

NASA-CR-191612

IN-61-CR  
136214  
P. 70

238800-12-X

# ROMPS CRITICAL DESIGN REVIEW DATA PACKAGE

M.E. DOBBS  
DECEMBER 1992

Prepared for:  
NASA Goddard Space Flight Center  
Space Technology Division  
Greenbelt, MD 20771

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Unclas

G3/61 0136214



(NASA-CR-191612) ROMPS CRITICAL  
DESIGN REVIEW DATA PACKAGE (ERIM)  
70 p



P.O. Box 134001  
Ann Arbor, MI 48113-4001

# SpARC ROMPS CDR INDEX

## PRESENTATION ORDER

7:40am 12/8/1992

page	sec.pg	dwg#	title	type	comments	section	status	in book
165	0		<b>Control System Detailed Design</b>	COVER	UPDATE		N	[ ]
<b>INTRO</b>								
166	1.01	422	Operational Concept	DWG	UPDATE		Done	[x]
167	1.02	MED/2	Control System Requirements	BUL	UPDATE			[x]
168	1.03	MED/3	Control System Requirements	BUL	UPDATE			[x]
<b>SYSTEM OVERVIEW</b>								
173	2.01	538	Flight and Ground Software Component Distribution	DFD	UPDATE		Done	[x]
194	2.02	542	Payload Software Interfaces/Platforms	WPX	UPDATE		Done	[x]
<b>SERVO</b>								
3.01		803	Nominal Operation of XP Servo	WPX	NEW		Done	[x]
3.02		440	Servo System Block Diagram					
3.03		801	XP Servo Code Outline Chart	DIA	NEW		Done	[x]
3.04			XP Memory Map and CPU Margin	WPX	NEW		N	[x]
<b>TESTBED &amp; SIMULATION RESULTS</b>								
4.01		813	Axis Data Summary	TBL	NEW		N	[x]
4.02		800	Testbed Phase II Preliminary Results	WPX	NEW		Done	[x]
<b>SYSTEM V CONTROLLER</b>								
5.01		924	Nominal Operation of the Zymate System V Controller		DONE		Done	[x]
5.02		923	Top Level DFD Zymate System V Controller Software		DONE		Done	[x]
5.03		905	EasyLab Remote Control Interface		UPDATE		Done	[x]
5.04			System V Memory Map and CPU Margin					
<b>ROBOT MODULE</b>								
6.01		915	Nominal Operation of the ROMPS Robot Module		DONE		Done	[x]
6.02		914	Robot Module DFD		DONE		Done	[x]
6.03		700	Command Variable Processing example Flow Chart of Absolute Move		Started		Done	[x]
6.04		702	EasyLab Program PUT.INTO.RACK Processing Flowchart				Done	[x]
<b>FURNACE MODULE</b>								
7.01		911	Nominal Operation of the ROMPS Furnace Module		DONE		Done	[x]
7.02		910	Furnace Module DFD		DONE		Done	[x]
7.03		701	Furnace Module Time/Temperature Chart					[ ]
<b>SCL EXPERIMENT SUPERVISOR</b>								
8.01		921	Nominal Operation of the SCL Experiment Supervisor		NEW		N	[x]
8.02		900	Top Level DFD SCL Experiment Supervisor Software		UPDATE			[x]
8.03		523	HH Bilevel Commands Packet Protocol		UPDATE		Done	[x]
8.04		524	ROMPS SCL Command Packet Protocol		UPDATE		Done	[x]
8.05		526	ROMPS DownLink Protocol		UPDATE		Done	[x]
8.06		917	SCL Runtime Engine DFD	DFD	NEW		Done	[x]
8.07		920	SCL Real Time Database Records Summary		NEW		Done	[x]
8.08		916	SCL Project Scripts, Rules, and Commands Summary		NEW		Done	[x]
8.09			SCL Memory Map and CPU Margin					
<b>SCL SCRIPT SAMPLE PROCESSING CONTROL</b>								
202	9.01	922	SCL Script Automated Sample Processing Overview	DIA	UPDATE		Done	[x]
<b>SCL EXPERIMENT SUPERVISOR FAULT HANDLING</b>								
10.01		918	Rule Based Shutdown of APC Script				Done	[x]
10.02		925	Rule Based Health and Safety Monitoring				Done	[x]
<b>BLOCK DIAGRAMS</b>								
218	11.01	814	Connection Diagram (foldout)	DWG	UPDATE		Done	[x]
11.02		436	XPC Board				Done	[x]
11.03		437	XPP Board				Done	[x]
11.04		434	ENC Board					
11.05		433	STP Board					
11.06		435	MUX Board				Done	[x]
<b>HH INTERFACE</b>								
12.01			HH/SC Interfaces					
<b>BATTERY SYSTEM</b>								
13.01			Encoder and Computer Battery Data				Done	[x]
13.02		632	Encoder Battery Backup Schematic			B	Done	[x]
13.03		638	Battery Source Schematic			B	Done	[x]
<b>WATCHDOG TIMERS</b>								
14.01			Reset and Watchdog Timer Signals					

**MECHANICAL/THERMAL**

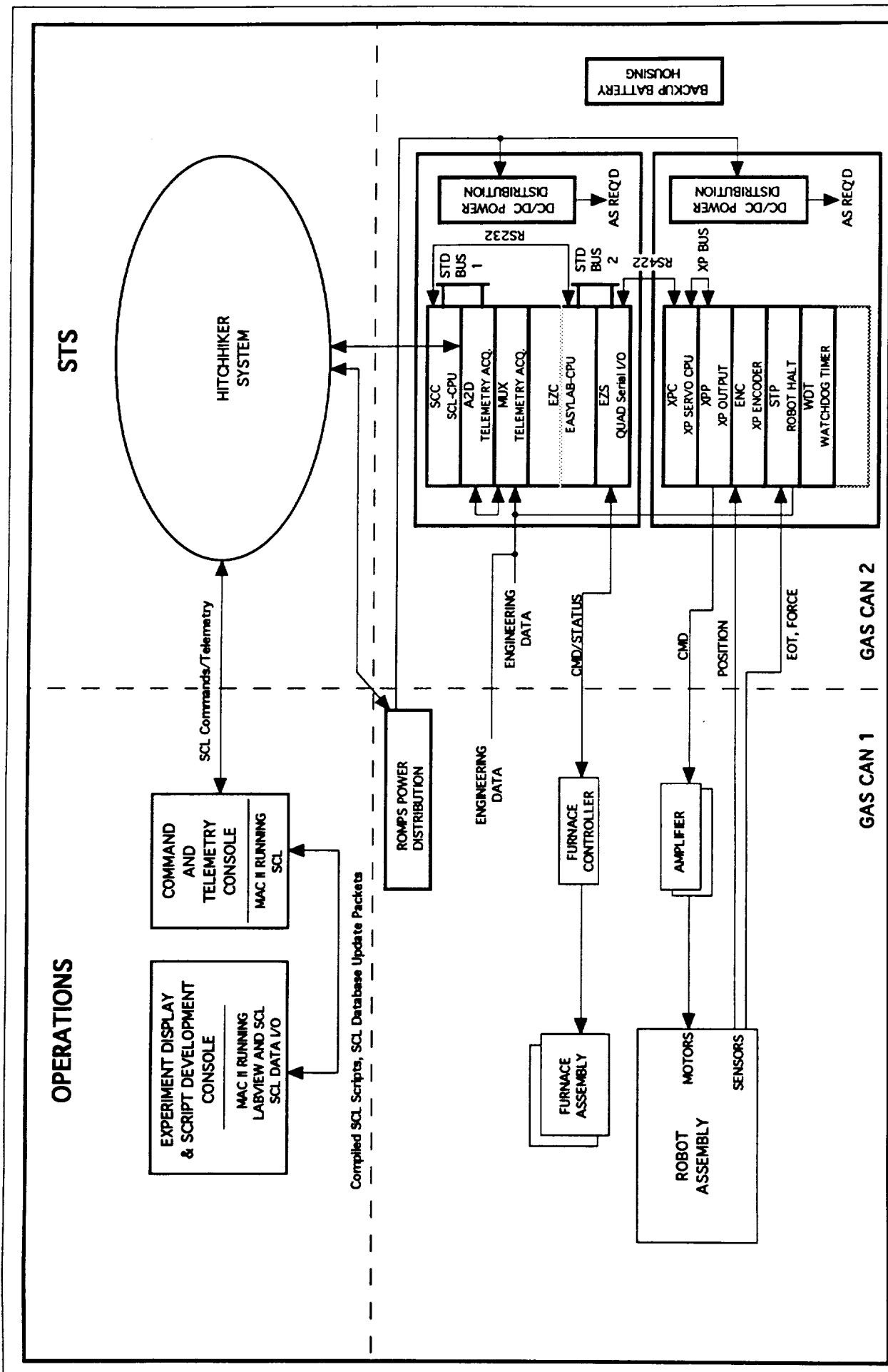
233	15.01	817	Board Outlines - SC1 & SC2	DWG	UPDATE	Done	[x]
231	15.02	MED/29	Control System Design - Weight & Power Summary	TBL	UPDATE		[x]
	15.03	257	S.C. GAS Assembly and C.G.		NEW	Done	[x]
232	15.04		SWRI Control Computer	photo		Done	[x]
	15.05		Payload Controller Layout				
	15.06	438	Interconnect Harness Diagram				
	15.07	258	GAS Adapter Plate				
	15.08		Thermal Design		NEW	Done	[x]
	15.09		Temperature Predictions		NEW	Done	[x]
	15.10		Control System Transient Response, Earth View, On		NEW	Done	[x]
	15.11	439	Heater Block Diagram				
	15.12		Control System Mechanical Design		NEW	Done	[x]
	15.13		Control System Stress Analysis		NEW	Done	[x]

**FAULT CONDITIONS & RECOVERY**

230	16.01	810	Fault Conditions and Responses (Paul's long chart)	TBL	UPDATE		[x]
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**SUMMARY**

17.01	MED/32		Status of Control System Nov92		UPDATE	N	[x]
17.02	815		Development Plan (Evolution from Zymate to ROMPS)		NEW	Done	[x]



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	SPACE AUTOMATION & ROBOTICS CENTER		4/6/92
	ENVIRONMENTAL RESEARCH INSTITUTE of MI		1/9/92
	ANN ARBOR, MI		DATE
		RoMPS OPERATIONAL CONCEPT	
		RoMPS	
		010-422	



## **CONTROL SYSTEM REQUIREMENTS**

**CARRIER** NSTS HITCHHIKER, 1/2 HEIGHT GAS ENCLOSURE, SEALED  
**POWER** +28 ±4 VDC UNREGULATED, DC ISOLATION  
**COMMAND** RS422, 1200 BAUD, ASYNCHRONOUS, LIMITED THRUPTUT  
4 DISCRETE COMMANDS FOR ENABLES/DISABLES & PROCESSOR BOOT  
**TELEMETRY** RS422, 1200 BAUD, ASYNCHRONOUS, ~100 C/S MAX. THRUPTUT

## **GENERAL**

AUTOMATIC EXECUTION OF EXPERIMENT  
MANUAL CONTROL OF ALL FUNCTIONS  
FAIL-SAFE OPERATION  
POWER-FAIL RECOVERY  
TELEMETRY - 1 SEC ENGINEERING, 30 SEC ENGINEERING, 3 SEC-1 DIAGNOSTICS  
EXPERIMENT SCHEDULE & PROCESS SCRIPT MODIFICATION & UPLOAD  
TELEMETRY LOGGING, DISPLAY, PLAYBACK  
MANUAL COMMANDING



## **ROBOT**

### **CONTROL SYSTEM REQUIREMENTS**

#### **4 DOF MATERIAL HANDLING ROBOT**

**±0.005" (14BIT) POSITION RESOLUTION & ACCURACY**

**200 SEC<sup>-1</sup> LOOP SAMPLE RATE**

**INCREMENTAL & HALL POSITION ENCODERS**

**END-OF-TRAVEL DETECTION**

**FORCE LIMIT DETECTION**

**±10VFS CONTROL OUTPUT TO MOTOR DRIVERS**

**DISCRETE OUTPUTS - POWER-TO-RELEASE BRAKE, DRIVER ENABLE**

**TELEMETRY - POSITION, EOT, FORCE, MOTOR V & I, TEMPS, MISC. STATUS**

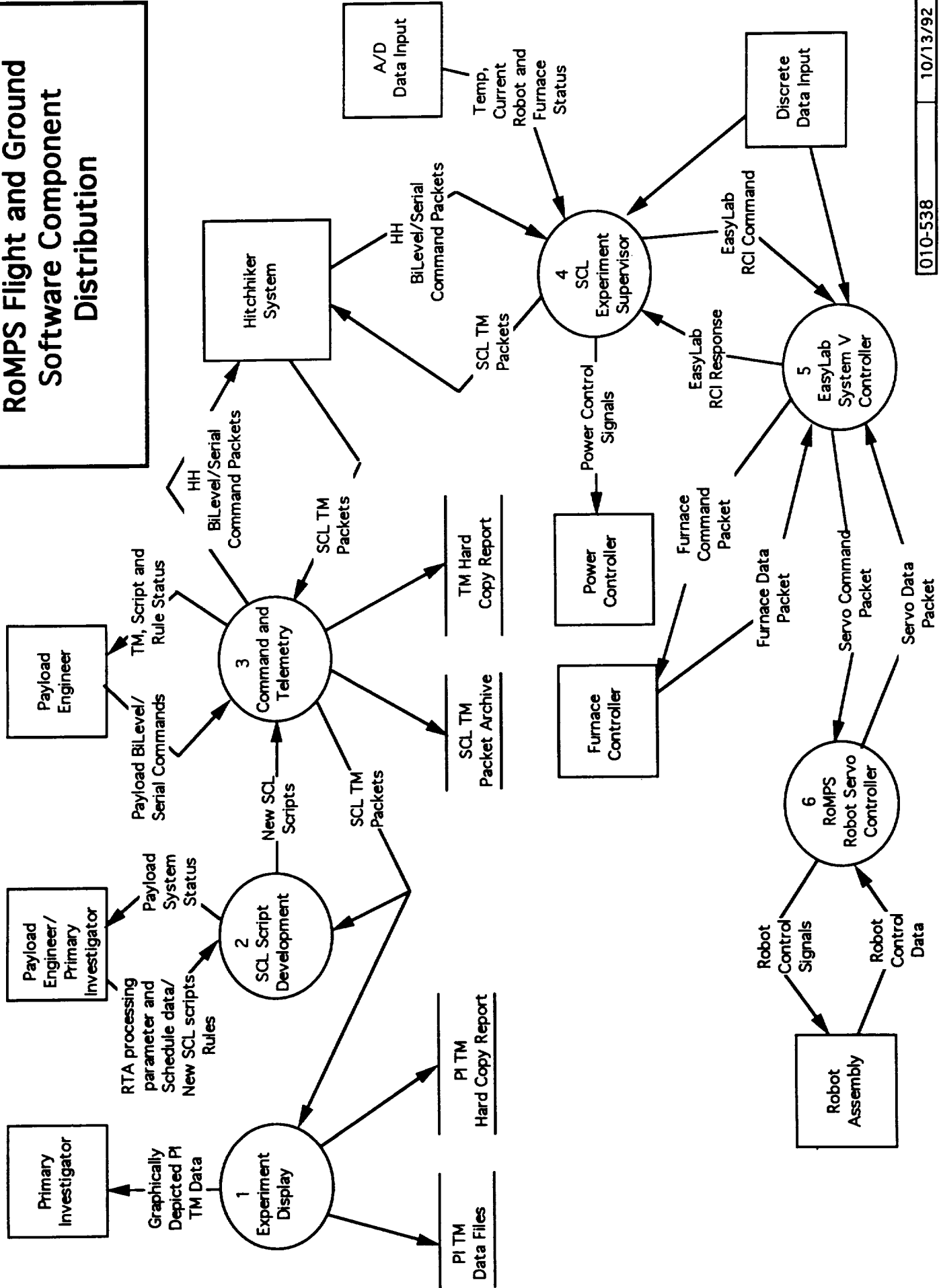
#### **MATERIAL RESEARCH FURNACE**

**UP TO 7 TEMPERATURE/TIME PLATEAUS**

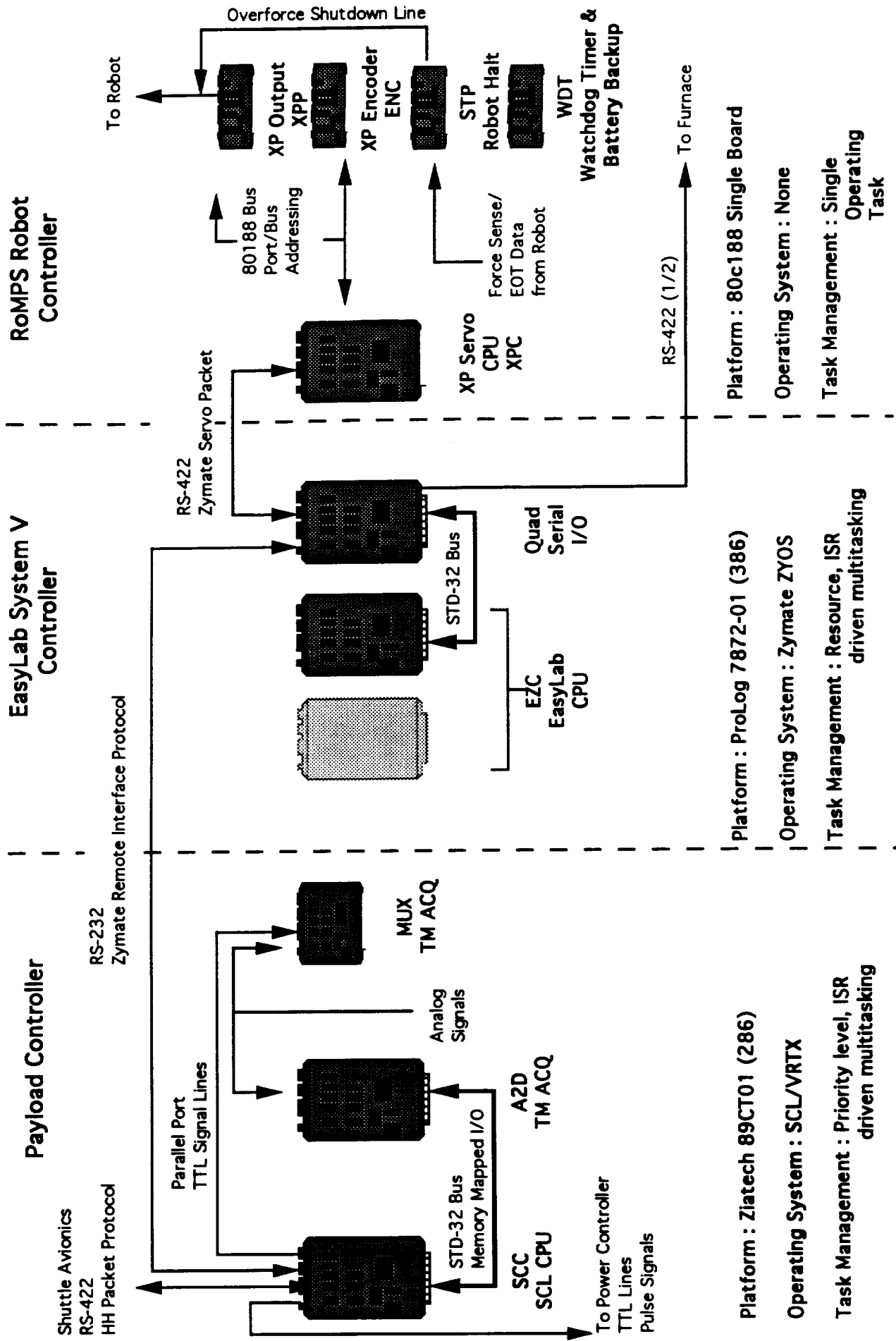
**SERIAL COMMAND & DISCRETE ENABLE TO FURNACE CONTROLLER**

**TELEMETRY - SETPOINT, LAMP V&I, REF TEMP, MISC. STATUS**

# ROMPS Flight and Ground Software Component Distribution

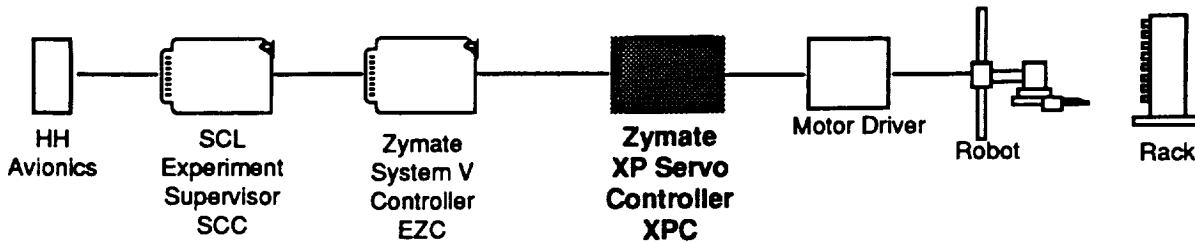


# RoMPS Payload Software Interfaces/Platforms





## Nominal Operation of the ROMPS XP Servo



### Upon Reset

#### 1) XP Servo Controller System Startup

- System Hardware (timers, UART, LEDs, etc.) is initialized and associated Interrupt Service Routines are installed
- Servo Control and Processing Control Data Structures are initialized

#### 2) Ready XP Servo Controller System for Main Processing Loop

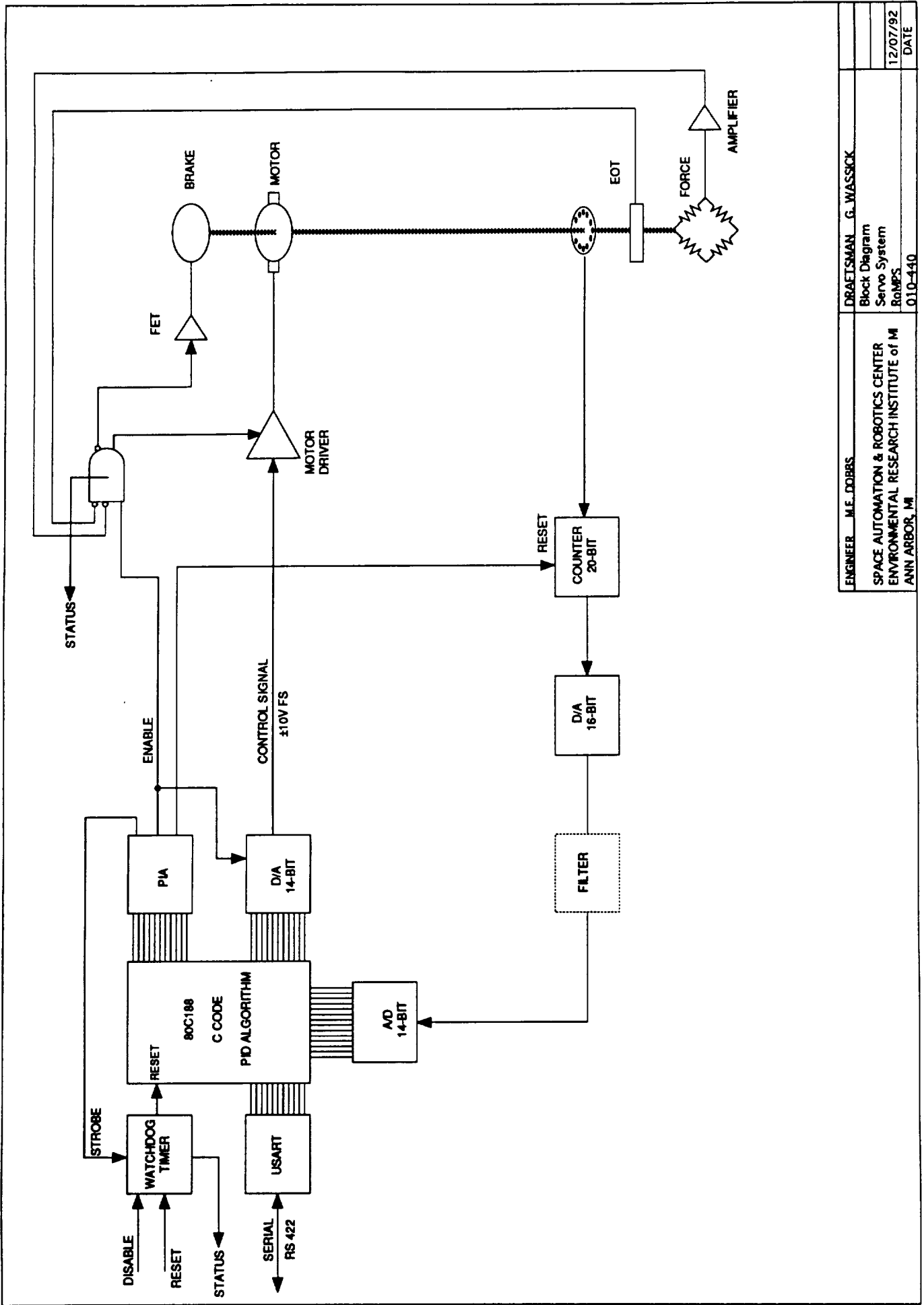
- Inhibit the D/As used for Axis Position Control
- Kick the Watch Dog Timer
- Execute Servo Control Algorithm 5 times to "Prime" the Servo Control intermediary data structures
- Set all Axis Control Target Positions to Current Position
- Set all Axis Control Speeds to Zero
- Initialize the Communication Structures used to communicate with the System V Controller
- Uninhibit the D/As used for Axis Control

#### 3) Begin Main Servo Processing Loop

##### *Loop Forever*

- Set the 5 millisecond Main Processing Loop Timer
- Execute the Servo Algorithm for Base and Gripper Axis
- Output the computed Control Voltages to the D/A used for Axis Control
- Kick Watch Dog Timer High
- Update the System Diagnostic LEDs
- Get/Process XP Servo Commands from the Zymate System V Controller  
**see XP Servo Command Tables**
- Wait for the remainder of 5 millisecond Main Processing Loop Timer
  - Kick Watch Dog Timer Low

##### *End Loop*



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Block Diagram Servo System RoMPS			12/07/92
010-440			DATE

# RoMPS XPC Servo Code Outline Chart

on 5 millisecond timer:

<b>timer2_interrupt</b>
decrement position timers decrement message timer clear tick

on unused interrupt:

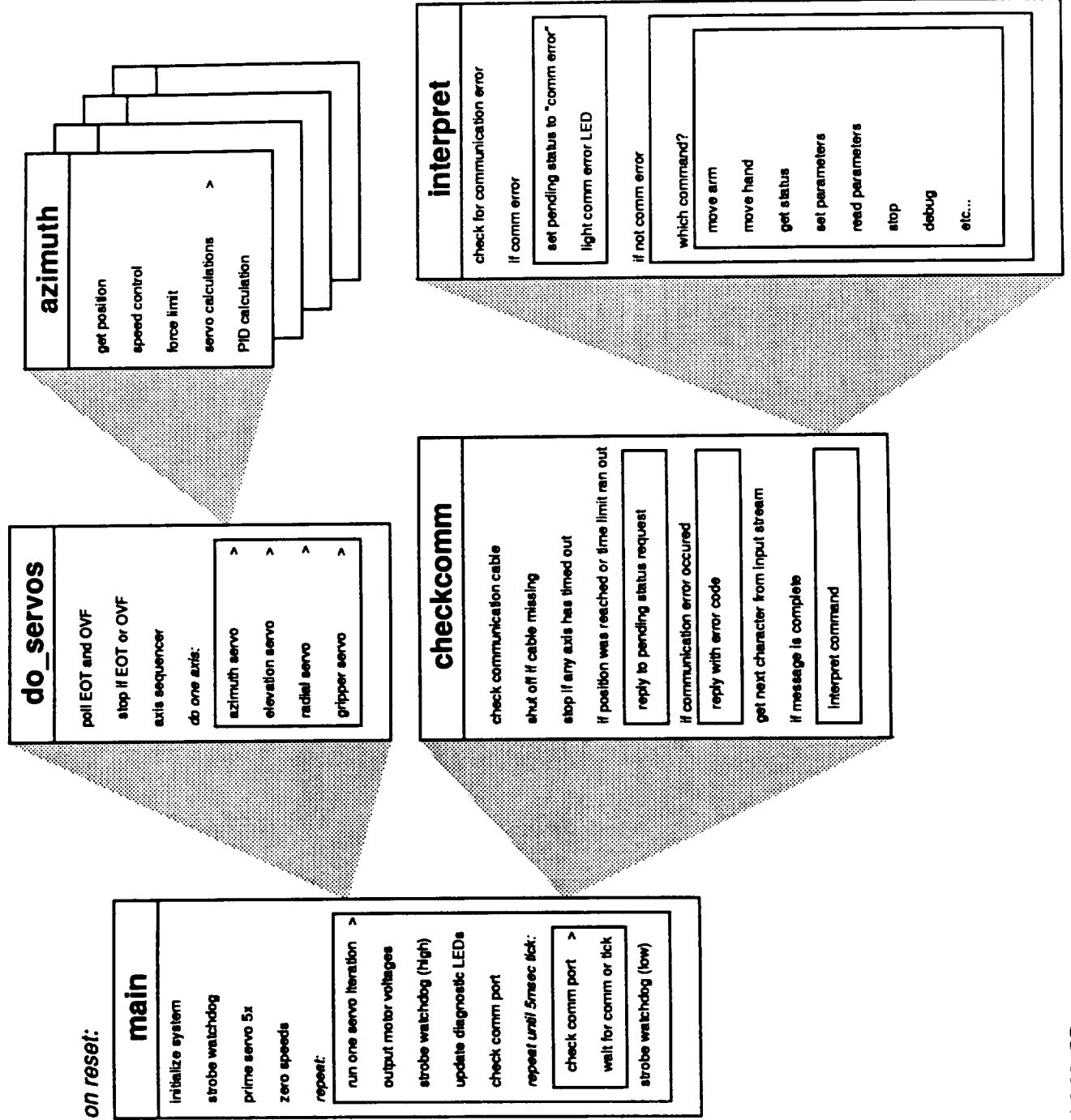
<b>unexpected_interrupt</b>
restart

on character received:

<b>USARTreceive</b>
put received character into buffer get receive status check for overrun

on character transmitted:

<b>USARTtransmit</b>
send next character check for empty buffer



on reset:

<b>main</b>
initialize system strobe watchdog prime servo 5z zero speeds repeat: run one servo iteration > output motor voltages strobe watchdog (High) update diagnostic LEDs check comm port repeat until 5msec tick: check comm port > wait for comm or tick strobe watchdog (low)

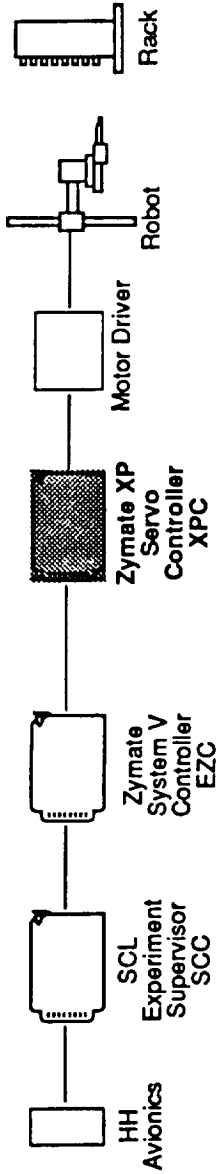
<b>azimuth</b>
get position speed control force limit servo calculations > PID calculation

<b>do_servos</b>
poll EOT and OVF stop if EOT or OVF axis sequencer do one axis: azimuth servo > elevation servo > radial servo > gripper servo >

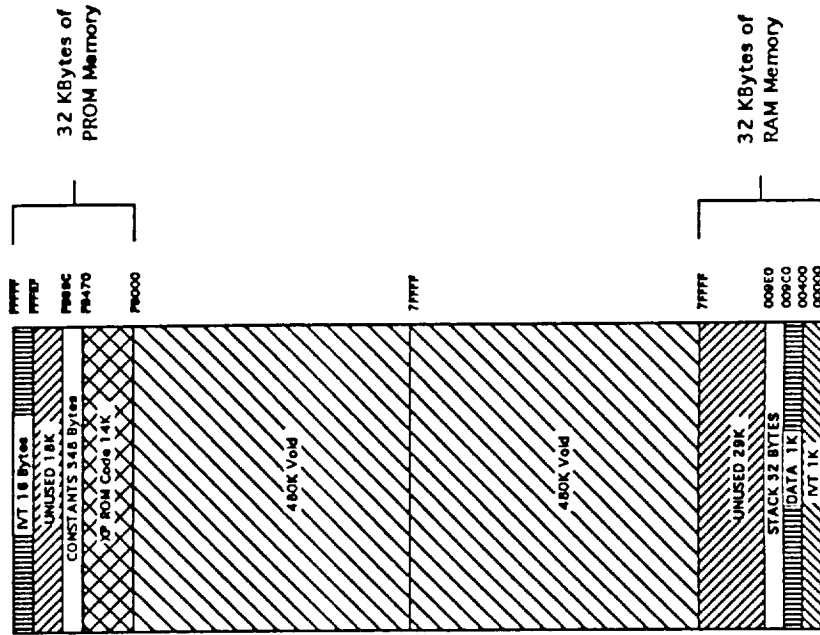
<b>interpret</b>
check for communication error if comm error set pending status to "comm error" light comm error LED if not comm error which command? move arm move hand get status set parameters read parameters stop debug etc...

<b>checkcomm</b>
check communication cable shut off if cable missing stop if any axis has timed out if position was reached or time limit ran out reply to pending status request if communication error occurred reply with error code get next character from input stream if message is complete interpret command

# XP FIRMWARE PERFORMANCE MARGIN



Memory Map



XP Firmware	BB Measured 6DOF	ROMPS Estimate 1DOF
Communication I/O	interrupt basis .8 msec worst case	interrupt basis .8 msec worst case
State Machine	0	.1 msec
PID Loop	1.6 msec complex code 6 axis 5 msec loop	.27 msec simpler code 1 axis 5 msec loop
Accutrack Interrupts	.1 msec est	0
CPU Margin	2X	4.3X

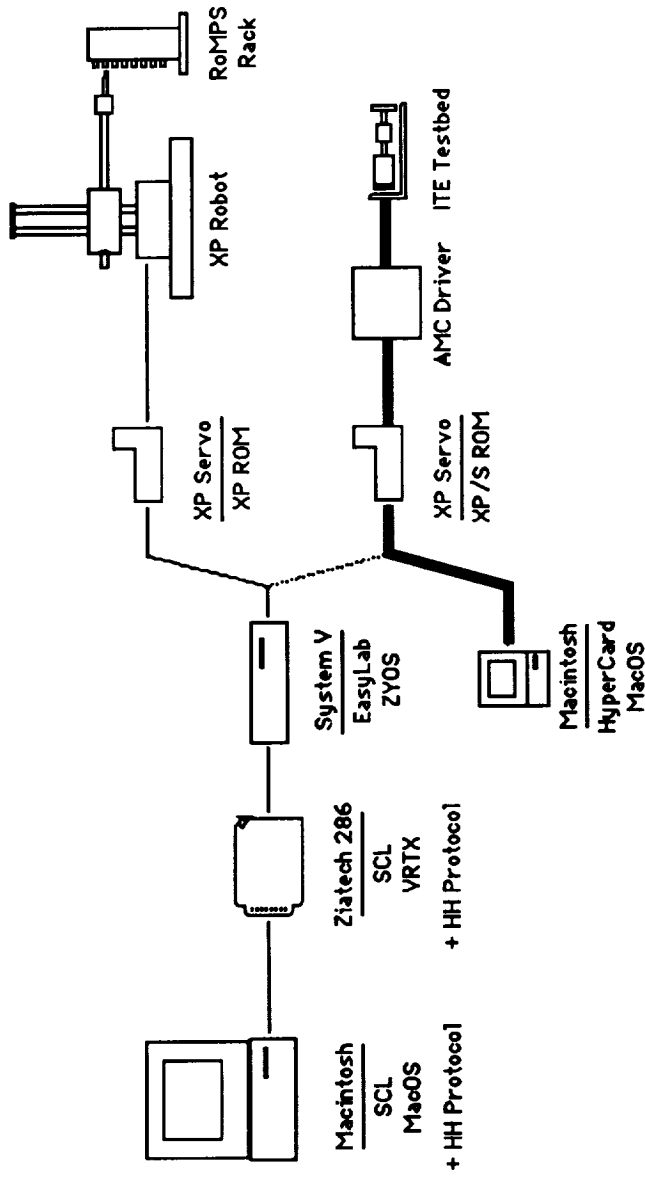
# HOMPS Axis Data Summary

	Elevation	Azimuth	Radial	Gripper	Testbed
Full Scale Travel	18"	44"	4.0"	0.7" (each side)	..
Resolution at End Effector	.004"	.005"	.004"	.004" (each side)	.0156 rev = 5.6°
Gear (effector/motor)	.079"/rev	.280"/rev	.00390"/rev	.00126"/rev	1
Revolutions Full Scale at Motor	227.9 rev	160 rev	1016 rev	560 rev	512 rev
Revolutions Resolution at Motor	.050 rev	.0182 rev	1.016 rev	3.2 rev	
Encoder Pitch at Motor	500 lines/rev	500 lines/rev	.495 lines/rev	3 lines/rev	256 lines/rev
Encoder Pitch at End Effector	6329 lines/inch	1786 lines/inch	127 lines/inch	2381 lines/inch	256 lines/rev
Decoder Gain	4 steps/line	4 steps/line	4 steps/line	4 steps/line	4
Full Scale Counts	455,700 steps	320,000 steps	2,012 steps	6,720 steps	..
Counter Size	19 bits = 524,288	19 bits = 524,288	11 bits = 2,048	13 bits = 8,192	19 bits = 524,288
Counter Steps for Resolution	101.6 steps	36.36 steps	2,012 steps	38.4 steps	
DAC Voltage at Full Scale	8.692V FS	6.104V	9.823V	8.203V	10.000V
Voltage for Resolution	1.93 mV	.694 mV	9.82 mV	46 mV	
A/D Count Range	14,241 counts	10,001 counts	16,093 counts	13,440 counts	16384

Motor Model #	RBEH 01502	RBEH 01201	RBEH 00401	RBE 00700	RBEH 00704
No Load Speed	1300 RPM	2500	14100	6500	2500
Moment of Inertia	.005 oz-in-sec <sup>2</sup>	0.0013	0.000027	0.00013	0.00045
Torque Constant	15.1 oz-in/vW	7.4	1.13	2.5	8.6
Motor Resistance	2.5 ohm	2.9	3.9	3.7	2.1
Motor Viscous Damping	.0017 oz-in/RPM	0.00035	0.0000124	0.000069	0.00032
Motor Hysteresis Drag Torque	2.44 oz-in	0.92	0.12	0.26	1.1
Motor Cogging Torque	3.6 oz-in	2.2	0.5	0.9	2.8

Gear Efficiency	0.9	0.6	0.5	0.21	..
Total Inertia	0.00706 oz-in-sec <sup>2</sup>	0.004	0.0000324	0.000425	.013 est
Total Viscous Friction	.0162 oz-in-sec	0.0033	0.000118	0.00066	.004 est
Total Coulomb Friction	10.34 oz-in	10.72	1.3	4.96	3.5 est
Accuracy Required (at motor)	±.05 rev	±.0145 rev	±1.00 rev	±3.2 rev	±.1 rev
Torque Required	9.24 oz-in	5.6	0.54	0.75	..
Speed Required	650 RPM	1250	7000	3250	1250

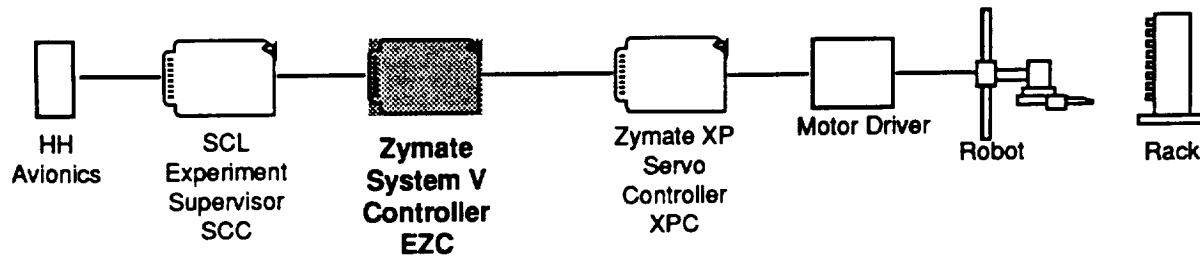
# RoMPS Testbed Phase II



XP COMMERCIAL TESTBED PHASE A RESULTS

PARAMETER	TESTBED	ELEV	AZIM	RAD	GRIP
FULL SCALE TRAVEL [REVS]	512	228	160	1016	560
RESOLUTION [%FS]	8.2 10 <sup>-3</sup> [14-bit = 6.1 10 <sup>-3</sup>	2.2 10 <sup>-2</sup>	1.2 10 <sup>-2</sup>	1.0 10 <sup>-1</sup>	5.7 10 <sup>-1</sup>
MAX VELOCITY [REV SEC <sup>-1</sup> ]	20 [MOTOR LIMIT]	10.8	20.8	117	54.2
SETTLE / DAMPING	CRITICAL				

# Nominal Operation of the Zymate System V Controller



## UPON RESET

### 1) Zymate Operating System (ZYOS) Startup

- System Hardware (timers, disk drives, etc.) is initialized and associated and Interrupt Service Routines initialized
- Memory, Task and Message Manager structures initialized
- Language Editor, EasyLab Interpreter, Disk Manager and Data Dictionary Manager structures initialized

### 2) Load the ROMPS Application Data Dictionary

- Read from ROM (flight) or disk (ground development) the AutoLoad System File Containing the ROMPS EasyLab programs, Robot PyTechnology, Furnace PyTechnology, Launch Rack PyTechnology

### 3) ZYOS Starts Task Dispatching

- The Robot and Furnace Module Tasks in turn become the active task, execute their module initialization code, then return to the task ready list to await for a command at their exchange
- Watchdog Timer Task begins execution

### 4) EasyLab Interpreter Executes Startup EasyLab Program

- The EasyLab Interpreter executes the ROMPS startup script AUTOSTART, which executes the command to put the system into Remote Control Mode

### 5) System Begins Normal EasyLab Processing

*Loop Forever*

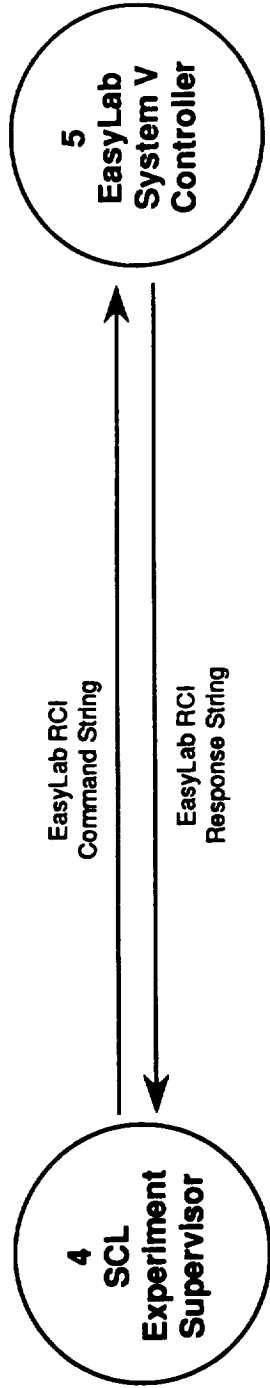
- Remote Control Interface Task waits to get a EasyLab Command to pass to Interpreter
- EasyLab Interpreter gets commands from RCI processing EasyLab Programs and forwarding Robot and Furnace Module Commands to their respective tasks
- Robot and Furnace Module process any commands sent to them, issuing commands themselves to the XP Robot Servo and the Furnace Controller

*End Loop*

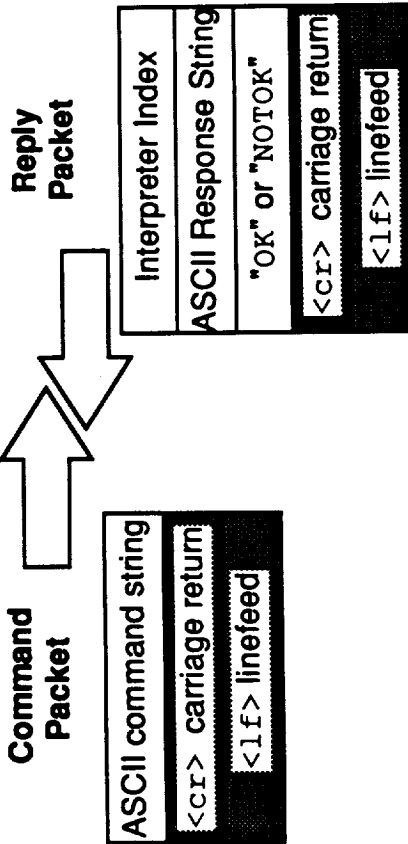




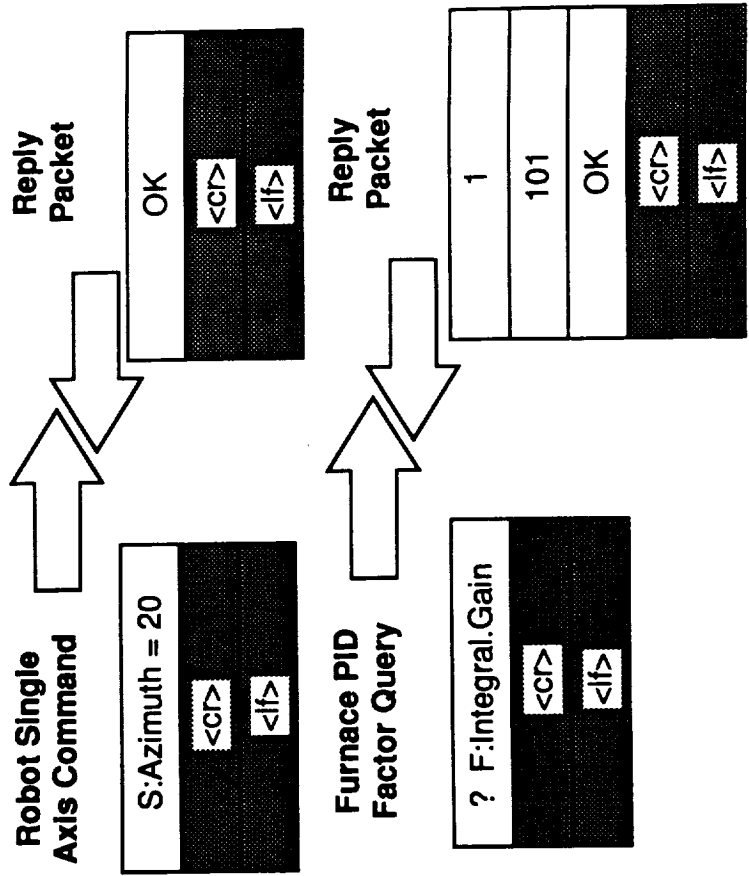
# ROMPS EasyLab Remote Control Interface Protocol



## Command/Reply Packets for Generic RCI Command

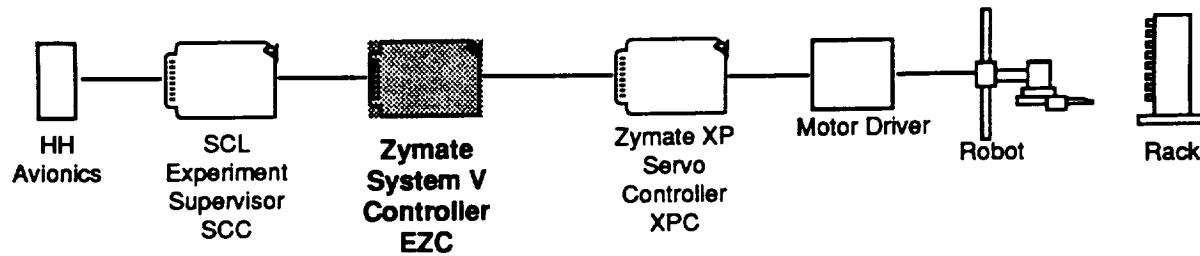


## Command/Reply Packets for Specific ROMPS RCI Commands





## Nominal Operation of the ROMPS Robot Module



### UPON Robot Module Becoming Active Task for the First Time

#### 1) Enter Robot Module into Zymate Operating System Environment

- Create a Module Login Entry in the Zymate Data Dictionary
- Create a Message Exchange between EasyLab Interpreter and Robot Module

#### 2) Initialize the Robot Modules Operating Parameters

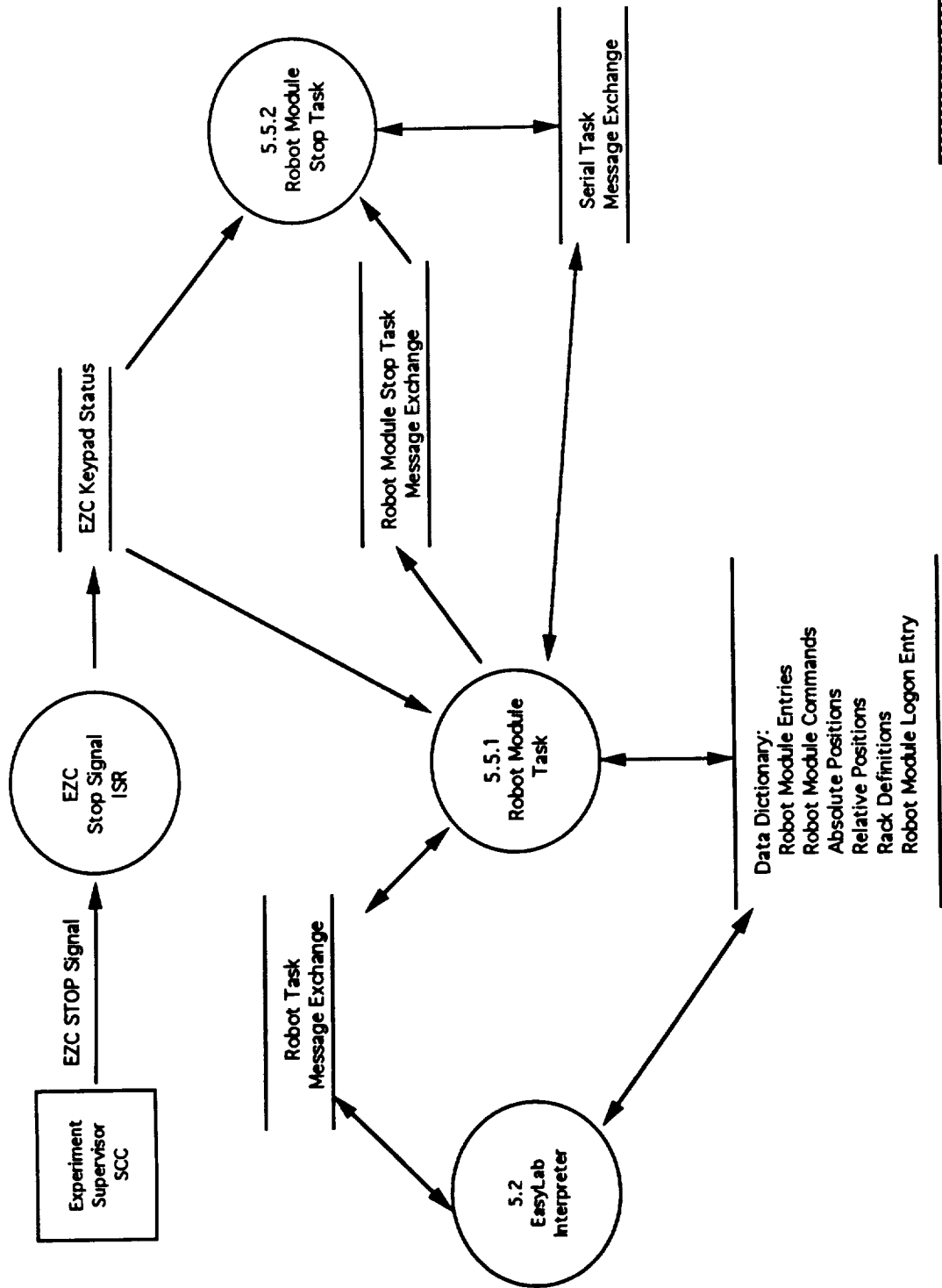
- Create a Message Exchange between Robot Module and Serial Task in order to communicate with XP Robot Servo via Serial Channel
- Create Stop task which monitors the STOP data structure during Moves
- Get user-unit to robot unit conversion factors from XP Robot Servo
- Get Present Base and Wrist Position from XP Robot Servo
- Compute default Base and Wrist Speeds, Accelerations, Robot Movement Wait and Transition parameters, send these settings to XP Robot Servo
- Send Base and Wrist Move commands for present position

#### 3) Robot Module Begins Normal Command Processing

##### *Loop Forever*

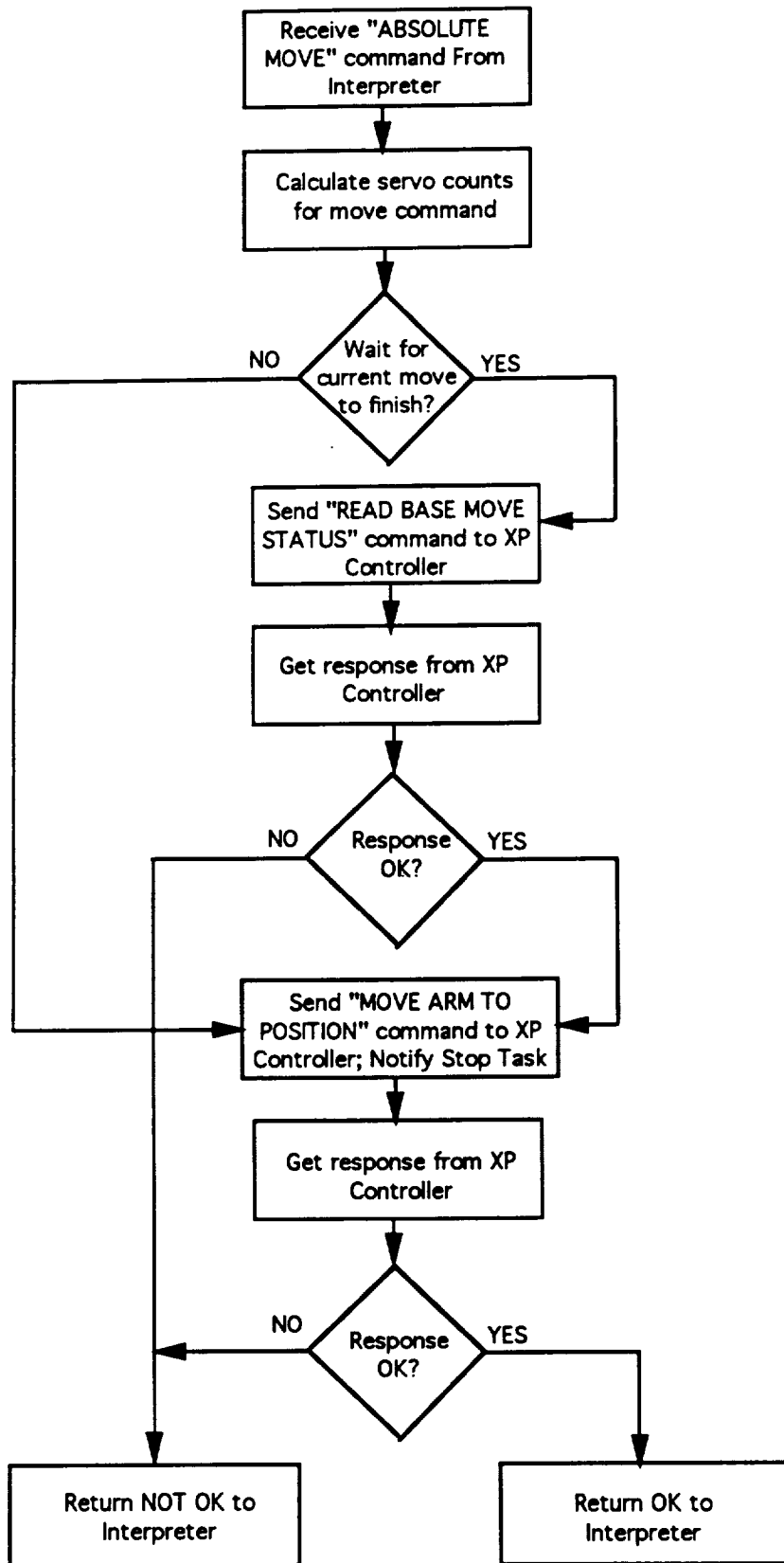
- Wait for a Command Message from the EasyLab Interpreter
- Get the Command Code from the Command Message
- Send the appropriate Robot Servo Commands and update the appropriate internal data stores corresponding to the Command Code contained in the Command Message, see Robot EasyLab Command Variable Table
- Return the Command Message to the Interpreter, setting the Return.To.Exec code to Success or Stop, Cont, Step or Abort code if an Robot Module Detected error condition occurred

##### *End Loop*

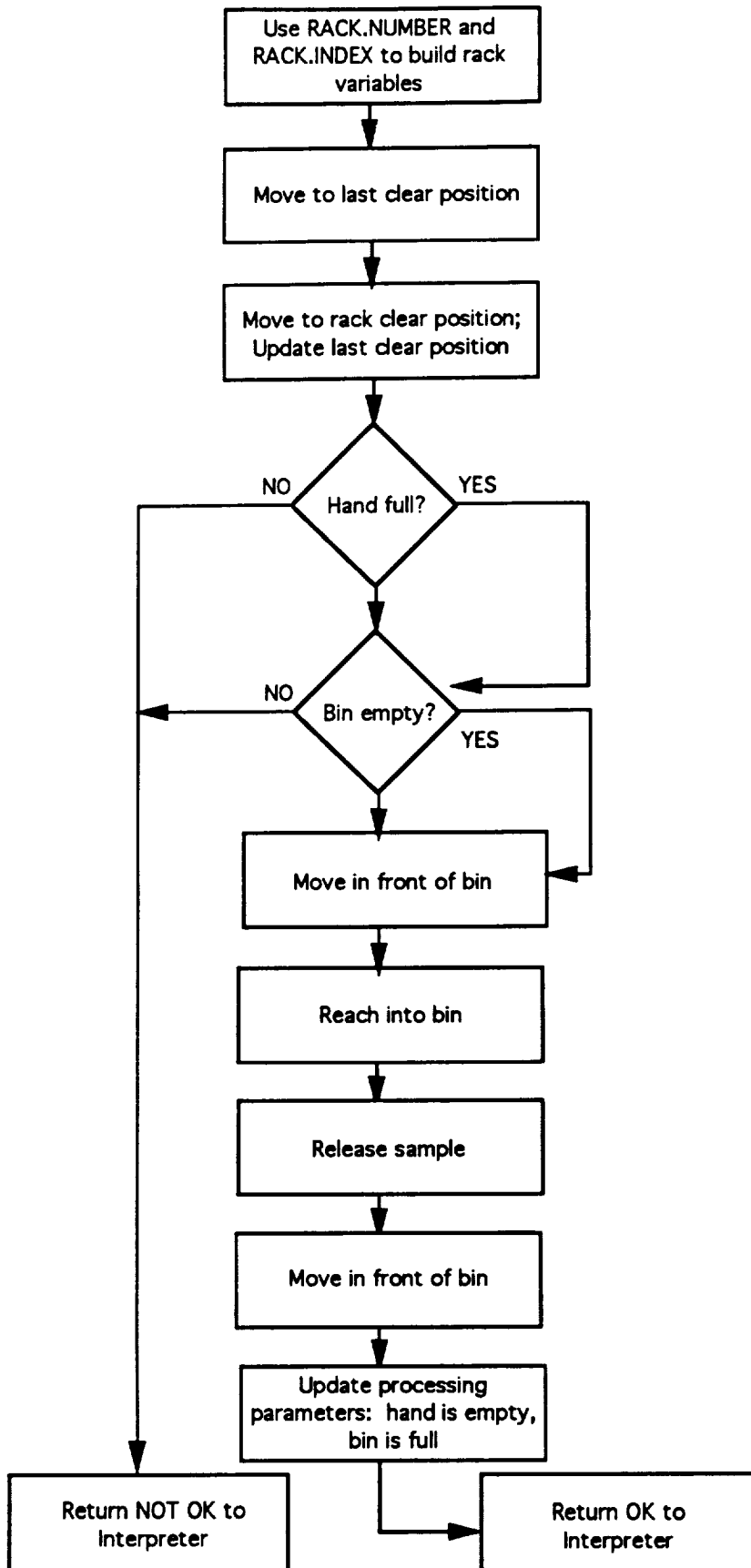


Zymate System V  
Controller Software  
Robot Module DFD

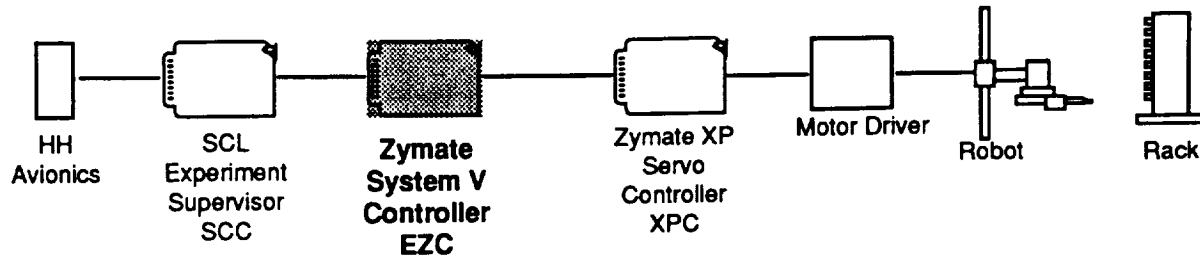
# ABSOLUTE MOVE COMMAND VARIABLE PROCESSING FLOW CHART



# EASLAB PROGRAM: PUT.INTO.RACK PROCESSING FLOW CHART



## Nominal Operation of the ROMPS Furnace Module



### UPON Furnace Module Becoming Active Task for the First Time

#### 1) Enter Furnace Module into Zymate Operating System Environment

- Create a Module Login Entry for the Furnace Module in the Zymate Data Dictionary
- Create a Message Exchange between EasyLab Interpreter and Furnace Module

#### 2) Initialize the Furnace Modules Operating Parameters

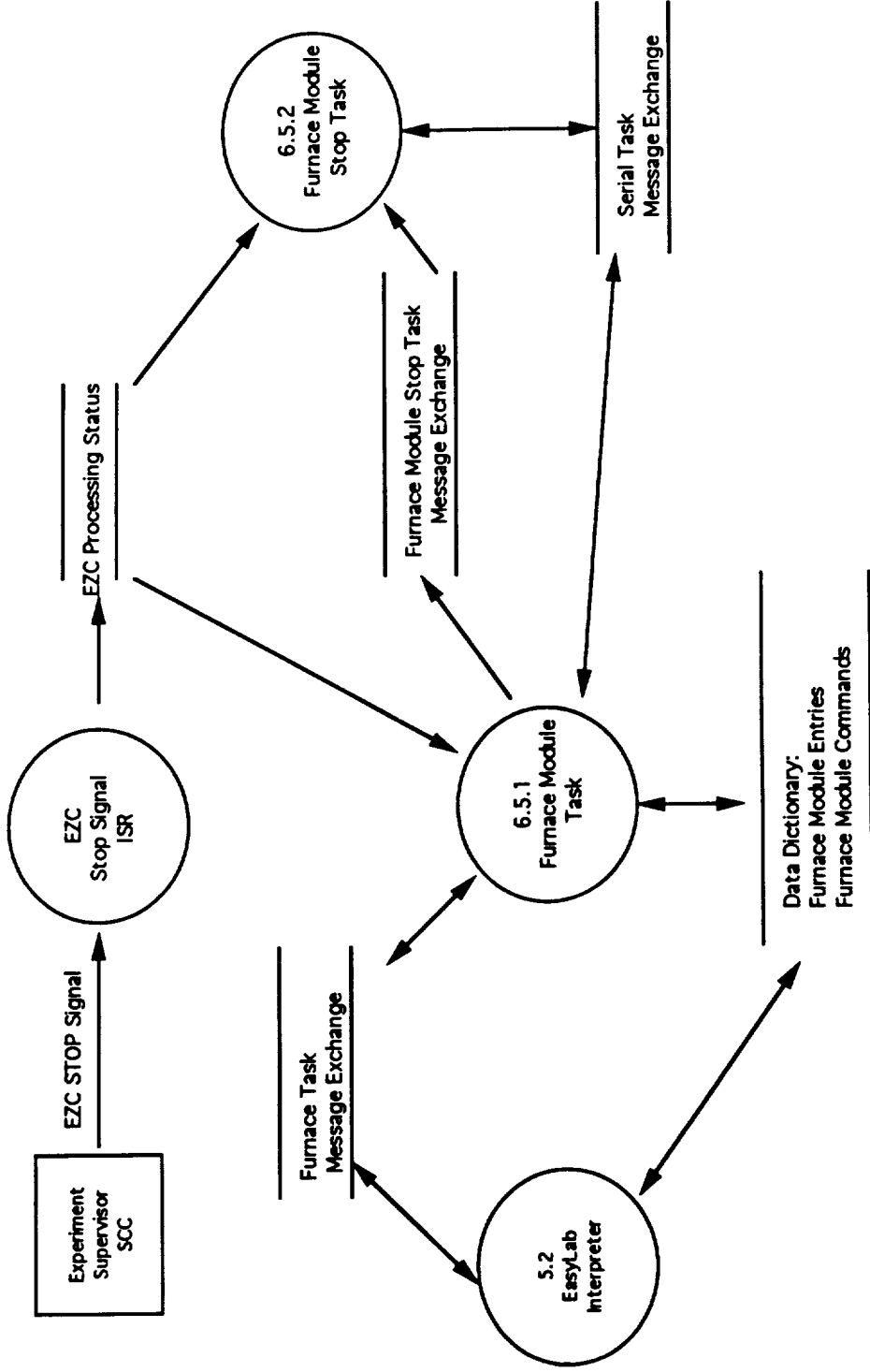
- Create a Message Exchange between Furnace Module and Serial Task in order to communicate with Furnace Controller via a Serial Channel
- Create Stop task which monitors the STOP data structure during Annealing Processing

#### 3) Furnace Module Begins Normal Command Processing

##### *Loop Forever*

- Wait for a Command Message from the EasyLab Interpreter
- Get the Command Code from the Command Message
- Send the appropriate Furnace Controller Commands and update the appropriate internal data stores corresponding to the Command Code contained in the Command Message, see **Furnace EasyLab Command Variable Table**
- If the Command Sent was an Execute.Heating.Profile Command
  - for each Initialized Profile.Temp
    - Send a Power/Temp Control Furnace Command for Profile.Temp
    - wait until Profile Time or STOP Task Detects a STOP Signal
    - reset all Profile.Temp and Profile.Time data stores
- Return the Command Message to the Interpreter, setting the Return.To.Exec code to Success or Stop, Cont, Step or Abort code if a Furnace Module Detected error condition occurred

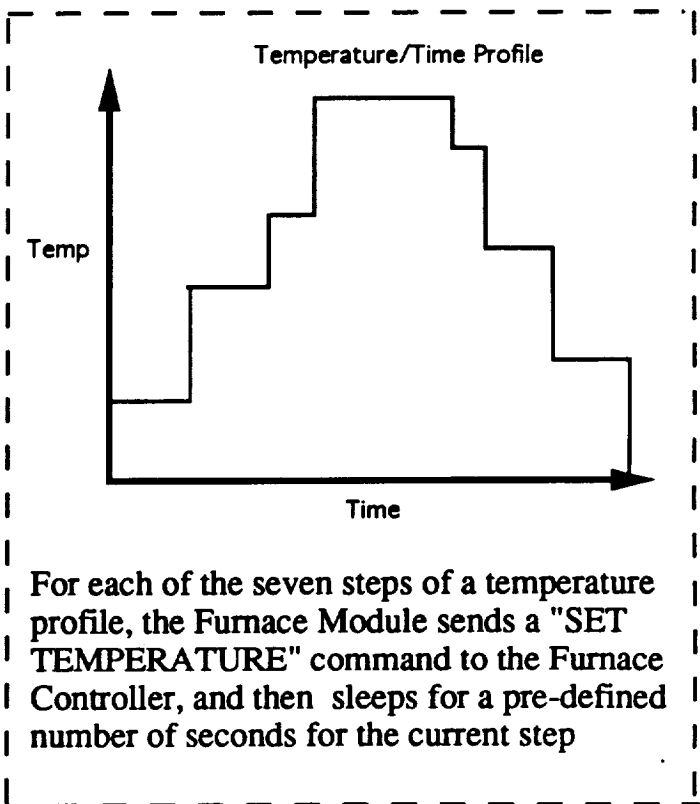
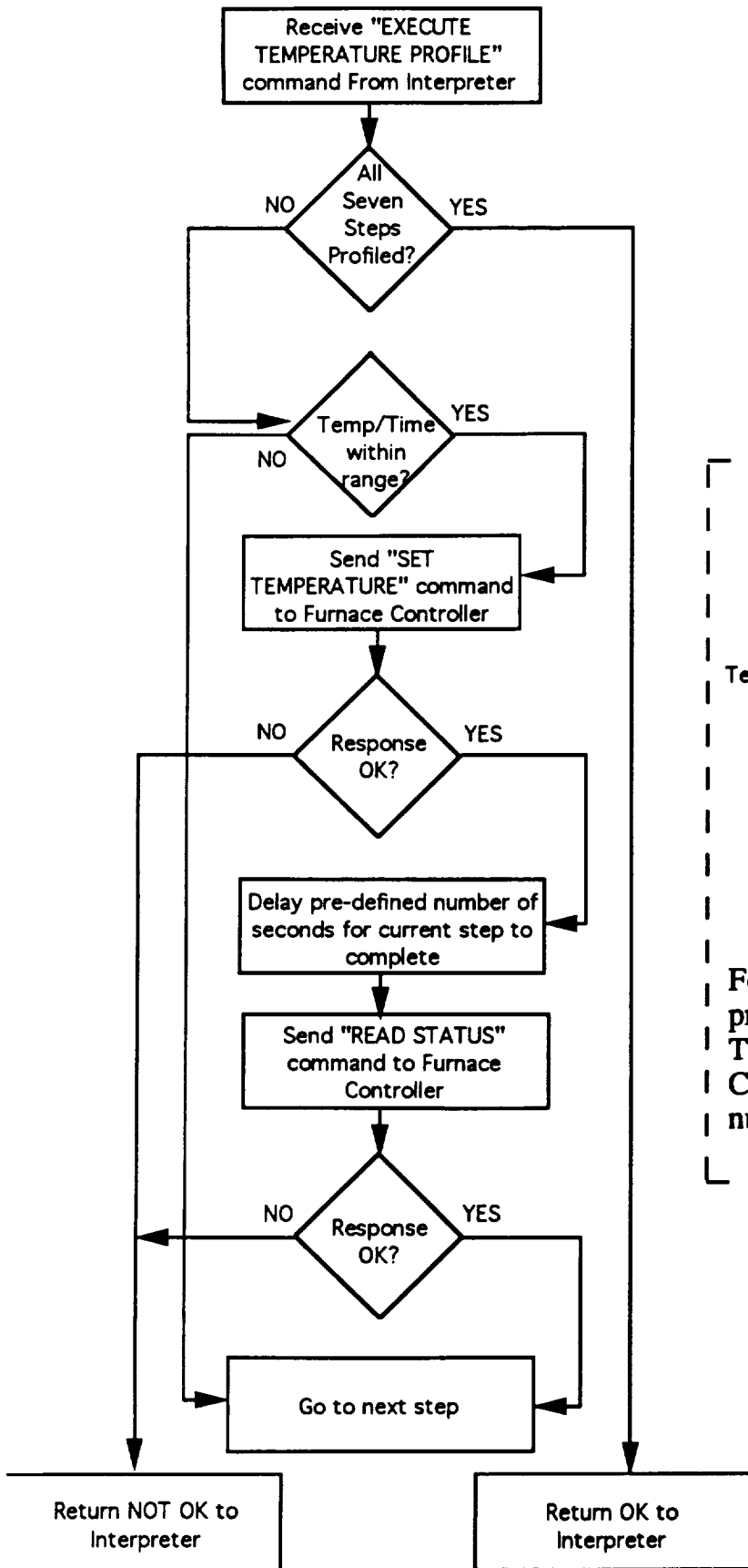
##### *End Loop*



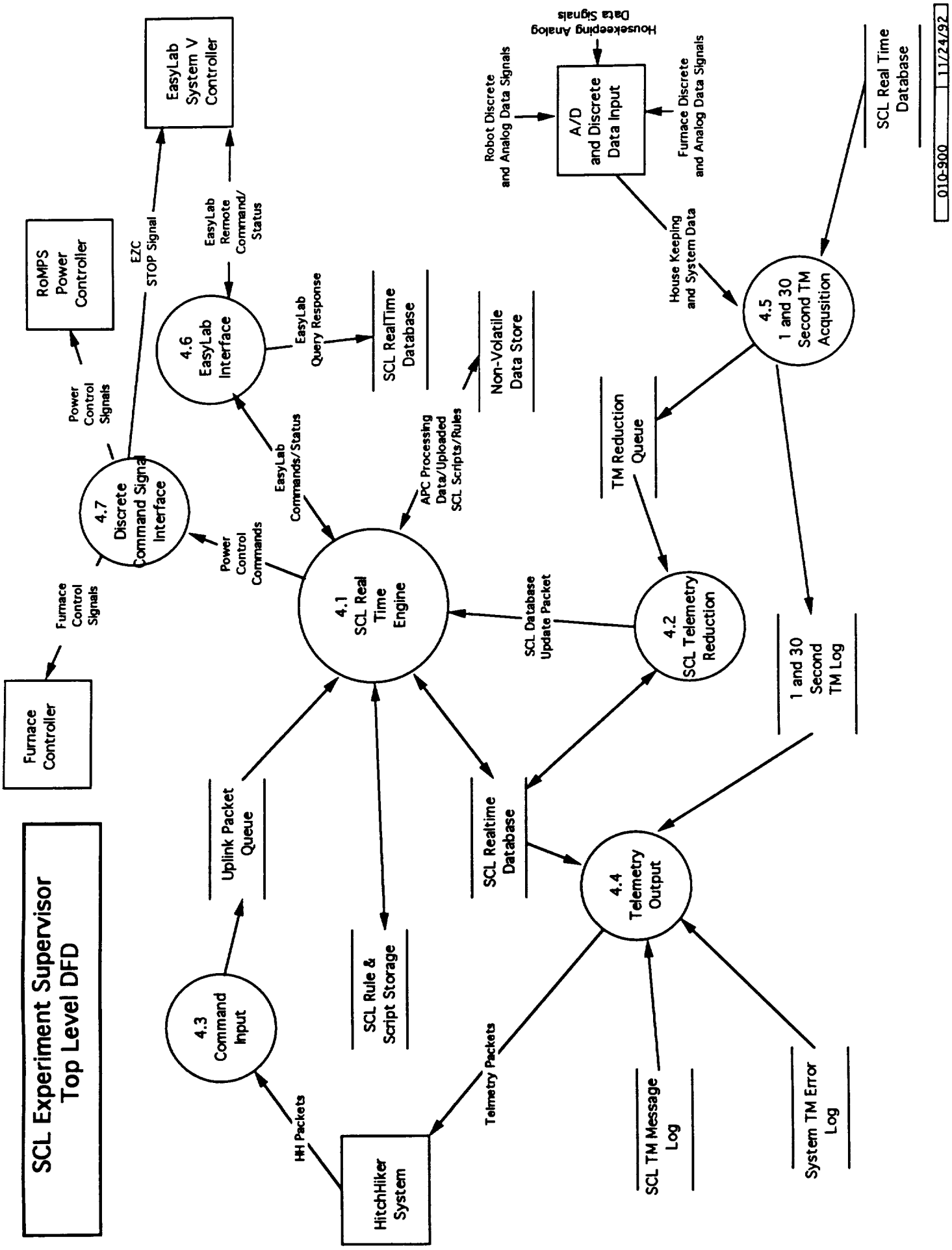
Zymate System V  
 Controller Software  
 Furnace Module DFD



## EXECUTE TEMPERATURE PROFILE COMMAND VARIABLE PROCESSING FLOW CHART

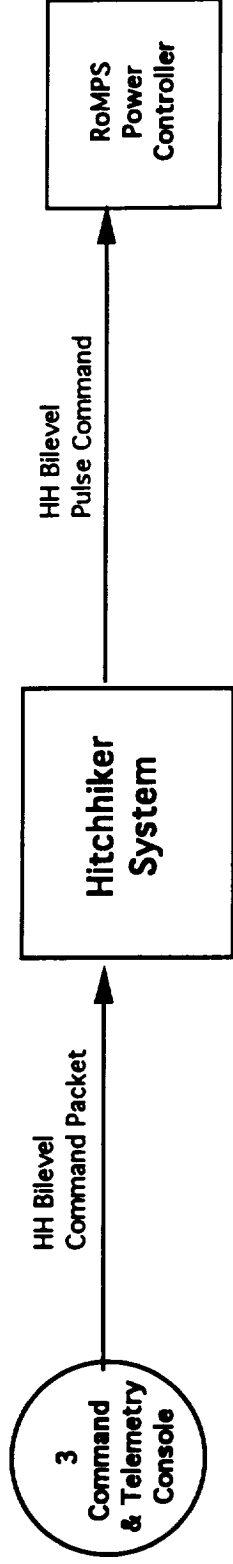


# SCL Experiment Supervisor Top Level DFD



# RoMPS Command Uplink Protocols

## HH Bilevel Command Packet Protocol



Synch Pattern	
Byte Count	
Customer ID, Type	
Pulse Settings	
Check Sum	

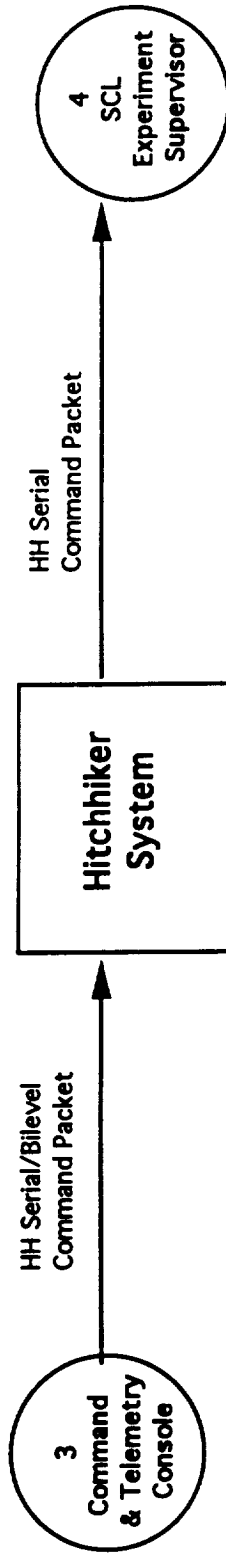
example of  
Generic Bilevel Command Packet

Synch Pattern	
Byte Count	
Customer ID, Type	
0 0 0 0	0 0 0 1
Check Sum	

example of  
Bilevel Command Packet for  
set HH\_BILEVEL to MASTER\_RESET

# RoMPS Command Uplink Protocols

## SCL-Command Packet Protocol



Synch Pattern
Byte Count
Customer ID, Type
SCL Command ID
SCL Command ID
Command Byte Count
Command Byte Count
Command Specific Data
••••
••••
Command Specific Data
Check Sum

example of Generic SCL-Command Packet

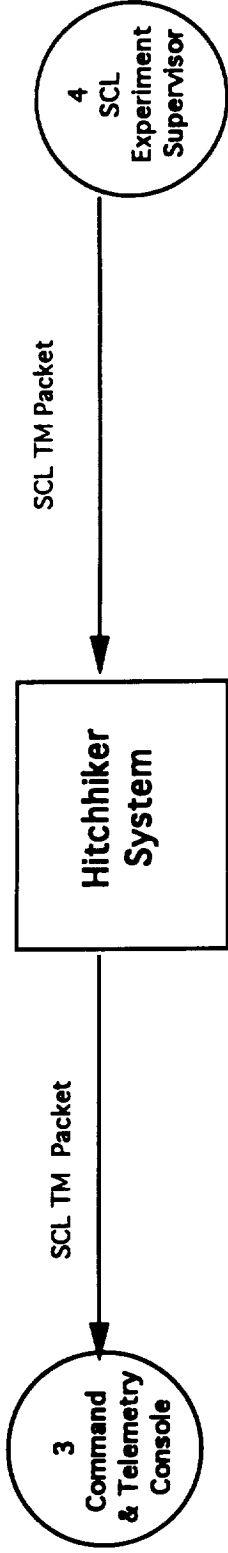
Synch Pattern
Byte Count
Customer ID, Type

SCL Command ID
Command Byte Count =
execute Token ID
system function Index of execute subroutine
argument 1 subcode
SPC script ID
Time Byte 1
Time Byte 3
argument 3 subcode
sample_id ID
script execution priority
Check Sum

example of SCL-Command Packet for execute SPS at 12:00:00 with sample\_id

# RoMPS Telemetry Downlink Protocols

## SCL 1 Second, 30 Second and Asynchronous Downlink Packet Protocol



1 Sec Sync Pattern
1 Sec Sync Pattern
Packet Size
SCL 1 Sec Dump ID
Time Stamp Byte 1
Time Stamp Byte 2
Time Stamp Byte 3
fixed field format, 1 second RoMPS data items dump

1 Second Telemetry Packet

30 Sec Sync Pattern
30 Sec Sync Pattern
Packet Size
SCL 30 Sec Dump ID
Time Stamp Byte 1
Time Stamp Byte 2
Time Stamp Byte 3
fixed field format, 30 second RoMPS data items dump
RTE/VRTX Status ID
RTE/VRTX Status Length
RoMPS SCL RTE and VRTX Status Data

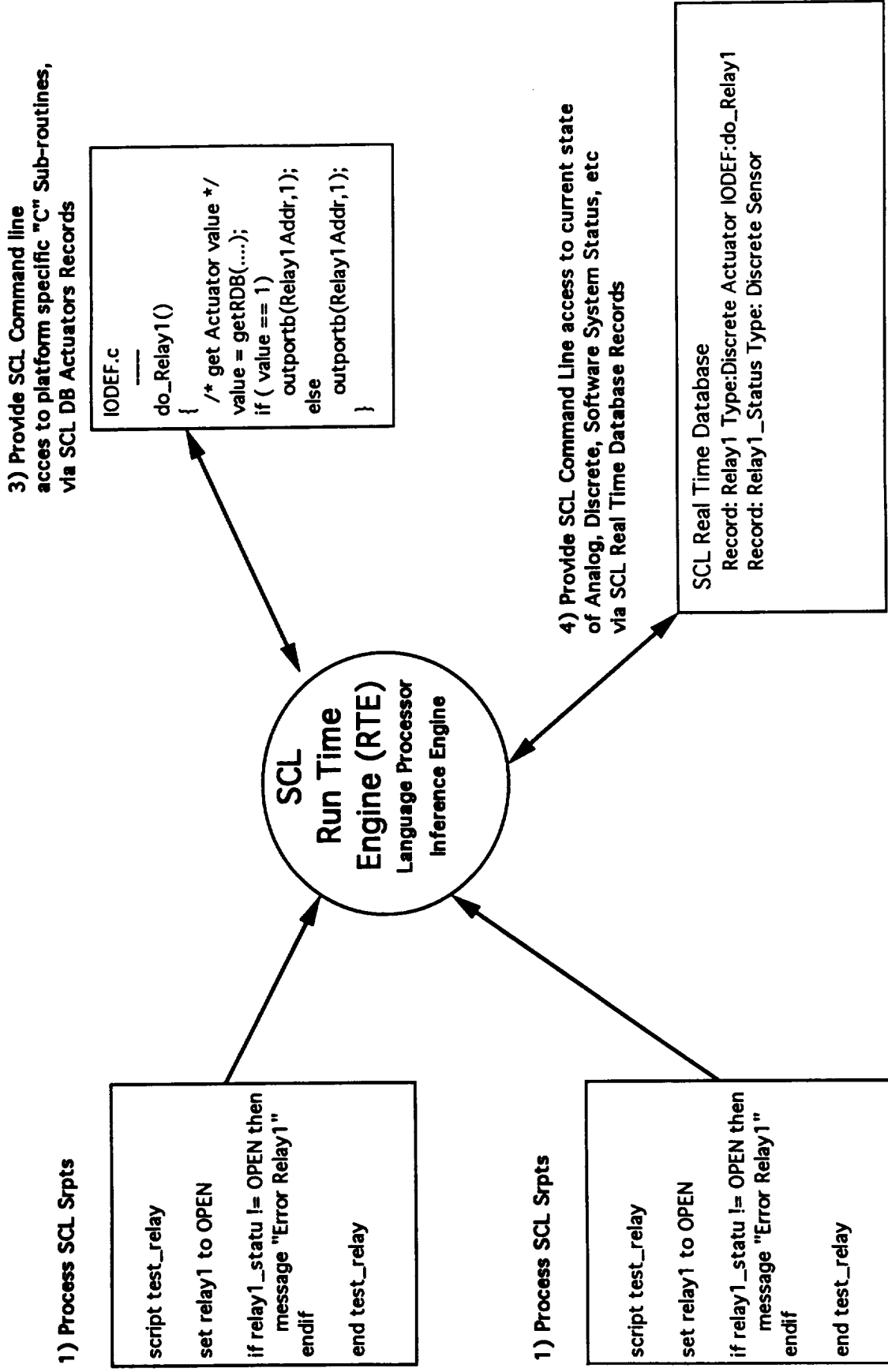
30 Second Telemetry Packet

Asynch Sync Pattern
Asynch Sync Pattern
Packet Size
System Error ID
System Error Size
System Error Records
EasyLab Error ID
EasyLab Error Size
EasyLab Error Record
SCL Query Result ID
Query Record Size
SCL Query Result Recs

zero or more of each sub packet type

Asynchronous Telemetry Packet

# Spacecraft Command Language Run Time Engine Data Flow Diagram



# Summary Table of Experiment Supervisor SCL Real Time Database Records

## Analog Sensor Records - Value represents current state of corresponding A/D Signal Level

Battery_Temp	Furnace_Lamp_Voltage	Furnace_Lamp_Current *	Sample_Temp
Cal_Sample_Temp(x2)	Furnace_Rel_Temp(x2)	Axis_Position(x4)	Axis_Force(x4) *
Axis_Motor_Temp(x4) *	Motor_Current *	Power_Bus_Voltage	Sys_Cntrl_Temp(x2)
Sys_Cntrl_Ref_Volt(x2)	Motor_Drive_Temp	Motor_Drive_Box_Temp	Robot_Ref_Volt
Ref_Voltage(x3)	Furn_Cntrl_Box_Temp	Isothermal_Block_Temp	Furn_Str_TC_Temp(x3)
Furn_Str_Temp(x5)	Power_Cntrl_Box_Temp	Pallet_Rack_Temp(x5)	GAS1_Rad_Temp(x3) *
GAS1_Base_Temp(x2) *	Motor_Velocity	Axis_Ctrl_Sig_Lvl(x4)	Motor_Current

## Discretes Sensor Records - Value represents current state of corresponding Parallel I/O Bit Signal Level

Furn_AB_Relay_Status	WD_Ena_Dis_Status	Bus_AB_Relay_Status	Battery_Relay_Status
Axis_OvF_Status(x4)	Sys_Enable_Relay_Status	Gen_Mtr_Drv_ENA_Status	Mtr_Drv_AB_Relay_Status
Axis_EOT_Top(x8) *	Axis_Brake_Status(x3)	Furnace_Ctrl_Enable_Status	XPC_WD_Timer_Status
Furn_WD_Status	EZC_WD_Timer_Status	Axis_Enable_Status(x4)	SCC_WD_Timer_Status

## Derived System Records - Value represents current status of SCL System Code

Num_ErrorLog_Packets	Num_MessageLog_Packets	Num_1and30Log_Packets	Num_Good_Packets_RCV
Num_Bad_Packets_RCV	EasyLab_Var_Query_Result		

## APC/SPC Records - Values are used by SCL Scripts and Rules to Control Processing Flow \*\*

Time_Profile(x7)	Temp_Profile(x7)	Sample_ID	Rack Number
Rack_Index	SPC_Processing_Step	Processing_Status	Min_Cooling_Time
Max_Cooling_Time	Min_Cooling_Temp	APC_Schedule_Index	APC_Schedule_ID
APC_ParametersID			

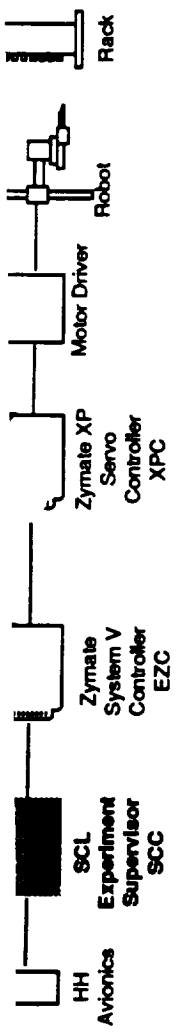
\* These SCL Database Records are monitored by Rules

\*\* These SCL Database Records are saved in non-volatile memory for recovery from power loss

# Summary Table of ROMPS Flight SCL Project Scripts, Rules, and Commands

Name	Type	FUNCTION
<b>Sample Pallet Processing Control</b>		
InitIAPCParametersX	SCRIPT	Initializes SCL Global Arrays with Initial Sample Processing Parameters
InitIAPCScheduleX	SCRIPT	Initializes SCL Global Array with Initial Sample Scheduling Parameters
SPC	SCRIPT	Issues EasyLab Commands to the Robot and Furnace for Sample Processing
APC	SCRIPT	Initializes Processing Parameter Records used by SPC, and calls SPC for each Sample in Schedule
Pause_Processing	SCRIPT	Stops SPC script from sending EasyLab commands until Processing_Resume script is invoked
Resume_Processing	SCRIPT	Resumes SPC script sending EasyLab Commands after Pause_Processing script
<b>Interface with Zymate System V Controller</b>		
EasyLab_Command	EXTERNAL COMMAND	Sends an EasyLab Command to System V Controller and returns response Status
EasyLab_Query	EXTERNAL COMMAND	Sends an EasyLab Command to System V Controller and returns response Status
Stop_EZC_Processing	ACTUATOR	Sets STOP_EZC_PROCESSING signal, which aborts System V Controller current EasyLab Program
Query_RobotStatus	SCRIPT	Issue EasyLab Queries for the Robot Status variables, create Message Log entries with results
Query_FurnaceStatus	SCRIPT	Issue EasyLab Queries for the Furnace Status variables, create Message Log entries with results
<b>Health and Safety/Process Control Monitoring</b>		
Monitor_Temp_Sensor_X	RULE(x9)	Stops Autonomous Processing Cycle if monitored SCL DB Sensor X exceeds Temp Range
Monitor_Current_Sensor_X	RULE(x1)	Stops Autonomous Processing Cycle if monitored SCL DB Sensor X exceeds Current Range
Monitor_EOT_Axis_X	RULE(x8)	Stops Autonomous Processing Cycle if monitored SCL DB EOT sensor X unexpectedly is hit
Monitor_Overforce_Axis_X	RULE(x8)	Stops Autonomous Processing Cycle if monitored SCL DB Overforce sensor X exceeds range
<b>Telemetry System Control</b>		
TM_Stream_ON/OFF	ACTUATOR(x2)	Enables transmission of Active TM Stream Packets to HH Interface
TM_Active_Stream	ACTUATOR	Sets TM Stream to be 1and30 Second, Error, or SCL message Packets
TM_Flush_Error_Log	ACTUATOR	Clear the Error TM Log of the packets currently stored in it
TM_Flush_Message_Log	ACTUATOR	Clear the 1and30_Second TM Log of the packets currently stored in it
TM_Flush_1and30_Log	ACTUATOR	Clear the SCL Message TM Log of the packets currently stored in it
TM_Reset_Good_Packets	ACTUATOR	Reset the Command Input Counter which records number of good packets received from HH
TM_Reset_Bad_Packets	ACTUATOR	Reset the Command Input Counter which records number of bad packets received from HH
<b>External Sub Systems Control</b>		
Furnace_Select_A/B	ACTUATOR(x2)	Sets/Clears control signals to Furnace Controller which selects Oven A or Oven B as active oven
PowerBus_Select_A/B	ACTUATOR(x2)	Pulses Power Bus Select A/B control lines to Power Distribution System
Motor_Drive_Enable/Disable	ACTUATOR(x2)	Sets/Clears Motor Drive A/B select signal level to Motor Drive Unit
Battery_Relay_Open/Close	ACTUATOR(x2)	Pulse Open/Close Battery Relay control signals to WDT Unit for encoder battery backup
Motor_Driver_Select_A/B	ACTUATOR(x2)	Sets/Clears Motor Driver A/B Select control signals level to Motor Drive Unit
Furnace_Reset	ACTUATOR	Resets the Furnace Controller by pulsing the Furnace Reset/WD Disable line
Furnace_WD_Enable/Disable	ACTUATOR(x2)	Sets/Clears the Furnace Reset/WD Disable control signal, which enables/disables Furnace WD timer
SCC_WDG_Timer_Strobe	ACTUATOR	Sets SCC Watchdog Strobe control signal level based on assigned value
XPC_Reset	ACTUATOR	Pulses the XPC reset line to the XPC servo controller computer
<b>SCL RealTime Clock Control</b>		
RTC_Reset	ACTUATOR	Resets the SCC Real Time Clock hardware and sets counters to 0
RTC_Set_HHMMSS	ACTUATOR	Sets the Hour, Minute, and Second counters of SCC Real Time Clock to assigned value

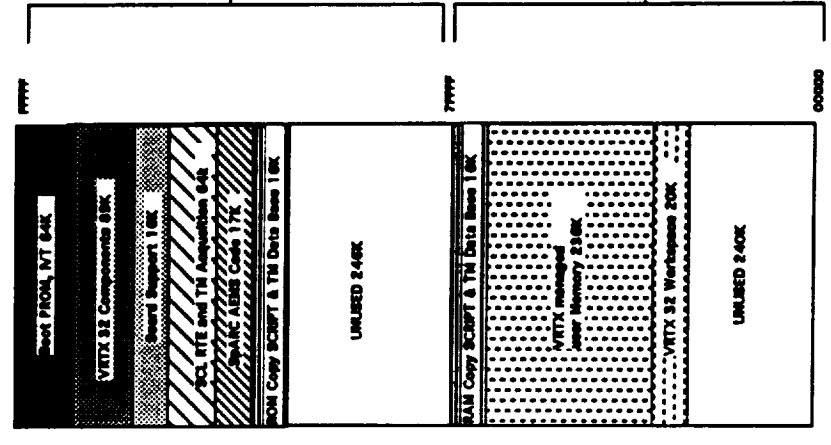




**SCL SOFTWARE PERFORMANCE/MARGIN**

SCL Experiment Supervisor	ARD-1 Measured V53	RoMPS Estimate V53
SCL System Code CPU Loading	23.8%	23.8%
SCL Rule Processing #lines of SCL CPU loading	n a 5% est	230 32%
SCL Script Processing #lines of SCL	n a	3 226 [144 samples + setup]
CPU loading	1% est	1.5% [mission average]
CPU Margin	50% est [other tasks in ARD]	42%

**RoMPS Experiment Supervisor Memory Map**

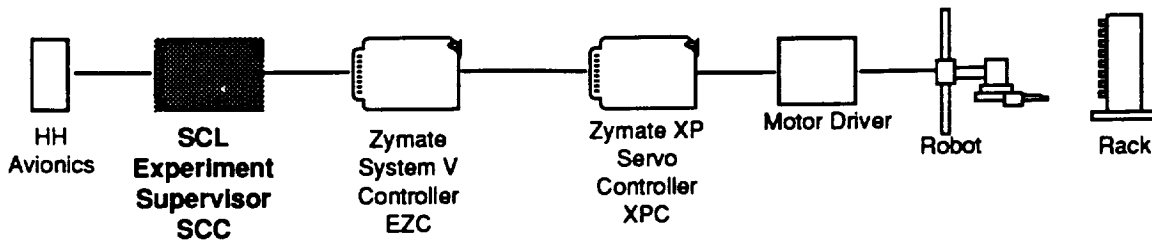


512 KBytes of PROM Memory

512 KBytes of RAM Memory

010-533-021032

# Nominal Operation of the SCL Experiment Supervisor



## UPON RESET

### 1) VRTX System Startup

- System Hardware (timers, UARTS, ADs, etc.) is initialized and associated and Interrupt Service Routines initialized
- Call VRTX initialization Routine
- Start SCL System Code Main Task

### 2) Execute SCL System Code Main Task

- Create Semaphores, Queues, and other VRTX data structures used for intertask communication
- Initialize Telemetry Log Data Structures used for buffering System Error, SCL Message, and 1 and 30 Second TM packets
- Initialize 1 second timer used to drive TM Acquisition Task
- Load SCL DB from ROM, update processing status records from battery backed RAM storage
- Start SCL System Code Tasks in Priority Level Multitasking mode: SCL RTE, SCL TM Reduction, Telemetry Acquisition, Command Input, and Telemetry Output

### 3) VRTX Starts SCL System Code Task Dispatching

*Multitask Scheduling Forever Between*

#### Telemetry Acquisition

- Collect all 1 Second Data Items, Create 1 Second Data Packet, Log to 1 and 30 Second TM Log, and Post to TM Reduction Queue

#### Telemetry Reduction

- Get 1 and 30 Second Packets from TM Reduction Queue, Update SCL Database Real Time Database, Send Database Update Packets to SCL Real Time Engine for records which have changed.

#### SCL Run Time Engine

- Upon Startup of Run Time Engine, execute Statup script
- Get Uplink Packets from Uplink Packet Queue, processing any Scheduled or Immediate script executions, data base assignments/queries, Run Time Engine Directives, project/script/rule/or database loads.
- Get SCL Data Base Update Packets from TM Reduction, and evaluate any Rules whose associated predicate SCL Database Records have changed

#### Command Input

- Get HH Packets from Hitchhiker System, 1 character at a time, strip off Hitchhiker protocol wrapper, and post to Uplink Packet Queue.

#### Telemetry Output

If Active Stream is 1 and 30 Second Packets

Get TM Packet from 1 and 30 Second TM Log, and Transmit to HH Serial Port

Else If Active Stream is Error Log Packets

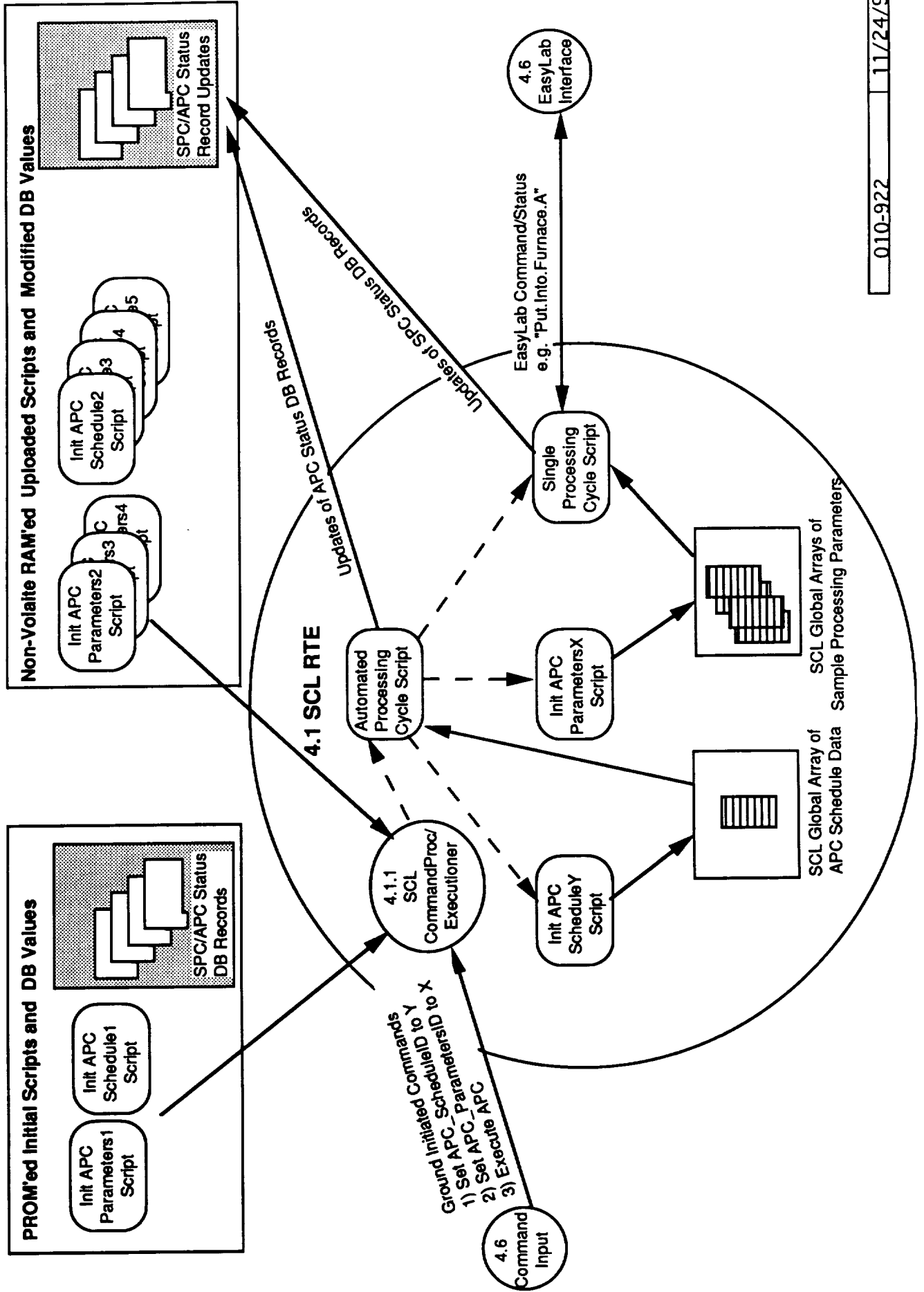
Get TM Packet from Error Log, and Transmit to HH Serial Port

If Active Stream is SCL TM Message Packets

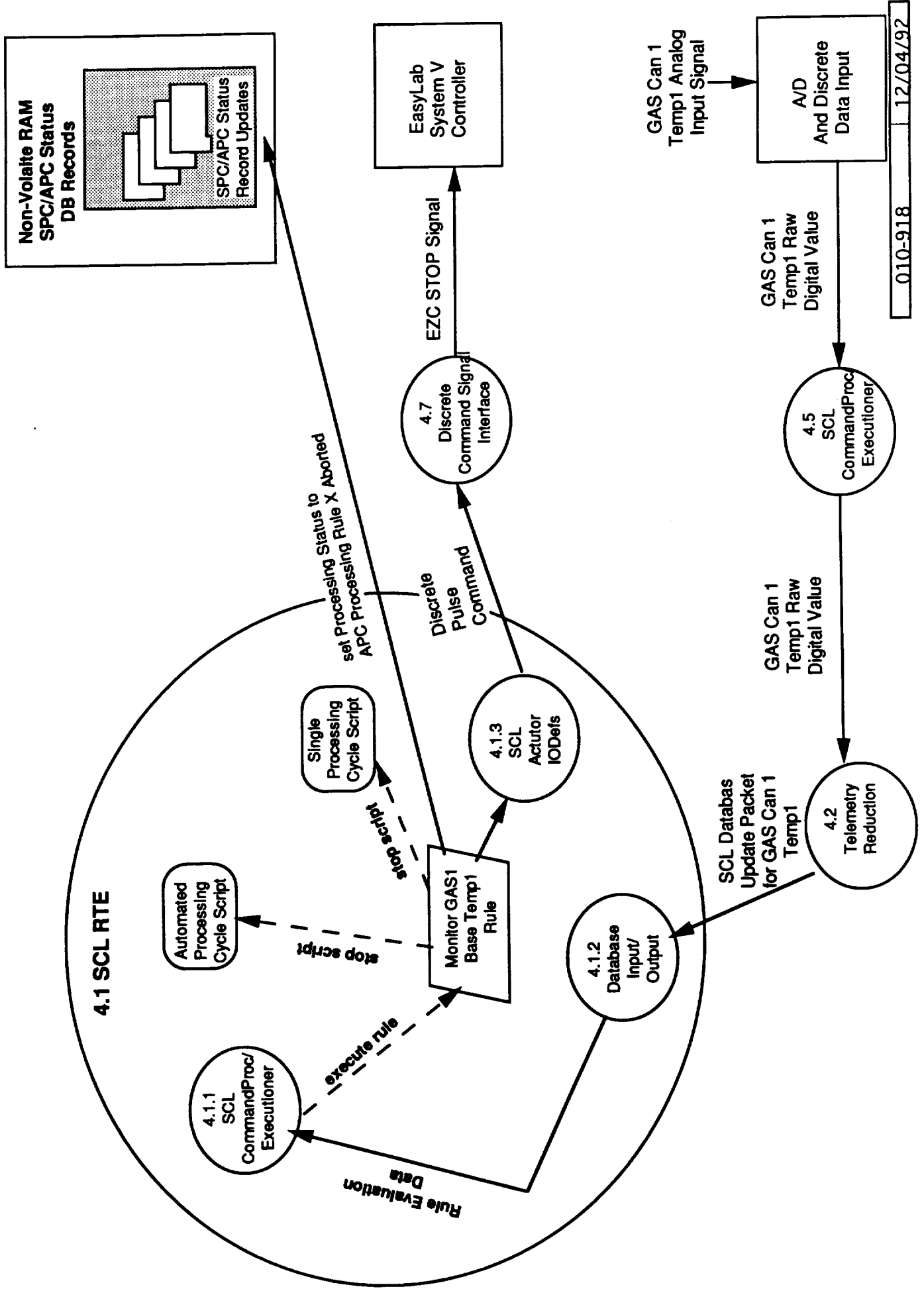
Get TM Packet from SCL TM Message Log, and Transmit to HH Serial Port

*End Loop*

# SCL Script Automated Sample Processing Overview



# Rule Based Automated Process...ig Script Shutdown Overview



## **Monitor\_GAS1\_Base\_Temp1 Rule**

-- Function : Monitors the value of the GAS Can 1 Base  
-- Temperature and if range exceeded stop APC processing

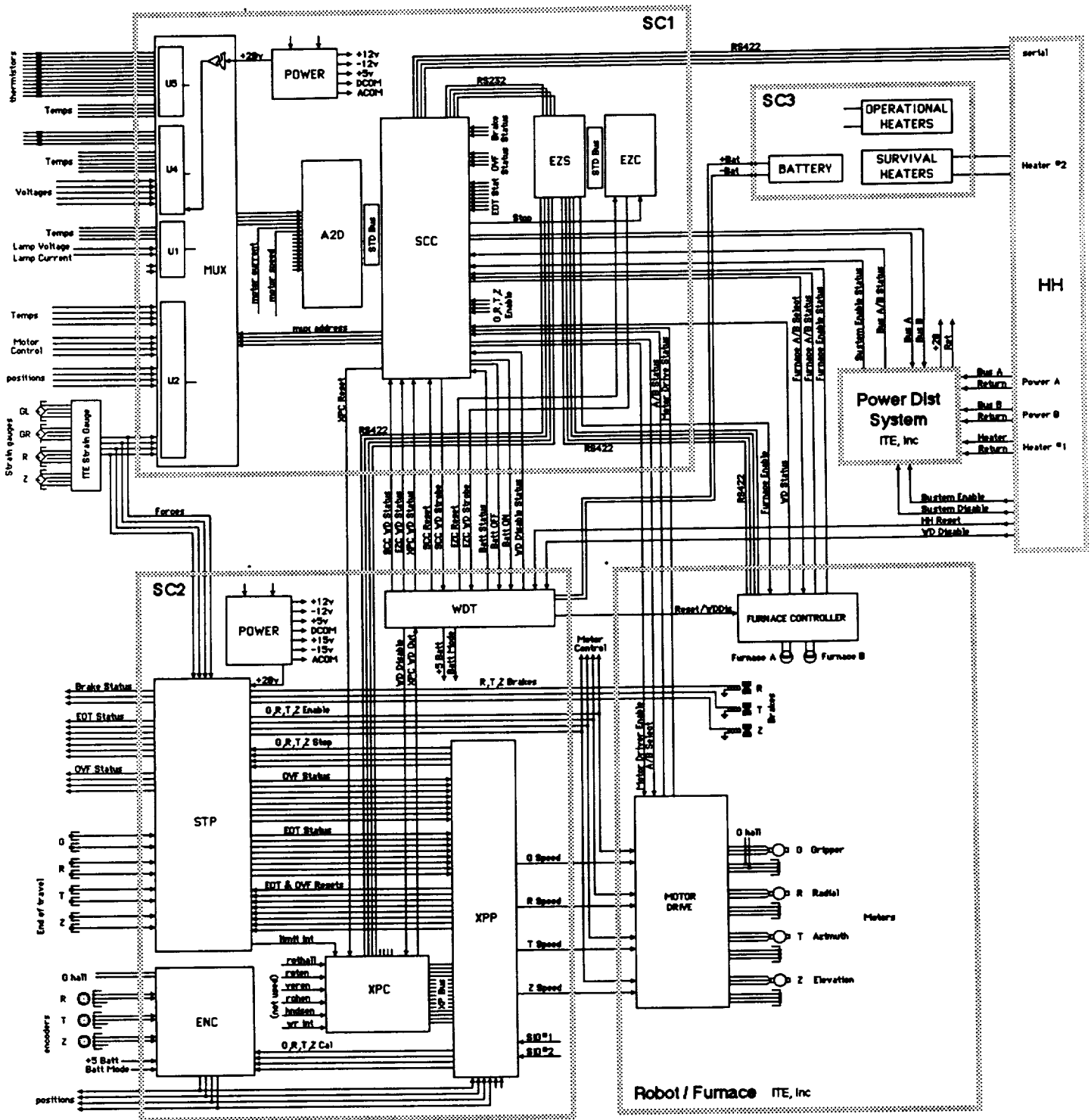
```
rule      Monitor_GAS1_BaseTemp1
subsystem SYS
priority  15          -- This rule preamble determines
activation yes       -- how and when this rule
continuous yes      -- is evaluated by Run Time Engine
```

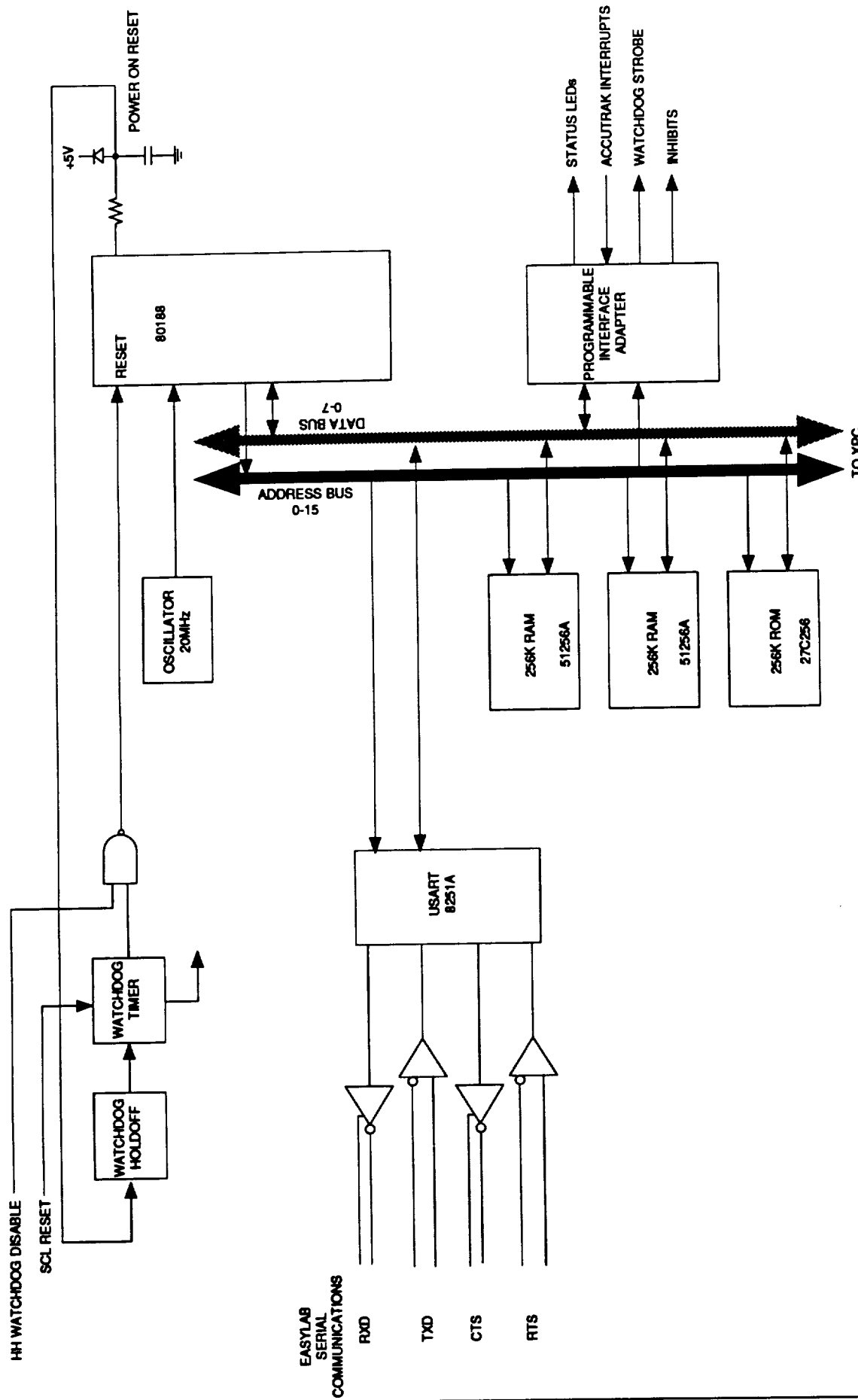
```
If GAS1_BaseTemp1 > MAX_GAS1_BASE_TEMP then
    stop APC
    stop SPC
    if (SPC_ProcessingStatus <> COMPLETE) then
        set SPC_ProcessingStatus to GAS1_BASITEMP1_SHUTDOWN
    endif
endif

end Monitor_GAS1_BaseTemp1
```

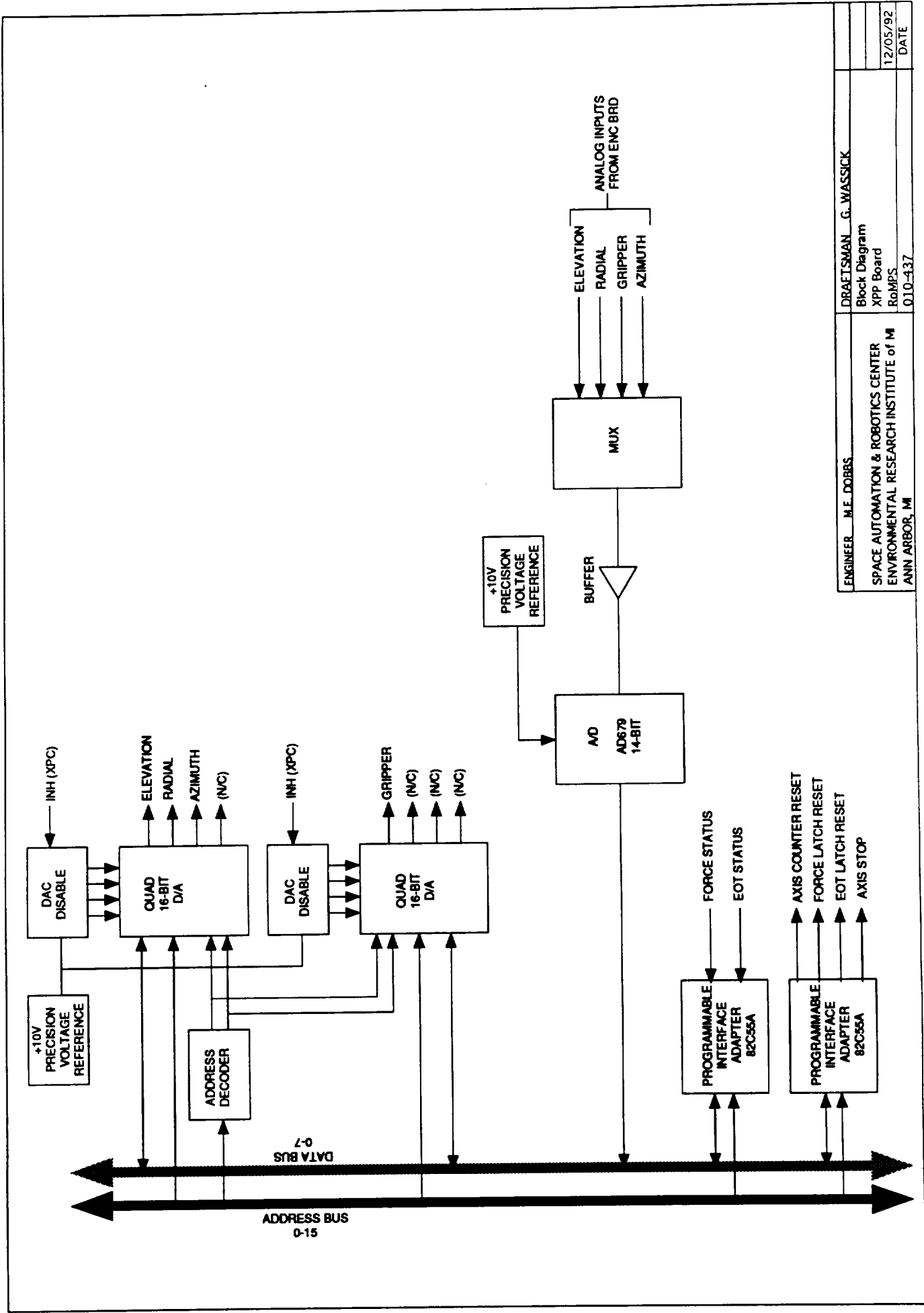
# RoMPS Connection Diagram

12/5/92 GD rev C



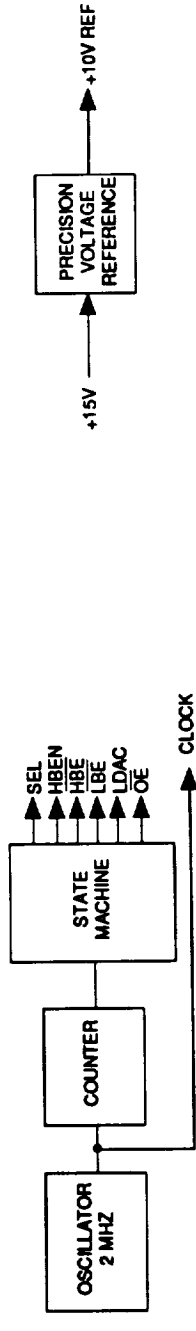
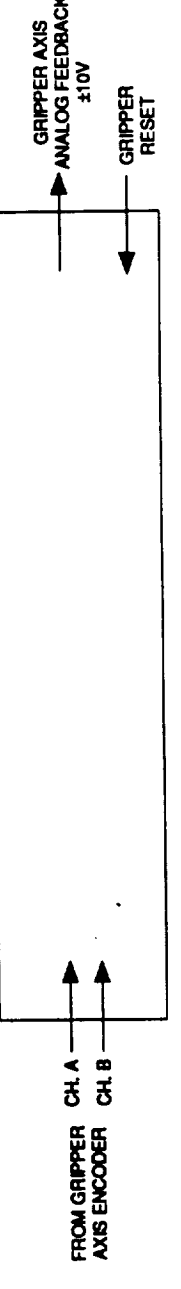
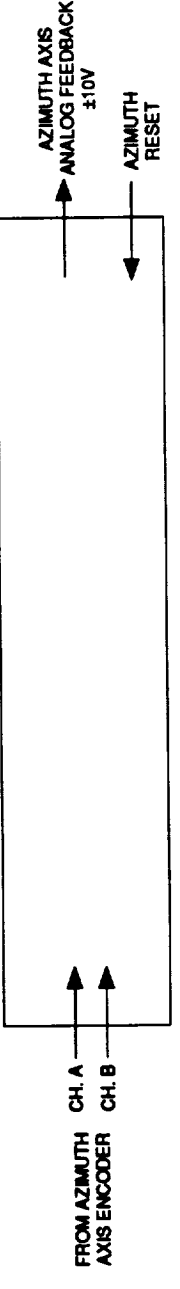
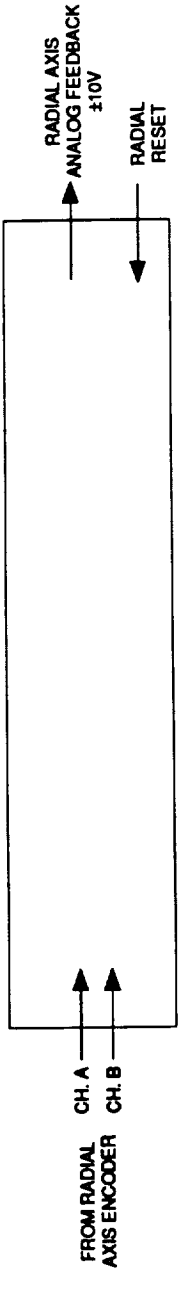
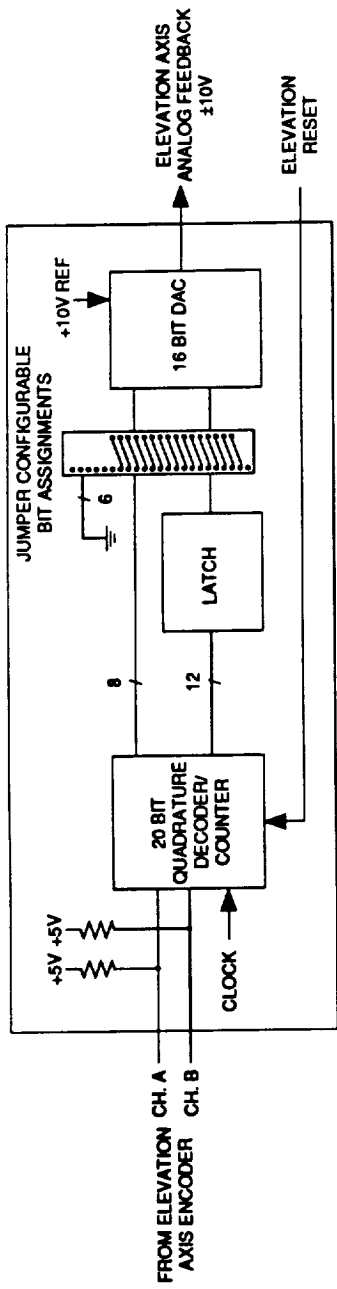


ENGINEER	M.E. DOBBS	DR/TEAM	G. WASSICK
SPACE AUTOMATION & ROBOTICS CENTER		Block Diagram	
ENVIRONMENTAL RESEARCH INSTITUTE of MI		XPC Board	
ANN ARBOR, MI		RoMPS	
		DATE	12/05/92
			010-436



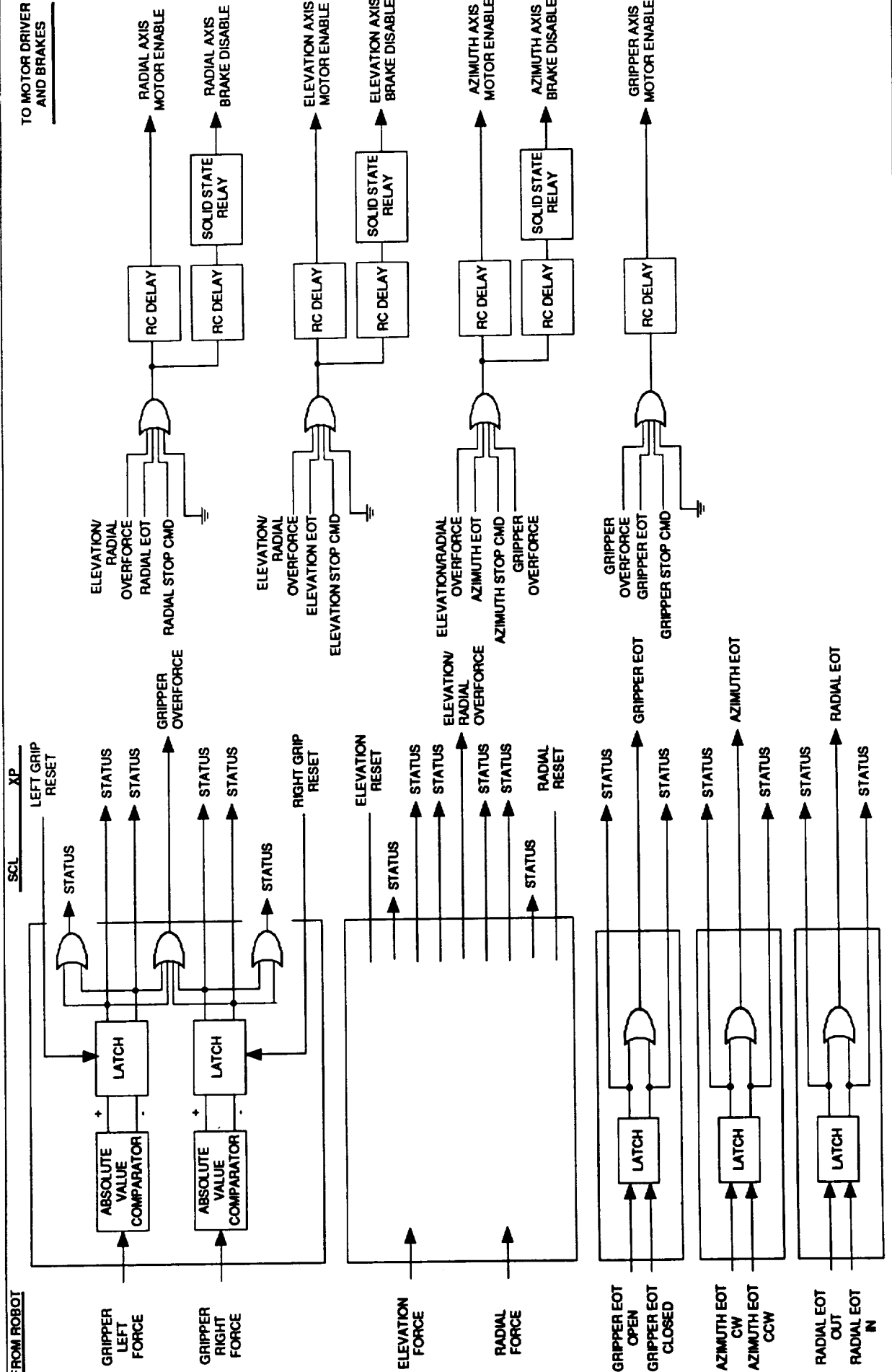
ENGINEER	M.E. DOBBS	DRAGTSMAN	G. WASSICK
SPACE AUTOMATION & ROBOTICS CENTER		Block Diagram	
ENVIRONMENTAL RESEARCH INSTITUTE of MI		XPP Board	
ANN ARBOR, MI		RoMPS	
		010-437	
		DATE	
		12/05/92	





MAX COUNT RATE = 14MHz  
 UPDATE RATE = 6µSec

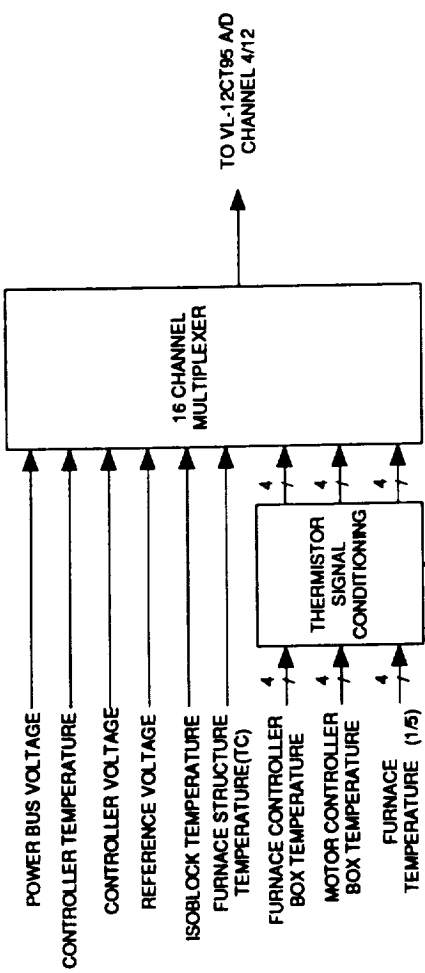
ENGINEER	M.E. DOBBS	DRAFTSMAN	G. WASSICK
SPACE AUTOMATION & ROBOTICS CENTER		ENC Board	
ENVIRONMENTAL RESEARCH INSTITUTE of MI		RaMPS	
ANN ARBOR, MI		010-434	
		DATE	
		12/04/92	



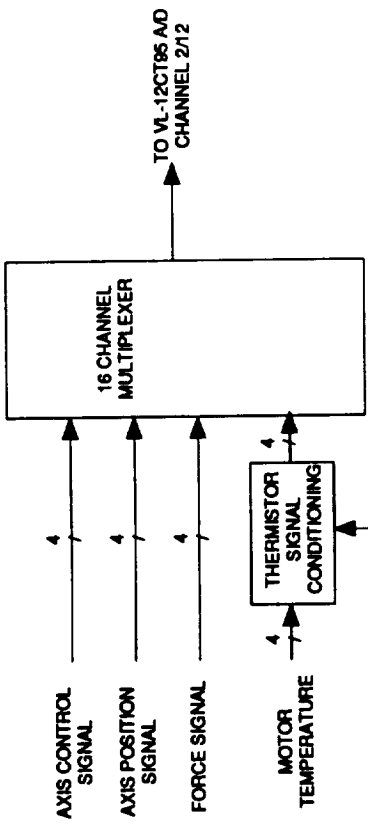
ENGINEER	M.E. DOBBS
DRAFTSMAN	G. WASSICK
Block Diagram	
STP BRD	
RoMPS	
DATE	12/04/92
010-433	

SPACE AUTOMATION & ROBOTICS CENTER  
 ENVIRONMENTAL RESEARCH INSTITUTE of M  
 ANN ARBOR, MI

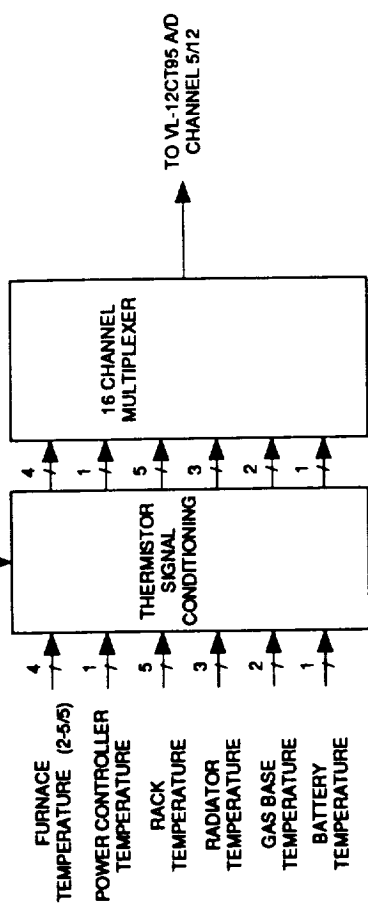
30 SEC TELEMETRY MULTIPLEXER #1



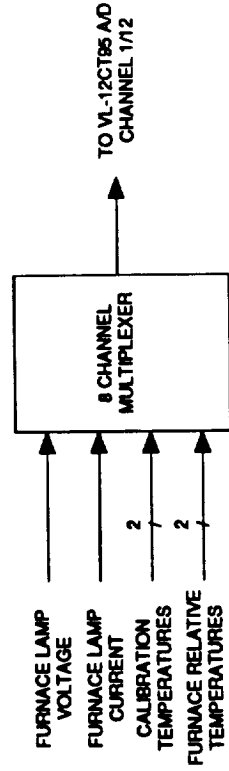
ROBOT 1 SEC TELEMETRY MUX



30 SEC TELEMETRY MULTIPLEXER #2



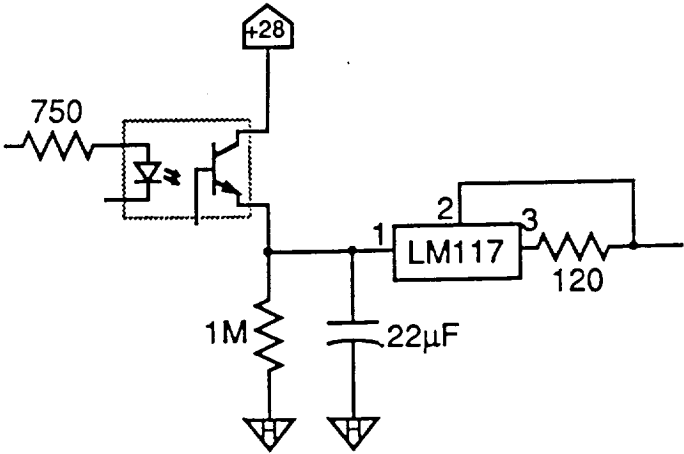
FURNACE 1 SEC TELEMETRY MUX



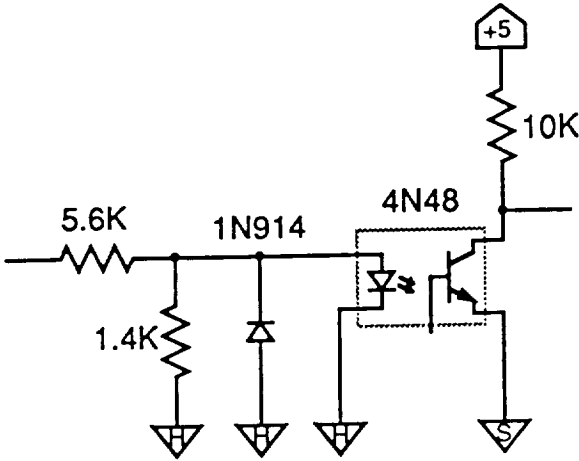
ENGINEER	M.F. DOBBS	DRAFTSMAN	G. WASSICK
SPACE AUTOMATION & ROBOTICS CENTER		Block Diagram	
ENVIRONMENTAL RESEARCH INSTITUTE of MI		MUX Board	
ANN ARBOR, MI		RoMPS	
		010-435	
		12/05/92	
		DATE	

# ROMPS Hitchhiker/System Controller Interfaces

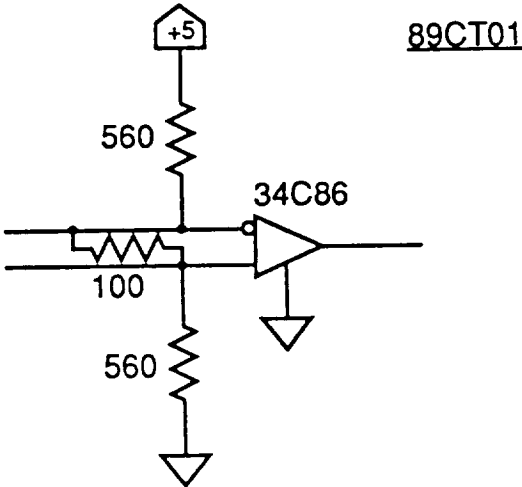
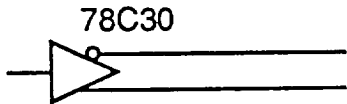
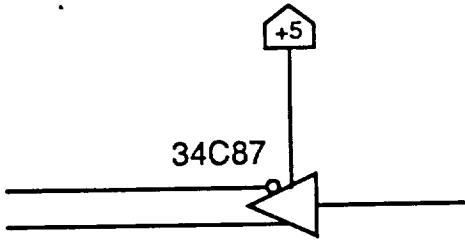
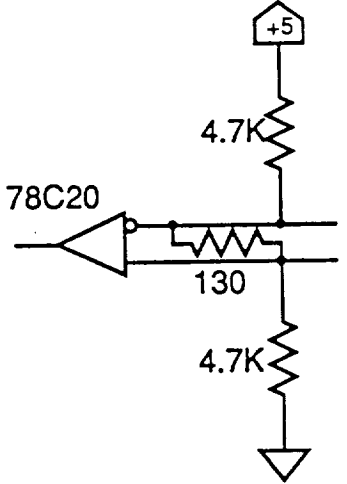
Hitchhiker



System Controller



**BILEVEL CMD**



**RS422 CMD**

### ALKALINE-MANGANESE DIOXIDE BATTERY

CELL SIZE D  
PART MN1300  
MFGR DURACELL  
SPEC n a  
NOM VOLT 1.5V  
RATED CAP 14,250 MAH @ 4.7 ohm to 0.8V @ 21°C  
est @ 11,000 MAH @ 4.7 ohm to 0.8V @ 0°C  
OPER TEMP -20°C TO +54°C  
STOR TEMP -20°C TO +54°C  
SHELF LIFE 4% Loss per Year  
INT. RES 0.1 OHM  
SHORT CKT est @ 15 amps w/o protection  
ENERGY 17.3 watt hours

### EXPERIMENT CONTROL SYSTEM APPLICATION

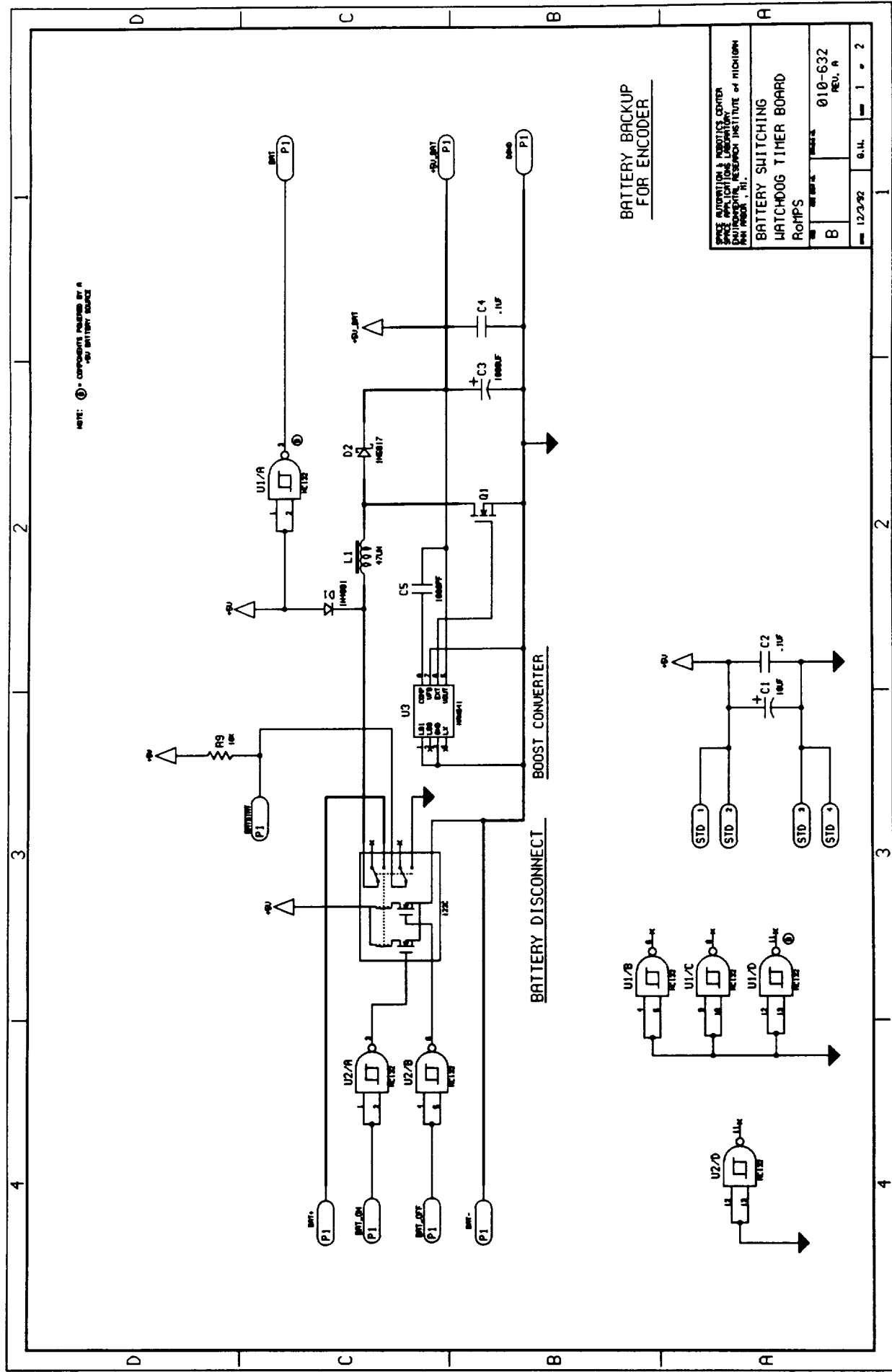
OP MODE Constant Power @ ~1 watt  
Intermittent Duty - Logic Circuits  
CAP est @ >10,000 mAh at final integration and test  
OP TIME >32 Hours with 2, three cell strings  
PROTECTION Two Fault Tolerant  
cell capacity at EOL current requirement  
ground leg fuse  
hot side diodes  
SHORT CKT 14 amp ~ ((3\*1.5)-0.4) / (3\*0.1) BOL  
FUSE 1 amp ~ ((3\*0.8)-0.4) / (3\*0.8) EOL  
2 Amp Fuse is ~3X Load at EOL

### LITHIUM THIONYL CHLORIDE BATTERY

CELL PC  
PART 3B880  
MFGR Electrochem  
SPEC manufactured under MIL-I-45208A  
NOM VOLT 3.6 V  
RATED CAP 1,000 MAH @ 3.4KOhm to 2.0V @ 25°C  
est @ 900 @ 0°C  
OPER TEMP -40°C TO +85°C  
STOR TEMP -40°C TO +85°C  
SHELF LIFE 5.5% Loss per Year  
INT. RES 0.6 < 1.0 Ohms  
SHORT CKT est @ < 6 amps w/o protection  
test results show about 180ma after 1sec  
short circuit temp rise of 42°C after 10 minutes  
ENERGY 3.6 watt hours

### EXPERIMENT CONTROL SYSTEM APPLICATION

OP MODE Constant Current @ 110 uAmps  
Intermittent Duty - Static Memory Backup  
CAP est @ 800 mAh at final integration and test  
OP TIME > 8,45 hours with single cell  
cell capacity at EOL  
PROTECTION Two Fault Tolerant  
hot side current limiting resistor  
hot side diodes  
SHORT CKT 30mA ~ (3.6-0.3) / 100 @ BOL  
17mA ~ (2.0-0.3) / 100 @ EOL  
FUSE 100 ohm resistor



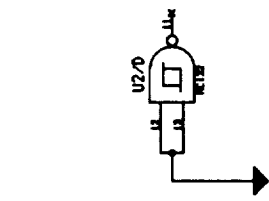
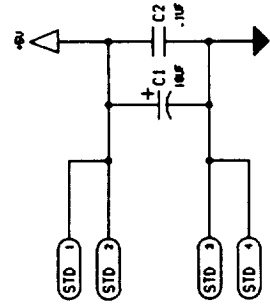
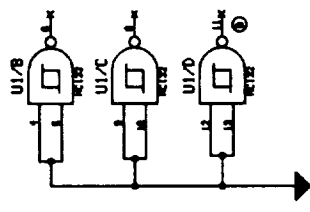
NOTE: ① - COMPONENTS INDICATED BY A  
 -00 BATTERY SOURCE

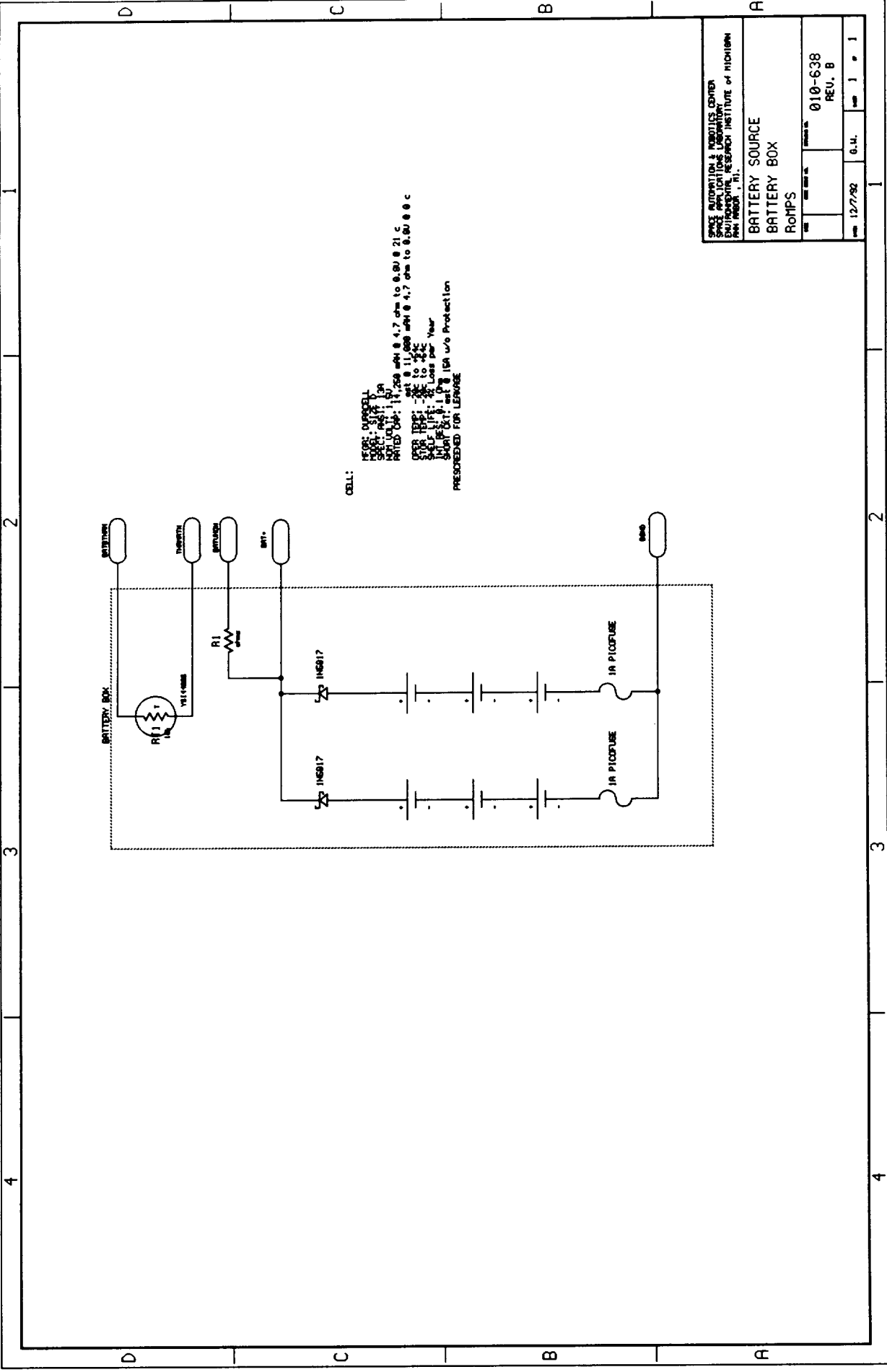
BATTERY BACKUP  
 FOR ENCODER

SPACE AUTOMATION & ROBOTICS CENTER SPACE AND CONTROL LABORATORY 300 WOODS DRIVE RESEARCH INSTITUTE OF MICHIGAN	
BATTERY SWITCHING WATCHDOG TIMER BOARD RoMPS	
REV. B	010-632 REV. A
DATE: 12/2/92	SCALE: 1 • 2

BATTERY DISCONNECT

BOOST CONVERTER



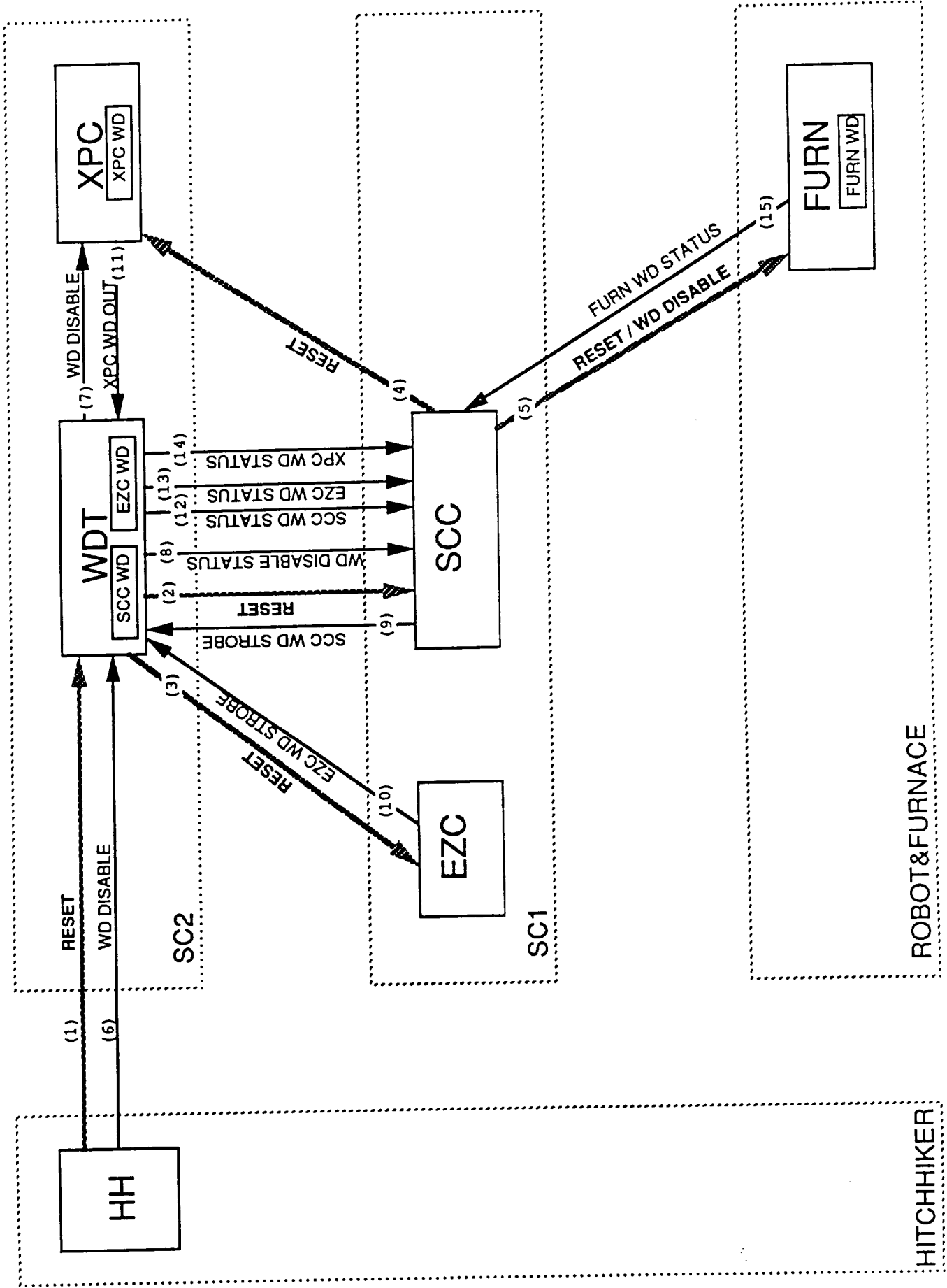


CELL:  
 TYPE: CURELL  
 MODEL: S-100  
 SPEC: 1.25 V  
 RATED CAP: 1.7, 250 mAh @ 4.7 ohm to 0.5U @ 21 c  
 OVER TEST: 200 to 250  
 S-CURVE LIFE: 20 Loss per Year  
 DATE: 12/7/92  
 PREPARED FOR LEAVAGE  
 PREPARED BY: J. L. P. (ER w/o Protection)

SPACE AUTOMATION & ROBOTICS CENTER SPACE APPLICATIONS LABORATORY EQUINOX DRIVE, RESEARCH INSTITUTE OF MICHIGAN ANN ARBOR, MI.	
BATTERY SOURCE BATTERY BOX RoMPS	
DATE: 12/7/92	REV: B
010-638	1 of 1

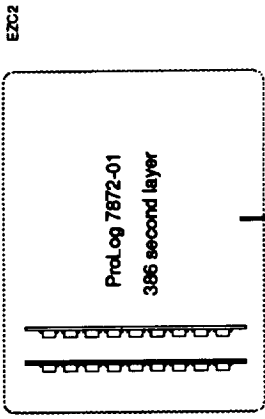
# ROMPS Reset and Watchdog Timer Signals

12/5/92 GD ... B

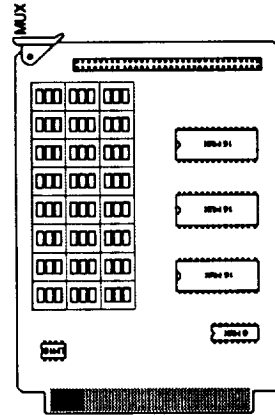
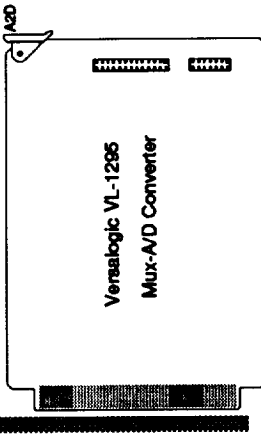
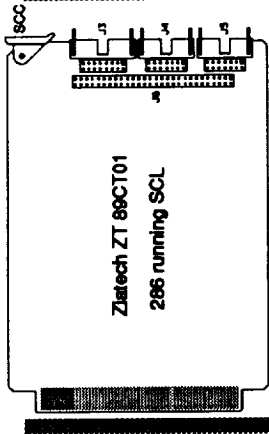
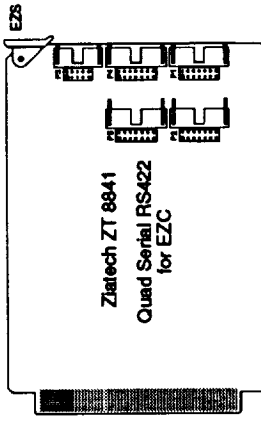
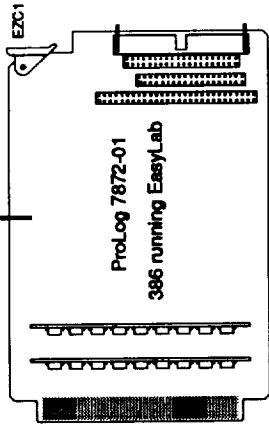




SC1 Boards

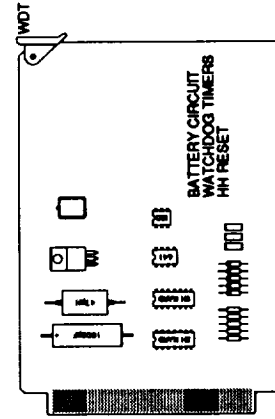
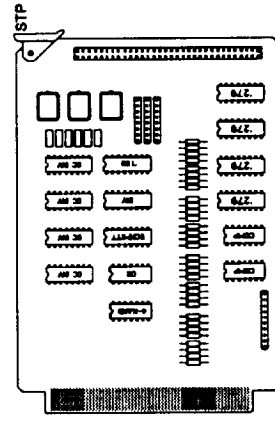
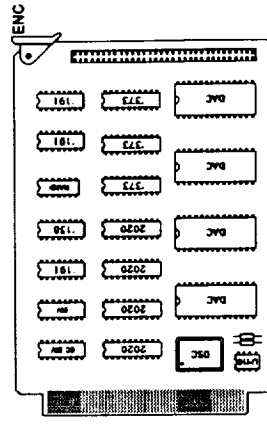
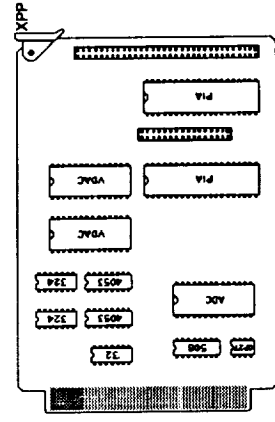
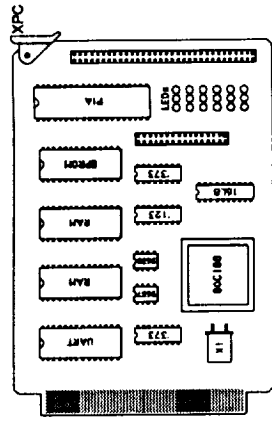


TAKES 2 SLOTS



818-877 11/20/88

SC2 Boards



818-877 11/20/88

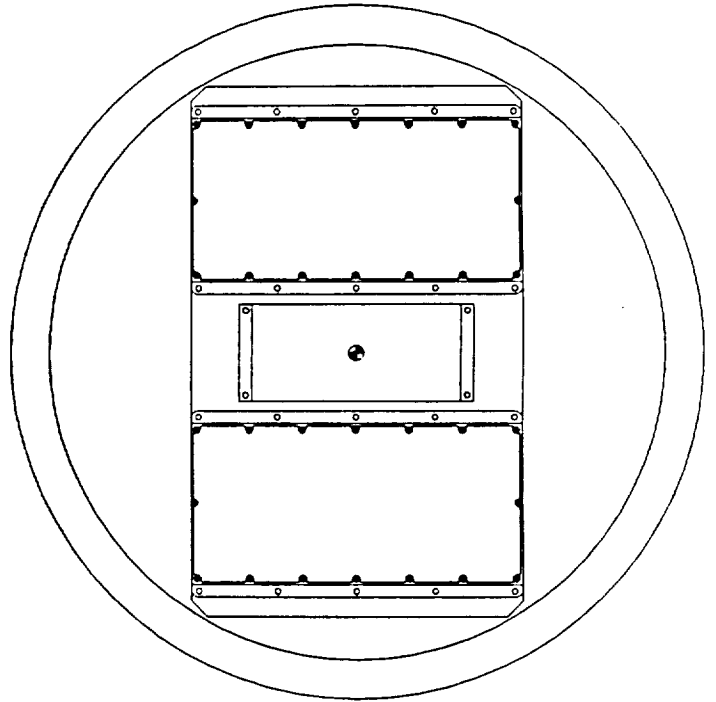
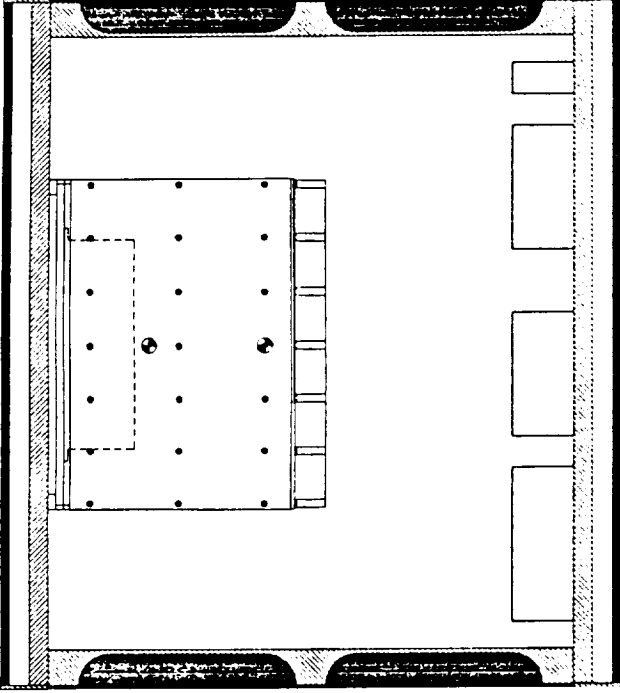
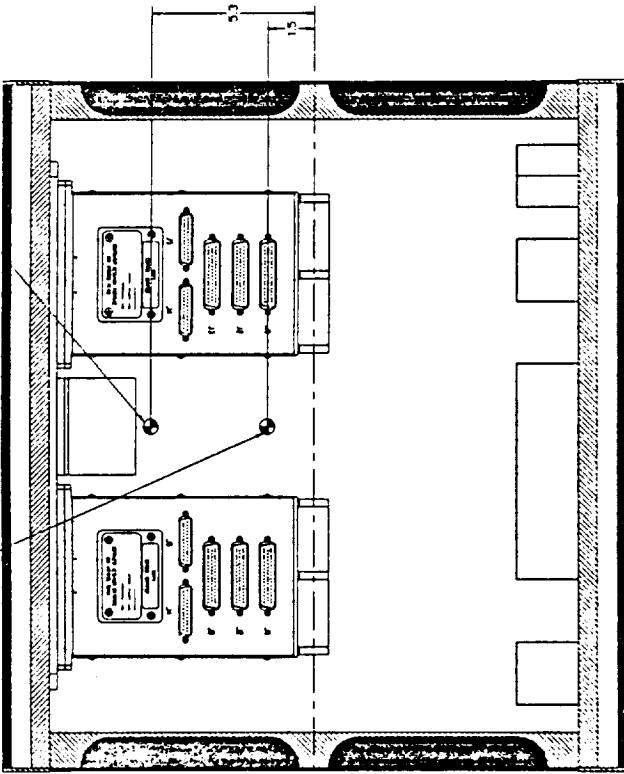
818-877 11/20/88



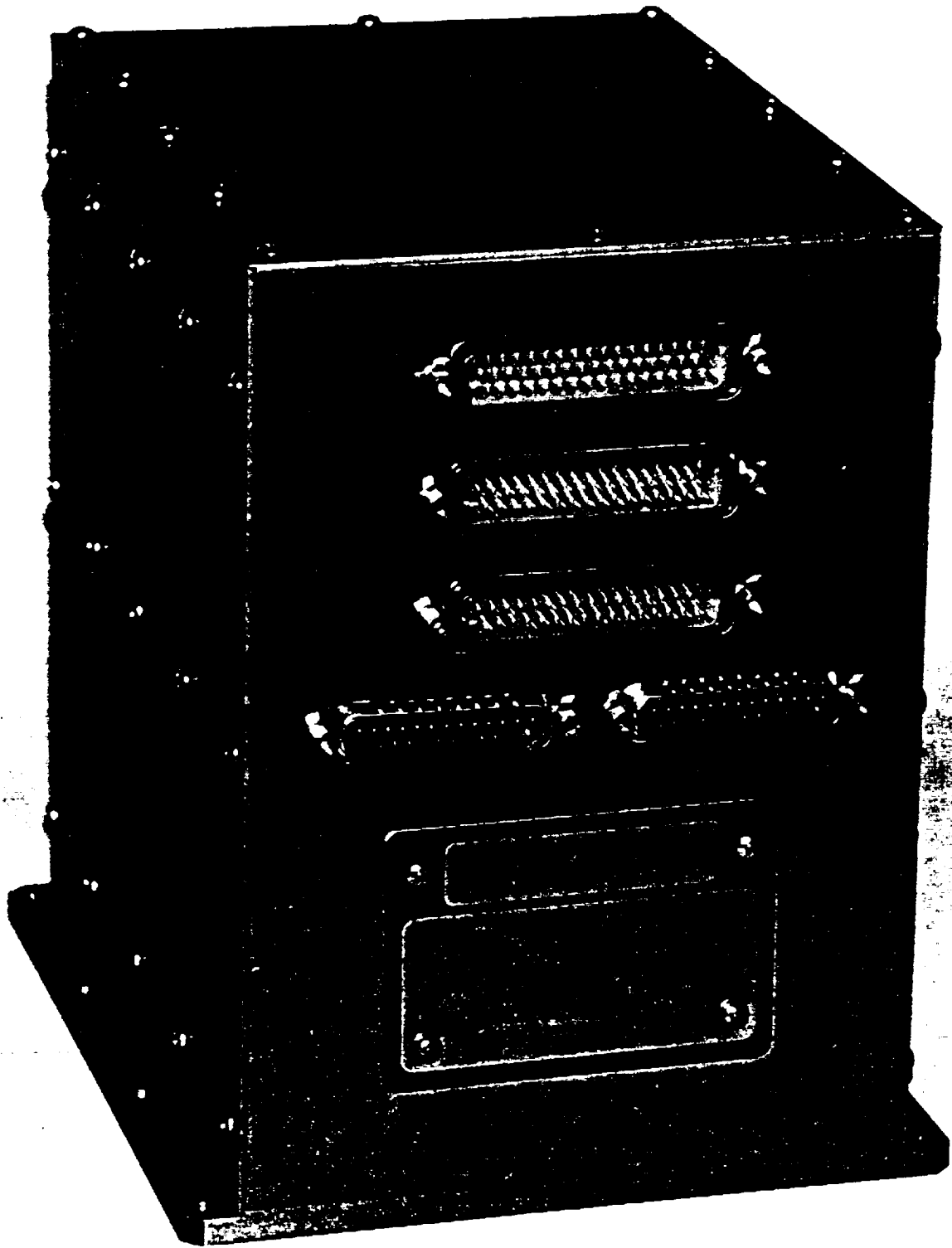
**CONTROL SYSTEM DESIGN  
WEIGHT & POWER SUMMARY**

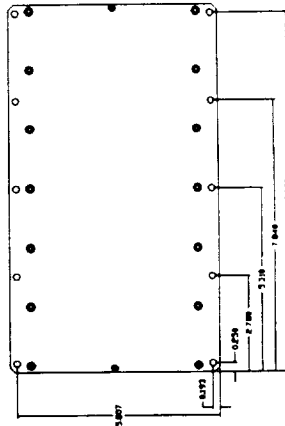
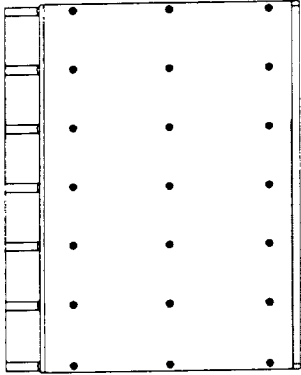
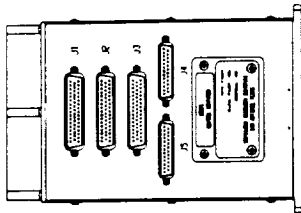
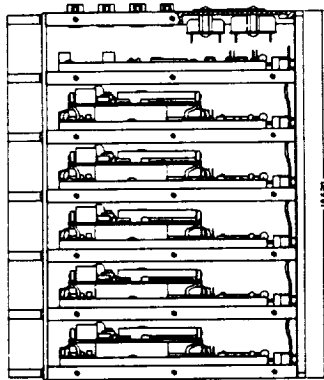
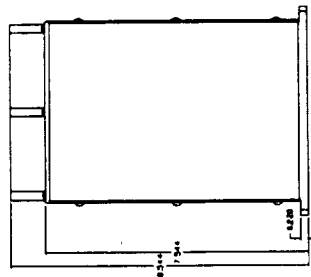
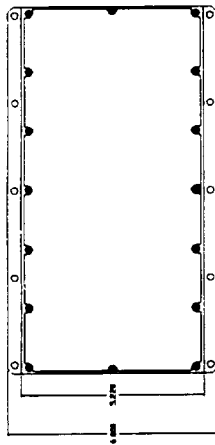
<b>ITEM</b>	<b>SIZE</b>	<b>MASS</b>	<b>POWER</b>
SUBASSEMBLY A	10.4 X 5.8 X 8.6	10 LBS	9.4 AVG
SCC PROCESSOR			
A2D ANALOG TO DIGITAL CONVERTER			
MUX SINGLE CONDITIONING			
EZC PROCESSOR			
SUBASSEMBLY B	10.4 X 5.8 X 8.6	10 LBS	12.0 AVG
XPC PROCESSOR			
ENC ENCODER INTERFACE			
XPP OUTPUT INTERFACE			
STP STOP CONTROL			
WATCHDOG TIMERS			
SUBASSEMBLY C	7.1 X 3.2 X 2.3	5 LBS	NA
BATTERY			
HARNES	NA	2	NA
HARDWARE	NA	5.75	NA
TOTAL	1/2 GAS	36.1 LBS	23.6 WATTS

EXPERIMENT & CAN CENTER OF GRAVITY

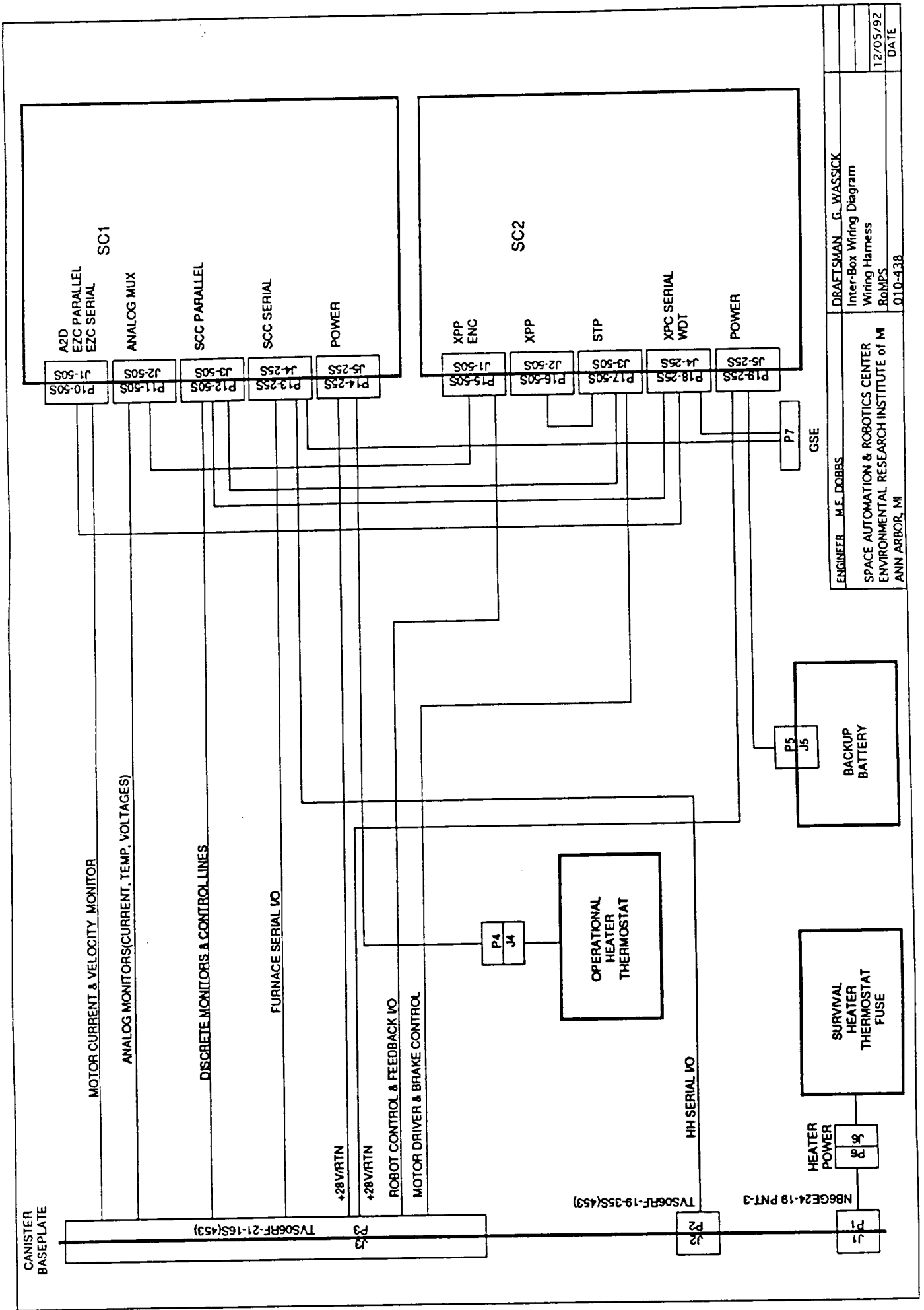


ENGINEER	R. E. OUADA	DRAFTERPERSON	N. J. THOMAS	UNITS: INCHES
SPACE AUTOMATION & ROBOTICS CENTER		EXPERIMENT LAYOUT		TOLERANCES
ENVIRONMENTAL RESEARCH INSTITUTE of MI		& CENTER OF GRAVITY		UNLESS SPECIFIED:
ANN ARBOR, MI		ROMPS		$\pm 0.005"$
		010-257		$\pm 30$ MINUTES
				DATE
				12/04/92





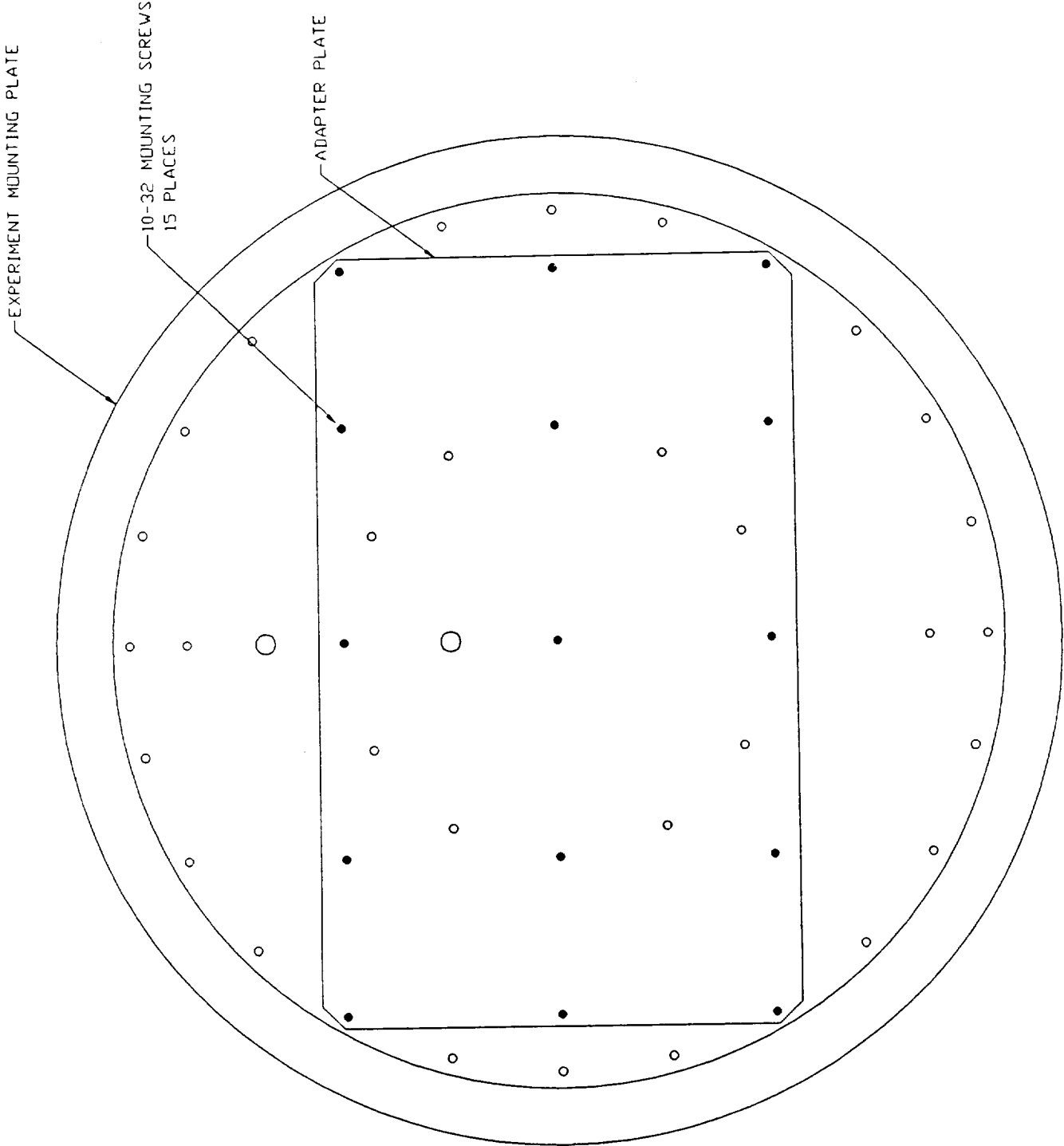
ENGINEER	R. E. QUADA	DRAFTERPERSON	N. J. THOMAS	UNITS:	IRCHES
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI			PAYLOAD CONTROLLER ROMPS 010-		TOLERANCES UNLESS SPECIFIED: ± 0.005" ± 30 MINUTES
					10/30/92 DATE



ENGINEER M.E. DOBBS  
 SPACE AUTOMATION & ROBOTICS CENTER  
 ENVIRONMENTAL RESEARCH INSTITUTE of MI  
 ANN ARBOR, MI

DRAFTSMAN G. WASSICK  
 Inter-Box Wiring Diagram  
 Wiring Harness  
 RaMPS  
 010-438

12/05/92  
 DATE



ENGINEER	RE GUADA	GRAFFERSCH N J THOMAS	UNITS	INCHES
SPACE AUTOMATION & ROBOTICS CENTER		ADAPTER PLATE/INSTRUMENT PLATE	TOLERANCES	UNLESS SPECIFIED
ENVIRONMENTAL RESEARCH INSTITUTE of MI		INTERFACE	$\pm 0.005"$	
ANN ARBOR, MI		RCMP5	$\pm 30$ MINUTES	
		010-258		
				DATE
				12/04/92

## Control System Thermal Design

- 2.5 cu. ft. container without insulated endcap
- 1/4" G-10 spacers under payload controllers and battery box
- Payload controller and battery box external surfaces irradiate
- Thermostatically controlled survival heaters on payload controllers and battery box
- Thermostatically controlled operational heaters on payload controllers and battery box

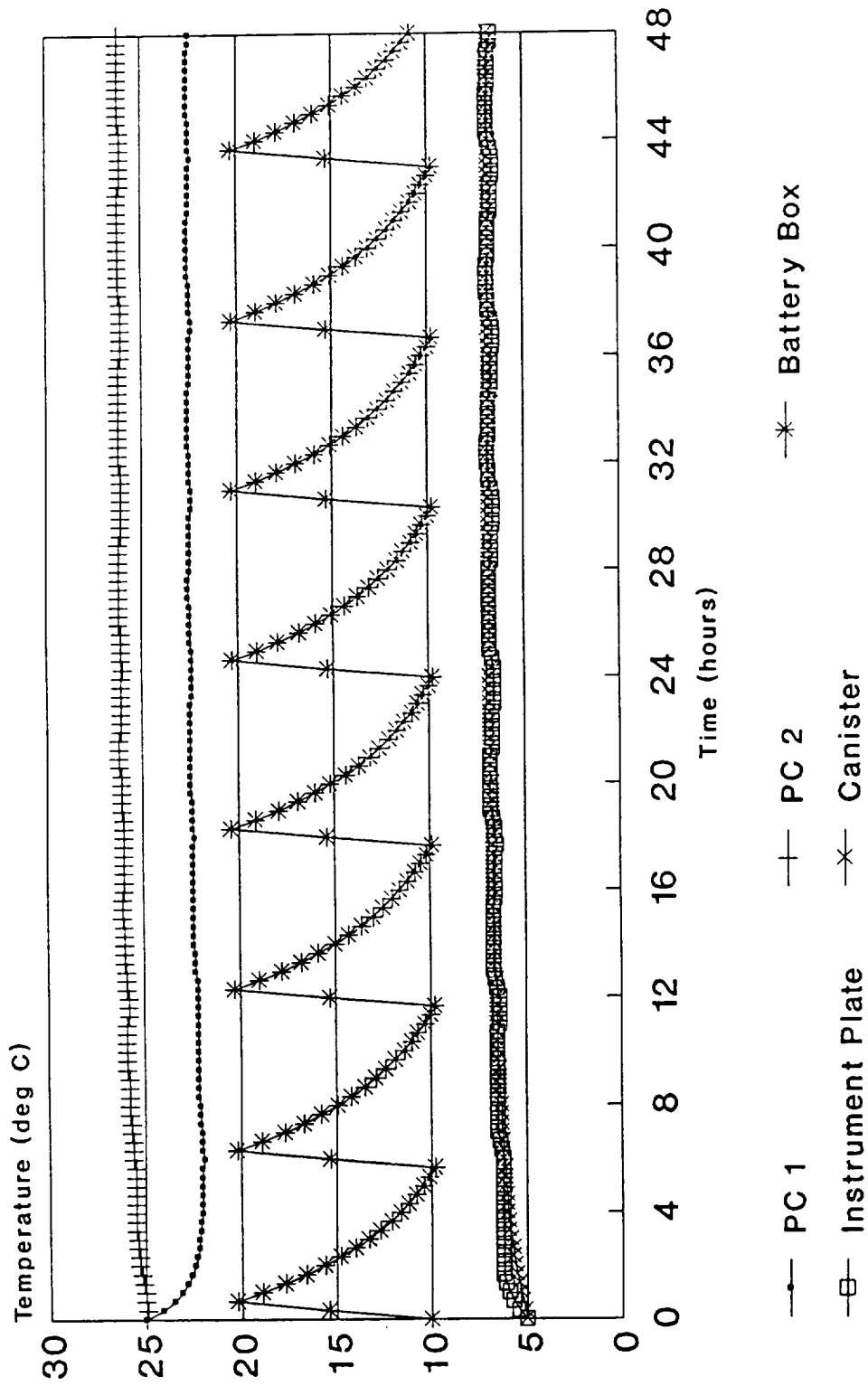


# Control System Temperature Predictions

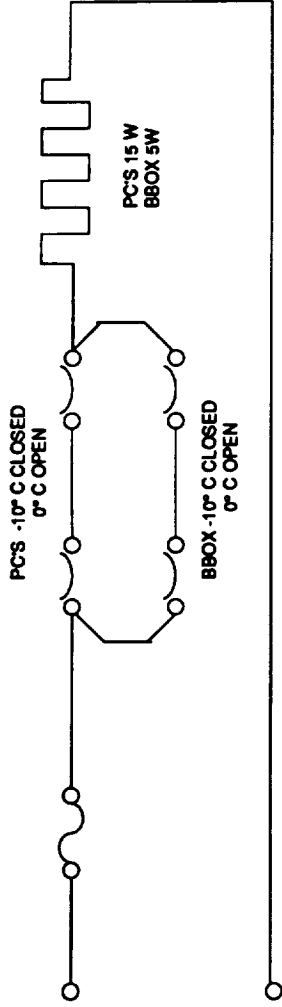
## Operation

	Temperature		Avg. Heater Power			
Case	PC 1	PC 2	B.B.	PC 1	PC 2	B.B.
Hot	-----		N.A.	-----		
Moderate	31 °C	34 °C	16 °C	0.0 W	0.0 W	0.0 W
Earth view	23	26	10/20	0.0	0.0	1.0
Mod. cold	0/10	3	10/20	3.0	0.0	5.0
Cold	0/10	0/10	10/20	9.0	6.0	6.0

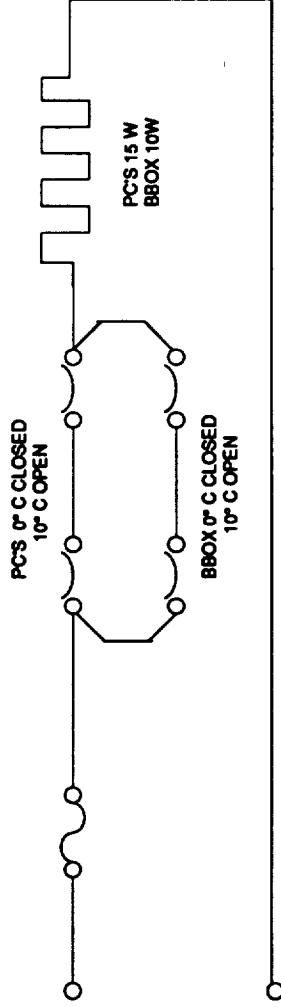
# Control System Transient Response Earth Viewing; Instrument On



**SURVIVAL HEATERS**



**OPERATIONAL HEATERS**



ENGINEER	M.E. DOBBS	DRAFTSMAN	G. WASSICK
SPACE AUTOMATION & ROBOTICS CENTER		Block Diagram	
ENVIRONMENTAL RESEARCH INSTITUTE of MI		Heaters	
ANN ARBOR, MI		RoMPS	
		010-439	
		12/07/92	
		DATE	

## Control System Mechanical Design

- Payload controller housings made of 6061-T6 aluminum
- Battery box made of 6061-T6 aluminum
- Adapter plate made of 6061-T6 aluminum
- Payload controller and battery box spacers made of G-10
- 160 ksi stainless steel fasteners used for mounting payload controllers and battery box

## Control System Stress Analysis

<u>Assembly</u>	<u>Item</u>	<u>Condition</u>	<u>Allowable Stress</u>	<u>F.S.</u>	<u>MOS</u>
Payload Controller	Mounting flanges	Bearing	50000 psi	2.0	>10
			67000	2.6	>10
			27000	2.6	>10
	10-32 screws	Combined	35000	2.0	>10
			42000	2.6	>10
			160000	2.6	0.5
Battery Box	Mounting flanges	Bearing	50000	2.0	>10
			67000	2.6	>10
			27000	2.6	>10
	10-32 screws	Combined	35000	2.0	>10
			42000	2.6	9.4
			160000	2.6	0.5
Adapter Plate	Mounting holes	Bearing	50000	2.0	>10
			67000	2.6	>10
			27000	2.6	>10
	10-32 screws	Combined	160000	2.6	0.5

# Fault Conditions and Responses

Fault	STP	XPC	EZC	SCC
<b>Robot SERVO USART Communication Errors</b> (USART cable disconnect, parity, overrun, or framing error) <b>Description:</b> In the process of receiving a command message from the Robot Module, a communication error is detected by USART.	N/A	<b>Detection</b> → : Servo Controller detects communication error while polling USART line status register.  <b>Action:</b> Servo Controller stops the robot and resets the USART.	<b>Detection</b> → : Robot Module times out waiting for a command response from the Servo Controller.  <b>Action:</b> Robot Module retries communication until retries are exhausted, terminates current command and sets error status. EasyLab interpreter terminates current EasyLab program. RCI returns NOTOK.	<b>Detection</b> → : SCC receives NOTOK error status from RCI.  <b>Action:</b> APC script diagnoses error and quits.
<b>Robot SERVO Communication Protocol Error</b> (Interbyte timeout, bad byte count, bad command code, bad checksum) <b>Description:</b> In the process of receiving a command message from the Robot Module, a communication protocol error is detected by the Servo Controller.	N/A	<b>Detection</b> → : Servo Controller detects communication protocol error.  <b>Action:</b> Servo Controller stops the robot and reports error status.	<b>Detection</b> → : Robot Module receives error status from Servo Controller/  <b>Action:</b> Robot Module retries communication until retries are exhausted, terminates current command and sets error status. EasyLab interpreter terminates current EasyLab program. RCI returns NOTOK.	<b>Detection</b> → : SCC receives NOTOK error status from RCI.  <b>Action:</b> APC script diagnoses error and quits.
<b>Robot Controller Current Over Limit</b> <b>Description:</b> One of the monitored current sensors exceeds its operating limits for some period.	N/A	<b>Detection</b> ← : Servo Controller receives STOP command from Robot Module. <b>Action:</b> Servo Controller sets target position to current position and aborts current move.	<b>Detection</b> ← : Robot Module receives ABORT signal from SCC. <b>Action:</b> Robot Module sends STOP command to Servo Controller.	<b>Detection</b> ← : SCC acquires current data every 1 Second and updates SCL DB. <b>Action:</b> Rule sets Robot Module ABORT signal and stops APC script.

# Fault Conditions and Responses

Fault	STP	XPC	EZC	SCC
<b>Robot SERVO End of Travel (Detected by STP)</b>  Description: During a robot move one of the 8 EOT sensors is set.	Detection → : Hardware Logic monitors EOT input signals and latches EOT event.  Action: Hardware Logic sets corresponding EOT status signal, disables all axes and applies brakes.	Detection → : Servo Controller receives EOT status signal from Hardware Logic during a 5 millisecond poll.  Action: Servo Controller sets target position to current position, aborts current move, and reports error status.	Detection → : Robot Module receives error status from Servo Controller during a GetLimitStatus command.  Action: Robot Module terminates current command and sets error status. EasyLab interpreter terminates current EasyLab program. RCI returns NOTOK.	Detection → : SCC receives NOTOK error status from RCI.  Action: APC script diagnoses error and quits.
<b>Robot SERVO End of Travel (Detected by SCC)</b>  Description: During a robot move one of the 8 EOT sensors is set.	Detection: N/A  Action: N/A	Detection ← : Servo Controller receives STOP command from Robot Module.  Action: Servo Controller sets target position to current position and aborts current move.	Detection ← : Robot Module receives ABORT signal from SCC.  Action: Robot Module sends STOP command to Servo Controller.	Detection ← : SCC acquires EOT status every 1 second and updates SCL database.  Action: Rule sets Robot Module ABORT signal and stops APC script.
<b>Robot SERVO Overforce (Detected by STP)</b>  Description: During a robot move one of the ITE strain gauge readings exceeds its nominal operating range.	Detection → : Hardware Threshold Logic monitors strain gauge input signals, and latches OVF event.  Action: Hardware Threshold Logic sets corresponding OVF status signal, disables all axes and applies brakes.	Detection → : Servo controller receives OVF status signal from Hardware Threshold Logic during a 5 millisecond poll.  Action: Servo Controller sets target position to current position, aborts current move, and reports error status.	Detection → : Robot Module receives error status from Servo Controller during a GetLimitStatus command.  Action: Robot Module terminates current command and sets error status. EasyLab interpreter terminates current EasyLab program. RCI returns NOTOK.	Detection → : SCC receives NOTOK error status from RCI.  Action: APC script diagnoses error and quits.
<b>Robot SERVO Overforce (Detected by SCC)</b>  Description: During a robot move one of the ITE strain gauge readings exceeds its nominal operating range.	Detection: N/A  Action: N/A	Detection ← : Servo Controller receives STOP command from Robot Module.  Action: Servo Controller sets target position to current position and reports error status.	Detection ← : Robot Module receives ABORT signal from SCC.  Action: Robot Module sends STOP command to Servo Controller.	Detection ← : SCC acquires ITE Strain Gauge Forces every 1 second and updates SCL database.  Action: Rule sets Robot Module ABORT signal and stops APC script.

# Fault Conditions and Responses

Fault	STP	XPC	EZC	SCC
<p><b>Robot SERVO Move Velocity Anomaly (Stall)</b></p> <p><b>Description:</b> During a move command, the arm or gripper does not move more than x counts for a duration of y seconds.</p>	<p><b>Detection:</b> N/A</p> <p><b>Action:</b> N/A</p>	<p><b>Detection</b> → : Servo Controller detects a velocity anomaly during execution of a move command.</p> <p><b>Action:</b> Servo Controller sets target position to current position, aborts current move and reports error status.</p>	<p><b>Detection</b> → : Robot Module receives error status from Servo Controller during a GetStatus command.</p> <p><b>Action:</b> Robot Module terminates current command and sets error status. EasyLab interpreter terminates current EasyLab program. RCI returns NOTOK.</p>	<p><b>Detection</b> → : SCC receives NOTOK error status from RCI.</p> <p><b>Action:</b> APC script diagnoses error and quits.</p>
<p><b>Robot SERVO Move Timeout</b></p>	<p><b>Detection:</b> N/A</p> <p><b>Action:</b> N/A</p>	<p><b>Detection</b> → : Servo Controller detects a failure to reach position before timing out during a move command.</p> <p><b>Action:</b> Servo Controller sets target position to current position, aborts current move and reports error status.</p>	<p><b>Detection</b> → : Robot Module receives error status from Servo Controller during a GetStatus command.</p> <p><b>Action:</b> Robot Module terminates current command and sets error status. EasyLab interpreter terminates current EasyLab program. RCI returns NOTOK.</p>	<p><b>Detection</b> → : SCC receives NOTOK error status from RCI.</p> <p><b>Action:</b> APC script diagnoses error and quits.</p>
<p><b>Description:</b> During a move command, the target position is not reached within the maximum allowed time.</p>	<p><b>Detection:</b> N/A</p> <p><b>Action:</b> N/A</p>	<p><b>Detection</b> → : Servo Controller detects a failure to reach position before timing out during a move command.</p> <p><b>Action:</b> Servo Controller sets target position to current position, aborts current move and reports error status.</p>	<p><b>Detection</b> → : Robot Module receives error status from Servo Controller during a GetStatus command.</p> <p><b>Action:</b> Robot Module terminates current command and sets error status. EasyLab interpreter terminates current EasyLab program. RCI returns NOTOK.</p>	<p><b>Detection</b> → : SCC receives NOTOK error status from RCI.</p> <p><b>Action:</b> APC script diagnoses error and quits.</p>



# Fault Conditions and Responses

Fault	Furnace CPU	XPC	EZC	SCC
<b>Furnace Controller USART Communication Errors</b> (parity, overrun, or framing error) <b>Description:</b> In the process of receiving a command message from the Furnace Module, a communication error is detected.	<b>Detection</b> → : Furnace Controller detects communication error.  <b>Action:</b> None.	<b>Detection:</b> N/A	<b>Detection</b> → : Furnace Module times out waiting for a command response from the Furnace Controller.  <b>Action:</b> Furnace Module retries communication until retries are exhausted, terminates current command and sets error status. EasyLab interpreter terminates current EasyLab program. RCI returns NOTOK.	<b>Detection</b> → : SCC receives NOTOK error status from RCI.
<b>Furnace Controller Communication Protocol Error</b> (Interbyte timeout, bad byte count, bad command code, bad checksum)	<b>Detection</b> → : Furnace Controller detects communication protocol error.	<b>Detection:</b> N/A	<b>Detection</b> → : Furnace Module receives error status from Furnace Controller.	<b>Detection</b> → : SCC receives NOTOK error status from RCI.
<b>Description:</b> In the process of receiving a command message from the Furnace Module, a communication protocol error is detected by the Furnace Controller.	<b>Action:</b> Furnace Controller reports error status.	<b>Action:</b> N/A	<b>Action:</b> Furnace Module retries communication until retries are exhausted, terminates current command and sets error status. EasyLab interpreter terminates current EasyLab program. RCI returns NOTOK.	<b>Action:</b> APC script diagnoses error and quits.
<b>Furnace Controller Current Over Limit</b>	<b>Detection</b> ← : Furnace Controller receives SET POWER = 0 command from Furnace Module. <b>Action:</b> Furnace Controller sets power level to 0.	<b>Detection:</b> N/A	<b>Detection</b> ← : Furnace Module receives ABORT signal from SCC.	<b>Detection</b> ← : SCC acquires current data every 1 Second and updates SCL DB.
<b>Description:</b> One of the monitored current sensors exceeds its operating limits for some period.	<b>Action:</b> Furnace Controller sets power level to 0.	<b>Action:</b> N/A	<b>Action:</b> Furnace Module sends SET POWER = 0 command to Furnace Controller.	<b>Action:</b> Rule sets Furnace Module ABORT signal and stops APC script.

# Fault Conditions and Responses

Fault	Furnace CPU	XPC	EZC	SCC
<b>Furnace Controller 28V Bus Too Low To Achieve Setpoint</b> Description: Setpoint cannot be achieved with 28 volt power supply.	Detection → : Furnace Controller determines that the current setpoint cannot be achieved. Action: Furnace Controller aborts current setpoint and reports error status.	Detection: N/A Action: N/A	Detection → : Furnace Module receives error status from Furnace Controller during a GetStatus command. Action: Furnace Module terminates current command and sets error status. EasyLab interpreter terminates current EasyLab program. RCI returns NOTOK.	Detection → : SCC receives NOTOK error status from RCI. Action: APC script diagnoses error and quits.
<b>Furnace Controller Temperature Over Limit (Detected by Furnace Controller)</b> Description: One of the monitored temperature sensors exceeds its operating limits for some period.	Detection → : Furnace Controller detects an overtemp condition.	Detection: N/A	Detection → : Furnace Module receives error status from Furnace Controller during a GetStatus command.	Detection → : SCC receives NOTOK error status from RCI.
<b>Furnace Controller Temperature Over Limit (Detected by SCC)</b> Description: One of the monitored temperature sensors exceeds its operating limits for some period.	Action: Furnace Controller sets power level to 0 and reports error status.	Action: N/A	Action: Furnace Module terminates current command and sets error status. EasyLab interpreter terminates current EasyLab program. RCI returns NOTOK.	Action: APC script diagnoses error and quits.
<b>Furnace Controller Temperature Out Of Range</b> Description: One of the monitored temperature sensors exceeds its operating limits for some period.	Detection ← : Furnace Controller receives SET POWER = 0 command from Furnace Module. Action: Furnace Controller sets power level to 0.	Detection ← : N/A Action: N/A	Detection ← : Furnace Module receives ABORT signal from SCC. Action: Furnace Module sends SET POWER = 0 command to Furnace Controller.	Detection ← : SCC acquires temperature data every 1 second and updates SCL database. Action: Rule sets Furnace Module ABORT signal and stops APC script.
<b>Furnace Controller Temperature Out Of Range</b> Description: Temperature or power setpoint is invalid.	Detection → : Furnace Controller determines that the current setpoint is invalid. Action: Furnace Controller aborts current setpoint and reports error status.	Detection: N/A Action: N/A	Detection → : Furnace Module receives error status from Furnace Controller during a GetStatus command. Action: Furnace Module terminates current command and sets error status. EasyLab interpreter terminates current EasyLab program. RCI returns NOTOK.	Detection → : SCC receives NOTOK error status from RCI. Action: APC script diagnoses error and quits.

# Fault Conditions and Responses

Fault	STP	XPC	EZC	SCC
<b>XPC WatchDog</b>	Detection: N/A	Detection: Servo Controller internal watchdog timer times out.	Detection: N/A	Detection: N/A
Description: The XPC watchdog timer circuitry fails to be strobed in the required time and the XPC processor is reset.	Action: N/A	Action: Servo Controller internal watchdog timer restarts the processor and resets outputs to safe states.	Action: N/A	Action: N/A
<b>EZC WatchDog</b>	Detection: N/A	Detection: N/A	Detection: WDT board watchdog timer times out.	Detection: N/A
Description: The EZC watchdog timer circuitry fails to be strobed in the required time and the EZC processor is reset.	Action: N/A	Action: N/A	Action: WDT board watchdog timer restarts the processor and resets furnace enable.	Action: N/A
<b>SCC WatchDog</b>	Detection: N/A	Detection: N/A	Detection: N/A	Detection: WDT board watchdog timer times out.
Description: The SCC watchdog timer circuitry fails to be strobed in the required time and the SCC processor is reset.	Action: N/A	Action: N/A	Action: N/A	Action: WDT board watchdog timer restarts the processor. SCC reads latched watchdog status for telemetry before clearing the latch.

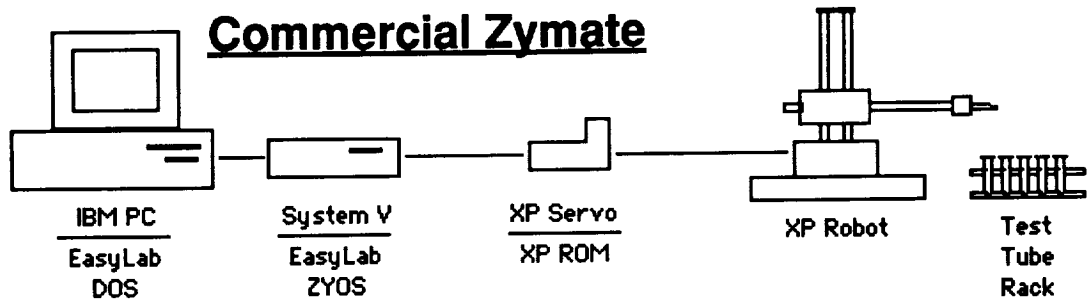
# Fault Conditions and Responses

<b>Fault</b>	<b>STP</b>	<b>XPC</b>	<b>EZC</b>	<b>SCC</b>
<b>Strain Gauge Open</b>	<p>Detection: STP OVF latch fails to reset after robot is moved.</p> <p>Action: Each axis OVF latch may be overridden by XPC if necessary.</p>	<p>Detection: Reads latches.</p> <p>Action: Performs override and move commands from EZC.</p>	<p>Detection: Gets status from XPC.</p> <p>Action: Sends commands to back off, retry, and if still OVF, to override the channel.</p>	<p>Detection: Gets report from EZC.</p> <p>Action: Diagnoses fault, sends command to recover.</p>
<b>Power Loss</b>	<p>Detection: N/A</p>	<p>Detection: WDT circuit detects loss of power. Brakes are energize-to-release type.</p>	<p>Detection: N/A</p>	<p>Detection: N/A</p>
Description: System Power is lost.	<p>Action: N/A</p>	<p>Action: WDT circuit provides uninterrupted battery-backed power to encoder circuits.</p>	<p>Action: N/A</p>	<p>Action: N/A</p>
<b>Power Up</b>	<p>Detection: N/A</p>	<p>Detection: XPC reset circuit detects power up.</p>	<p>Detection: Processor is restarted by WDT and by its own POC circuit.</p>	<p>Detection: Processor is restarted by WDT and by its own POC circuit.</p>
Description: System Power returns.	<p>Action: Motor drives are disabled and brakes applied at startup by XPC outputs.</p>	<p>Action: XPC reset circuit restarts processor and resets outputs to safe states.</p>	<p>Action: Software is initialized, stored programs are retained, but any operations not completed before power loss are aborted. Furnace is disabled.</p>	<p>Action: Software is initialized, stored programs are retained, any scripts not completed before power loss are aborted, stored data is retained as acquired before power loss, including rule states.</p>

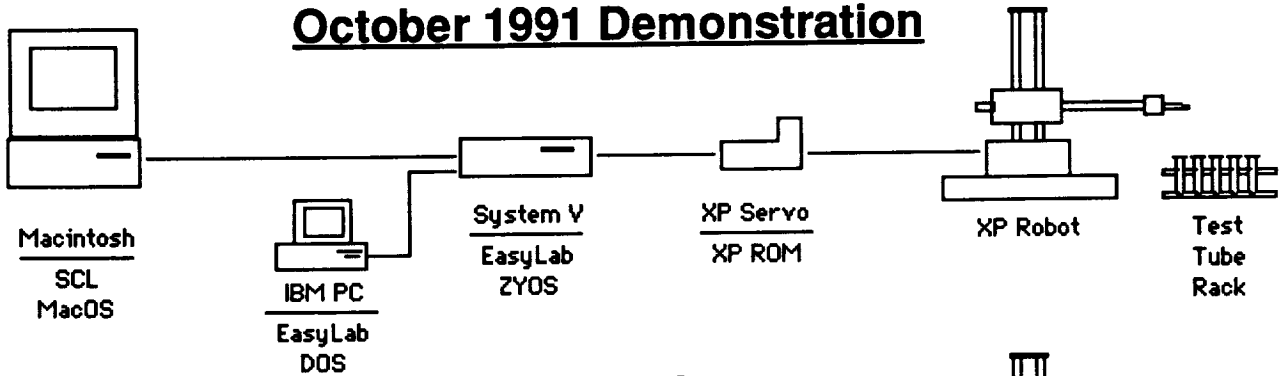
CONTROL SYSTEM ELEMENT	HARDWARE		SOFTWARE		BREADBOARD		DESIGN	
	STATUS		STATUS		STATUS		HERITAGE	
<b>SCC Processor</b>								
Realtime Engine	COTS		COTS		BrBd 100%		OCp, ARD pgm	
HH serial i/o	Des 100%		Oper by 12/31		planned		OCp, ARD pgm	
command	na		Oper by 12/31				OCp, ARD pgm	
telemetry	na		Des 100%				OCp, ARD pgm	
a/d	COTS		COTS				OCp, ARD pgm	
mux	Des 100%		Des 80%				OCp, FHPE pgm	
<b>EZC Processor</b>								
<b>EASyLAB</b>	COTS		Oper by 12/15		BrBd 100%		Zymark, System V	
robot	na		Des 100%		planned		Zymark, 80%, Robot	
furnace	na		Des 100%		planned		Zymark, 50%, Vortexer	
serial i/o	COTS		COTS		BrBd 100%		OCp, ARD pgm	
<b>SERVO Controller</b>								
xpc	Des 100%		Des 100%		BrBd 100% + simulation		Zymark, Zymate	
enc	Des 100%		incl		BrBd 100%		Zymark, Zymate	
xpp	Des 100%		incl		BrBd 100%		Zymark, Zymate	
stp	Des 100%		Des 80%					
watchdog	Des 100%		Des 100%					
battery	Des 100%		na		planned			
PID algorithm	na		Des 85%		BdBd 80%			
serial i/o	na		Des 100%		BrBd 100%			
<b>MECHANICAL</b>	Des 100%		na				SwRI, Qual'd to 17grms	
<b>THERMAL</b>	Des 100%						COSMOS, Sinda, Traysis	

# Evolution from Zymate to ROMPS

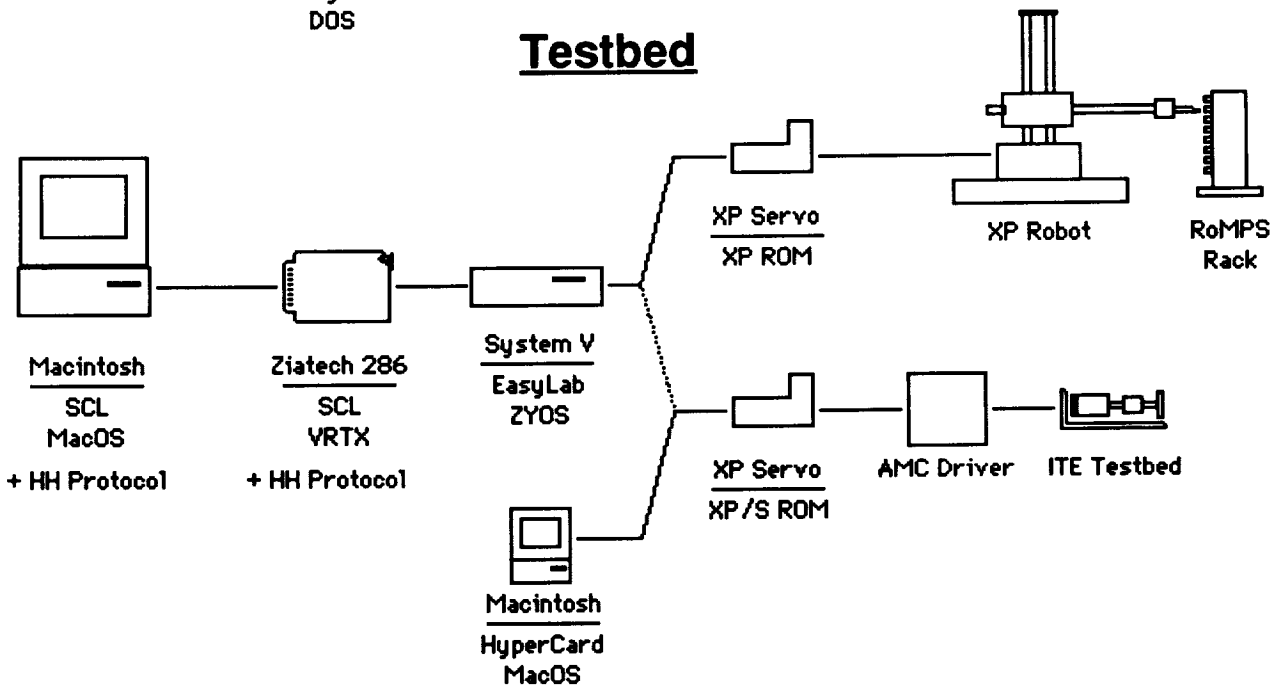
## Commercial Zymate



## October 1991 Demonstration



## Testbed



## Flight

