THE ISAAC NEWTON GROUP OF TELESCOPES

WILLIAM HERSCHEL TELESCOPE

TELESCOPE CONTROL SYSTEM

CAMAC

SYSTEM DESCRIPTION
MODULE BIT ALLOCATION TABLES
AND TROUBLESHOOTING GUIDE

REV 1.0

Author : E. J. Mills (Electronics Group)
Date : June 2002
Source : ~eng/document_archive/electronics/wht/whtcamac/whtcamac.doc

This document is also available in PDF format in the public_html directory at:
http://www.ing.iac.es/~eng/electronics/wht/telescope/wht_camac.pdf

TABLE OF CONTENTS

TABLE OF FIGURES

DOCUMENT HISTORY

Rev 1.0 First released June 2002 E. J. MILLS

ACKNOWLEDGEMENTS

Marion Fisher (ex R.G.O.)

For her notes on the DEC ALPHA version of CAMTEST which I have included in this document

Overview

CAMAC (**C**omputer **A**utomated **M**easurement **A**nd **C**ontrol) is a control/data acquisition system based on CRATES and MODULES which was originally developed in the 1960's for the nuclear research industry (CERNE). It conforms to a standard both in mechanical and electronic specifications.

CAMAC is used to interface the various mechanisms of the telescope to and from the **TCS** (**T**elescope **C**ontrol **S**ystem). This being a **DEC ALPHA** computer running VMS. The term TCS as used in this document refers to both the telescope control software and the computer that it runs on. It performs various tasks such as reading the telescope's position encoders, moving the dome, adjusting the focus, *etc.*

The crate's CAMAC BUS consists of 24 read/write lines which are used to pass data between the TCS and the outside world. The bus also carries lines for module number decoding, module sub-addressing, function codes, control signals, power rails and interrupt handling. In CAMAC terminology, these interrupts are known as LAM's (Look At Me). The bus is extended out to the other crates in the system using a high density twisted pair DATAWAY cable.

The WHT CAMAC equipment comprises of four crates. A SYSTEM crate located in the bottom of the rack containing the TIME SERVICE and DEC ALPHA TCS computer (in the computer room) and three BRANCH crates located in the telescope control equipment racks behind the Observing Console. Due to maximum cable length restrictions between the DEC ALPHA computer and the CAMAC dataway controller in the system crate, these are mounted in close proximity. The three branch crates are located in the MARCONI rack, the NASMYTH rack and the CLIP CENTRE rack.

The branch address is **B6**. This being determined by the location within the system crate of the double width **BRANCH COUPLER** module. In this case fitted in Slots 19/20. The crate addresses on the branch are determined by a small rotary switch on the branch **CRATE CONTROLLER** module. These being **C1**, **C2** and **C3** respectively. As crate 3 is the last in the chain, the CAMAC dataway is terminated using a **BRANCH TERMINATOR** module.

According to CAMAC convention, the TCS addresses the crates using the following protocol:

B	Branch number	1 to 7	System crate is always B0 C0
C	Crate number	1 to 7	Determined by switch on Crate Controller
N	Module number	1 to 23	Slots 24/25 reserved for Crate Controller
A	Module sub-address	0 to 15	I/O, A or B channels *etc.*
F	Function	0 to 31	Read, write, test or set LAM *etc.*

The diagram on page 50 shows the general layout of the WHT CAMAC SYSTEM. As the Time Service is an integral part of the TCS, the connections from it to CAMAC are shown also.

It should be noted that the Time Service not only provides accurate time (UTC) to the TCS via CAMAC, but also generates clock frequencies and pulses relative to UTC. These are used to synchronise the telescope's position encoders and to provide a clock (1MHz) for the MARCONI servo system.

See the manual: ING TIME SERVICE for a detailed description of how the time is read into CAMAC.

CRATE ASSIGNMENTS AND FUNCTIONS

System Crate B0 C0

- Provides the interface between CAMAC and the DEC ALPHA computer via the **HYTEC 1386** PCI controlled ACB CAMAC dataway controller.
- Reads UTC (year, day number of year, hours, minutes and seconds) from the Time Service. This data is in BCD format and read into the TCS using a **PR2402** parallel input register.
- Generates milliseconds referenced to UTC using the **LP34** module.
- Contains the **ED12** module which provides a 20Hz strobe pulse for staticising the encoders and generates the interrupt (LAM) signal for the TCS. The TCS is updated at 50mS (20Hz) intervals.
- Contains the **BR CPR 4-1** BRANCH COUPLER to allow access to the remote crates.

Branch Crate B6 C1 (MARCONI CRATE)

- Reads the INCREMENTAL gear encoders for the ALTITUDE and AZIMUTH axes
- Reads the INCREMENTAL roller encoders for the ALTITUDE and AZIMUTH axes (*not used*)
- Reads the INCREMENTAL encoder for the PRIME FOCUS turntable
- Reads the INCREMENTAL encoder for the CASS turntable
- Outputs the drive commands and rates for the ALTITUDE and AZIMUTH servos
- Outputs the drive commands and rates for the CASS and PRIME FOCUS turntables
- Outputs the drive commands and rates for the telescope FOCUS servo
- Reads in the pulse train from the four AZIMUTH TAPE encoder heads (*not currently used*)

Branch Crate B6 C2 (NASMYTH CRATE)

- Reads the INCREMENTAL encoders for the Nasmyth DS and CWS rotators
- Outputs the drive commands and rates for the Nasmyth DS and CWS servos
- Reads the ABSOLUTE encoders for the Nasmyth DS and CWS rotators
- Reads the ABSOLUTE encoders for the ALTITUDE and AZIMUTH axes
- Reads the ABSOLUTE encoders for the CASS and PRIME FOCUS turntables
- Reads the ABSOLUTE BCD encoder for the telescope FOCUS

Branch Crate B6 C3 (CLIP CENTRE CRATE)

- Controls (writes) shutter (*not used*) and dome movement and direction. Sets the dome speed.
- Reads the top and bottom dome shutter position (*never implemented*)
- Reads the mirror cover status and telescope configuration (*i.e*. Focal station selected)
- Reads the ABSOLUTE encoder for dome position (via TEM-L)
- Reads the telescope alarm panel status
- Reads the whether the telescope is in Engineering or Computer mode
- Controls (writes) the mirror cover position (OPEN, CLOSED or STOPPED)
- Controls (writes) whether the telescope is in Engineering or Computer mode
- Reads the manual select (override) push buttons
- Reads the Dome and Shutter status indicators (via TEM-L).
- Reads the telescope's TRANSDUCER system (mirrors and azimuth bearing)
- Reads the telescope tube temperature sensors for automatic focus compensation

SYSTEM CRATE

Module address: B 0 C 0 N 8

Type: **ED12** RGO built Clock Pulse Generator

Function: Provides 8 pulsed outputs software selectable using the 1MHz signal from the Time Service.

Output rate set to 20Hz. One output is used for clocking the encoder modules. Another is used as a strobe for the **LP34** Millisecond Generator. This module also provides the LAM to the DEC ALPHA computer via the interconnecting cable.

Camtest: *e.g.* EXEC 0 0 8 0 0 To read the data register.

CAMAC COMMANDS	FUNCTION	RESPONSE
A0 F0	Read data register	Q = 1
A0 F16	Overwrite data register	Q = 1
A15 F8	Test LAM	Q =1 if LAM set
A1 F9	Clear rate multiplier and filter	
A15 F10	Clear LAM	
A15 F24	Disable LAM	
A15 F26	Enable LAM	
A15 F27	Test LAM enabled	Q = 1 if enabled
A1 F24	Disable rate multiplier	
A1 F26	Enable rate multiplier	
A1 F27	Test rate multiplier enabled	Q =1 if enabled
Z	Initialise	
X	returned for all valid commands	X =1 if valid

CONNECTOR	SIGNAL
LEMO coax SK1 Input	1MHz clock input from Time Service
LEMO coax SK2 Output	20Hz to LP34 Millisecond Generator strobe input
LEMO coax SK6 Output	20Hz (CAMCLK) to encoder interface modules

Module address: B 0 C 0 N 10

Type: **PR2402** Parallel Input Register

Function: Reads UTC data in BCD format from the Time Service.

Camtest:

EXEC	0	0	10	0	0	To read register A	The current time in hrs:mins:secs
EXEC	0	0	10	1	0	To read register B	The current day number and year

REGISTER A	BIT	FUNCTION (bcd coded)	
A0	1	1	secs x 1
A0	2	2	secs x 1
A0	3	4	secs x 1
A0	4	8	secs x 1
A0	5	10	secs x 10
A0	6	20	secs x 10
A0	7	40	secs x 10
A0	8	-	
A0	9	1	mins x 1
A0	10	2	mins x 1
A0	11	4	mins x 1
A0	12	8	mins x 1
A0	13	10	mins x 10
A0	14	20	mins x 10
A0	15	40	mins x 10
A0	16	-	
A0	17	1	hours x 1
A0	18	2	hours x 1
A0	19	4	hours x 1
A0	20	8	hours x 1
A0	21	10	hours x 10
A0	22	20	hours x 10
A0	23/24	Not used	

REGISTER B	BIT	FUNCTION (bcd coded)	
A1	1	1	days x 1
A1	2	2	days x 1
A1	3	4	days x 1
A1	4	8	days x 1
A1	5	10	days x 10
A1	6	20	days x 10
A1	7	40	days x 10
A1	8	80	days x 10
A1	9	100	days x 100
A1	10	200	days x 100
A1	11	400	days x 100
A1	12	800	days x 100
A1	13	1	years x 1
A1	14	2	years x 1
A1	15	4	years x 1
A1	16	8	years x 1
A1	17	10	years x 10
A1	18	20	years x 10
A1	19	40	years x 10
A1	20	80	years x 10
A1	21	-	
A1	22	-	
A1	23	-	
A1	24	-	

Module address: B 0 C 0 N 11

Type: **LP34** RGO built Millisecond Generator

Function: Generates milliseconds using the 1MHz and 1ppS signals from the Time Service.

Camtest : EXEC 0 0 11 0 0 To read register A
EXEC 0 0 11 1 0 To read register B

REGISTER A	BIT	FUNCTION
A0	1	2^0 mSecs Current time
A0	2	2^1 mSecs "
A0	3	2^2 mSecs "
A0	4	2^3 mSecs "
A0	5	2^4 mSecs "
A0	6	2^5 mSecs "
A0	7	2^6 mSecs "
A0	8	2^7 mSecs "
A0	9	2^8 mSecs "
A0	10	2^9 mSecs "
	13/24	Not used

REGISTER B	BIT	FUNCTION
A1	1	2^0 mSecs Strobed time
A1	2	2^1 mSecs "
A1	3	2^2 mSecs "
A1	4	2^3 mSecs "
A1	5	2^4 mSecs "
A1	6	2^5 mSecs "
A1	7	2^6 mSecs "
A1	8	2^7 mSecs "
A1	9	2^8 mSecs "
A1	10	2^9 mSecs "
	13/14	Not used

SOCKET	FUNCTION	FROM
Input LEMO 1	1MHz clock	Time Service
Input LEMO 2	1 pulse per second	Time Service
Input LEMO 3	Strobe input	ED012

BRANCH 6 CRATE 1 (MARCONI)

Module address: B 6 C 1 N 1

Type: **LP37** RGO built Fan-Out module

Function: Provides 20Hz buffered output signals which are used to strobe the AZIMUTH TAPE ENCODER **RGO32bit** counters in the MARCONI crate. A link is also made from this module to provide a 20Hz signal to strobe the 32 bit counters in the NASMYTH crate via the **ED011** module.

Note: This module is NOT addressable by CAMAC. It simply uses the PSU rails in the crate to power the module. All outputs are electrically the same.

Co-axial link cables: See table below

LEMO CONNECTOR	FUNCTION
A	20Hz Input from ED013 (clock out)
B	
C	
1A	20Hz output to RGO32BIT counter Az Tape (head 4)
2A	20Hz output to RGO32BIT counter Az Tape (head 3)
3A	20Hz output to RGO32BIT counter Az Tape (head 2)
1B	20Hz output to RGO32BIT counter Az Tape (head 1)
2B	20Hz output (CAMCLK) to ED011 module (NASMYTH crate)
3B	
1C	
2C	
3C	

Module address: B 6 C 1 N 2

Type: **ED013** RGO built Incremental Encoder interface module

Function: Provides 6 buffered output signal groups coming from the following encoders and passes these signals to each of their associated **RGO32bit** counters via individual connectors.

- ALTITUDE GEAR
- ALTITUDE ROLLER
- AZIMUTH GEAR
- AZIMITH ROLLER
- PRIME FOCUS TURNTABLE
- CASSEGRAIN TURNTABLE

A 20Hz strobe signal CAMCLK (derived from the **ED012** module in the SYSTEM crate) is feed to the CLK INPUT on this module. This signal is then distributed to the modules above.

A link is also made from the CLK OUT connector supplying 20Hz to the **LP37** module.

Note: This module is NOT addressable by CAMAC. It simply uses the PSU rails in the crate to power the module.

Module address: B 6 C 1 N 3

Type: **RGO 32 BIT COUNTER**

Function: Reads the quadrature signals from the ITEK incremental **ALTITUDE GEAR ENCODER** and converts the data to an up/down binary value.

Camtest: *eg*. EXEC 6 1 3 0 0 To read the 16 LSB's of Register 1

The CAMAC schedule below shows the most useful diagnostic commands.
Refer to the RGO 32 BIT counter manual for the full command set.

CAMAC COMMANDS	FUNCTION	RESPONSE
A0 F0	Read 16 LSB's of Register 1	Q = 1 X = 1
A1 F0	Read 16 MSB's of Register 1	Q = 1 X = 1
A2 F0	Read 16 LSB's of Register 2	Q = 1 X = 1
A3 F0	Read 16 MSB's of Register 2	Q = 1 X = 1
A12 F2	Read and clear the LAM status register	Q = 1 X = 1
A15 F8	Test LAM	Q = 1 if enabled X = 1
A0 F9	Clear the counter	Q = 1 X = 1
A0 F10	Clear all LAM's	Q = 0 X = 1
A0 F27	Test the Zero Marker counter clear facility	Q = 1 if enabled X = 1
A2 F27	Test the encoder zero reference strobe enable flag	Q = 1 if set X = 1

Notes:

- This module is clocked at 20Hz from the **ED013** module in slot 2
- Register 1 Is staticised by the external 20Hz clock

Module address: B 6 C 1 N 4

Type: **RGO 32 BIT COUNTER**

Function: Reads the quadrature signals from the **ALTITUDE ROLLER ENCODER** and converts the data to an up/down binary value.

Camtest: *eg*. EXEC 6 1 4 1 0 To read the 16 MSB's of Register 1

The CAMAC schedule below shows the most useful diagnostic commands.
Refer to the RGO 32 BIT counter manual for the full command set.

CAMAC COMMANDS	FUNCTION	RESPONSE
A0 F0	Read 16 LSB's of Register 1	Q = 1 X = 1
A1 F0	Read 16 MSB's of Register 1	Q = 1 X = 1
A2 F0	Read 16 LSB's of Register 2	Q = 1 X = 1
A3 F0	Read 16 MSB's of Register 2	Q = 1 X = 1
A12 F2	Read and clear the LAM status register	Q = 1 X = 1
A15 F8	Test LAM	Q = 1 if enabled X = 1
A0 F9	Clear the counter	Q = 1 X = 1
A0 F10	Clear all LAM's	Q = 0 X = 1
A0 F27	Test the Zero Marker counter clear facility	Q = 1 if enabled X = 1
A2 F27	Test the encoder zero reference strobe enable flag	Q = 1 if set X = 1

Notes:

- <u>The roller encoders are not currently used by the TCS and have been disabled.</u>
- This module is clocked at 20Hz from the **ED013** module in slot 2

Module address: B 6 C 1 N 5

Type: **RGO 32 BIT COUNTER**

Function: Reads the quadrature signals from the ITEK incremental **AZIMUTH GEAR ENCODER** and converts the data to an up/down binary value.

Camtest: *eg.* EXEC 6 1 5 2 0 To read the 16 LSB's of Register 2

The CAMAC schedule below shows the most useful diagnostic commands.
Refer to the RGO 32 BIT counter manual for the full command set.

CAMAC COMMANDS	FUNCTION	RESPONSE
A0 F0	Read 16 LSB's of Register 1	Q = 1 X = 1
A1 F0	Read 16 MSB's of Register 1	Q = 1 X = 1
A2 F0	Read 16 LSB's of Register 2	Q = 1 X = 1
A3 F0	Read 16 MSB's of Register 2	Q = 1 X = 1
A12 F2	Read and clear the LAM status register	Q = 1 X = 1
A15 F8	Test LAM	Q = 1 if enabled X = 1
A0 F9	Clear the counter	Q = 1 X = 1
A0 F10	Clear all LAM's	Q = 0 X = 1
A0 F27	Test the Zero Marker counter clear facility	Q = 1 if enabled X = 1
A2 F27	Test the encoder zero reference strobe enable flag	Q = 1 if set X = 1

Notes:

- This module is clocked at 20Hz from the **ED013** module in slot 2
- Register 1 Is staticised by the external 20Hz clock

Module address: B 6 C 1 N 6

Type: **RGO 32 BIT COUNTER**

Function: Reads the quadrature signals from the **AZIMUTH ROLLER ENCODER** and converts the data to an up/down binary value.

Camtest: *eg*. EXEC 6 1 6 3 0 To read the 16 MSB's of Register 2

The CAMAC schedule below shows the most useful diagnostic commands.
Refer to the RGO 32 BIT counter manual for the full command set.

CAMAC COMMANDS	FUNCTION	RESPONSE
A0 F0	Read 16 LSB's of Register 1	Q = 1 X = 1
A1 F0	Read 16 MSB's of Register 1	Q = 1 X = 1
A2 F0	Read 16 LSB's of Register 2	Q = 1 X = 1
A3 F0	Read 16 MSB's of Register 2	Q = 1 X = 1
A12 F2	Read and clear the LAM status register	Q = 1 X = 1
A15 F8	Test LAM	Q = 1 if enabled X = 1
A0 F9	Clear the counter	Q = 1 X = 1
A0 F10	Clear all LAM's	Q = 0 X = 1
A0 F27	Test the Zero Marker counter clear facility	Q = 1 if enabled X = 1
A2 F27	Test the encoder zero reference strobe enable flag	Q = 1 if set X = 1

Notes:

- The roller encoders are not currently used by the TCS and have been disabled.
- This module is clocked at 20Hz from the **ED013** module in slot 2

Module address: B 6 C 1 N 7

Type: **RGO 32 BIT COUNTER**

Function: Reads the quadrature signals from the T + R incremental **PRIME FOCUS TURNTABLE ENCODER** and converts the data to an up/down binary value.

Camtest: *eg*. EXEC 6 1 7 0 9 To clear the counter

The CAMAC schedule below shows the most useful diagnostic commands.
Refer to the RGO 32 BIT counter manual for the full command set.

CAMAC COMMANDS	FUNCTION	RESPONSE
A0 F0	Read 16 LSB's of Register 1	Q = 1 X = 1
A1 F0	Read 16 MSB's of Register 1	Q = 1 X = 1
A2 F0	Read 16 LSB's of Register 2	Q = 1 X = 1
A3 F0	Read 16 MSB's of Register 2	Q = 1 X = 1
A12 F2	Read and clear the LAM status register	Q = 1 X = 1
A15 F8	Test LAM	Q = 1 if enabled X = 1
A0 F9	Clear the counter	Q = 1 X = 1
A0 F10	Clear all LAM's	Q = 0 X = 1
A0 F27	Test the Zero Marker counter clear facility	Q = 1 if enabled X = 1
A2 F27	Test the encoder zero reference strobe enable flag	Q = 1 if set X = 1

Notes:

- This module is clocked at 20Hz from the **ED013** module in slot 2

Module address: B 6 C 1 N 8

Type: **RGO 32 BIT COUNTER**

Function: Reads the quadrature signals from the T + R incremental **CASSEGRAIN TURNTABLE ENCODER** and converts the data to an up/down binary value.

Camtest: *eg.* EXEC 6 1 8 12 2 To read and clear the LAM status register

The CAMAC schedule below shows the most useful diagnostic commands.
Refer to the RGO 32 BIT counter manual for the full command set.

CAMAC COMMANDS	FUNCTION	RESPONSE
A0 F0	Read 16 LSB's of Register 1	Q = 1 X = 1
A1 F0	Read 16 MSB's of Register 1	Q = 1 X = 1
A2 F0	Read 16 LSB's of Register 2	Q = 1 X = 1
A3 F0	Read 16 MSB's of Register 2	Q = 1 X = 1
A12 F2	Read and clear the LAM status register	Q = 1 X = 1
A15 F8	Test LAM	Q = 1 if enabled X = 1
A0 F9	Clear the counter	Q = 1 X = 1
A0 F10	Clear all LAM's	Q = 0 X = 1
A0 F27	Test the Zero Marker counter clear facility	Q = 1 if enabled X = 1
A2 F27	Test the encoder zero reference strobe enable flag	Q = 1 if set X = 1

Notes:

- This module is clocked at 20Hz via the **ED13** fan-out module in slot 2

Module address: B 6 C 1 N 9

Type: **OR 48** (Dual output register)

Function: Register A (0) Writes control bits to ALTITUDE servo
Register B (1) Writes control bits to AZIMUTH servo

Camtest:

e.g.	EXEC	6	1	9	0	16	0000005	gives -ve full range	(Altitude servo)
e.g.	EXEC	6	1	9	0	16	0800005	gives zero	(Altitude servo)
e.g.	EXEC	6	1	9	1	16	0FFFF05	gives +ve full range	(Azimuth servo)
e.g.	EXEC	6	1	9	1	16	0800005	gives zero	(Azimuth servo)

REGISTER A	**BIT**	**FUNCTION** ALTITUDE DRIVE
A0	1	TRACKING ON
A0	2	SPARE
A0	3	COMP. CONTROL ON
A0	4	SERVO ON
A0	5	CHANNEL SELECT
A0	6	COUNTER ENABLE
A0	7	ENCODER SELECT
A0	8	RATE GEN. ENABLE
A0	9	1 RATE BIT (LSB)
A0	10	2
A0	11	3
A0	12	4
A0	13	5
A0	14	6
A0	15	7
A0	16	8
A0	17	9
A0	18	10
A0	19	11
A0	20	12
A0	21	13
A0	22	14
A0	23	15 (MSB)
A0	24	SIGN BIT

REGISTER B	**BIT**	**FUNCTION** AZIMUTH DRIVE
A1	1	TRACKING ON
A1	2	SPARE
A1	3	COMP. CONTROL ON
A1	4	SERVO ON
A1	5	CHANNEL SELECT
A1	6	COUNTER ENABLE
A1	7	ENCODER SELECT
A1	8	RATE GEN. ENABLE
A1	9	1 RATE BIT (LSB)
A1	10	2
A1	11	3
A1	12	4
A1	13	5
A1	14	6
A1	15	7
A1	16	8
A1	17	9
A1	18	10
A1	19	11
A1	20	12
A1	21	13
A1	22	14
A1	23	15 (MSB)
A1	24	SIGN BIT

Module address: B 6 C 1 N 10

Type: **OR 48** (Dual output register)

Function: Register A (0) Writes control bits to the CASS rotator servo
Register B (1) Writes control bits to the PRIME FOCUS rotator servo

Camtest:
e.g. EXEC 6 1 10 0 16 0000005 gives -ve full range (CASS rotator servo)
e.g. EXEC 6 1 10 0 16 0800005 gives zero (CASS rotator servo)
e.g. EXEC 6 1 10 1 16 0FFFF05 gives +ve full range (Prime focus rotator servo)
e.g. EXEC 6 1 10 1 16 0800005 gives zero (Prime focus rotator servo)

REGISTER A	BIT	FUNCTION CASS TT CONTROL
A0	1	TRACKING ON
A0	2	SPARE
A0	3	COMP. CONTROL ON
A0	4	SERVO ON
A0	5	CHANNEL SELECT
A0	6	COUNTER ENABLE
A0	7	ENCODER SELECT
A0	8	RATE GEN. ENABLE
A0	9	1 RATE BIT (LSB)
A0	10	2
A0	11	3
A0	12	4
A0	13	5
A0	14	6
A0	15	7
A0	16	8
A0	17	9
A0	18	10
A0	19	11
A0	20	12
A0	21	13
A0	22	14
A0	23	15 (MSB)
A0	24	SIGN BIT

REGISTER B	BIT	FUNCTION PF TT CONTROL
A1	1	TRACKING ON
A1	2	SPARE
A1	3	COMP. CONTROL ON
A1	4	SERVO ON
A1	5	CHANNEL SELECT
A1	6	COUNTER ENABLE
A1	7	ENCODER SELECT
A1	8	RATE GEN. ENABLE
A1	9	1 RATE BIT (LSB)
A1	10	2
A1	11	3
A1	12	4
A1	13	5
A1	14	6
A1	15	7
A1	16	8
A1	17	9
A1	18	10
A1	19	11
A1	20	12
A1	21	13
A1	22	14
A1	23	15 (MSB)
A1	24	SIGN BIT

Module address: B 6 C 1 N 11

Type: **OR 48** (Dual output register)

Function: Register A (0) Writes control bits to the FOCUS servo
Register B (1) Not used

Camtest: *e.g.* EXEC 6 1 11 0 16 0000005 gives -ve full range
e.g. EXEC 6 1 11 0 16 0800005 gives zero
e.g. EXEC 6 1 11 0 16 0FFFF05 gives +ve full range

REGISTER A	BIT	FUNCTION DS. TT CONTROL
A0	1	TRACKING ON
A0	2	SPARE
A0	3	COMP. CONTROL ON
A0	4	SERVO ON
A0	5	CHANNEL SELECT
A0	6	COUNTER ENABLE
A0	7	ENCODER SELECT
A0	8	RATE GEN. ENABLE
A0	9	1 RATE BIT (LSB)
A0	10	2
A0	11	3
A0	12	4
A0	13	5
A0	14	6
A0	15	7
A0	16	8
A0	17	9
A0	18	10
A0	19	11
A0	20	12
A0	21	13
A0	22	14
A0	23	15 (MSB)
A0	24	SIGN BIT

Module address: B 6 C 1 N 12

Type: **RGO 32 BIT COUNTER**

Function: Reads the signals from the incremental **AZIMUTH TAPE ENCODER HEAD 1** and converts the data to an up/down binary value.

Camtest: *eg*. EXEC 6 1 12 0 0 To read the 16 LSB's of Register 1

The CAMAC schedule below shows the most useful diagnostic commands.
Refer to the RGO 32 BIT counter manual for the full command set.

CAMAC COMMANDS	FUNCTION	RESPONSE
A0 F0	Read 16 LSB's of Register 1	Q = 1 X = 1
A1 F0	Read 16 MSB's of Register 1	Q = 1 X = 1
A2 F0	Read 16 LSB's of Register 2	Q = 1 X = 1
A3 F0	Read 16 MSB's of Register 2	Q = 1 X = 1
A12 F2	Read and clear the LAM status register	Q = 1 X = 1
A15 F8	Test LAM	Q = 1 if enabled X = 1
A0 F9	Clear the counter	Q = 1 X = 1
A0 F10	Clear all LAM's	Q = 0 X = 1
A0 F27	Test the Zero Marker counter clear facility	Q = 1 if enabled X = 1
A2 F27	Test the encoder zero reference strobe enable flag	Q = 1 if set X = 1

Notes:

- The azimuth tape encoder is not currently used by the TCS and is disabled.
- This module is clocked at 20Hz via the **LP37** fan-out module in slot 1

Module address: B 6 C 1 N 13

Type: **RGO 32 BIT COUNTER**

Function: Reads the signals from the incremental **AZIMUTH TAPE ENCODER HEAD 2** and converts the data to an up/down binary value.

Camtest: *eg.* EXEC 6 1 13 1 0 To read the 16 MSB's of Register 1

The CAMAC schedule below shows the most useful diagnostic commands.
Refer to the RGO 32 BIT counter manual for the full command set.

CAMAC COMMANDS	FUNCTION	RESPONSE
A0 F0	Read 16 LSB's of Register 1	Q = 1 X = 1
A1 F0	Read 16 MSB's of Register 1	Q = 1 X = 1
A2 F0	Read 16 LSB's of Register 2	Q = 1 X = 1
A3 F0	Read 16 MSB's of Register 2	Q = 1 X = 1
A12 F2	Read and clear the LAM status register	Q = 1 X = 1
A15 F8	Test LAM	Q = 1 if enabled X = 1
A0 F9	Clear the counter	Q = 1 X = 1
A0 F10	Clear all LAM's	Q = 0 X = 1
A0 F27	Test the Zero Marker counter clear facility	Q = 1 if enabled X = 1
A2 F27	Test the encoder zero reference strobe enable flag	Q = 1 if set X = 1

Notes:

- The azimuth tape encoder is not currently used by the TCS and is disabled.
- This module is clocked at 20Hz via the **LP37** fan-out module in slot 1

Module address: B 6 C 1 N 14

Type: **RGO 32 BIT COUNTER**

Function: Reads the signals from the incremental **AZIMUTH TAPE ENCODER HEAD 3** and converts the data to an up/down binary value.

Camtest: *eg.* EXEC 6 1 14 2 0 To read the 16 LSB's of Register 2

The CAMAC schedule below shows the most useful diagnostic commands.
Refer to the RGO 32 BIT counter manual for the full command set.

CAMAC COMMANDS	FUNCTION	RESPONSE
A0 F0	Read 16 LSB's of Register 1	Q = 1 X = 1
A1 F0	Read 16 MSB's of Register 1	Q = 1 X = 1
A2 F0	Read 16 LSB's of Register 2	Q = 1 X = 1
A3 F0	Read 16 MSB's of Register 2	Q = 1 X = 1
A12 F2	Read and clear the LAM status register	Q = 1 X = 1
A15 F8	Test LAM	Q = 1 if enabled X = 1
A0 F9	Clear the counter	Q = 1 X = 1
A0 F10	Clear all LAM's	Q = 0 X = 1
A0 F27	Test the Zero Marker counter clear facility	Q = 1 if enabled X = 1
A2 F27	Test the encoder zero reference strobe enable flag	Q = 1 if set X = 1

Notes:

- The azimuth tape encoder is not currently used by the TCS and is disabled.
- This module is clocked at 20Hz via the **LP37** fan-out module in slot 1

Module address: B 6 C 1 N 15

Type: **RGO 32 BIT COUNTER**

Function: Reads the signals from the incremental **AZIMUTH TAPE ENCODER HEAD 4** and converts the data to an up/down binary value.

Camtest: *eg*. EXEC 6 1 15 3 0 To read the 16 MSB's of Register 2

The CAMAC schedule below shows the most useful diagnostic commands.
Refer to the RGO 32 BIT counter manual for the full command set.

CAMAC COMMANDS	FUNCTION	RESPONSE
A0 F0	Read 16 LSB's of Register 1	Q = 1 X = 1
A1 F0	Read 16 MSB's of Register 1	Q = 1 X = 1
A2 F0	Read 16 LSB's of Register 2	Q = 1 X = 1
A3 F0	Read 16 MSB's of Register 2	Q = 1 X = 1
A12 F2	Read and clear the LAM status register	Q = 1 X = 1
A15 F8	Test LAM	Q = 1 if enabled X = 1
A0 F9	Clear the counter	Q = 1 X = 1
A0 F10	Clear all LAM's	Q = 0 X = 1
A0 F27	Test the Zero Marker counter clear facility	Q = 1 if enabled X = 1
A2 F27	Test the encoder zero reference strobe enable flag	Q = 1 if set X = 1

Notes:

- The azimuth tape encoder is not currently used by the TCS and is disabled.
- This module is clocked at 20Hz via the **LP37** fan-out module in slot 1

BRANCH 6 CRATE 2 (NASMYTH)

Module address: B 6 C 2 N 1

Type: **ED011** RGO built Incremental Encoder interface module

Function: Provides 2 buffered output signal groups coming from the following encoders and passes these signals to each of their associated **RGO32bit** counters via individual connectors.

- NASMYTH DS GEAR (GRACE)
- NASMYTH CWS GEAR (GHRIL)

A 20Hz strobe signal CAMCLK (derived from the **LP37** module in the MARCONI crate) is fed to the CLK INPUT on this module. This signal is then distributed to the modules above.

Note: This module is NOT addressable by CAMAC. It simply uses the PSU rails in the crate to power the module.

Module address: B 6 C 2 N 3

Type: **RGO 32 BIT COUNTER**

Function: Reads the quadrature signals from the T + R incremental **NASMYTH TT DS** (Drive Side) encoder (GRACE) and converts the data to an up/down binary value.

Camtest: *eg.* EXEC 6 2 3 0 0 To read the 16 LSB's of Register 1

The CAMAC schedule below shows the most useful diagnostic commands.
Refer to the RGO 32 BIT counter manual for the full command set.

CAMAC COMMANDS	FUNCTION	RESPONSE
A0 F0	Read 16 LSB's of Register 1	Q = 1 X = 1
A1 F0	Read 16 MSB's of Register 1	Q = 1 X = 1
A2 F0	Read 16 LSB's of Register 2	Q = 1 X = 1
A3 F0	Read 16 MSB's of Register 2	Q = 1 X = 1
A12 F2	Read and clear the LAM status register	Q = 1 X = 1
A15 F8	Test LAM	Q = 1 if enabled X = 1
A0 F9	Clear the counter	Q = 1 X = 1
A0 F10	Clear all LAM's	Q = 0 X = 1
A0 F27	Test the Zero Marker counter clear facility	Q = 1 if enabled X = 1
A2 F27	Test the encoder zero reference strobe enable flag	Q = 1 if set X = 1

Notes:

These modules are clocked at 20Hz via the **ED011** fan-out module in slot 1

Module address: B 6 C 2 N 4

Type: **RGO 32 BIT COUNTER**

Function: Reads the quadrature signals from the T + R incremental **NASMYTH TT CWS** (Cable Wrap Side) encoder (GHRIL) and converts the data to an up/down binary value.

Camtest: *eg.* EXEC 6 2 4 1 0 To read the 16 MSB's of Register 1

The CAMAC schedule below shows the most useful diagnostic commands.
Refer to the RGO 32 BIT counter manual for the full command set.

CAMAC COMMANDS	FUNCTION	RESPONSE
A0 F0	Read 16 LSB's of Register 1	Q = 1 X = 1
A1 F0	Read 16 MSB's of Register 1	Q = 1 X = 1
A2 F0	Read 16 LSB's of Register 2	Q = 1 X = 1
A3 F0	Read 16 MSB's of Register 2	Q = 1 X = 1
A12 F2	Read and clear the LAM status register	Q = 1 X = 1
A15 F8	Test LAM	Q = 1 if enabled X = 1
A0 F9	Clear the counter	Q = 1 X = 1
A0 F10	Clear all LAM's	Q = 0 X = 1
A0 F27	Test the Zero Marker counter clear facility	Q = 1 if enabled X = 1
A2 F27	Test the encoder zero reference strobe enable flag	Q = 1 if set X = 1

Notes:

These modules are clocked at 20Hz via the **ED011** fan-out module in slot 1

Module address: B 6 C 2 N 7

Type: **OD2411** Dual Output Driver

Function: Register A Writes control bits to the GRACE rotator servo
Register B Writes control bits to the GHRIL rotator servo

Camtest:

e.g.	EXEC	6	2	7	0	16	0000005	gives -ve full range	(DS rotator)
e.g.	EXEC	6	2	7	0	16	0800005	gives zero	(DS rotator)
e.g.	EXEC	6	2	7	1	16	0FFFF05	gives +ve full range	(CWS rotator)
e.g.	EXEC	6	2	7	1	16	0800005	gives zero	(CWS rotator)

REGISTER A	**BIT**	**FUNCTION** DS. TT CONTROL
A0	1	TRACKING ON
A0	2	SPARE
A0	3	COMP. CONTROL ON
A0	4	SERVO ON
A0	5	CHANNEL SELECT
A0	6	COUNTER ENABLE
A0	7	ENCODER SELECT
A0	8	RATE GEN. ENABLE
A0	9	1 RATE BIT (LSB)
A0	10	2
A0	11	3
A0	12	4
A0	13	5
A0	14	6
A0	15	7
A0	16	8
A0	17	9
A0	18	10
A0	19	11
A0	20	12
A0	21	13
A0	22	14
A0	23	15 (MSB)
A0	24	SIGN BIT

REGISTER B	**BIT**	**FUNCTION** CWS. TT CONTROL
A1	1	TRACKING ON
A1	2	SPARE
A1	3	COMP. CONTROL ON
A1	4	SERVO ON
A1	5	CHANNEL SELECT
A1	6	COUNTER ENABLE
A1	7	ENCODER SELECT
A1	8	RATE GEN. ENABLE
A1	9	1 RATE BIT (LSB)
A1	10	2
A1	11	3
A1	12	4
A1	13	5
A1	14	6
A1	15	7
A1	16	8
A1	17	9
A1	18	10
A1	19	11
A1	20	12
A1	21	13
A1	22	14
A1	23	15 (MSB)
A1	24	SIGN BIT

Module address: B 6 C 2 N 9

Type: **HY450-4** Parallel I/O Register

Function: Register I Reads **NASMYTH TT DS** (GRACE) absolute T + R encoder
Register O Outputs encoder control signals

Camtest: *e.g.* EXEC 6 2 9 0 0 Reads the encoder bits.

REGISTER I	**BIT**	**FUNCTION** Read encoder bits
A0	1	2^0 1 encoder unit = 6.48 arcmins
A0	2	2^1
A0	3	2^2
A0	4	2^3
A0	5	2^4
A0	6	2^5
A0	7	2^6
A0	8	2^7
A0	9	2^8
A0	10	2^9
A0	11	2^{10}
A0	12	2^{11}
A0	13	2^{12}
	14/24	Not used

REGISTER O	**BIT**	**FUNCTION** Output control signals
A1	1	INHIBIT LSB
	2/24	Not used

Module address: B 6 C 2 N 11

Type: **HY450-4** Parallel I/O Register

Function: Register I Reads **NASMYTH TT CWS** (GHRIL) absolute T + R encoder
Register O Outputs encoder control signals

Camtest: *e.g.* EXEC 6 2 11 0 0 Reads the encoder bits.

REGISTER I	BIT	FUNCTION Read encoder bits
A0	1	2^0 1 encoder unit = 6.45 arcmins
A0	2	2^1
A0	3	2^2
A0	4	2^3
A0	5	2^4
A0	6	2^5
A0	7	2^6
A0	8	2^7
A0	9	2^8
A0	10	2^9
A0	11	2^{10}
A0	12	2^{11}
A0	13	2^{12}
	14/24	Not used

REGISTER O	BIT	FUNCTION Output control signals
A1	1	INHIBIT LSB
	2/24	Not used

Module address: B 6 C 2 N 13

Type: **HY450-4** Parallel I/O Register

Function: Register I Reads the **ALTITUTE** Coarse and Fine BALDWIN absolute encoders
Register O Outputs encoder control signals

Camtest: *e.g.* EXEC 6 2 13 0 0 Reads the ALTITUDE encoder bits

REGISTER I	**BIT**	**FUNCTION** Read encoder bits	
A0	1	2^0	FINE BALDWIN ENCODER
A0	2	2^1	1 encoder unit = 0.483398 arcsecs
A0	3	2^2	
A0	4	2^3	
A0	5	2^4	
A0	6	2^5	
A0	7	2^6	
A0	8	2^7	
A0	9	2^8	
A0	10	2^9	
A0	11	2^{10}	
A0	12	2^{11}	
A0	13	2^{12}	
A0	14	2^{13}	
A0	15	2^{14}	
A0	16	2^{15}	
A0	17	2^0	COARSE BALDWIN ENCODER
A0	18	2^1	1 encoder unit = 1.4 degrees
A0	19	2^2	
A0	20	2^3	
A0	21	2^4	
A0	22	2^5	
A0	23	2^6	
A0	24	2^7	

REGISTER O	**BIT**	**FUNCTION** Output control signals
A1	1	ALT. COARSE ENCODER - GATE
A1	2	ALT. COARSE ENCODER - REVERSE COUNT
A1	3	ALT. FINE ENCODER - GATE
A1	4	ALT. FINE ENCODER - REVERSE COUNT
	5/24	Not used

Module address: B 6 C 2 N 15

Type: **HY450-4** Parallel I/O Register

Function: Register I Reads the **AZIMUTH** Coarse and Fine BALDWIN absolute encoders
Register O Outputs encoder control signals

Camtest: *e.g.* EXEC 6 2 15 0 0 Reads the AZIMUTH encoder bits

REGISTER I	**BIT**	**FUNCTION** Read encoder bits	
A0	1	2^0	FINE BALDWIN ENCODER
A0	2	2^1	1 encoder unit = 0.483398 arcsecs
A0	3	2^2	
A0	4	2^3	
A0	5	2^4	
A0	6	2^5	
A0	7	2^6	
A0	8	2^7	
A0	9	2^8	
A0	10	2^9	
A0	11	2^{10}	
A0	12	2^{11}	
A0	13	2^{12}	
A0	14	2^{13}	
A0	15	2^{14}	
A0	16	2^{15}	
A0	17	2^0	COARSE BALDWIN ENCODER
A0	18	2^1	1 encoder unit = 1.4 degrees
A0	19	2^2	
A0	20	2^3	
A0	21	2^4	
A0	22	2^5	
A0	23	2^6	
A0	24	2^7	

REGISTER O	**BIT**	**FUNCTION** Output control signals
A1	1	AZ. COARSE ENCODER - GATE
A1	2	AZ. COARSE ENCODER - REVERSE COUNT
A1	3	AZ. FINE ENCODER - GATE
A1	4	AZ. FINE ENCODER - REVERSE COUNT
	5/24	Not used

Module address: B 6 C 2 N 17

Type: **HY450-4** Parallel I/O Register

Function: Register I Reads the **CASSEGRAIN TT** absolute T + R encoder
Register O Outputs encoder control signals

Camtest: *e.g.* EXEC 6 2 17 0 0 Reads the CASS. turntable encoder bits

REGISTER I	**BIT**	**FUNCTION** Read encoder bits
A0	1	2^0 1 encoder unit = 4.5 arcmins
A0	2	2^1
A0	3	2^2
A0	4	2^3
A0	5	2^4
A0	6	2^5
A0	7	2^6
A0	8	2^7
A0	9	2^8
A0	10	2^9
A0	11	2^{10}
A0	12	2^{11}
A0	13	2^{12}
	14/24	Not used

REGISTER O	**BIT**	**FUNCTION** Output control signals
A1	1	INHIBIT LSB
	2/24	Not used

Module address: B 6 C 2 N 19

Type: **HY450-4** Parallel I/O Register

Function: Register I Reads the **PRIME FOCUS TT** absolute T + R encoder
Register O Outputs encoder control signals

Camtest: *e.g.* EXEC 6 2 19 0 0 Reads the PRIME FOCUS turntable encoder bits

REGISTER I	**BIT**	**FUNCTION** Read encoder bits
A0	1	2^0 1 encoder unit = 6.48 arcmins
A0	2	2^1
A0	3	2^2
A0	4	2^3
A0	5	2^4
A0	6	2^5
A0	7	2^6
A0	8	2^7
A0	9	2^8
A0	10	2^9
A0	11	2^{10}
A0	12	2^{11}
A0	13	2^{12}
A0	14/24	Not used

REGISTER O	**BIT**	**FUNCTION** Output control signals
A1	1	INHIBIT LSB
	2/24	Not used

Module address: B 6 C 2 N 21

Type: **HY450-4** Parallel I/O Register

Function: Register I Reads the telescope **FOCUS** 20 bit BCD absolute encoder
Register O Not used *

Camtest: *e.g.* EXEC 6 2 21 0 0 Reads the FOCUS encoder bits

REGISTER I	BIT	FUNCTION Read encoder bits	
A0	1	1]	BCD data unit = 3 microns
A0	2	2]	
A0	3	4]	
A0	4	8]	first decade
A0	5	10]	
A0	6	20]	
A0	7	40]	
A0	8	80]	second decade
A0	9	100]	
A0	10	200]	
A0	11	400]	
A0	12	800]	third decade
A0	13	1000]	
A0	14	2000]	
A0	15	4000]	
A0	16	8000]	forth decade
A0	17	10000]	
A0	18	20000]	
A0	19	40000]	
A0	20	80000]	fifth decade
	21/24	Not used	

Notes:

* Although Channel O is not used, there is a connector going to this socket. However, this register is not read by the TCS.

BRANCH 6 CRATE 3 (CLIP CENTRE)

Module address: B 6 C 3 N 2

Type: **OD48** Dual 24 bit Digital Output Module

Function: Register A Shutter control (via TEM-L) Never was implemented
Register B Dome speed and control (via TEM-L)

Camtest: *e.g.* EXEC 6 3 2 1 16 1535 Move dome CW at full speed (hex 5FF)
EXEC 6 3 2 1 16 1047 Move dome CCW at half speed (hex 57F)

REGISTER A	BIT	FUNCTION Shutter control (**NOT USED**)
A0	1	TOP SHUTTER - MAIN RAISE
A0	2	TOP SHUTTER - MAIN LOWER
A0	3	TOP SHUTTER - MICRO RAISE
A0	4	TOP SHUTTER - MICRO LOWER
A0	5	BOTTOM SHUTTER - MAIN RAISE
A0	6	BOTTOM SHUTTER - MAIN LOWER
A0	7	BOTTOM SHUTTER - MICRO RAISE
A0	8	BOTTOM SHUTTER - MICRO LOWER
A0	9	TOP SHUTTER ENCODER GATE
A0	10	BOTTOM SHUTTER ENCODER GATE
A0	11/16	SPARE
	17/24	Not used

REGISTER B	BIT	FUNCTION Dome speed and control
A1	1	1] DOME SPEED (BCD data)
A1	2	2]
A1	3	4]
A1	4	8] First decade
A1	5	10]
A1	6	20]
A1	7	40]
A1	8	80] Second decade
A1	9	DOME MOTORS ON
A1	10	DRIVE DOME C. W. >>>
A1	11	DRIVE DOME C.C.W <<<
A1	12/16	SPARE
	17/24	Not used

Module address: B 6 C 3 N 3

Type: **IR48** TTL Input register

Function: Register A * Reads the **TOP SHUTTER** absolute BALDWIN encoder
Register B * Reads the **BOTTOM SHUTTER** absolute BALDWIN encoder

Camtest: *e.g.* EXEC 6 3 3 0 0 Reads the TOP SHUTTER encoder bits

REGISTER A	**BIT**	**FUNCTION** Read TOP SHUTTER encoder bits
A0	1	2^0 1 encoder unit = 0.352 degrees
A0	2	2^1
A0	3	2^2
A0	4	2^3
A0	5	2^4
A0	6	2^5
A0	7	2^6
A0	8	2^7
A0	9	2^8
A0	10	2^9
	11/24	Not used

REGISTER B	**BIT**	**FUNCTION** Read BOTTOM SHUTTER encoder bits
A1	1	2^0 1 encoder unit = 0.352 degrees
A1	2	2^1
A1	3	2^2
A1	4	2^3
A1	5	2^4
A1	6	2^5
A1	7	2^6
A1	8	2^7
A1	9	2^8
A1	10	2^9
	11/24	Not used

Notes:

* This function was never implemented.

The 10 bit Baldwin absolute encoders were removed from the shutter drives many years ago (in fact the internal glass encoder discs were broken) and the TEM-L boards associated with shutter control have since been removed from the dome TEM-L cabinet and now serve as spares.

Module address: B 6 C 3 N 4

Type: **IR48** TTL Input Register

Function: Register A Not used
Register B Tells TCS which focal station is in use and mirror cover status

Camtest: *e.g.* EXEC 6 3 4 1 0 Read the focal station and mirror cover status

REGISTER B	BIT	FUNCTION Inputs focal station selected and mirror cover status
A1	1	FOCAL STATION - CASS
A1	2	FOCAL STATION - PRIME
A1	3	FOCAL STATION - NASMYTH DS (GRACE)
A1	4	FOCAL STATION - NASMYTH CWS (GHRIL)
A1	5	FOCAL STATION - BROKEN CASS
A1	6	NASMYTH MIRROR STOWED
A1	7	PRIMARY MIRROR COVER - CLOSED
A1	8	PRIMARY MIRROR COVER - OPEN
A1	9	SECONDARY MIRROR COVER - OFF
	10/24	Not used

Module address: B 6 C 3 N 5

Type: **HY450-4** Parallel I/O Register

Function: Register I Reads the **DOME** absolute T + R encoder
Register O Outputs encoder control signals

Camtest: *e.g.* EXEC 6 3 5 0 0 Reads the dome encoder bits

REGISTER I	**BIT**	**FUNCTION (IN)** Read dome encoder bits
A0	1	2^0 1 encoder unit = 0.352 degs
A0	2	2^1
A0	3	2^2
A0	4	2^3
A0	5	2^4
A0	6	2^5
A0	7	2^6
A0	8	2^7
A0	9	2^8
A0	10	2^9
	11/24	Not used

REGISTER O	**BIT**	**FUNCTION (OUT)** Output control signals
A1	1	DOME ENCODER GATE
	2/24	Not used

Module address: B 6 C 3 N 6

Type: **IR48** TTL Input register

Function: Register A Reads alarm status
Register B Reads alarm status

Camtest: *e.g.* EXEC 6 3 6 0 0 Read alarms on register A
e.g. EXEC 6 3 6 1 0 Read alarms on register B

REG A	BIT	FUNCTION
A0	1	ALT PRE-LIMIT -
A0	2	ALT LIMIT -
A0	3	ALT PRE-LIMIT +
A0	4	ALT LIMIT +
A0	5	AZ PRE-LIMIT -
A0	6	AZ LIMIT -
A0	7	AZ PRE-LIMIT +
A0	8	AZ LIMIT +
A0	9	DOME OBSCURATION
A0	10	PF TT LIMIT -
A0	11	PF TT LIMIT +
A0	12	CASS TT LIMIT -
A0	13	CASS TT LIMIT +
A0	14	CASS C.WRAP LIMIT -
A0	15	CASS C.WRAP LIMIT +
A0	16	FOCUS LIMIT -
A0	17	FOCUS LIMIT +
A0	18	ACCESS PARK TIE
A0	19	DOME INTERLOCK
A0	20	AP3 ACCESS BARRIER
A0	21	REVOLVING FLOOR LATCH
A0	22	ALT FINAL LIMIT
A0	23	OIL PADS
A0	24	POWER AMP FAULT

REG B	BIT	FUNCTION
A1	1	GEARBOX OIL *
A1	2	OIL PUMP TRIPPED
A1	3	OIL ALT FILTER
A1	4	OIL AZ FILTER
A1	5	OIL HIGH TEMPERATURE
A1	6	OIL LOW LEVEL
A1	7	OIL ALT FLOW DIVIDER
A1	8	OIL AZ FLOW DIVIDER
A1	9	NITROGEN LOW
A1	10	MIRROR DEFINER L. CELL
A1	11	MIRROR HIGH
A1	12	MAINS
A1	13	WIND **
A1	14	RAIN **
A1	15	ICE **
A1	16	DUST **
A1	17	NASMYTH TT LIMIT DS -
A1	18	NASMYTH TT LIMIT DS +
A1	19	NASMYTH TT LIMIT CWS-
A1	20	NASMYTH TT LIMIT CWS+
	21-24	Not used

Notes:

* Slow Cycle Warning (gearbox oil)
** Never implemented (probably there are others !)

Module address: B 6 C 3 N 8

Type: **OD48** Dual 24 bit Digital Output Module

Function: Register A Force Engineering Mode and mirror cover control
Register B Not used

Camtest: *e.g.* EXEC 6 3 8 0 16 0001 Put telescope into Engineering Mode

REGISTER A	BIT	FUNCTION
A0	1	FORCE ENGINEERING MODE
A0	2	PRIMARY MIRROR COVER - OPEN
A0	3	PRIMARY MIRROR COVER - CLOSE
A0	4	PRIMARY MIRROR COVER - STOP
	5/24	Not used

Module address: B 6 C 3 N 9

Type: **PR2402** Parallel Input Register

Function: Register A Not used
Register B Read manual mode (override) push buttons

Camtest: *e.g.* EXEC 6 3 9 1 0 Read override push buttons on Engineering desk

REGISTER B	BIT	FUNCTION Read manual select push buttons
A1	1	Not used
A1	2	Not used
A1	3	SHUTTER
A1	4	DOME
A1	5	FOCUS
A1	6	PRIMARY MIRROR COVER
A1	7	SPARE
	8/24	Not used

Module address: B 6 C 3 N 10

Type: **PR2402** Parallel Input Register

Function: Register A Read engineering switches and emergency stop
Register B Read dome status

Camtest: *e.g.* EXEC 6 3 10 0 0 Read telescope engineering/computer status
EXEC 6 3 10 1 0 Read the dome status (via TEM-L)

REGISTER A	**BIT**	**FUNCTION** Telescope status
A0	1	EMERGENCY STOP (1= Not actuated)
A0	2	COMPUTER RESET (1= Reset button enabled)
A0	3	TELESCOPE POWER ON
A0	4	COMPUTER MODE SELECTED
	5/24	Not used

REGISTER B	**BIT**	**FUNCTION** Dome status
A1	1	DOME ON REMOTE CONTROL
A1	2	DOME POWER ON
A1	3	TOP SHUTTER ON REMOTE CONTROL
A1	4	TOP SHUTTER POWER ON
A1	5	TOP SHUTTER OVERTRAVEL
A1	6	TOP SHUTTER TORQUE TRIP
A1	7	BOTTOM SHUTTER ON REMOTE CONTROL
A1	8	BOTTOM SHUTTER POWER ON
A1	9	BOTTOM SHUTTER OVERTRAVEL
A1	10	BOTTOM SHUTTER TORQUE TRIP
A1	11	BOTTOM SHUTTER IN PARKED POSITION
A1	12	PLATFORM PIN OUT (DOME INTERLOCK)
A1	13	SHUTTERS CLOSED
	14/24	Not used

Module address: B 6 C 3 N 11

Type: **ADC 1232** 32 Channel Analogue to Digital Converter module (12 bit sampling)

Function: Reads the voltages from the telescope LVDT transducers mounted around the primary mirror, the azimuth bearing and the secondary mirror suspension points. Used to compensate for flexure and non-concentricity in these components.

Camtest: *e.g.* EXEC 6 3 11 4 0 Read the value returned from the No 1 azimuth bearing transducer

CHANNEL NUMBER	CAMAC COMMANDS	FUNCTION	RESPONSE
1	A0 F0	Transducer 1 Primary mirror 1 0 deg *	Q = 1 X = 1
2	A1 F0	Transducer 2 Primary mirror 2 180 deg *	Q = 1 X = 1
3	A2 F0	Transducer 3 Az bearing 3	Q = 1 X = 1
4	A3 F0	Transducer 4 Az bearing 4	Q = 1 X = 1
5	A4 F0	Transducer 5 Az bearing 1	Q = 1 X = 1
6	A5 F0	Transducer 6 Az bearing 2	Q = 1 X = 1
7	A6 F0	Transducer 7 Secondary mirror 1	Q = 1 X = 1
8	A7 F0	Transducer 8 Secondary mirror 2	Q = 1 X = 1
9	A8 F0	Transducer 9 Secondary mirror 3	Q = 1 X = 1
10	A9 F0	Transducer 10 Spare	
11	A10 F0	Transducer 11 Not fitted	
12	A11 F0	Transducer 12 Not fitted	
13	A12 F0	Transducer 13 Not fitted	
14	A13 F0	Transducer 14 Not fitted	
15	A14 F0	Transducer 15 Not fitted	
16	A15 F0	Transducer 16 Not fitted	

Notes

* The primary mirror transducers are not currently read by the TCS

Module address: B 6 C 3 N 12

Type: **ADC 1232** 32 Channel Analogue to Digital Converter module (12 bit sampling)

Function: Reads the voltages corresponding to values of temperatures from the PT100 platinum sensors mounted on the telescope tube structure and mirror. The tube temperature sensors are used to monitor expansion or contraction of the truss and provide data for focus tracking corrections. Also reads the primary mirror cover position.

Camtest: *e.g.* EXEC 6 3 12 14 0 Read the value returned for the primary mirror cover position.

CHANNEL NUMBER	CAMAC COMMANDS	FUNCTION	RESPONSE
1	A0 F0	Tube top temperature sensor	Q = 1 X = 1
2	A1 F0	Upper truss temperature sensor CWS	Q = 1 X = 1
3	A2 F0	Upper truss temperature sensor DS	Q = 1 X = 1
4	A3 F0	Mirror side temperature sensor *	Q = 1 X = 1
5	A4 F0	Lower truss temperature sensor	Q = 1 X = 1
6	A5 F0	Mirror air temperature sensor *	Q = 1 X = 1
7	A6 F0	Mirror cover temperature sensor *	Q = 1 X = 1
8	A7 F0	Dome temperature sensor *	Q = 1 X = 1
9	A8 F0	Dew-point temperature sensor *	Q = 1 X = 1
10	A9 F0	External temperature sensor *	Q = 1 X = 1
11	A10 F0	Balance weight 1 position *	Q = 1 X = 1
12	A11 F0	Balance weight 2 position *	Q = 1 X = 1
13	A12 F0	Balance weight 3 position *	Q = 1 X = 1
14	A13 F0	Balance weight 4 position *	Q = 1 X = 1
15	A14 F0	Primary mirror cover position	Q = 1 X = 1
16		Not used	

CHANNEL NUMBER	CAMAC COMMANDS	FUNCTION	RESPONSE
17	A0 F1	Axial load cell 1 *	Q = 1 X = 1
18	A1 F1	Axial load cell 2 *	Q = 1 X = 1
19	A2 F1	Axial load cell 3 *	Q = 1 X = 1
20	A3 F1	Radial load cell 1 *	Q = 1 X = 1
21	A4 F1	Radial load cell 2 *	Q = 1 X = 1
22	A5 F1	Radial load cell 3 *	Q = 1 X = 1
23/32		Not used	

Notes

* Although many (but not all) of these sensors are connected, they are not currently read by TCS

APPENDIX

CAMAC TEST ON THE DEC ALPHAS

To run CAMTEST, first open up a new LAT session window on the TCS X-terminal. Open a connection to the DEC ALPHA (WHT name… LPAS4)

Username: ENGINEER
Password: ********** (in printed copy)

When logged in:

Option> camtest

The software will load and after a short time the prompt below will be displayed.

CAMTEST>

The following is a very basic guide to the use of CAMTEST. For more help, type HELP inside CAMTEST. Commands are NOT case sensitive and can be abbreviated where appropriate.

To send a single CAMAC instruction:

CAMTEST> execute B C N A F DATA

Where B C N A F are the Branch, Crate, module station Number, sub-Address and Function numbers respectively. DATA is only needed for a write instruction (F16). Insert one space between each number.

The result will be displayed on the screen showing the B C N A F data, read and write data and the Q response.

To see the results of all previous instructions, type:

SHOW EXEC.

This list can be deleted by: DELETE EXEC

A CAMAC instruction can be repeated with a specified period, enter:

EXECUTE/REPEAT=*n*/PERIOD=*m* B C N A F DATA

Where *n* is the number of times to repeat the instruction and *m* is the period between the instructions expressed in milliseconds. The default is 1 Second if *m* is not given.

To break out of a repeat sequence, use `Control C'.

Examples:

EXEC 4 2 11 1 0	Will do a single read of a module in Branch 4, Crate 2, slot Number 11 and sub-Address 1 (*e.g.* Channel B)
EXEC /REPEAT=100/PERIOD 4 2 11 1 0	Will perform 100 reads at intervals of 1 sec. The results can be viewed by SHOW EXEC
EXEC 4 1 2 0 16 124	Will write the data 124 to the specified CAMAC register

You can create a sequence of instructions for execution later using the ADD command. The format is:

ADD B C N A F DATA Where data is only required for a write instruction.

The sequence can be listed by:

SHOW INSTRUCTIONS and executed by EXECUTE.

The list can be deleted by:

DELETE INSTRUCTIONS.

The last line can be deleted by:

DELETE/LAST INSTRUCTIONS.

The **output** of an instruction can be displayed in binary, octal, decimal, or hexadecimal. Use the command RADIX to change it. Examples below show how the results are displayed in the CAMTEST window.

```
CAMTEST> radix binary
CAMTEST> exec 4 3 8 0 16 1184800   (e.g. Write an alternate 24 bit pattern)

B  C  N  A  F     Write data                    Read data                     Q
4  3  8  0  0     101010101010101010101010    000000000000000000000000    1

CAMTEST> radix hexadecimal
CAMTEST> exec 0 0 10 0 0       (e.g. Read the Time Service:  hrs:mins:secs)

B  C  N  A  F     Write data                    Read data                     Q
0  0  10 0  0      00000000                     00143418                      1
```

You can create a text file containing CAMTEST commands. The INPUT command is used to read a file and execute the instructions.

INPUT READ_MECS.DAT

Will execute each line in the file READ_MECS.DAT sequentially. When the end of the file is reached, CAMTEST will resume taking input from the terminal.

To exit from CAMTEST :

CAMTEST> exit

Type: EXIT again at the Options prompt to close down the session.

TROUBLESHOOTING CAMAC

Most problems with CAMAC can be diagnosed using the CAMTEST program which is available on all the DEC ALPHA computers. See the previous section on how to use CAMTEST.

Whenever changing modules in a crate, always **SHUTDOWN** the DEC ALPHA telescope control system (TCS) before **SWITCHING OFF** the CAMAC crate. Switching off a crate or taking it **OFF LINE** whilst the TCS is running can cause the control software to crash. From the User prompt enter:

USER> tcsexit and wait for the TCS to run down.

CAMTEST can also be run simultaneously with the TCS *e.g*. Monitoring the raw data from an encoder module whilst the telescope is tracking, dome moving *etc*. However, when examining individual bits, it is better to start up CAMTEST **WITHOUT** the TCS running. The reason being is that the TCS is constantly updating CAMAC and can overwrite the bits that are under test.

The notes below have been written to provide the technician with some idea of how to use CAMTEST to isolate problems. This is by no means a definitive treatise on solving every problem with CAMAC that may arise. In practice, especially during an emergency callout, try to isolate the CAMAC module associated with the problem and change the module with a spare. Detailed investigations can be carried out in `slow time` during the day!

DIAGNOSTIC TOOLS FOR CAMAC AND GENERAL CRATE FAILURES

All CAMAC crates contain a DTM4 or similar dataway test monitor. Although this module can be read from or written to using CAMTEST instructions, it will show **ALL** activity on the bus irrespective of whether it is being directly addressed. There are 24 LED's for the READ Lines, 24 LED's for the WRITE lines and other LED's for ADDRESS and FUNCTION codes , control lines and LAM.

When CAMAC is under the control of the TCS, some of the dataway monitor LED's will be flickering (at 20Hz). This is a good sign that the TCS is at least communicating with CAMAC. If activity is seen on the SYSTEM crate, but **NOT** on a BRANCH crate then possibly the problem is just that a branch crate has been knocked OFF-LINE.

Check that the **ON-LINE** switches both on the BRANCH COUPLER (in the system crate) and the CRATE CONTROLLER (located in slots 24/25 in the branch crates) are in the ON position. If this is not the problem then suspect either a faulty Branch Coupler or Crate Controller. Spares are available.

If there is NO activity on the SYSTEM crate then suspect the HYTEC 1386 PCI Dataway Controller, the PCI interface board within the DEC ALPHA or the cable connecting the computer to the Dataway Controller.

Another good test to see if the TCS is communicating with the system crate is to read the Time Service. All three telescope CAMAC systems use the same module configurations in the system crate. The Time Service BCD data (hrs:mins:secs) are read into CAMAC using a PR2402 Parallel Input Register in slot 10.

The "A" channel of the PR2402 (sub-address = 0) receives this data.

Start CAMTEST and enter at the prompt:

CAMTEST> exec 0 0 10 0 0

The result displayed should be the current UTC value. Check it against the control room time displays. Repeating the command (or making CAMTEST perform multiple reads) will show the seconds updating.

TESTING THE CAMAC SYTEM MANUALLY

If a problem is suspected with the computer to CAMAC link, it is possible to test CAMAC as a standalone system using the **SC-TST-1** Test Controller. This at least will prove that the system crate is working correctly, is addressing it's own modules or can address modules in branch crates.

To do this, proceed as follows:

- After bringing down the TCS (using TCSEXIT) , run down the DEC ALPHA using the SHUT account .
- When the DEC ALPHA computer has run down and returned the OK prompt, switch it off.
- Switch off the SYSTEM CRATE and remove the HYTEC 1386 (no need to remove the front panel cable).
- In it's place, fit an **MX-CTR-3** Executive Crate controller (slots 24/25).
- Fit the **SC-TST-1** Test Controller in a spare slot. n.*b*. This module is triple width and will require 3 spare adjacent slots.
- Fit an ARBITRATION BUS cable (with 4 pin LEMO's each end) between the Executive Controller and the 'IN' socket on the SC-TST-1 . These are kept in the INT electronics workshop in the draw near the CAMAC test rack .
- Power on the system crate and check for activity. Toggling the C/Z switch on the MX-CTR-3 is advisable.

The SC-TST-1 contains two rows of switches (Operation 1 and 2) allowing module address, sub address and functions to be set up or modules in branch crates to be checked. The test module can work in 3 modes:

1. Continuous (Clocking at 1MHz)
2. Slow speed (at 10Hz)
3. Single step

A typical test procedure would be to use the SC-TST-1 in conjunction with a Word Generator module such as the WGR 241. Put this module into any spare slot and set up the SC-TST-1 (N switches) to address that slot and perform an F0 (read) command using the left hand column of switches (operation 1). Set up the right hand column of switches (operation 2) to the module number of the DTM4 and select the F16 (write) function.

Put the SC-TST-1 into either continuous or 10Hz mode and toggle the switches on the Word Generator. If all is working correctly, you will see the switch patterns selected appearing on the READ leds on the DTM4 and the same pattern being written to the WRITE leds. *e.g.*

- Write all ones 111111111111111111111111
- Write all zeros 000000000000000000000000
- Alternate bits 101010101010101010101010
- Reverse bits 010101010101010101010101

These manual tests will prove that the problem lies with the HYTEC 1386 , the cable or PCI DEC ALPHA interface card.

Refer to the drawing on page 55 which shows the MANUAL TEST SETUP.

BUS HANGUPS

These fortunately are rare, but a faulty module can hold bits on the bus which will generally show up as bad data being returned from ALL the modules within a crate and the telescope doing "strange" things! This is particularly so if the faulty or stuck bit/s are of a lower order. The reason being that the telescope's mechanisms driven or read by CAMAC conventionally use BIT 1 and upwards.

If the dataway monitor shows bits set after the crate has been taken OFF LINE and the C/Z buttons toggled on the branch CRATE CONTROLLER or the C/Z switch toggled on the HYTEC 1386 DATAWAY CONTROLLER (if the problem is in the system crate) then a faulty module is probably causing the problem.

The solution here is to remove (slide back) all the modules within the crate just leaving the dataway monitor (DTM4 or equivalent) and CRATE CONTROLLER in place and see if the bits clear on the DTM4 after toggling the C/Z buttons or switch. If all the bits are clear then re-seat the modules one at a time until the stuck bit re-appears on the dataway monitor.

MISSING X or Q RESPONSE

All CAMAC modules generate an X and Q response. These are flags generated within the modules to tell the computer that a valid command has been received (X=1) or that a certain condition has been achieved (Q=1) or in some cases Q=0. The dataway monitor has LED's to show the status of these two flags.

However, on one occasion, the computer failed to see a change of the Q response although the module which was generating it (in this case a 3340 serial interface) was working correctly! The fault was eventually traced to the BRANCH COUPLER in the system crate. A faulty CRATE CONTROLLER or HYTEC 1386 module could also have been responsible.

Note
The bottom line here is with ANY bus related problems, change the HYTEC 1386 followed by the BRANCH COUPLER in the system crate then the branch CRATE CONTROLLERS. A faulty module (or cable) on the dataway can cause all sorts of problems and are the most difficult to solve. Simply changing these components is the best solution.

POWER SUPPLY UNIT FAILURES

CAMAC crate PSU's deliver +/- 6V between 20/40A and a +/- 24V low current supply. It should be noted that most modules contain a fuse and a voltage regulator to reduce the incoming +6V supply to the +5V required for the TTL logic. Some lightly populated modules don't use voltage regulators at all, but instead use a high current diode in series with the incoming +6V supply and rely on the 0.6V drop across the junction to derive a nominal +5V supply for the module.

PSU failures were once a common problem usually with the heavily loaded +6V supply failing due to overheating. This was caused primarily by the cooling fans wearing out and stopping. Power supply failures have now been greatly alleviated by replacing the heavy current linear supplies with a switched mode PSU. These have been fitted into existing CAMAC PSU boxes and can be identified by their light weight! The older units being extremely heavy and often difficult to manipulate into the guide rails in the back of the crate.

A small test box with a selector switch and 4 LED'S that plugs into the 9 pin `D` type connector on the front of the crate can be used to check the health of the PSU. Sockets on the box enable a test meter to be connected for a more accurate measurement. The PSU test box is kept in the INT electronics workshop in the draw near the CAMAC test rack. If a PSU is suspected as faulty, replace it with a spare. There should be one close by.

MODULE FAILURES

To cover every problem is impossible, but basically, module failures can be divided into two classes:

1. Those which affect the telescope directly (pointing, tracking and rotators)

2. Those which cause problems with the telescope sub-systems (focus, dome rotation *etc*)

Modules used for telescope control (pointing, tracking and rotators)

Position encoders

On the WHT, both **ABSOLUTE** and **INCREMENTAL** encoders are used. The modules associated with these are:

- For ABSOLUTE encoders – **HYTEC 450-4**
- For INCREMENTAL encoders - **RGO32BIT** counters (formally the HYTEC – 900 module)

ABSOLUTE ENCODERS

n.b. It should be noted that the ABSOLUTE encoders are used ONLY to initialise the incremental encoder RGO32BIT counters to a known value and do NOT play a part in telescope operation once the TCS has started.

If the telescope can't find targets, check that both the ABSOLUTE and INCREMENTAL encoders are in close agreement by typing:

USER> page enc

If there is a significant difference in values, suspect the HYTEC 450- 4 module. However, if the problem is in ALTITUDE or AZIMUTH, more likely a lamp has failed in either the FINE or COARSE Baldwin absolute encoders associated with these axes. Replacement of these lamps is covered in another document.

If an absolute encoder is found to have a problem, the telescope can be 'zeroset' to a known datum using the **ZEROSET ALT TARGET** or **ZEROSET AZ TARGET** TCS commands.

INCREMENTAL ENCODERS

As a preliminary check, look at the LED bar displays on the counter modules. When the telescope is slewing or tracking, the RGO32BIT counter modules will be counting either up or down depending on the direction that the telescope is moving. This applies to the rotators also.

n.b. This may NOT apply to the AZIMUTH tape encoder (or AZIMUTH and ALTITUDE roller encoder) modules. These systems were/are experimental and are currently not read by the TCS.

This check will prove at least the RGO32BIT COUNTERS are receiving data from the encoders. However, seeing the LED bar display `counting` does not necessarily mean that the counter modules are working correctly.

Using the RGO32BIT module description within this document, use CAMTEST (and with the telescope moving VERY SLOWLY in Engineering Mode), test for bits changing sequentially in the LSB's (A0 F0) and MSB's (A1 F0) of Register 1.

If in any doubt, change what you suspect could be a faulty module with a spare.

Modules used for the telescope sub-systems

Such problems could show up as the telescope focus or dome refusing to move (or not stopping) or returning the wrong position or status. The focus temperature tracking not working *etc*. The most common problems here are loosing a bit (or several bits) in an Input Register or Output Driver module.

In the case of the WHT, no test boxes exist with switches or LEDs for testing the inputs (or outputs) of the parallel I/O modules. If a problem arises, simply change the module associated with the function and check if the fault clears.

Spare modules are available and stored in the green cabinet behind the blue racks.

IMPORTANT

ALWAYS PUT A LABEL ON A FAULTY MODULE STATING WHAT THE PROBLEM IS AND NEVER PUT FAULTY MODULES BACK INTO THE SPARES CABINET!

If the fault is just a lost bit, these can usually be repaired on site. With more difficult problems, the module is sent back (to HYTEC) for repair.

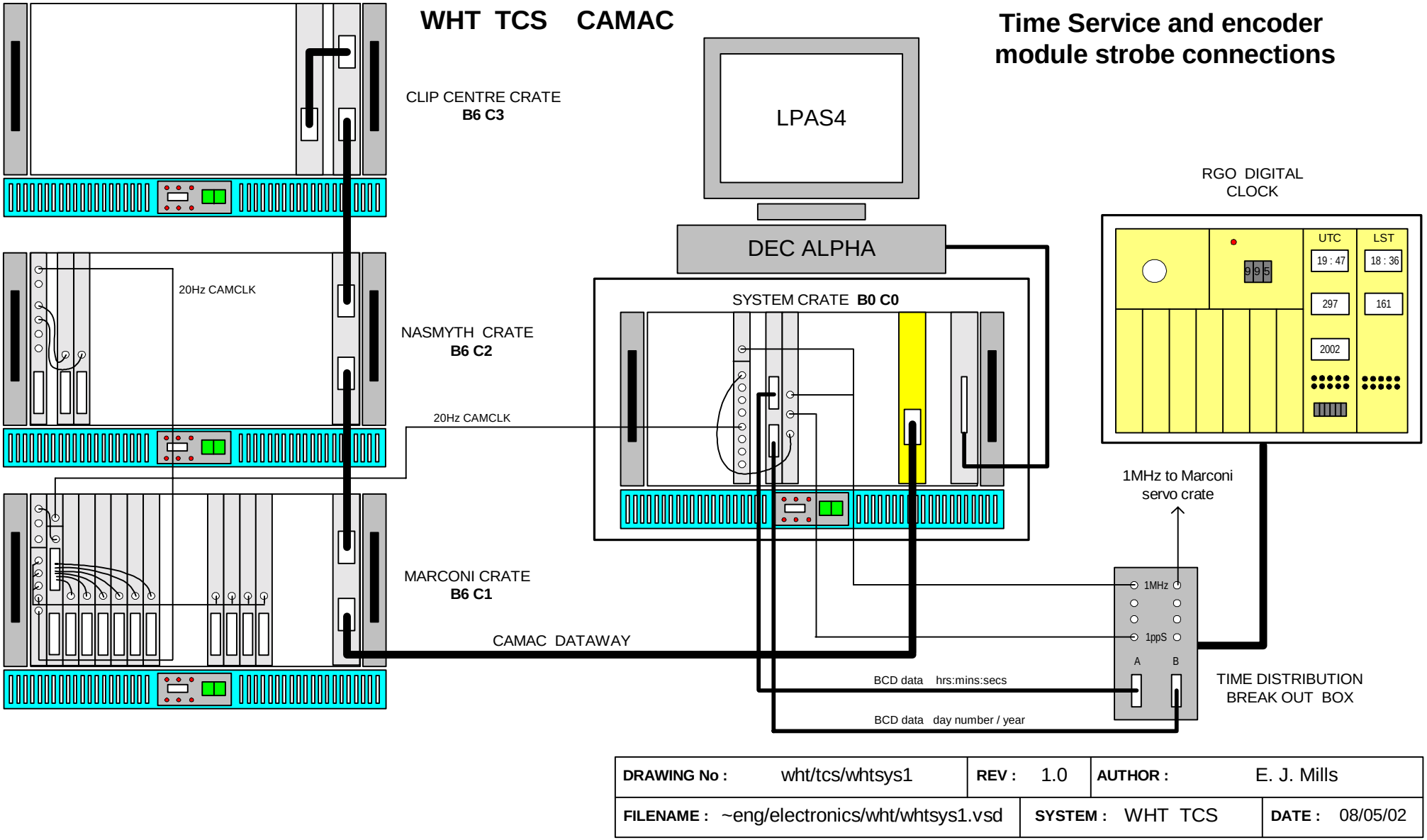
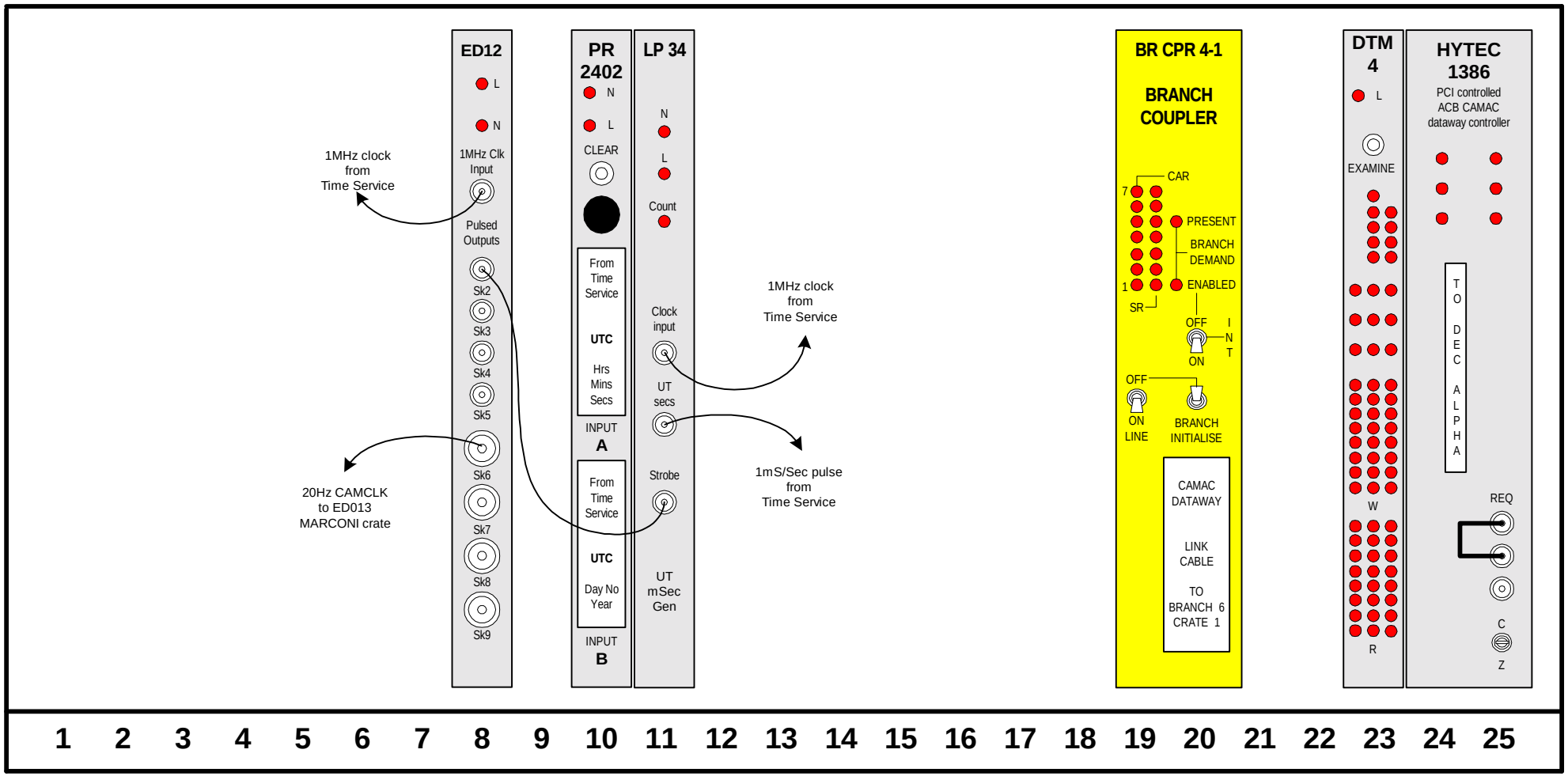


Figure 1 WHT CAMAC Crate layout, Dataway and Time Service cables



DRAWING No :	wht/tcs/cam/crate0	**REV :**	1.0	**AUTHOR :**	E. J. Mills
FILENAME :	~eng/electronics/wht/whtcam0.vsd	**SYSTEM :**	WHT camac	**DATE :**	26/4/02

Figure 2 WHT CAMAC System crate

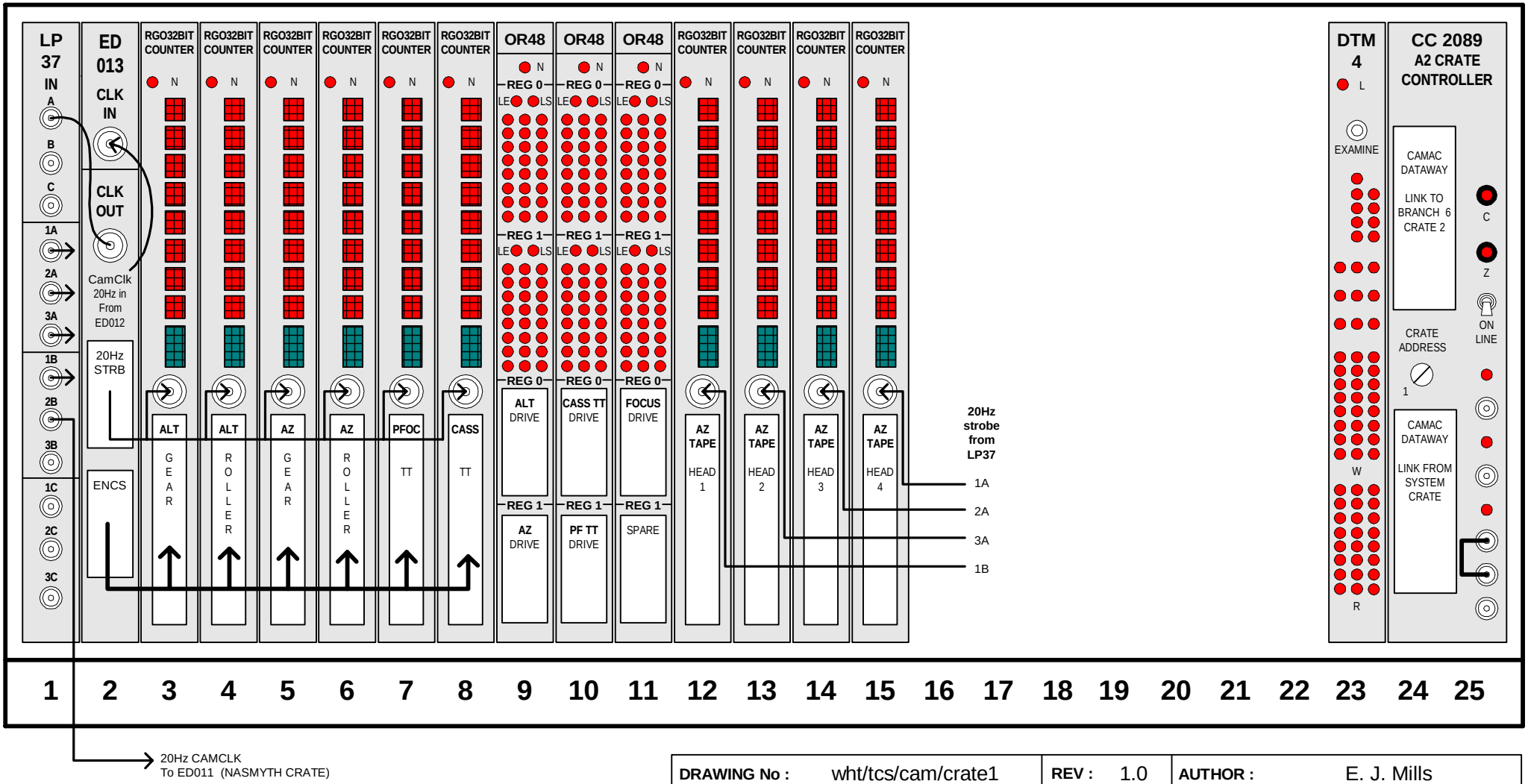
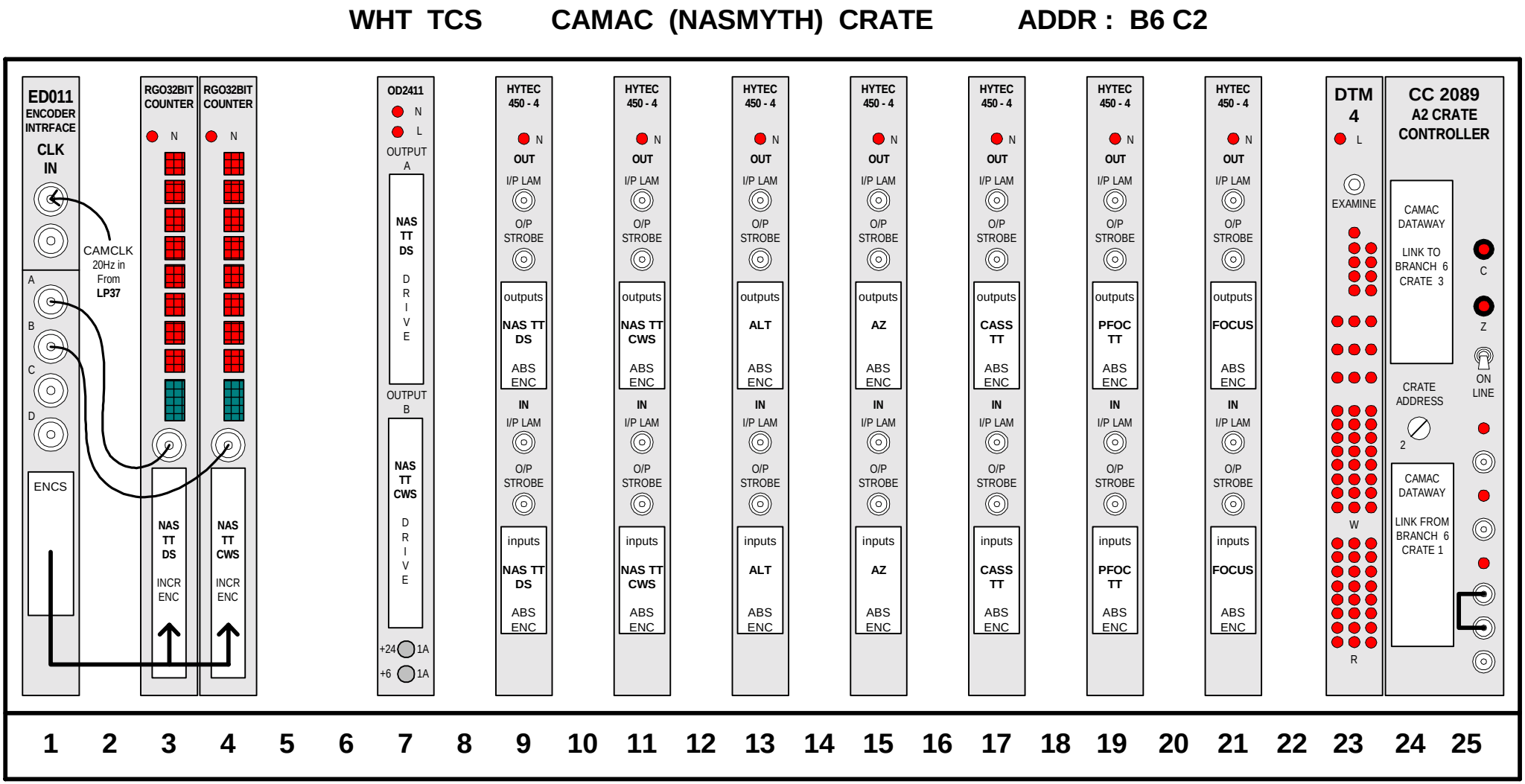


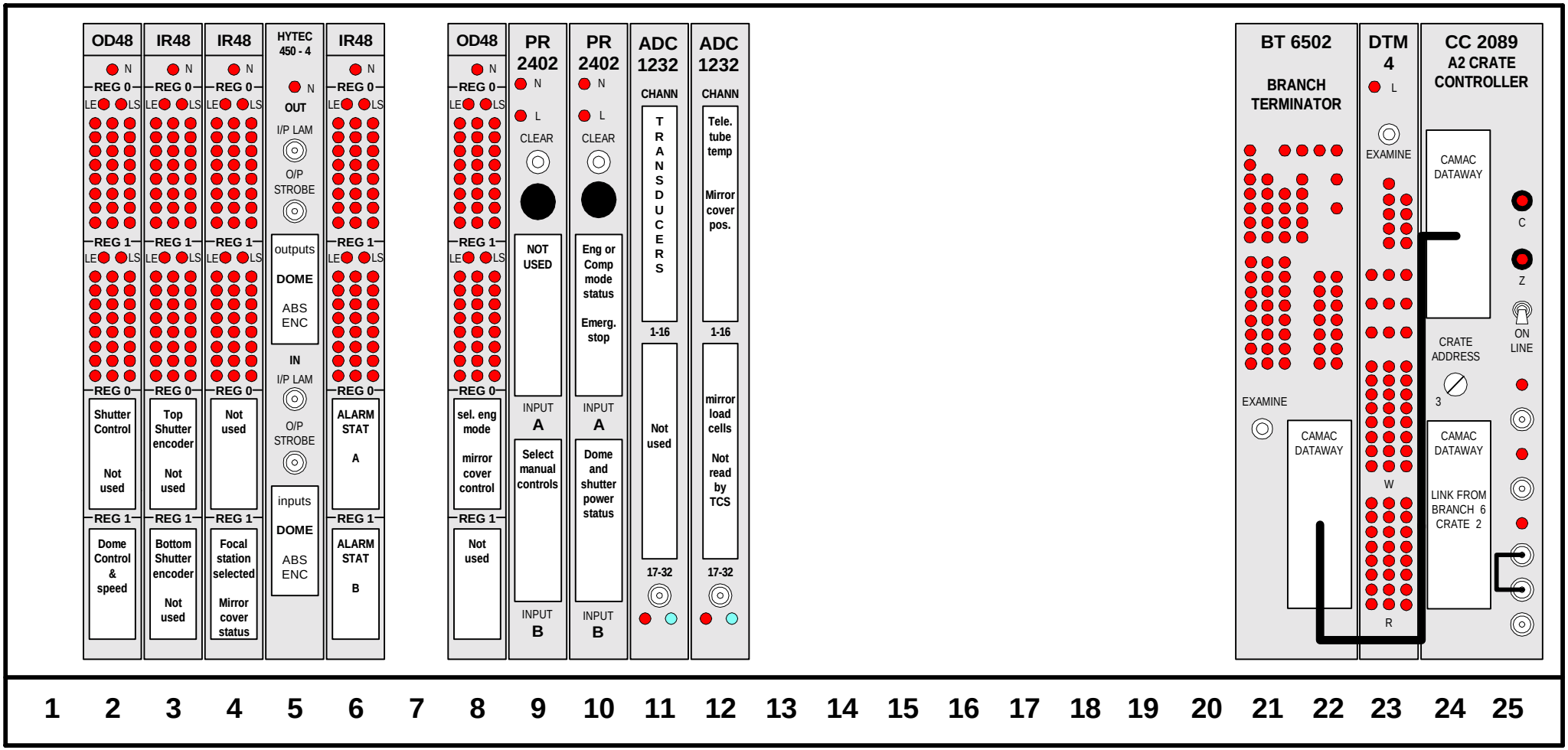
Figure 3 WHT CAMAC Branch crate 1



NAS Turntable DS (DRIVE SIDE) **GRACE/UES**
NAS Turntable CWS (CABLE WRAP SIDE) **GHRIL**

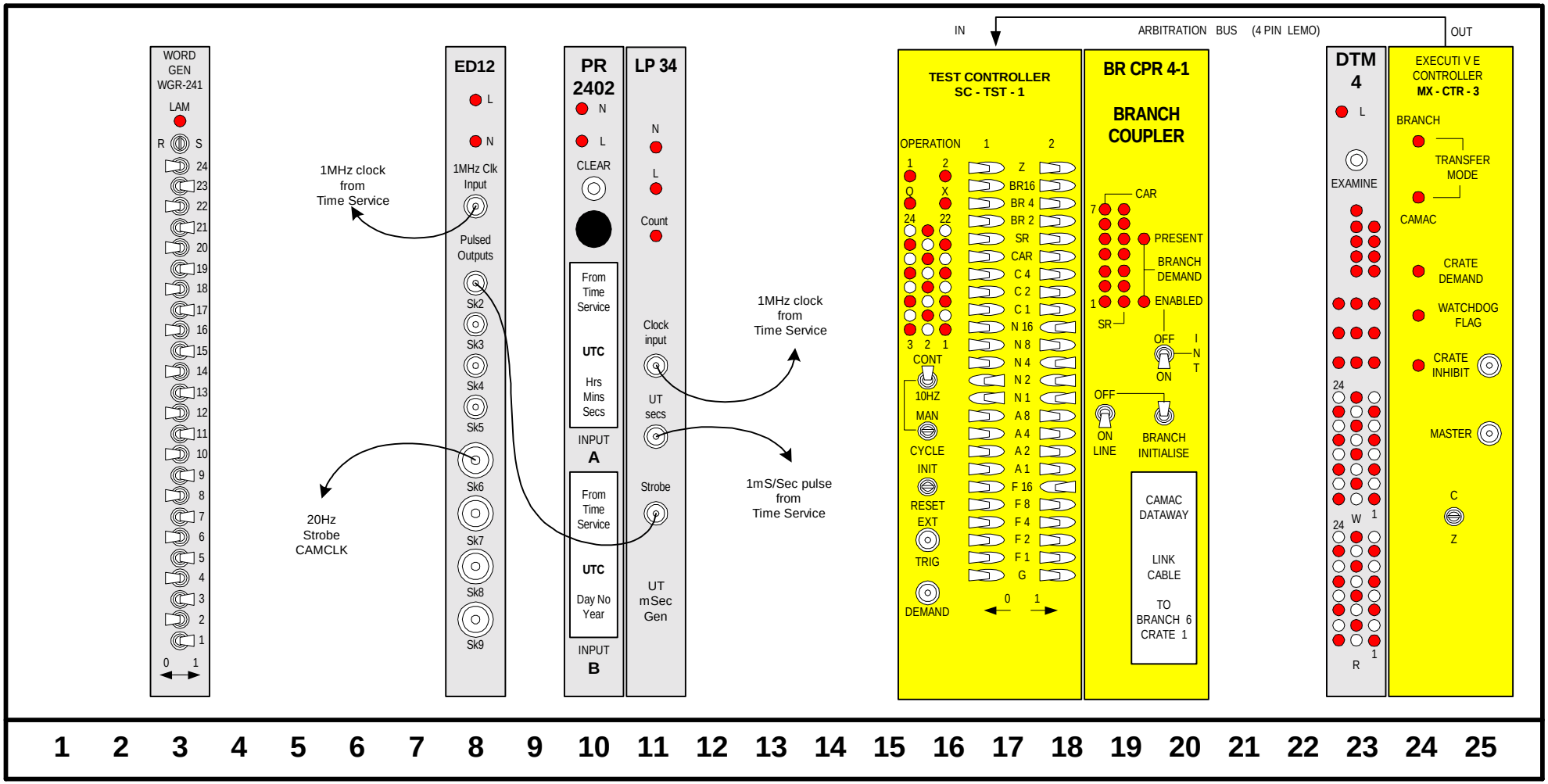
DRAWING No :	wht/tcs/cam/crate2	**REV :**	1.0	**AUTHOR :**	E. J. Mills
FILENAME :	~eng/electronics/wht/whtcam2.vsd	**SYSTEM :**	WHT camac	**DATE :**	30/04/02

Figure 4 WHT CAMAC Branch crate 2



DRAWING No :	wht/tcs/cam/crate3	**REV :**	1.0	**AUTHOR :**	E. J. Mills
FILENAME :	~eng/electronics/wht/whtcam3.vsd	**SYSTEM :**	WHT camac	**DATE :**	2/5/02

Figure 5 WHT CAMAC Branch crate 3



Switches on modules are shown in correct positions to produce an alternate bit pattern (Read= N3 A0 F0 Write N23 A0 F16)

DRAWING No :	wht/tcs/cam/test-setup	**REV :**	1.0	**AUTHOR :**	E. J. Mills
FILENAME :	~eng/electronics/wht/whtcam4.vsd	**SYSTEM :**	CAMAC	**DATE :**	19/6/02

Figure 6 WHT CAMAC Test module setup in system crate