 3 different equalizer settings for each signal: std, alt1, and alt2.
- **98 - 9B:** There are 4 signals which are returned to the formatters for analysis; they are called M1 and M2, for each of formatters 1 and 2. The source of each of these signals is chosen by a 1 of 8 selector, which this command sets. The 8 different signals derive from Output A and B, Head 1 and 2, and read or bypass mode. Bypass mode, which reroutes the write signal back through the read circuitry, is useful in diagnosing problems.
- **9C:** The onboard data extractor allows a small amount of data (32 bits) to be captured. This command selects which of the outputs of the 4 bit-synchronizers is to be the source of the captured data.
- **9D:** The desired chunk of data is specified by its location relative to the sync word. This command specifies the delay in bits from the sync pattern to the target piece of data. A value of 0 will extract bits 63 - 32 of the sync pattern itself.
- **9E:** The sync detection is accomplished by a general purpose pattern-matching IC, the TDC1023. It will match anywhere from 1 – 64 bits of data against a preloaded pattern. If the number of matching bits is greater than a preset threshhold, then sync is detected. This command preloads said threshhold. In the presence of a high parity rate percentage, it becomes increasing unlikely that a long sync word will be perfectly matched. By setting the threshhold a few bits less than the total number of bits in the sync word, one might still be able to detect syncs, yet have a suitably small percentage of false syncs.
- **9F:** A 1 written to this location will initiate the data extraction process. For correct results, one must have preloaded the various monitor module control words.
- **A0 - A3:** A sync word of 64 bits should be written by the user to this location, before initiating data extraction. When word **A3** is received, the full pattern is downloaded into the sync-extraction IC. Hence, one would normally write the words sequentially, **A0** through **A3**.

- **A4 - A7:** This 64 bit mask tells which of the bits in the sync word are significant. Once again, the last word, in this case **A7**, initiates the download. The purpose for this feature is that one may not always desire a full 64 bit sync pattern. For example, by preloading 36 1's, followed by 28 0's, the Mark 3 36-bit sync pattern can be accommodated.

- **A8:** The AT&T T7033 clock-recovery chip has a user-selectable frequency range over which it can lock up to the input signal. The value commanded here is passed along to the chip unchanged, as a hex number in the range 01–59. Two common values are 34, for 4.5 Mbit/s clock speed, and 24, for 9 Mb/s. Refer to either the T7033 data sheet, or the monitor module interface description for the meaning of other values.

Transport Module

- **B0:** If a 1 is written to this location, any current movement of the tape is stopped. If there is a positioning request (**B7**), an unload (**B4**), or a fast forward or rewind (**B2**) active, these are also killed. *Actually, most of the single-bit commands can have any value written to them and still work, but it is probably a good idea to write a 1, just in case.*

- **B1:** This command will start the drive in the indicated direction (1 = forward). The speed will generally have been preset by writing to **B5**.

- **B2:** When this command is issued, the drive will be started in the indicated direction at top speed (330 ips), and unless otherwise disturbed, will continue on to the lowtape point. This command is equivalent to enabling lowtape (**B6**), setting the capstan speed (**B5**) to 330.00, and starting the drive (**B1**).

- **B3:** This command will load the tape into the vacuum column. This is accomplished by several cycles of small motions. In each cycle the reel motor brakes are released and the reel servos are energized for 0.5 s, followed by 0.5 s of brakes on, and reel servos de-energized. In this fashion the tape is fed into the vacuum columns a little bit at a time, so that no messy overshoot or runaway conditions occur. These energization cycles are terminated either by a normal vacuum sense (see bit 6 of **73**), or the completion of 5 full cycles. If the latter condition obtains, it is reported in bit 2 of **74**.

  In version 6 and later of RECON, bit 0 controls the automatic reading of the bar code upon successful conclusion of a load operation. Bit 0 equal to 0 implies a bar code read request. Internally, the software just issues a bar code read command (**BE**), with bit 1 (checksum enable) set to whatever its prior value was.

- **B4:** After the last observation is recorded on a tape, one generally wants to rewind the tape as quickly as possible, and then unload it, in a gentle fashion, onto the supply reel. RECON accomplishes this by rewinding at 330 ips until the low tape point, then ramping down to 90 ips to spin off the takeup reel. The user can tell when the tape is unloaded by monitoring bit 5 of the general status word (**73**), to see when the tape-positioning bit clears.

- **B5:** This command sets the capstan reference speed (see also command **BB**) in units of 0.01 ips. The recommended range would thus be 0 – 33000. This command does not initiate motion, that is done by **B1**, but it does specify the speed that will later be used.

- **B6:** By clever use of the reel pack detectors (see monitor word **31**), the transport is able to sense the approaching end of the tape, and automatically stop before running off the end of either reel. Command word **B6** enables/disables this feature. For normal operation low tape would be kept in the enabled state. The unload command, **B4**, will disable low tape automatically when necessary.

- **B7:** The RECON firmware will position the transport to any requested footage in the range 0 – 65535 in response to this command. In order to do so, the algorithm relies upon the offset speed feature. It ramps up to high speed for a predetermined length of time, and back down to 0 speed, hopefully at the requested footage. If the position is not within 1 foot (revision 5) of the commanded position, another cycle of positioning will be started, and so on. Generally, a second iteration is not necessary.

- **B8:** At times, such as after a power failure in the middle of a tape, it may be desirable to force the internal footage counter to some arbitrary value. For example, one might use the take-up reel-pack (location **32**) as the best available estimate, and store the value to **B8**.

- **B9:** The capstan size constant is an arbitrary number which is inversely proportional to the diameter of the capstan for this particular drive. Due to manufacturing (in)tolerances, the diameters can vary by as much as 1 part in 700. In order to have a requested speed of 270.00 ips mean, as closely as possible, the same tape speed on all transports, we adjust the capstan size constant. The calibration is performed by playing back a reference recording and adjusting the size constant so that the bits come off at the nominal rate. In normal operations, the capstan size constant will be downloaded once upon power-up.

- **BA:** The brake and servo release, when activated by writing 1 to this location, will release the reel motor brakes, and de-energize the reel servo's. In this state, both reels can be turned freely by hand.

- **BB:** This command is used in conjunction with **BC** to specify an offset speed which the transport is to run at. The units are 0.01 ips. The offset speed register is a second target speed (in addition to the reference speed) which the drive can be requested to run at, for the interval requested in **BC**. Of course, the actual speed of the drive is determined by the current contents of the ramp register (not user-accessible), which continuously endeavours to match the active target speed, whether it be reference or offset. Slewing to an offset speed for a pre-determined length of time is the method normally used to synchronize correlators.

- **BC:** The length of time that the active target register is switched to the offset register is determined by the contents of this command. This command also triggers the switchover to the offset register, just by being issued. The units are in 0.01 s.

- **BD:** Set the tape thickness in kÅ. Nominally the transport assumes the tape thickness to 268 kÅ, or 26.8 microns, appropriate to Fuji H621E. As new, thinner-based tapes become available, one will need to let the transport know what is being used. The thickness is used in the calculation of the reel pack lengths (**30** – **31**) from the pack diameters.

- **BE:** The bar code primitive command controls the basic reading of the bar codes. Bit 0, when set, requests that the tape be moved slowly and the bar code read off of the reel. This action is allowable only when the transport is in the ready state – vacuum OK, and servos energized, and not moving. Otherwise an error will be reported in the error word, **74**. The Opticon bar code reader can optionally examine the last character read, and interpret it as a checksum character. Bit 1 is used to control this option in the firmware: setting it to 1 *enables* the checking of the checksum, while 0 *disables* the checksum feature. If the checksum fails, the reader will timeout and an unsuccessful read error (word **74**, bit 10) will be reported. One can enter this checking mode, for example, by issuing a 2 to location **BE**, without actually trying to perform a read. The default mode is to have checksums enabled. Most users will find it convenient to read the bar code upon loading the tape, by writing a 0 to **B3**.

- **BF:** Some users find it desirable to modify the *low tape point*, at which an automatic stop is initiated (see also **B6**). This number, which is nominally 5000 (1324 hex), is proportional to the radius of the reel pack at the low tape point. Small increases or decreases in its value will allow more tape or less tape, respectively, to be left on the end of the reel.

Head Positioner

- **C0:** In an attempt to free the user from worrying about actual locations of recorded passes on the tape, a system of index positions was developed. RECON maintains a table of pass locations in kÅin RAM, so that the user need only specify an index number, and the headstack will move to the appropriate spot across the tape (see **C8**). This command will set the index number to be used either for a subsequent download of a position (**C1**), or an actual move to an indexed position (**C8**). The allowable values are 0 – 31.

- **C1:** Download an index position value in kÅ, for the current index number (see **C0**), to a table in RAM. RECON can then subsequently use this value for indexed moves (**C8**). The normal procedure would be to download the whole index position table once upon power-up, with multiple command pairs using **C0** and **C1**.

- **C2:** It seems a general characteristic of the Honeyweell transports that there is a direction-dependent tracking offset; i.e., the tape shifts slightly when the changing from forward to reverse tape motion. The amount of this bias can be determined by calibration of each specific transport. One can then position the headstack to a location that is slightly offset in order to counteract this effect, and so achieve transport interchangeability. The actual offsets are kept (perhaps inconsistently) in the headblock parameter table (see **C4**), but since the head is normally positioned while the drive is at rest, one must tell RECON, in advance of head motion, which direction the drive is about to go. The only positioning command to make use of the direction-dependent offsets is the indexed move, **C8**.

- **C3:** The active head number, which in principle can run from 1 – 4, specifies to which head do commands **C4** – **CE** apply. Although we have provided an expansion path for the control of four headstacks, the version 5 of RECON supports two headstacks. Indeed, there are numerous spots in the recorder design where only one, or perhaps two headstacks are accommodated.

- **C4:** The headblock parameter number is an integer in the range 0 – 10. Location **C4** should be preloaded with the desired number prior to either downloading a parameter value (**C5**), or reading out the current value from RAM (**40**). They are stored in this indirect scheme in order to save MCB address space. The headblock parameters are necessary because the headblock mechanisms can not be manufactured with tight enough tolerances to allow "blind" operation. Instead, each headblock must be calibrated - all of the critical operating parameters must be measured - and a table of the resulting values downloaded to the transport before operation. For each headblock, the following parameters are necessary:

0–3: The inchworm can go in two directions, *in* toward the deckplate, or *out* away from it. The inchworm motors can also travel at two quite different speeds, *fast* and *slow*. The four different speeds of travel, as measured, are entered here.

4–7: The position of the inchworm-driven headblock assembly is measure by an LVDT. This device converts single-dimensional motion, more or less linearly, into a signed voltage. The scales for travel in the positive direction from center (i.e. in towards the deckplate), differ somewhat from the scale in the negative half of travel. The two linear proportionality constants are in headblock locations 4 and 5. A further complication may arise if there is significant non-linearity in the voltage as a function of position, and provision has been made (but is not currently being used) for quadratic correction terms, in both positive and negative directions. These parameters are given through locations 6 and 7.

8–9: Although the Honeywell model 96 transport guides tape very well, there are significant differences from machine to machine in the exact tape path across the heads, when going in forward and reverse directions. There can also be a substantial "DC shift" of the track locations in either direction. To accommodate this, parameters 8 and 9 allow the user to specify (after prior measurement, of course) the direction-dependent shifts. The only command which these values have an effect on is **C8**, the so-called indexed move. Absolute (**C6**) and relative (**C7**) movement commands do not use these parameters.

10: It is possible that in the future we will want to correct the LVDT-inferred position for temperature effects. To that end, parameter 10 allows one to specify a linear correction factor for LVDT error as a function of headblock temperature.

- **C5:** The operand of this command will get written into the headblock parameter memory appropriate to the current active head (**C3**), and the currently active headblock index number (**C4**).

- **C6:** This command will move the headstack to the specified absolute position in kÅ. There are no correction factors applied, other than the necessary polynomial coefficients to convert LVDT voltages to positions. The move will be performed at slow speed, if the resulting timer duration is less than the maximum ($\sim 2.4s$). Otherwise, the move will be made at (the less-precise) fast speed. If, after the first timed move, the error in the headstack position is greater than 5 kÅ, a second round of correction will be made. This iterative process will be carried out until the error is less than the criterion. If this iterative movement does not converge within 15 seconds, the motion will be aborted, and a head movement timeout will be posted (bit 9 of monitor word **74**). *The usual reasons for timeout will be mis-calibrated inchworm speeds or a "sticky" inchworm motor.*

- **C7:** The relative move command simply reads the current position of the headstack, adds in the amount of the relative move, and issues an absolute move to the location of their sum.

- **C8:** The indexed move command allows the most-straightforward operation of this multiple-pass recorder. The intended mode of usage is for one to set up an index position table, usings commands **C0** and **C1**, for all desired passes, at the time of tape drive initialization. Subsequently, whenever the position of the headstack needs to be changed, one merely sets the desired index position in **C0**, and issues this command (**C8**). If there is a forward-reverse offset, it is applied. Note that the direction of intended tape motion (**C2**) must first be set. Furthermore, the operand of this command allows an additional, arbitrary, offset to be applied – if one is desired.

- **C9:** This command will find the strongest signal peak within ± (operand) kÅof the current position. To do so, the program will perform a 2 stage "gridpoint" search, with the finest spacing of 20 kÅin version 5. Head number 1 is assumed (v. 5). If the detected power is time-varying (for example, due to poor head to tape contact), then the algorithm might be fooled into finding a location that is not the time-averaged maximum of the cross-track profile. For this reason, the output of the total power detector is low-pass filtered, with a time constant of $\sim 50ms$.

- **CA:** Auto-tracking is a servo mechanism by which a pre-recorded track can be followed along a tape, even in the presence of tracking errors (signatures). This word enables the auto-tracking feature, and specifies the period of time in seconds, between successive attempts to find the peak of power. Each attempt to find the peak will continue to move the headstack across the tape, until the power has "crested" and is going back down. A triangular profile is then fit to the largest 3 power measurements, and the head is positioned to its peak. This periodic peaking can only be stopped by the abort-head-motion command (**CB**). The track which is peaked-up upon is that track routed through Head 1, output A, and is selected by command **90**.

- **CB:** The abort-head-motion command will immediately stop any current head motion, and will also shutdown any head-positioning commands that are currently active. This affects commands **C6** through **CA**. The status bits pertaining to head motion in the general status word (**73**), bits 2, 4, 9, and 10, will also be cleared.

- **CC – CD:** All motion of the headstack is ultimately accomplished via these commands, although the user would normally choose to interface with one of the higher level commands, **C6** – **C8**. The inchworm controller will allow motion in two directions, in (towards the deckplate) and out, and at two speeds, slow and fast. After these binary choices are made in word **CC**, a delay should be written to **CD**, to initiate the motion. Since the units of delay are $40\mu s$, and the command is 16 bits, the maximum delay that can be specified is $\sim 2.62s$. The distance which the inchworm will travel is, of course, the product of the delay and the inchworm speed, which is discussed at some length under command **C4**.

- **CE:** This is a primitive command to measure the current location of the active headstack. Internally, it is implemented by activating the LVDT oscillator and reading the LVDT output voltage. The result is then converted to an equivalent position by application of the constants described under command **C4**. All software-initiated moves of the headstack are terminated with execution of the command, so that the value returned in location **42** reflects the current resting spot. The only time a user should need to issue this command is when the headstack is positioned manually, by the front-panel buttons.

A/D Board

- **D0 - D3:** The XYCOM A/D board has 4 analog outputs, which are configured with jumpers to lie in the range 0 – 10 volts. Each of these commands sets the output level, in mv, for one channel. The mapping of output channels to actual signals can be found in atod.hh. For example, channel 0 is the vacuum motor control voltage, and channel 3 is a voltage proportional to the head A write current.

- **D4:** A feature has been added to allow the vacuum motor to be en/dis - abled, independent of changes to the motor control voltage, **D0**. This allows the user to power the vacuum down and restore it later without having to remember at what voltage it was set.

- **D5 - D6:** There is a mechanical transducer in the transport that produces an output voltage which varies linearly with the state of the vacuum. Although the linearity is reasonably good, the coefficients vary from machine to machine. One needs to calibrate the performance of the vacuum sensor by comparing the appropriate A/D input (**57**) to an "eyeball" reading of the Honeywell pressure gauge, for several different points in the vacuum regime. A straight line is fit to the data, and two coefficients - the Y-intercept and the slope - are estimated. It is these two numbers that are written into words **D5** and **D6**, in order to have the pressure reported in monitor word **64** make sense.

Mark 3A Clock Recovery Module

When the VLBA drive is used to supply reproduce data for a Mark 3A correlator there is an additional module necessary. In addition to recovering the NRZM clock waveforms for each of the parallel tracks, the clock recovery module has a generalized 32x32 cross-point array switch, in order to flexibly map input tracks to output channels for the correlator.

- **D8:** The AT&T T7033 clock-recovery chip has a user-selectable frequency range over which it can lock up to the input signal. The value commanded here is passed along to the chip unchanged, as a hex number in the range 01–59. Two common values are 34, for 4.5 Mbit/s clock speed, and 24, for 9 Mb/s. Refer to either the T7033 data sheet, or the clock recovery module interface description for the meaning of other values.

- **D9:** The 32x32 cross-point array switch allows each of the 32 output tracks to select its input from any one of the 32 input tracks. In order to set one cross point of this switch, a Mark 3 input track in the range -1–30 is written to this address, after the output track is chosen using DA. *Note that the internal track numbering is different from both Mk3A and VLBA conventions.* Mark 3 tracks 1–28 correspond to VLBA tracks 4–31. The "augmented" Mark 3 tracks, (-1,0,29,30), correspond to VLBA tracks (2,3,32,33). The VLBA tracks (0,1,34,35) are inaccessible to the CRM hardware.

- **DA:** The Mk3A output track (1–32) corresponding to the input track in command D9 is set up here. On the output side, tracks are numbered by the Mark 3 correlator convention. Tracks 1–28 are currently (91.1.24) connected to the Mark 3 correlators, and tracks 29–32 are output on the CRM connectors, but are *not* currently connected to any correlator. The normal sequence of events would be to select the output track, then the input track, since it is the triggering value. Note that multiple output tracks may receive the same input track, but each output track receives only one input. In other words, fan-out is allowed, but not fan-in. A final feature of the switch is the ability to set all output tracks to the same input track, with a single command. This *common mode* assignment is accomplished by writing 32 decimal to this location.

- **DB:** In order to simplify track assignment for the vast majority of setups, and to emulate the Mk3A Lin board as closely as possible, the tracks can also be assigned 7 at a time, by output groups. In the Mark 3 track-numbering scheme, tracks 1,3,5,...,13 are group 1 (group 1), tracks 2,4,...,14 are group 2, tracks 15,17,...,27 are group 3, and tracks 16,18,...,28 are group 4. This command assigns one output group (specified in bits 8–10) of 7 tracks to the corresponding 7 tracks of the input group (bits 0–2). Four such *parallel mode* commands are necessary to set up for mode A, for example (the command arguments in hex would be 101, 202, 303, and 404).

- **DC:** Similar to the above command, output groups can also be assigned to a single input track in *common mode*. The input track is specified in bits 0–4.

CPU Board

- **E0 - E1:** For purposes of debugging and trouble-shooting, an ability to directly access the CPU memory space was implemented. One can examine program data areas, or any of the memory-mapped locations that are used to communicate with the other VME boards. The 24-bit address is first set up in locations **E0** and **E1**, with **E0** getting the high-order bits (23–16). If the address is within the valid address space of the world according to RECON, then monitor location **70** will contain the 16 bit word at that address.
- **E2:** After the address is set up by the above command, a write to E2 will put the 16-bit operand into the specified memory address. This function is analogous to a BASIC POKE.
- **E3:** Sometimes one merely wants to enable a feature by turning on a single bit. This command will logically OR the operand with the data pointed to by **E0** and **E1**, and replace that data.
- **E4:** If one wants to disable some feature on a memory-mapped board, one can use this command to logically AND the operand into the memory value, and thus selectively turn off bits.
- **EE:** One can envisage situations in which the CPU has "headed South" (gone catatonic), and a remote reset may be necessary. If the hardware of the MCB interface is still operating, the CPU (and for that matter, the whole VME backplane) can be reset by issuing the bit pattern AE51 (base sixteen) to MCB location **EF**. Since this action is implemented by the MCB interface hardware, the corresponding command through the RS-232 front panel port will have no effect.