238800-12-X

ROMPS CRITICAL DESIGN REVIEW DATA PACKAGE

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DECEMBER 1992

Prepared for:
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Space Technology Division
Greenbelt, MD 20771

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SpARC
Space Automation
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SpARC ROMPS CDR INDEX

7:40am 12/8/1992

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MECHANICAL/THERMAL

233	15.01	817	Board Outlines - SC1 & SC2	DWG	UPDATE	Done	[x]
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	15.11	439	Heater Block Diagram				
	15.12		Control System Mechanical Design		NEW	Done	[x]
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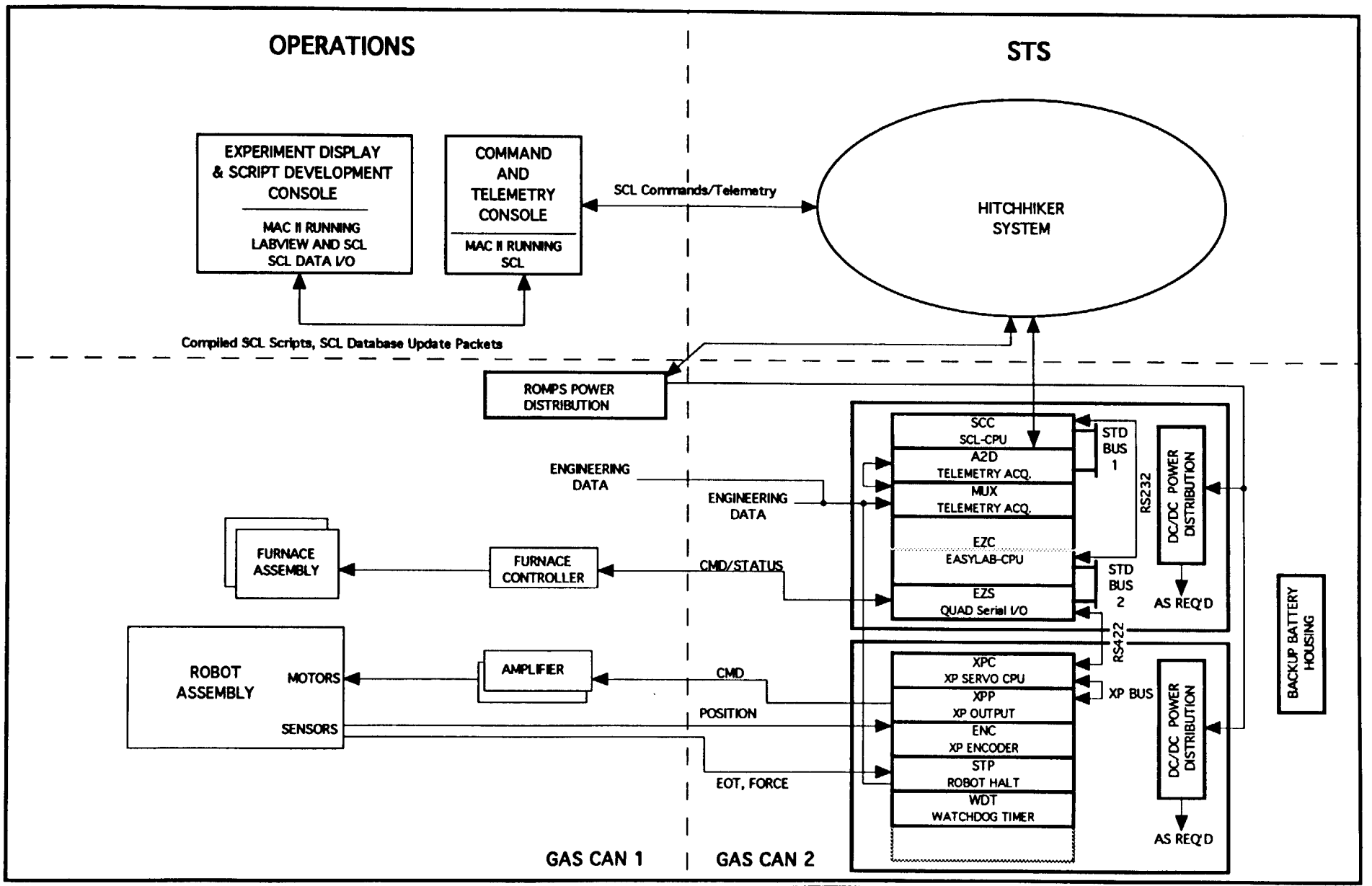
FAULT CONDITIONS & RECOVERY

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

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]



ENGINEER M. F. Dobbs	DRAFTSMAN	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	RoMPS OPERATIONAL CONCEPT RoMPS 010-422	12/2/92 4/6/92 1/9/92 DATE

1.00

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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 THRUPUT
4 DISCRETE COMMANDS FOR ENABLES/DISABLES & PROCESSOR BOOT

TELEMETRY RS422, 1200 BAUD, ASYNCHRONOUS, ~100 C/S MAX. THRUPUT

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

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ROBOT
CONTROL SYSTEM REQUIREMENTS

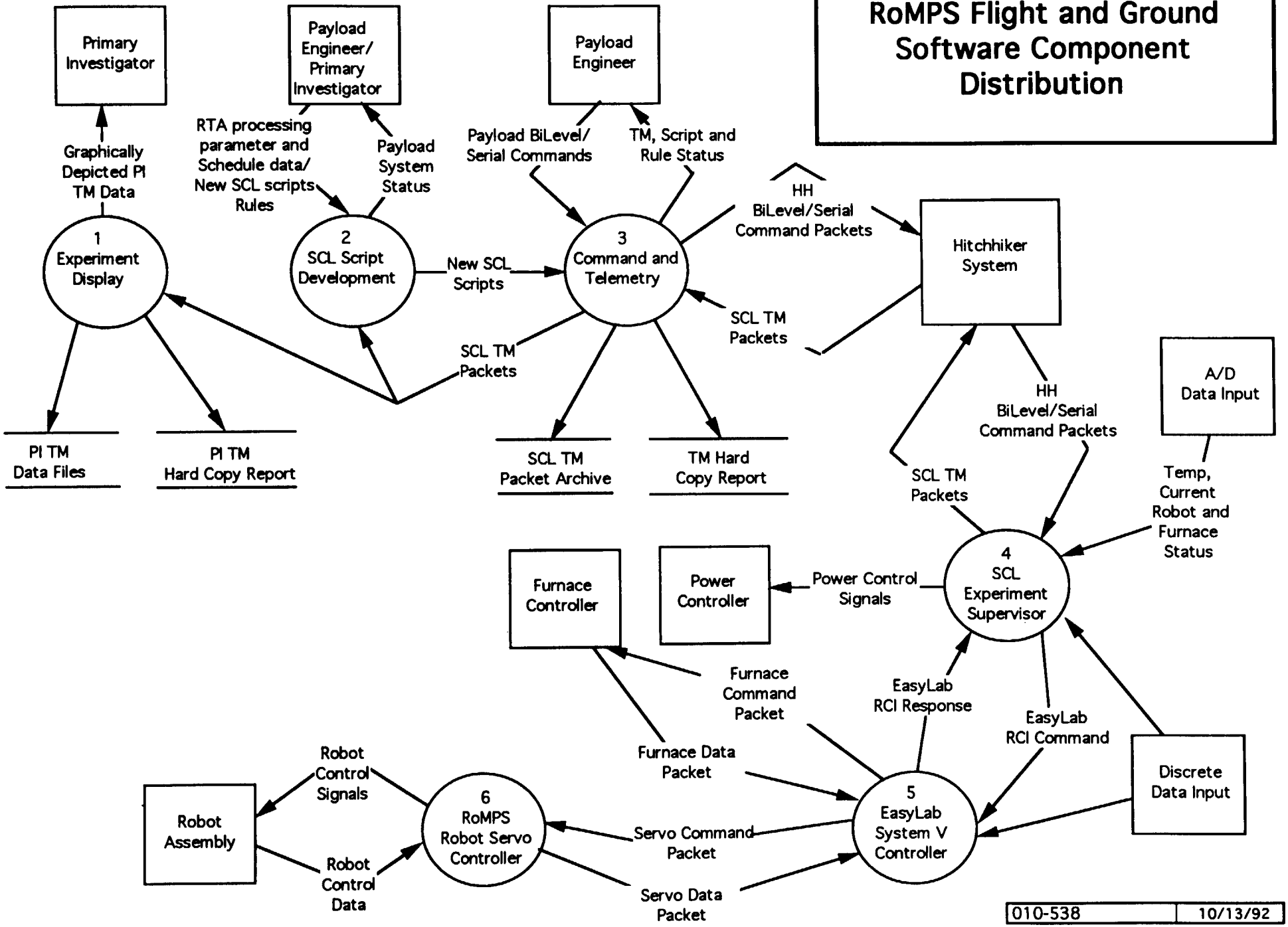
4 DOF MATERIAL HANDLING ROBOT

- ±0.005" (14BIT) POSITION RESOLUTION & ACCURACY
- 200 SEC^{-1} 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

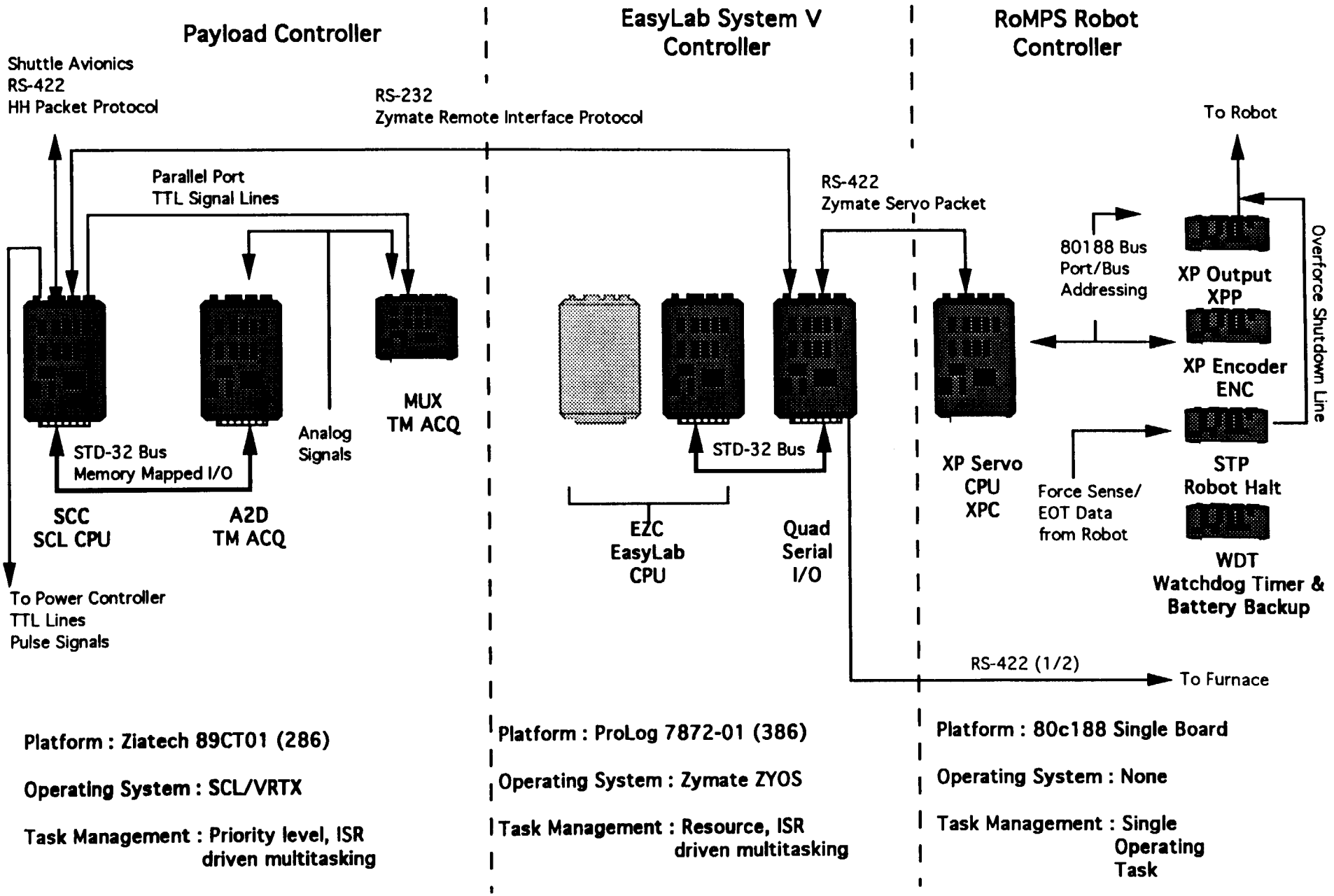
- UP TO 7 TEMPERATURE/TIME PLATEAUS
- SERIAL COMMAND & DISCRETE ENABLE TO FURNACE CONTROLLER
- TELEMETRY - SETPOINT, LAMP V&I, REF TEMP, MISC. STATUS

RoMPS Flight and Ground Software Component Distribution



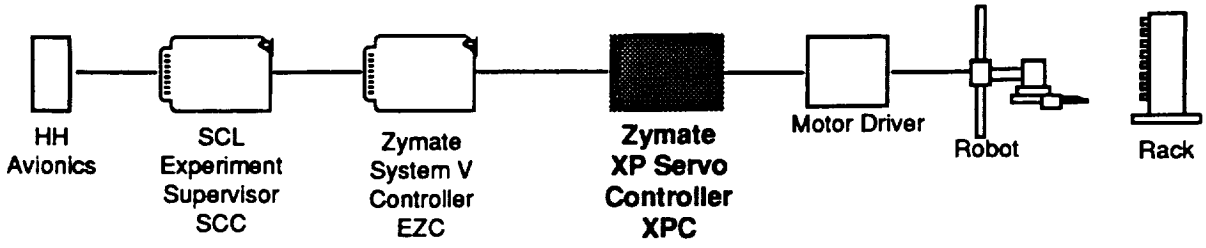
010-538	10/13/92

RoMPS Payload Software Interfaces/Platforms



010-542	11/9/92

Nominal Operation of the ROMPS XP Servo



Upon Reset

1) XP Servo Controller System Startup

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

2) Ready XP Servo Controller System for Main Processing Loop

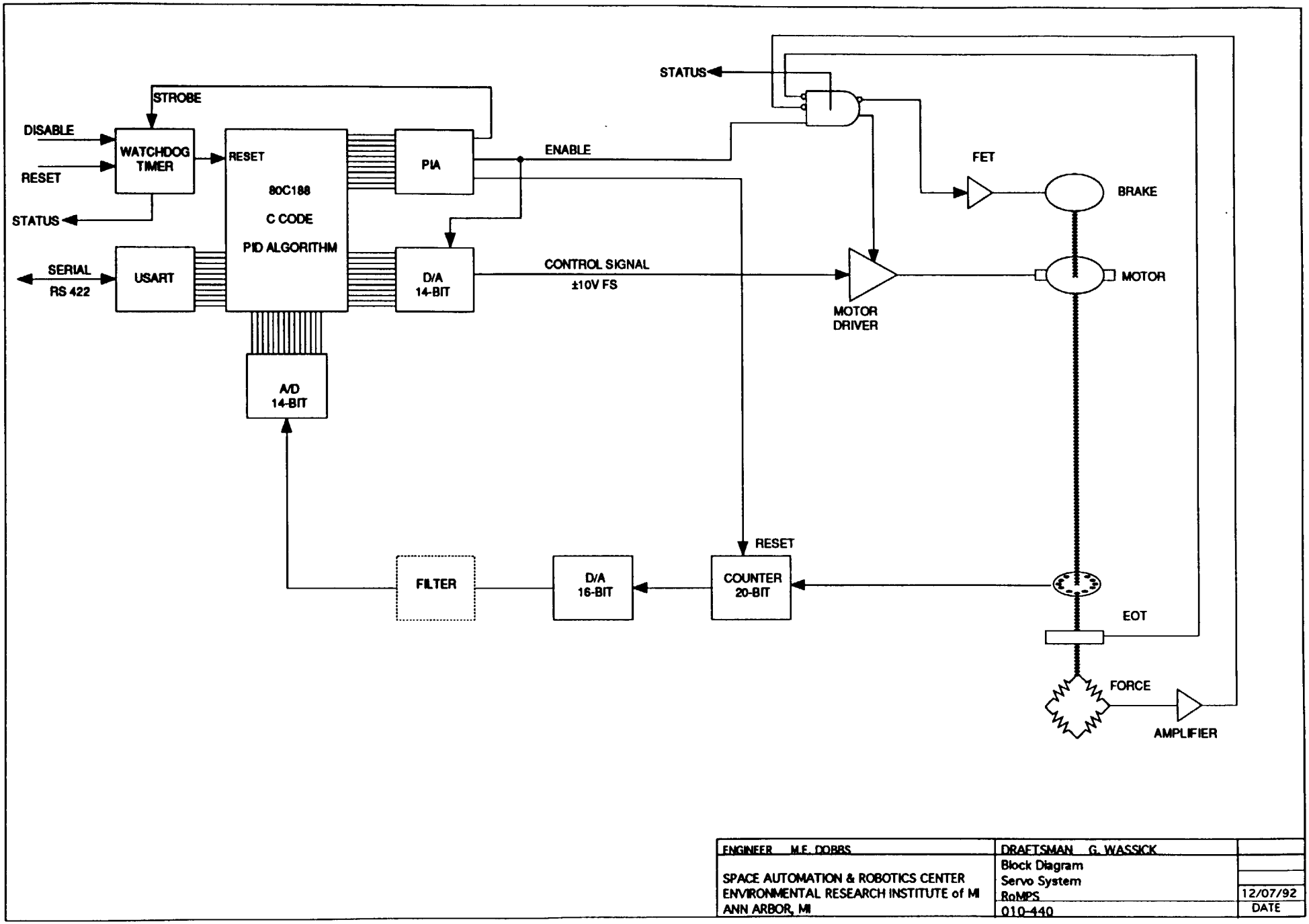
- Inhibit the D/As used for Axis Position Control
- Kick the Watch Dog Timer
- Execute Servo Contol Algorithm 5 times to "Prime" the Servo Control intermediary data structures
- Set all Axis Control Target Positions to Current Position
- Set all Axis Control Speeds to Zero
- Initiallize the Communication 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



ENGINEER M.F. DOBBS	DRAFTSMAN G. WASSICK	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	Block Diagram Servo System RoMPS 010-440	12/07/92 DATE

RoMPS XPC Servo Code Outline Chart

on reset:

main

- initialize system
- strobe watchdog
- prime servo 5x
- 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)

do_servos

- poll EOT and OVF
- stop if EOT or OVF
- axis sequencer
- *do one axis:*
  - azimuth servo >
  - elevation servo >
  - radial servo >
  - gripper servo >

azimuth

- get position
- speed control
- force limit
- servo calculations >
- PID calculation

checkcomm

- 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 occured
  - reply with error code
- get next character from input stream
- if message is complete
  - Interpret command

interpret

- 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...

on 5 millisecond timer:

timer2_interrupt

- decrement position timers
- decrement message timer
- clear tick

on unused interrupt:

unexpected_interrupt

- restart

on character received:

USARTreceive

- put received character into buffer
- get receive status
- check for overrun

on character transmitted:

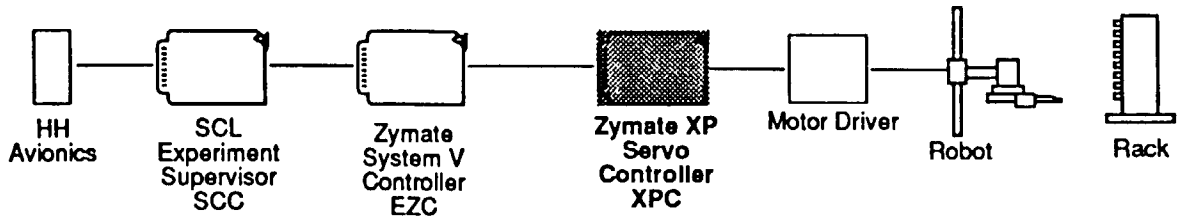
USARTtransmit

- send next character
- check for empty buffer

11/5/92 GD

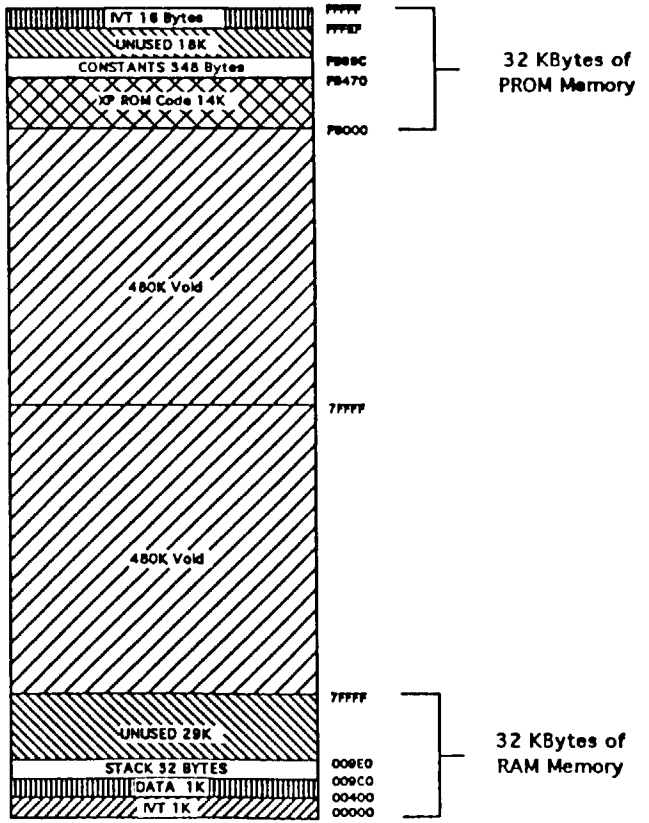
010-801	11/24/92

XP FIRMWARE PERFORMANCE MARGIN



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

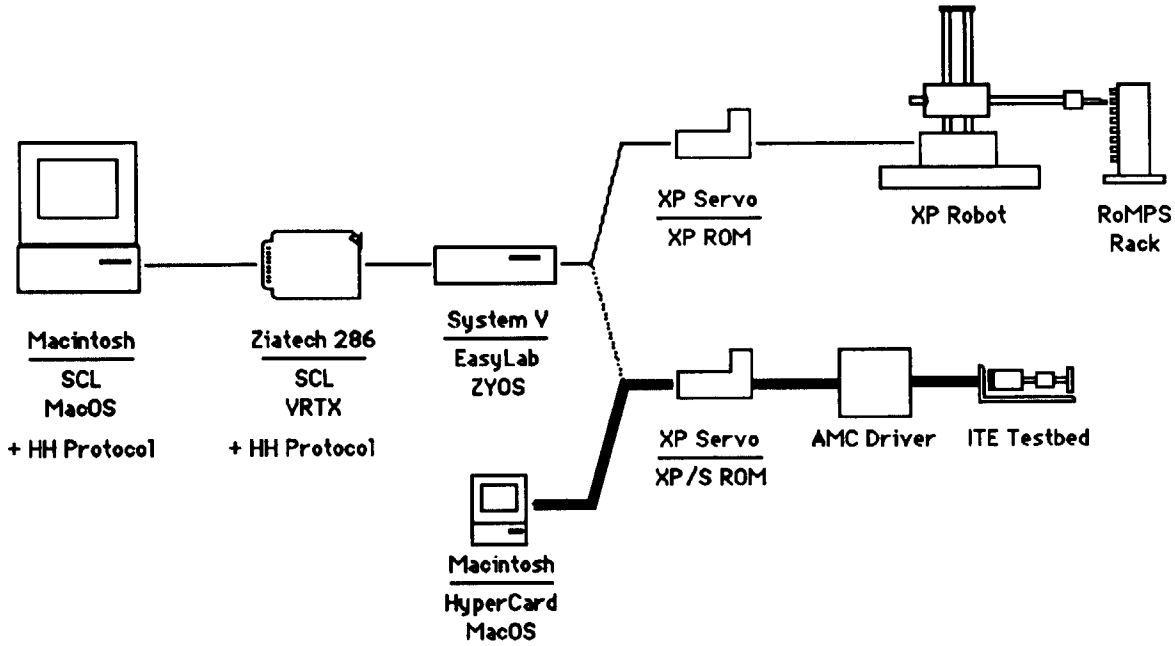
Memory Map



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-sec2	0.0013	0.000027	0.00013	0.00045
Torque Constant	15.1 oz-in/√W	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-sec2	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

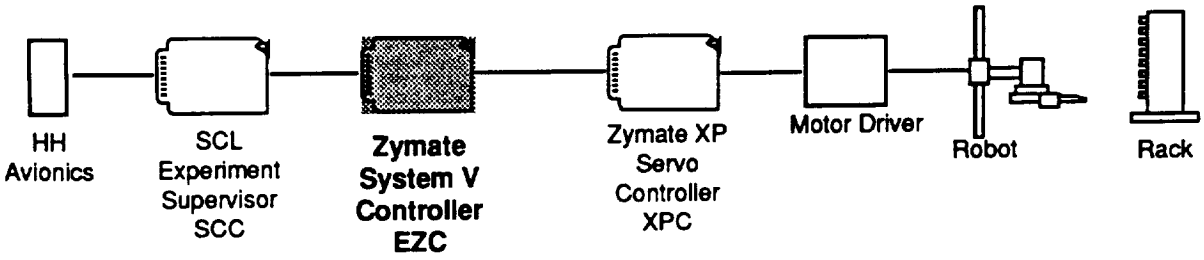
RoMPS Testbed Phase II



XP COMMERCIAL TESTBED PHASE A RESULTS

PARAMETER	TESTBED	ELEV	AZIM	RAD	GRIP
FULL SCALE TRAVEL [REV'S]	512	228	160	1016	560
RESOLUTION [%FS]	$8.2\ 10^{-3}$ [14-bit $=6.1\ 10^{-3}$	$2.2\ 10^{-2}$	$1.2\ 10^{-2}$	$1.0\ 10^{-1}$	$5.7\ 10^{-1}$
MAX VELOCITY [REV SEC^{-1}]	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 assocciated and Interupt Service Routines initiallized
- Memory, Task and Message Manager structures inittiallized
- Language Editor, EasyLab Interpreter, Disk Manager and Data Dictionary Manager structures initiallized

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

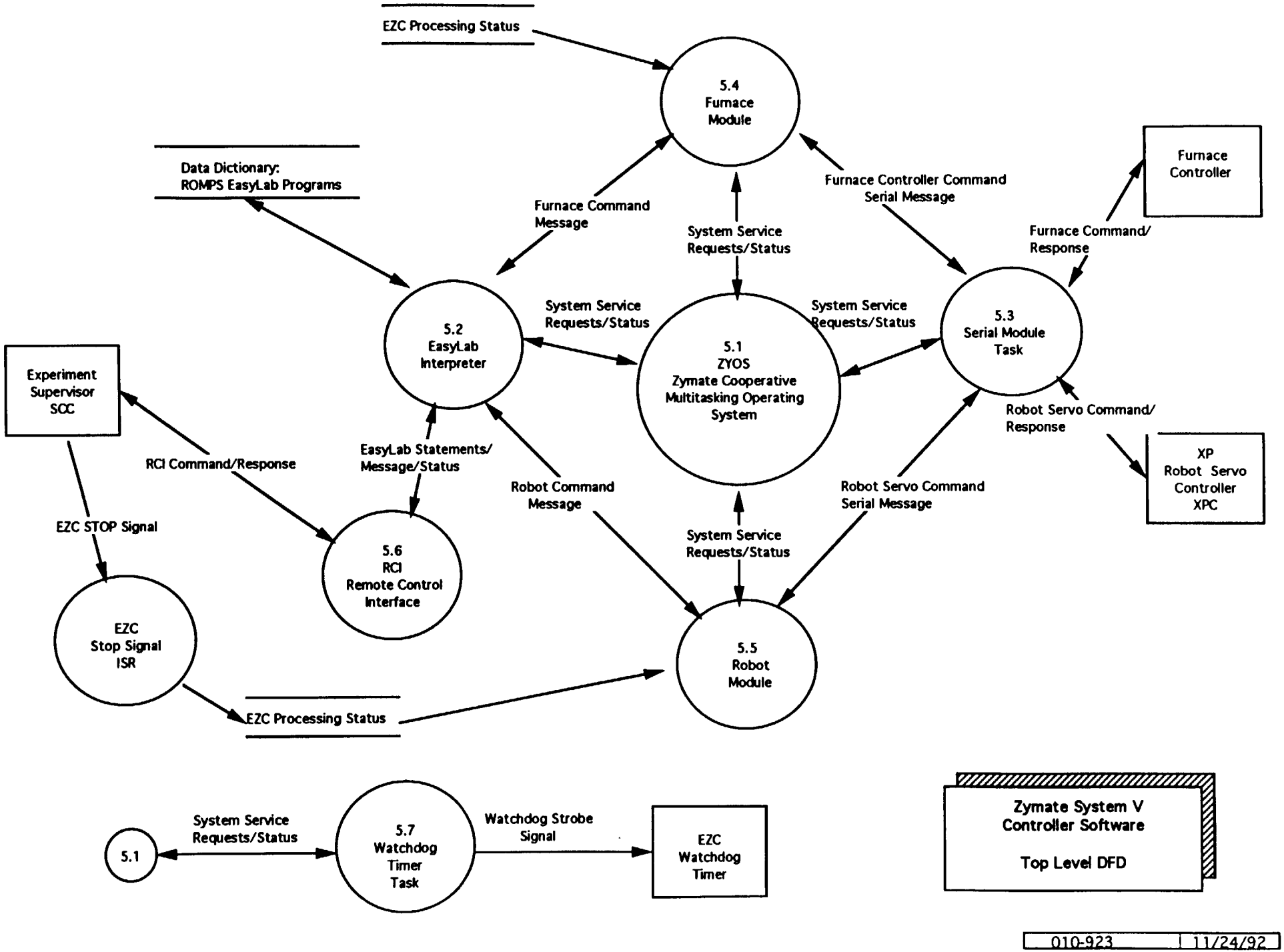
- The EasyLab Intrepeter exectutes the ROMPS startup script AUTOSTART, which executes the command to put the system into Remote Control Mode

5) System Begins Normal EasyLab Processing

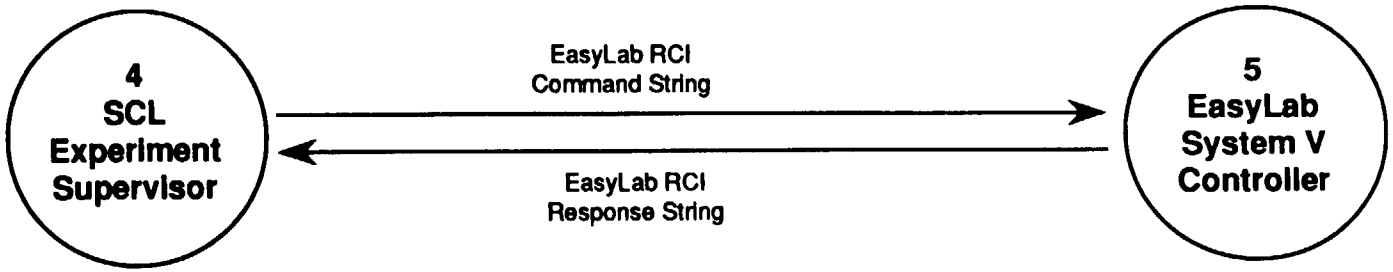
Loop Forever

- 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

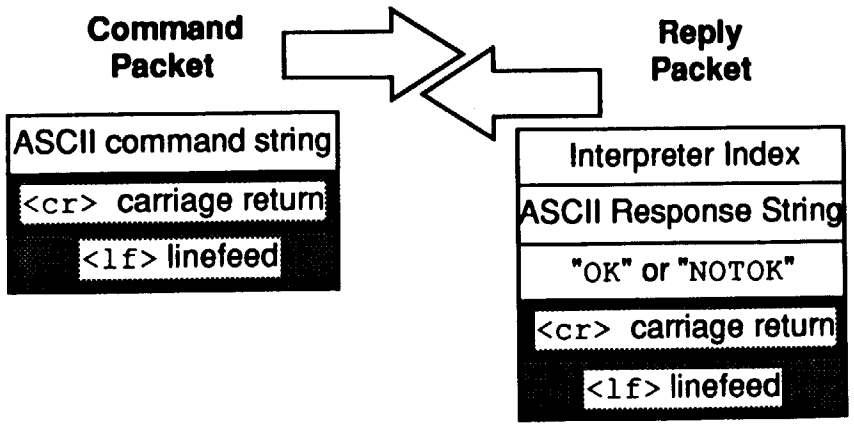
End Loop


EZC Processing Status
5.4
Furnace
Module
Data Dictionary:
ROMPS EasyLab Programs
Furnace Command
Message
System Service
Requests/Status
Furnace Controller Command
Serial Message
Furnace
Controller
Furnace Command/
Response
5.2
EasyLab
Interpreter
System Service
Requests/Status
5.1
ZYOS
Zymate Cooperative
Multitasking Operating
System
System Service
Requests/Status
5.3
Serial Module
Task
Experiment
Supervisor
SCC
RCI Command/Response
EasyLab Statements/
Message/Status
Robot Command
Message
Robot Servo Command/
Response
XP
Robot Servo
Controller
XPC
EZC STOP Signal
5.6
RCI
Remote Control
Interface
System Service
Requests/Status
Robot Servo Command
Serial Message
EZC
Stop Signal
ISR
5.5
Robot
Module
EZC Processing Status
5.1
System Service
Requests/Status
5.7
Watchdog
Timer
Task
Watchdog Strobe
Signal
EZC
Watchdog
Timer
Zymate System V
Controller Software
Top Level DFD
010-923
11/24/92

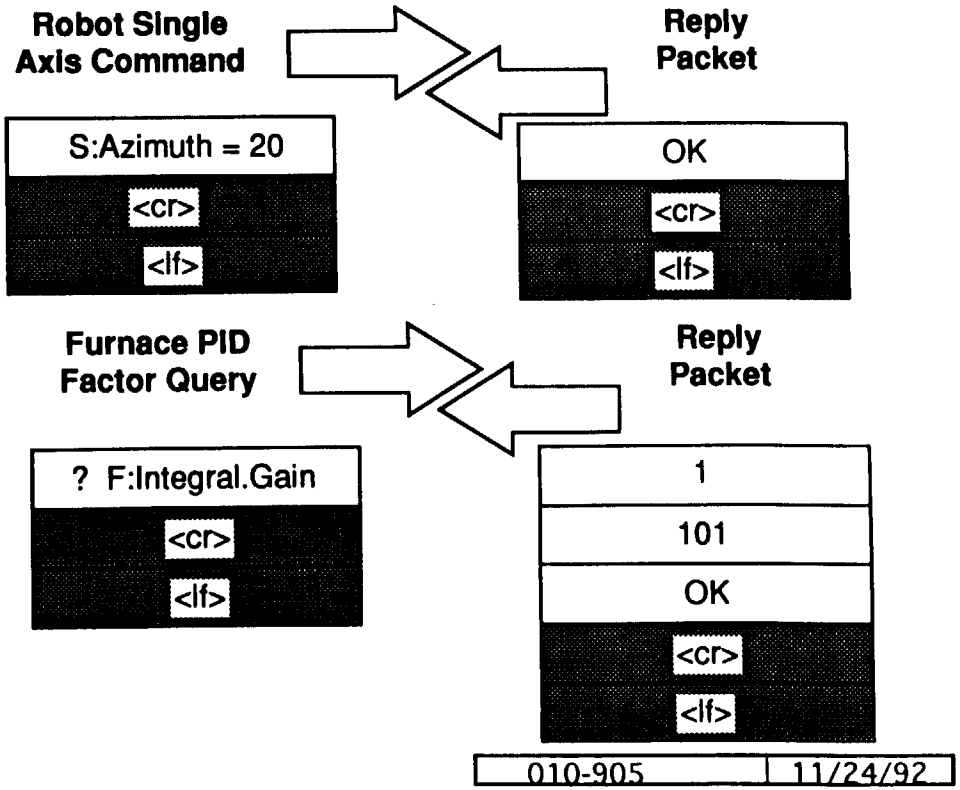
ROMPS
EasyLab Remote Control Interface Protocol

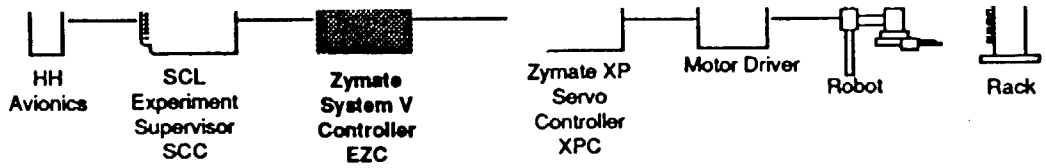


Command/Reply Packets for Generic RCI Command



Command/Reply Packets for Specific ROMPS RCI Commands

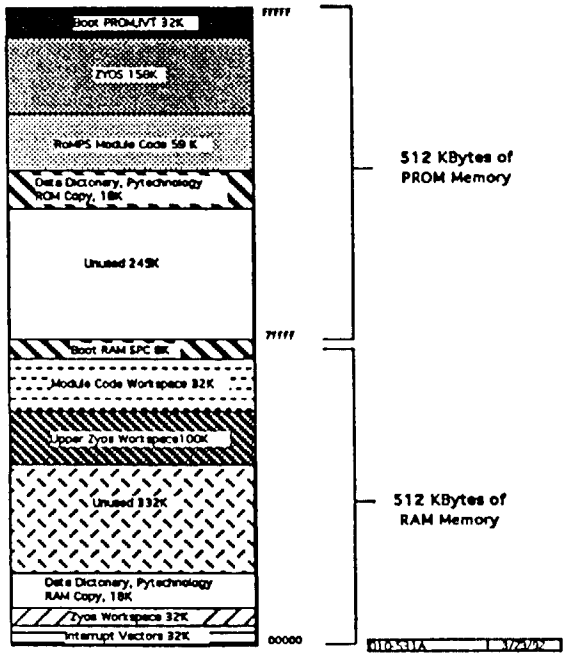




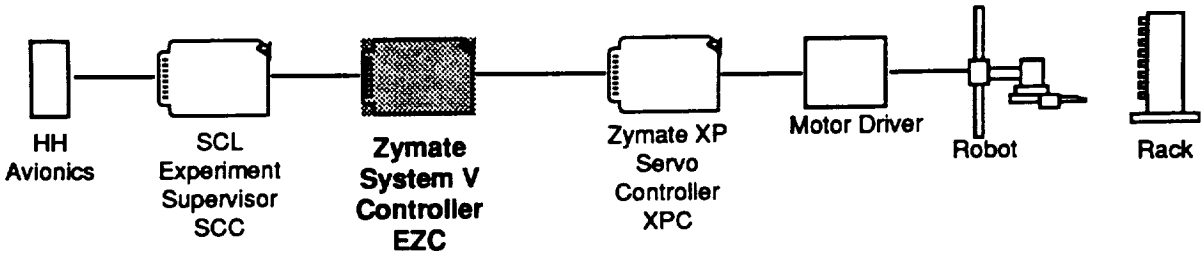
SYSTEM V EASYLAB SOFTWARE PERFORMANCE/MARGIN

EZC Experiment Controller	Commercial CPU 80188	RoMPS CPU 80386
# lines of EasyLab for "move sample to rack"	20	20
EZC Interpreter Thruput in lines-per-second	10 sec^{-1}	100 sec^{-1}
Software Time vs Mechanism Time [assuming 50% elevation + 100% radial, azimuth & gripper]	2 sec vs 35 sec	0.2 sec vs 35 sec
CPU Margin	17x	170x

RoMPS EasyLab System V Controller Memory Map



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) Initiallize the Robot Modules Operating Paramters

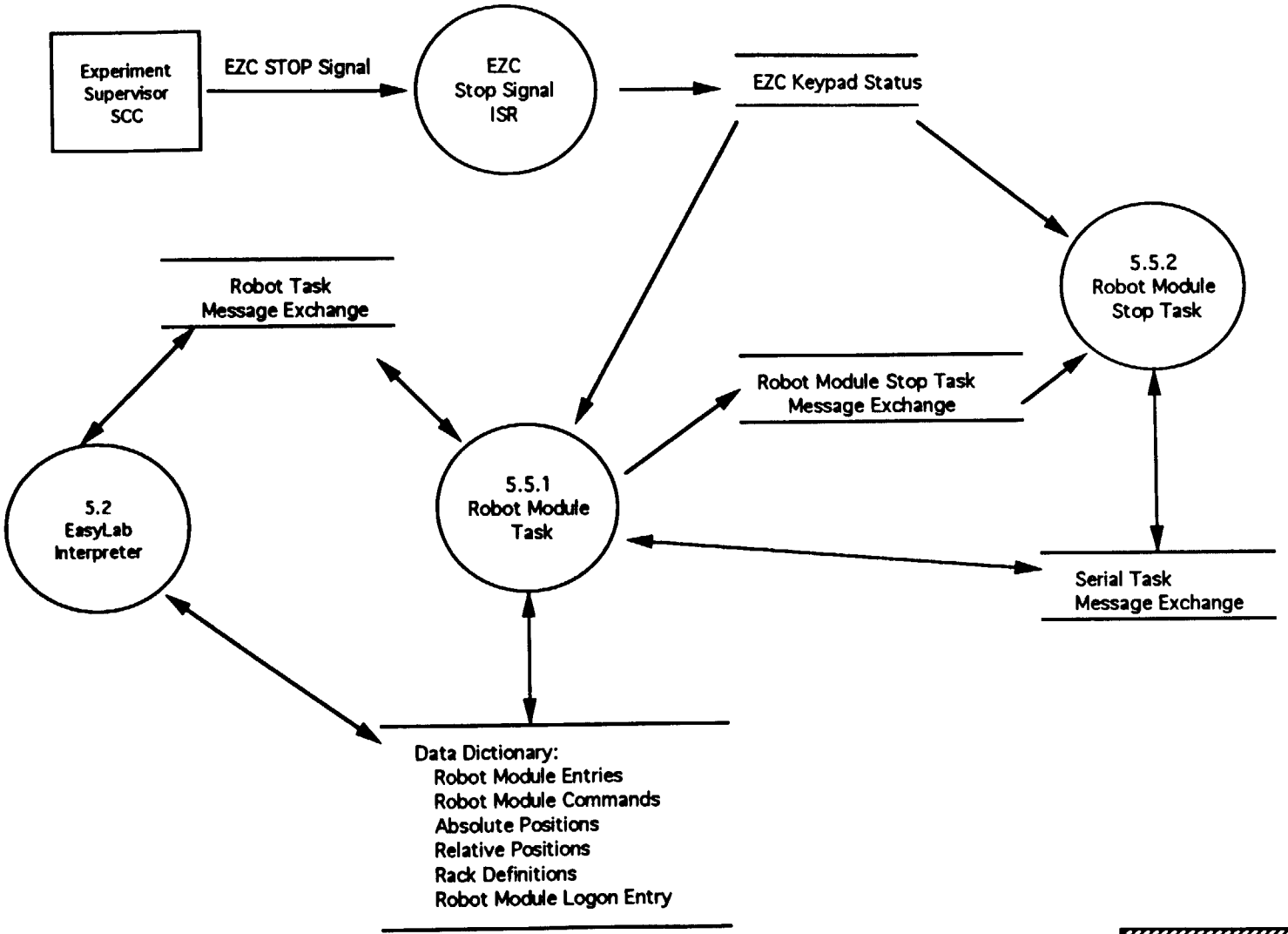
- Create a Message Exchange between Robot Module and Serial Task in order to communicate with XP Robot Servo via Serial Channel
- Create Stop task which monitors the STOP data structure during Moves
- Get user-unit to robot unit conversion factors from XP Robot Servo
- Get Present Base and Wrist Position from XP Robot Servo
- Compute default Base and Wrist Speeds.Accellerations, 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

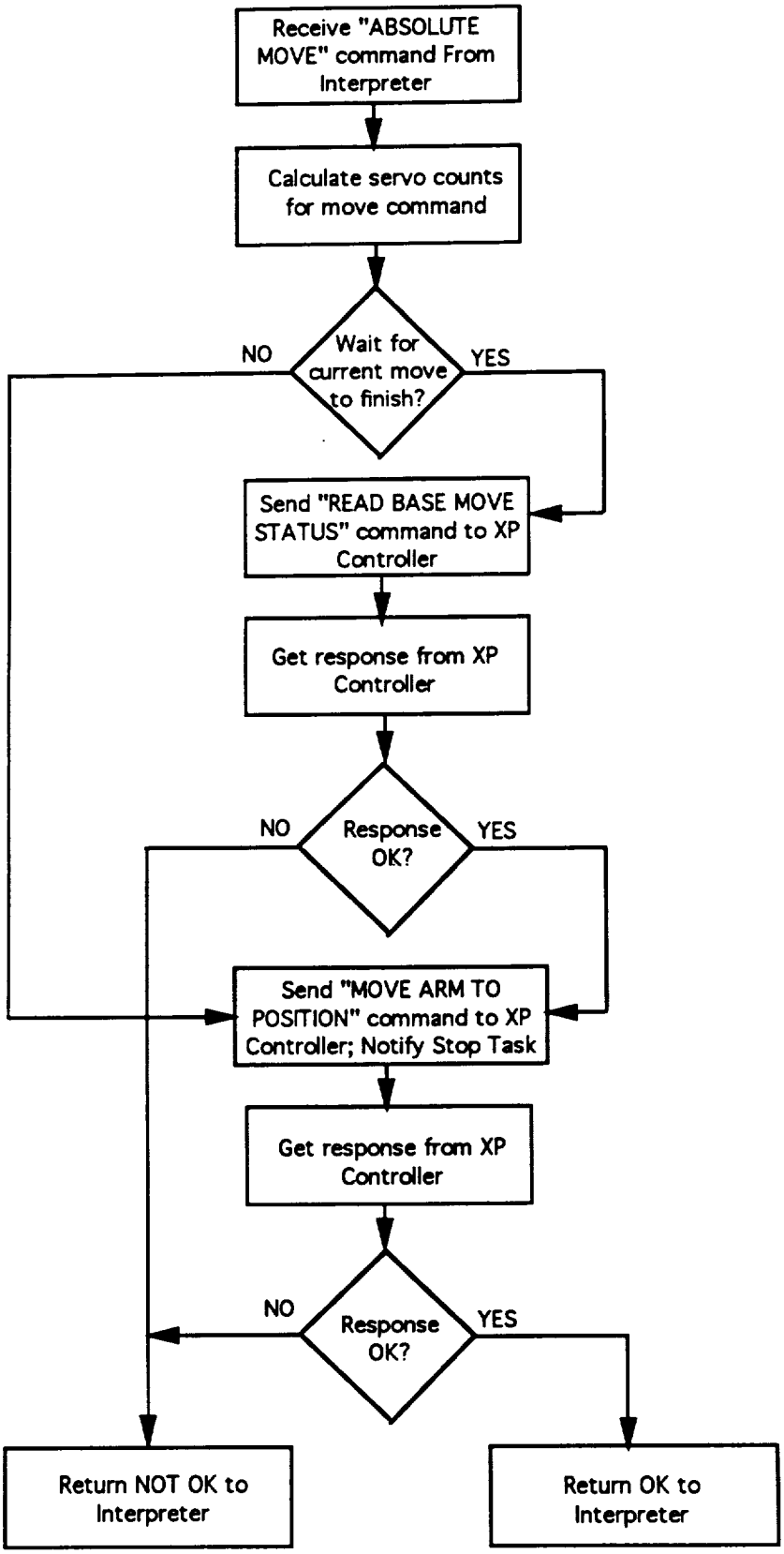
End Loop



Zymate System V
Controller Software

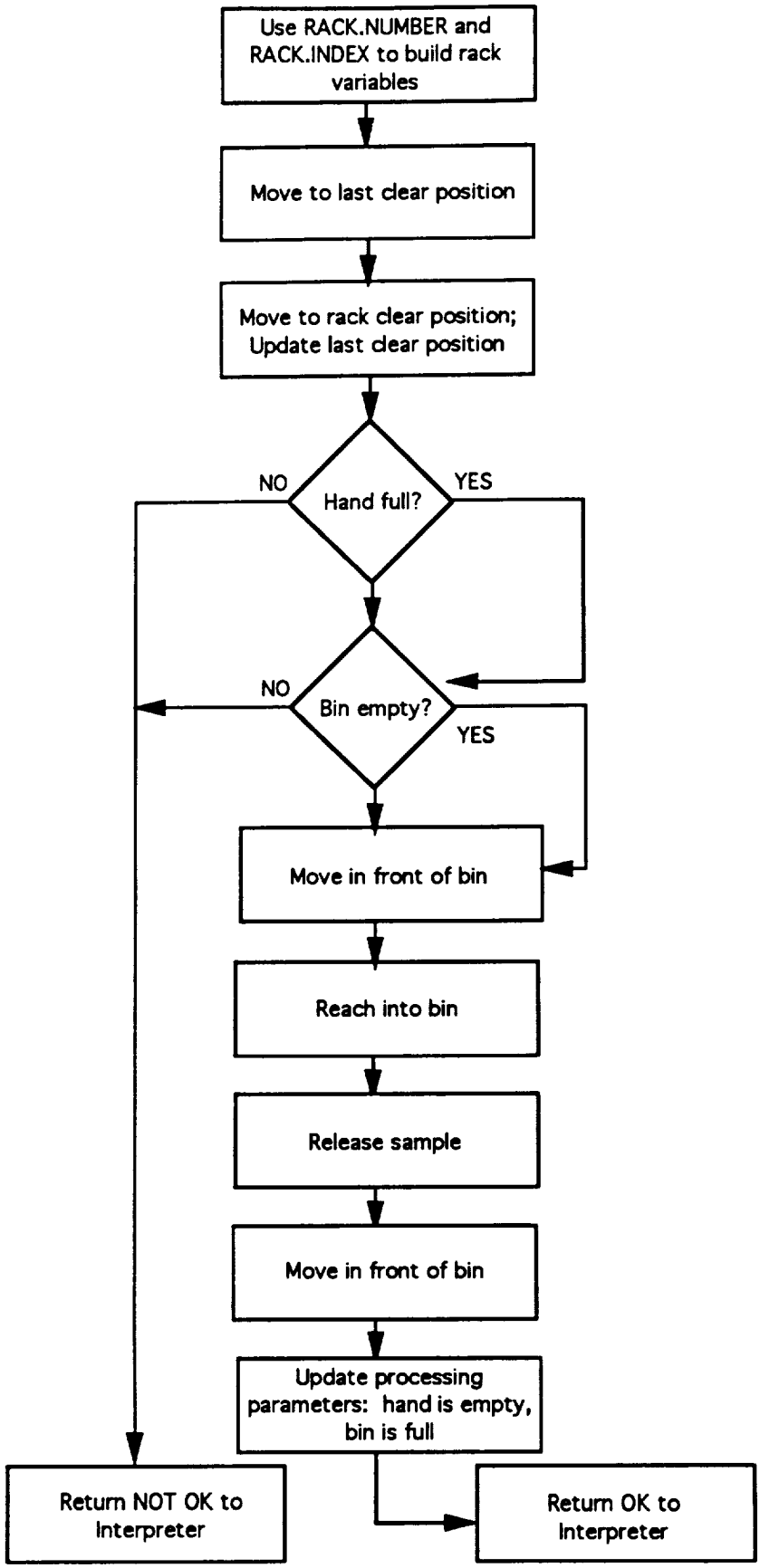
Robot Module DFD

ABSOLUTE MOVE COMMAND VARIABLE PROCESSING FLOW CHART



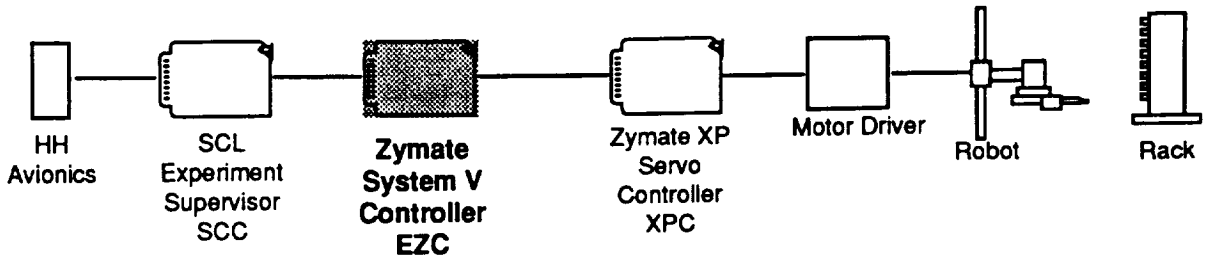
010-700	11/24/92

EASYLAB PROGRAM: PUT.INTO.RACK
PROCESSING FLOW CHART



010-702	11/24/92

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) Initiallize the Furnace Modules Operating Paramters

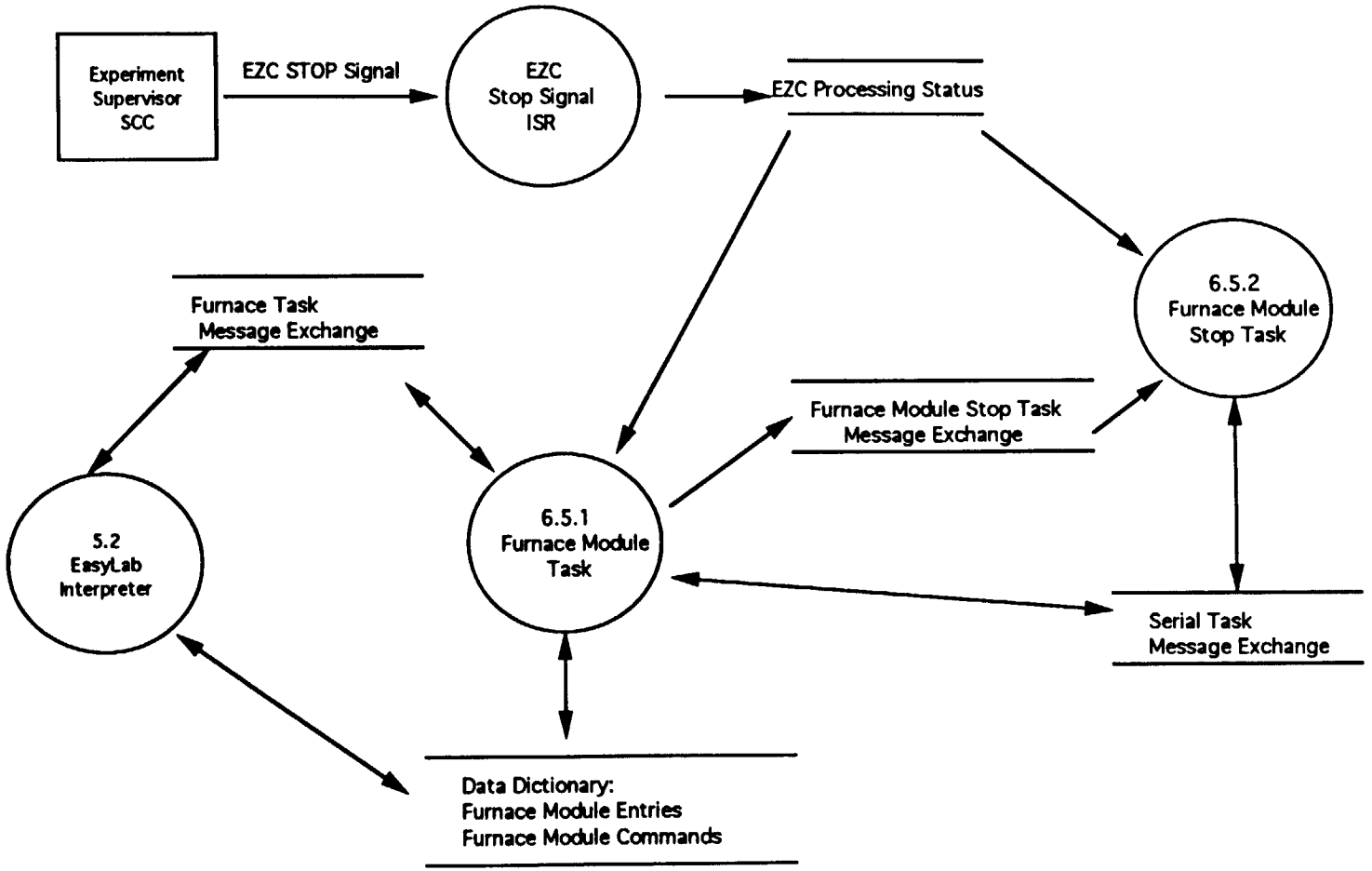
- Create a Message Exchange between Furnace Module and Serial Task in order to communicate with Furnace Controller via a Serial Channel
- Create Stop task which monitors the STOP data structure during Annealing Processing

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

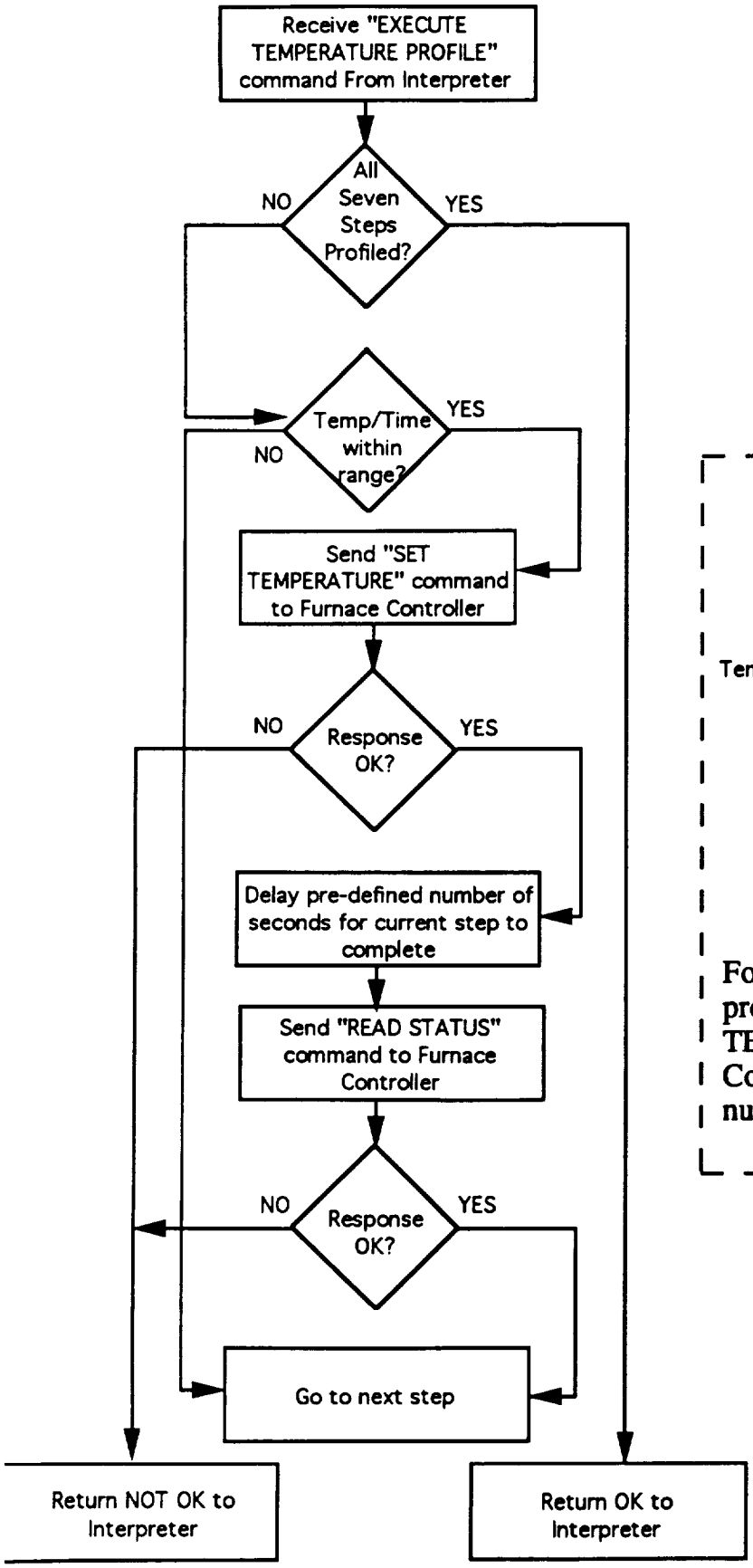


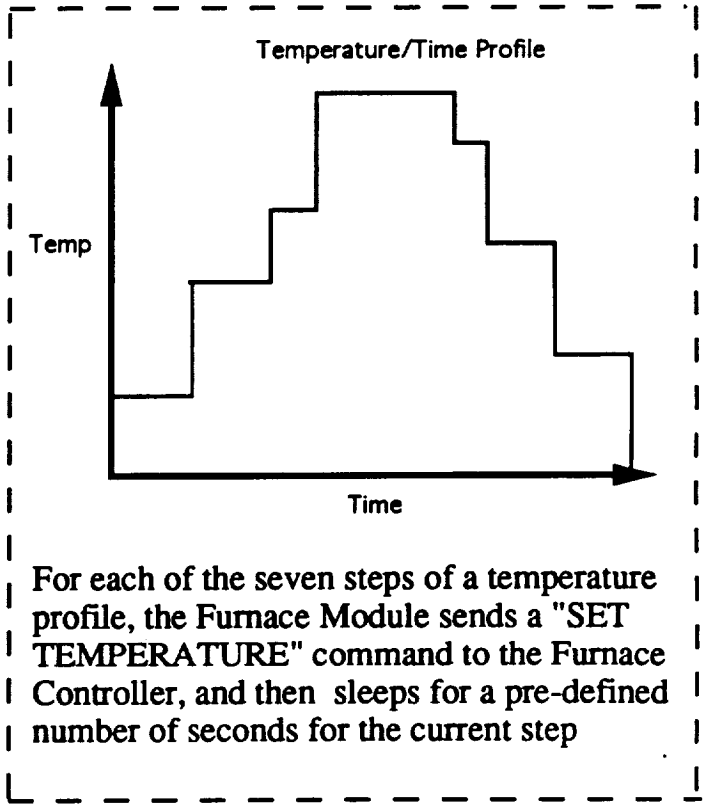
Zymate System V
Controller Software

Furnace Module DFD

010-910	11/24/92

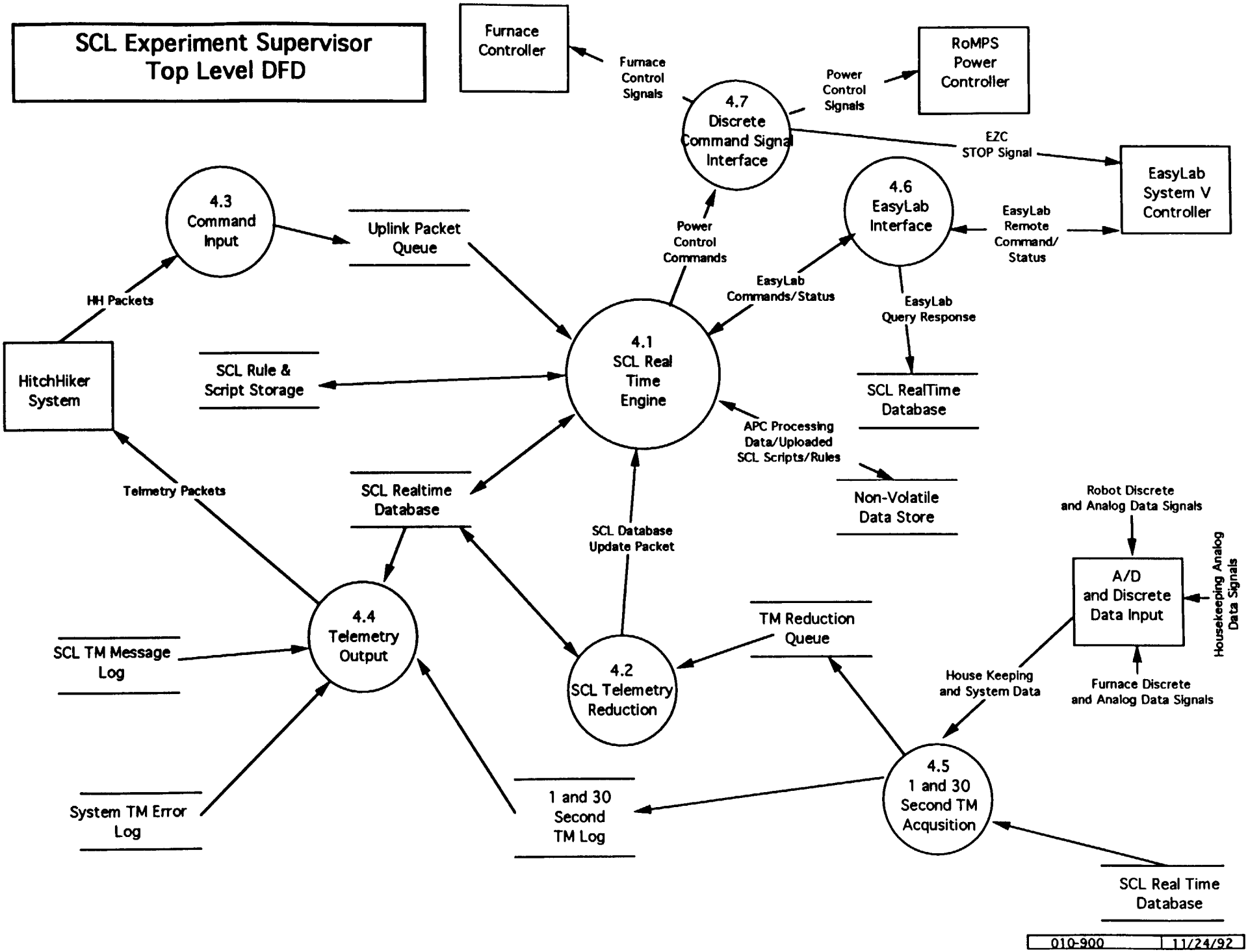
EXECUTE TEMPERATURE PROFILE COMMAND
VARIABLE PROCESSING FLOW CHART





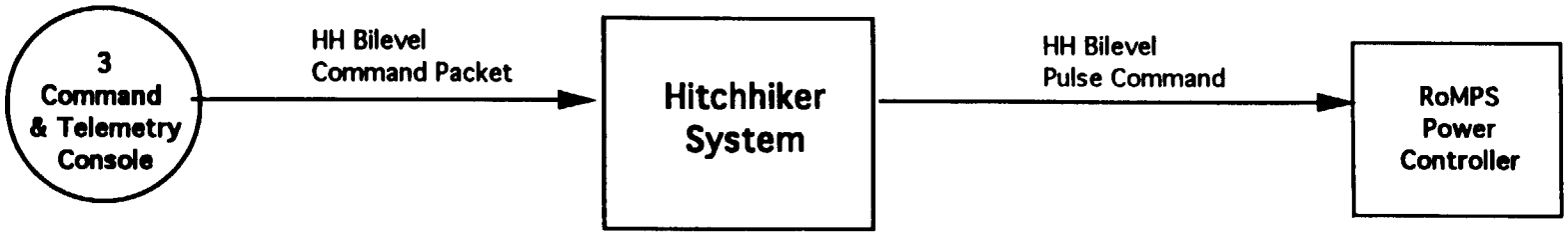
For each of the seven steps of a temperature profile, the Furnace Module sends a "SET TEMPERATURE" command to the Furnace Controller, and then sleeps for a pre-defined number of seconds for the current step

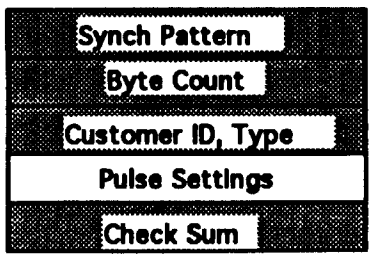
010-701	11/24/92


SCL Experiment Supervisor
Top Level DFD
Furnace Controller
Furnace Control Signals
4.7 Discrete Command Signal Interface
Power Control Signals
RoMPS Power Controller
EZC STOP Signal
EasyLab System V Controller
4.3 Command Input
Uplink Packet Queue
Power Control Commands
4.6 EasyLab Interface
EasyLab Remote Command/ Status
HH Packets
EasyLab Commands/Status
EasyLab Query Response
HitchHiker System
SCL Rule & Script Storage
4.1 SCL Real Time Engine
SCL RealTime Database
APC Processing Data/Uploaded SCL Scripts/Rules
Non-Volatile Data Store
Telmetry Packets
SCL Realtime Database
SCL Database Update Packet
Robot Discrete and Analog Data Signals
A/D and Discrete Data Input
Housekeeping Analog Data Signals
4.4 Telemetry Output
TM Reduction Queue
SCL TM Message Log
4.2 SCL Telemetry Reduction
House Keeping and System Data
Furnace Discrete and Analog Data Signals
4.5 1 and 30 Second TM Acqusition
System TM Error Log
1 and 30 Second TM Log
SCL Real Time Database
010-900
11/24/92

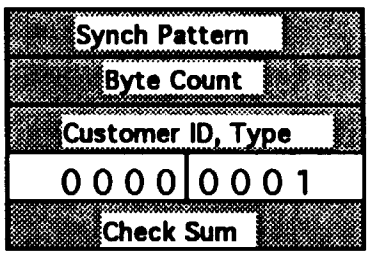
RoMPS Command Uplink Protocols

HH Bilevel Command Packet Protocol





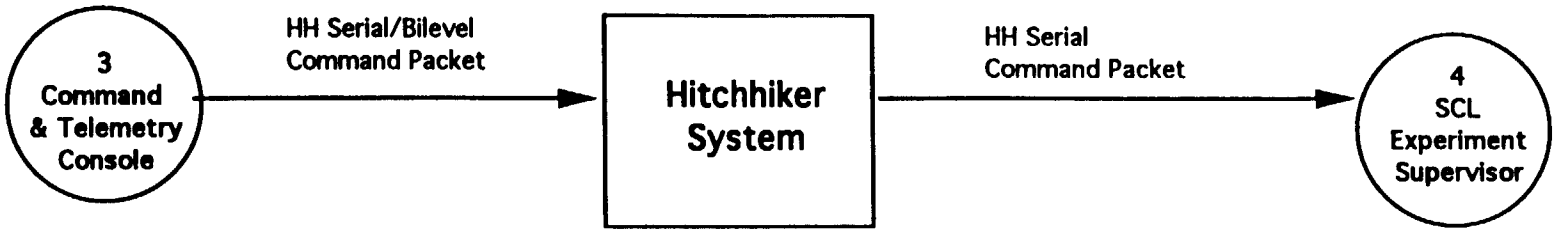
example of
Generic Bilevel Command Packet

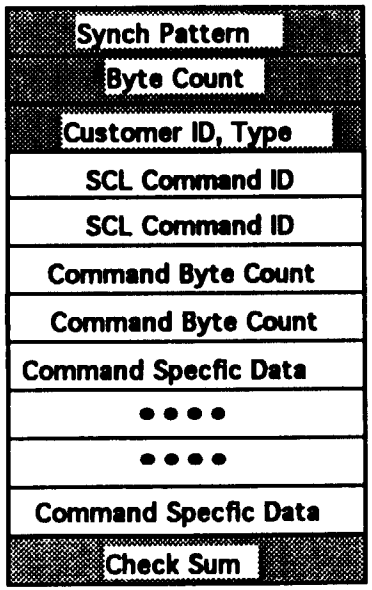


example of
Bilevel Command Packet for
set HH_BILEVEL to MASTER_RESET

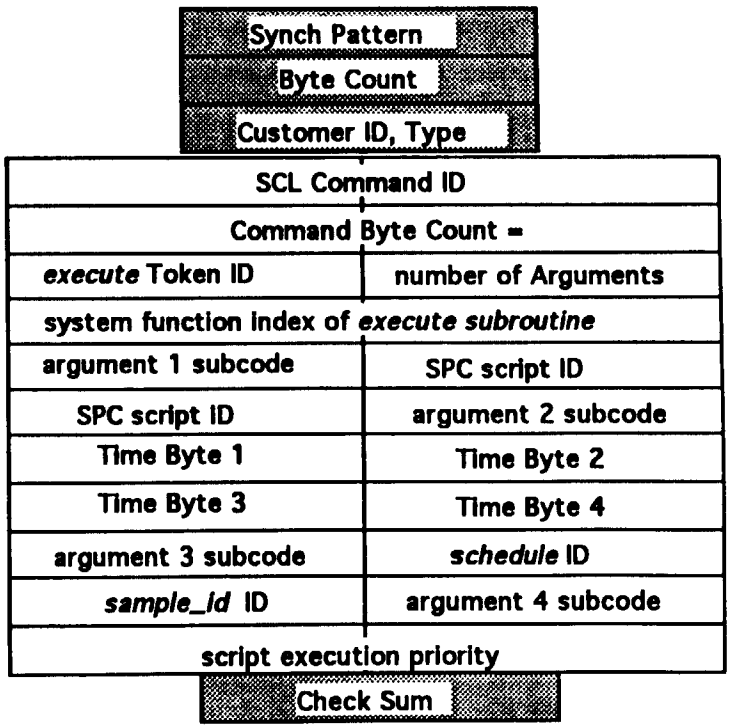
RoMPS Command Uplink Protocols

SCL-Command Packet Protocol





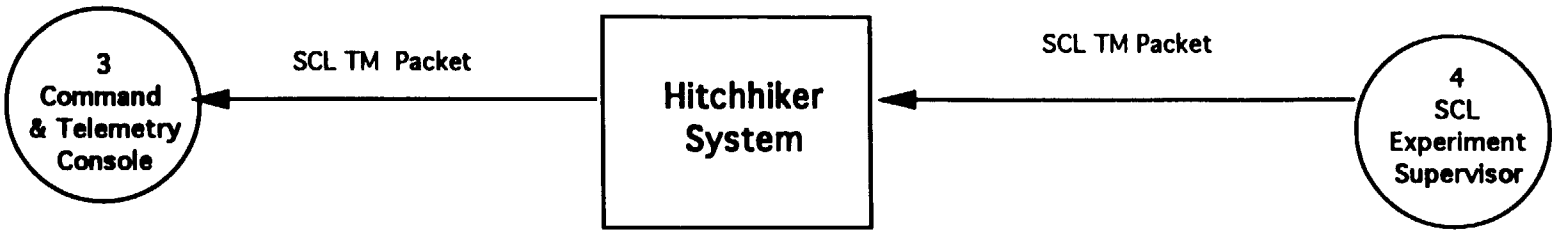
example of
Generic SCL-Command Packet

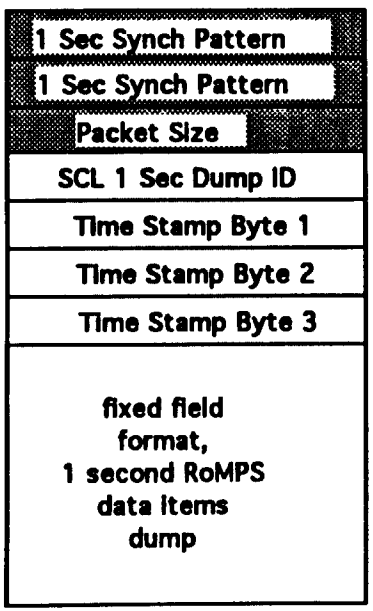


example of SCL-Command Packet for
exectute SPS at 12:00:00 with sample_id

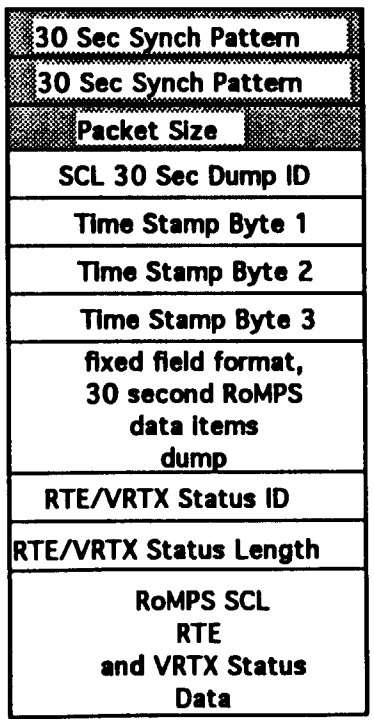
RoMPS Telemetry Downlink Protocols

SCL 1 Second, 30 Second and Asynchronous Downlink Packet Protocol

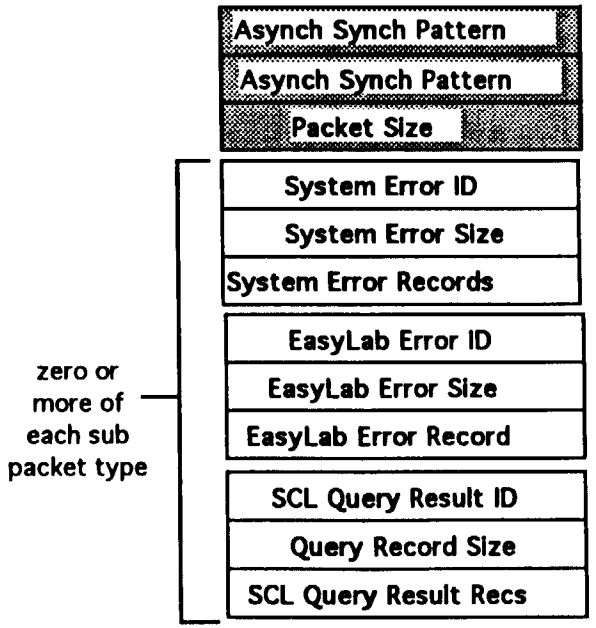




1 Second Telemetry Packet



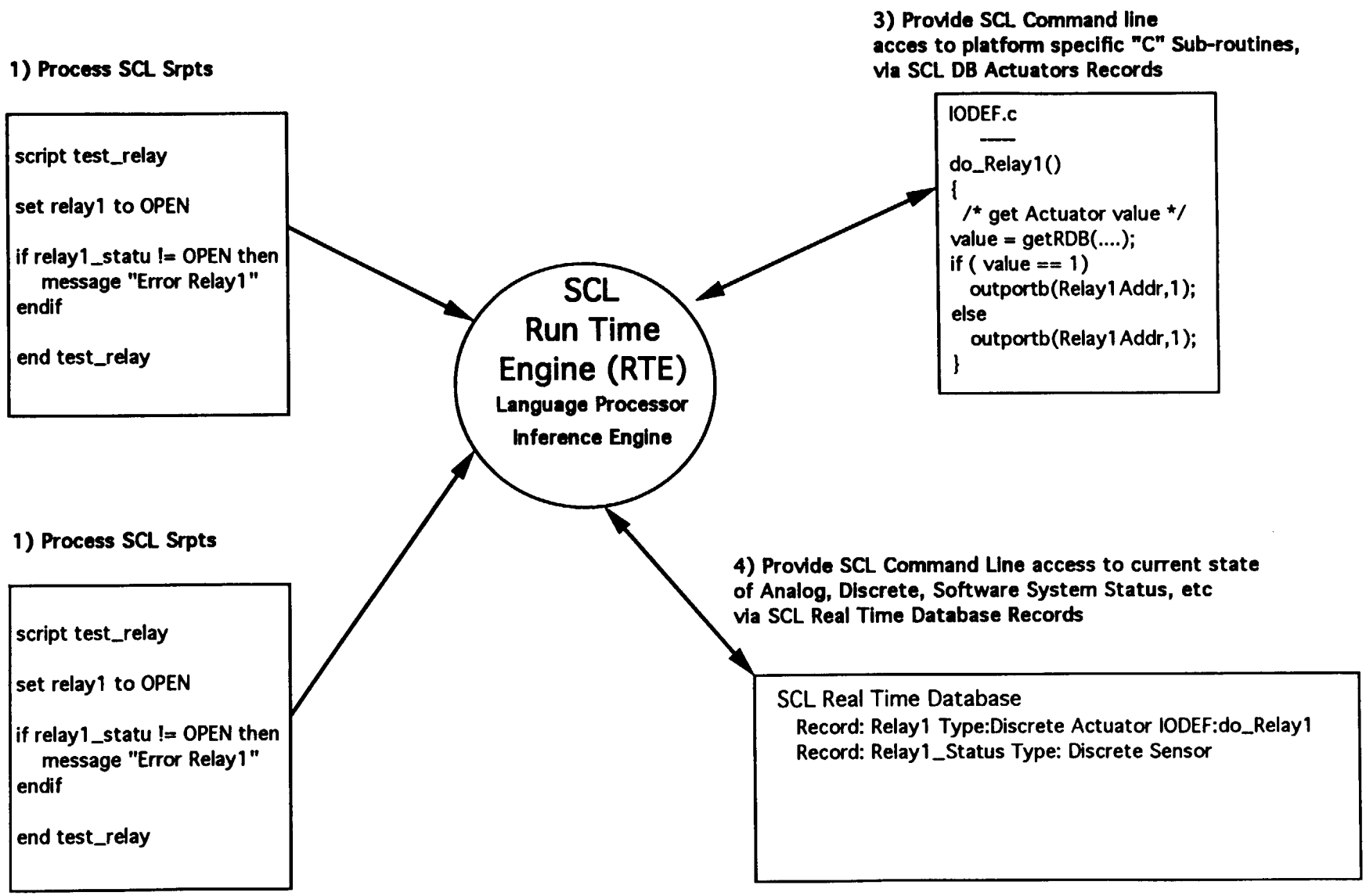
30 Second Telemetry Packet



Asynchronous Telemetry Packet

010-526	3/23/92

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 **

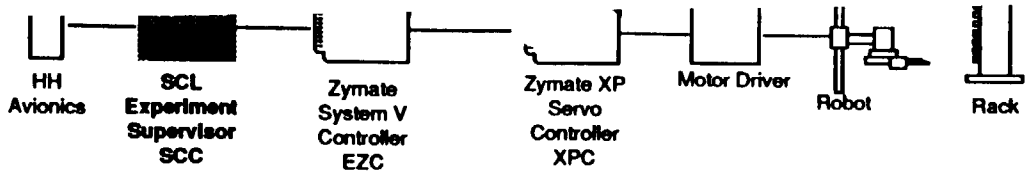
Time_Profile(x7)	Temp_Profile(x7)	Sample_ID	Rack Number
Rack_Index	SPC_Processing_Step	Proccessing_Status	Min_Cooling_Time
Max_Cooling_Time	Min_Cooling_Temp	APC_Schedule_Index	APC_Schedule_ID
APC_ParametersID			

* *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

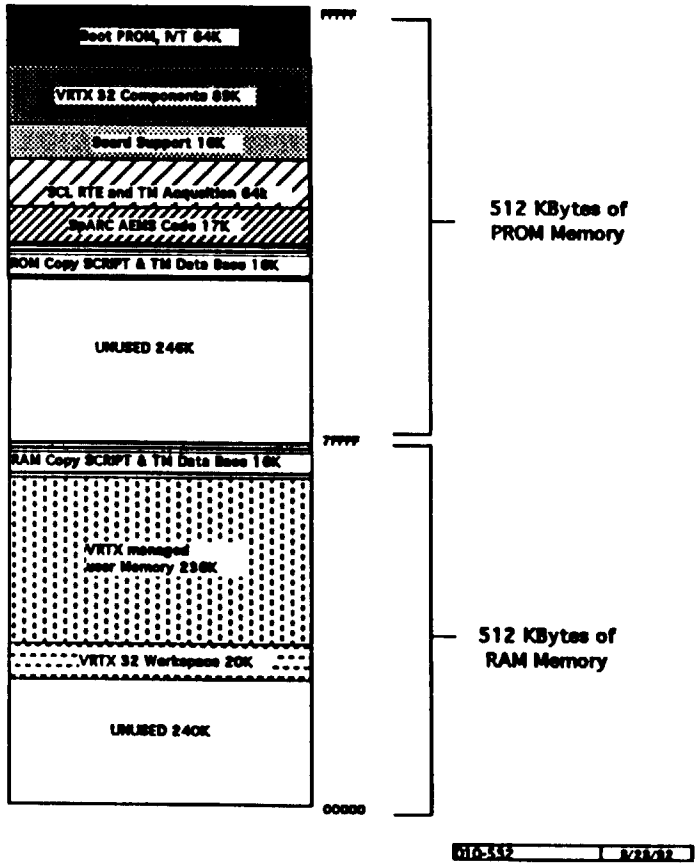
Name	Type	FUNCTION
Sample Pallet Processing Control		
InitAPCParametersX	SCRIPT	Initiallizes SCL Global Arrays with Initial Sample Processing Parameters
InitAPCScheduleX	SCRIPT	Initiallizes SCL Global Array with Initial Sample Scheduling Parameters
SPC	SCRIPT	Issues EasyLab Commands to the Robot and Furnace for Sample Processing
APC	SCRIPT	Initiallizes Processing Parameter Records used by SPC, and calls SPC fore 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
Interface with Zymate System V Controller		
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
Health and Safety/Process Control Monitoring		
Monitor_Temp_Sensor_X	RULE(x9)	Stops Autonomous Processing Cycle if monitored SCL DB Sensor X execedes Temp Range
Monitor_Current_Sensor_X	RULE(x1)	Stops Autonomous Processing Cycle if monitored SCL DB Sensor X execedes 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 excedes range
Telemetry System Control		
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
External Sub Systems Control		
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
SCL RealTime Clock Control		
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



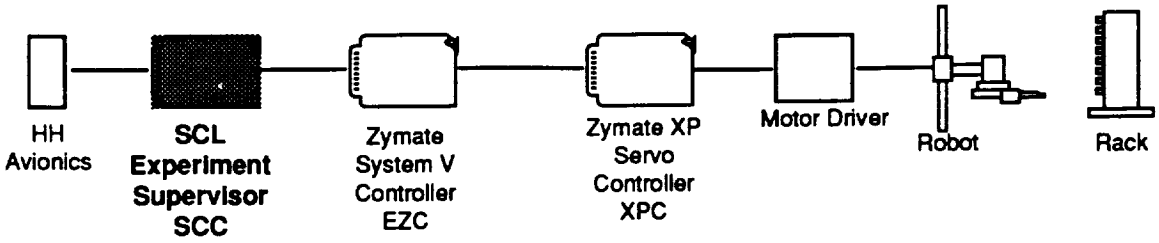
SCL SOFTWARE PERFORMANCE/MARGIN

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	3226 [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



Nominal Operation of the SCL Experiment Supervisor



UPON RESET

1) VRTX System Startup

- System Hardware (timers, UARTS, ADs, etc.) is initialized and assocciated and Interupt Service Routines initiallized
- Call VRTX initiallization 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
- Initiallize Telemetry Log Data Structures used for buffering System Error, SCL Message, and 1 and 30 Second TM packets
- Initiallize 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 Telemetery 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 Reducition, and evaluate any Rules whose associated predicate SCL Database Records have changed

Command Input

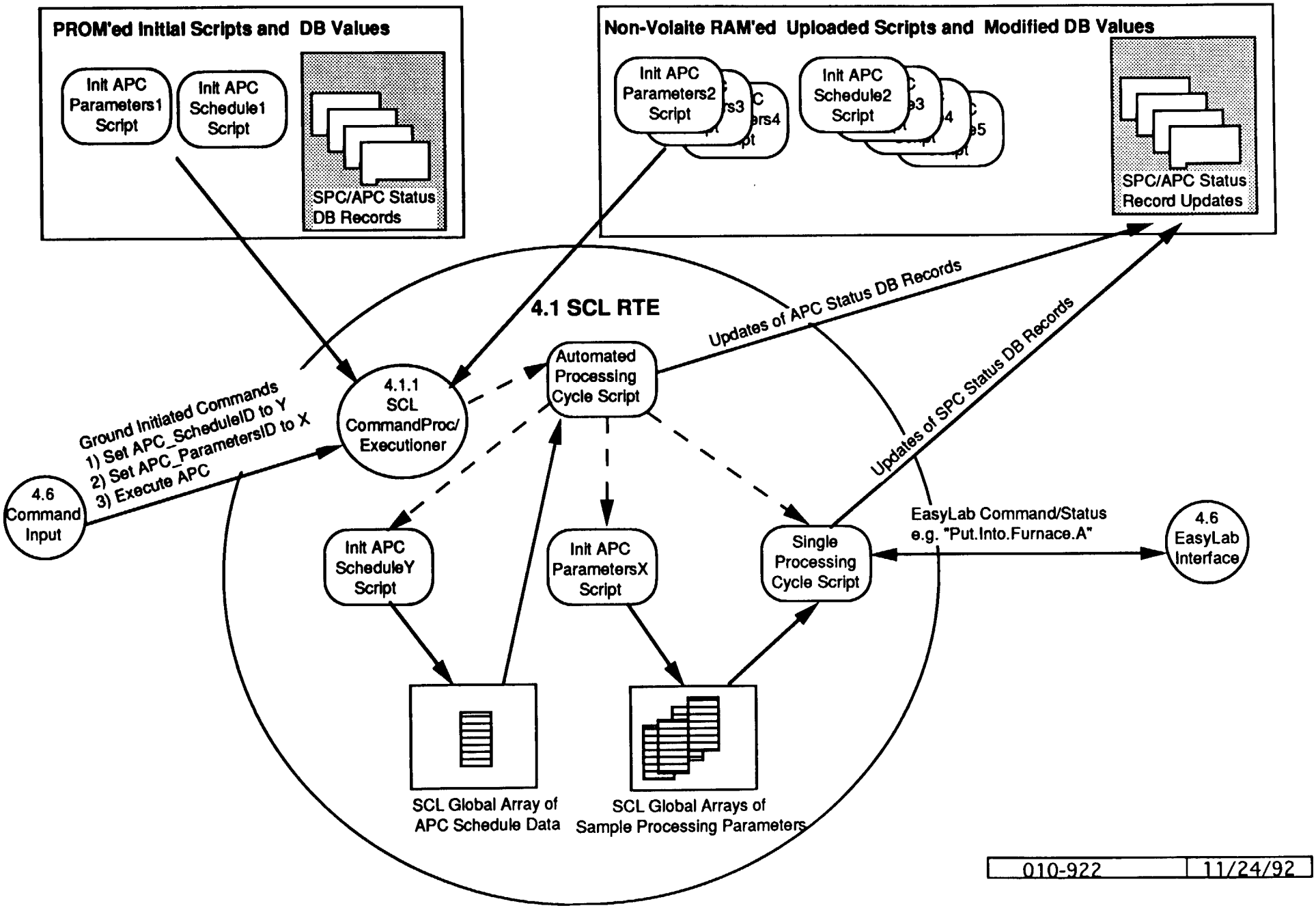
- Get HH Packets from Hitchhiker System, 1 character at a time, strip off Hitchhiker protocol wrapper, and post to Uplink Packet Queue.

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

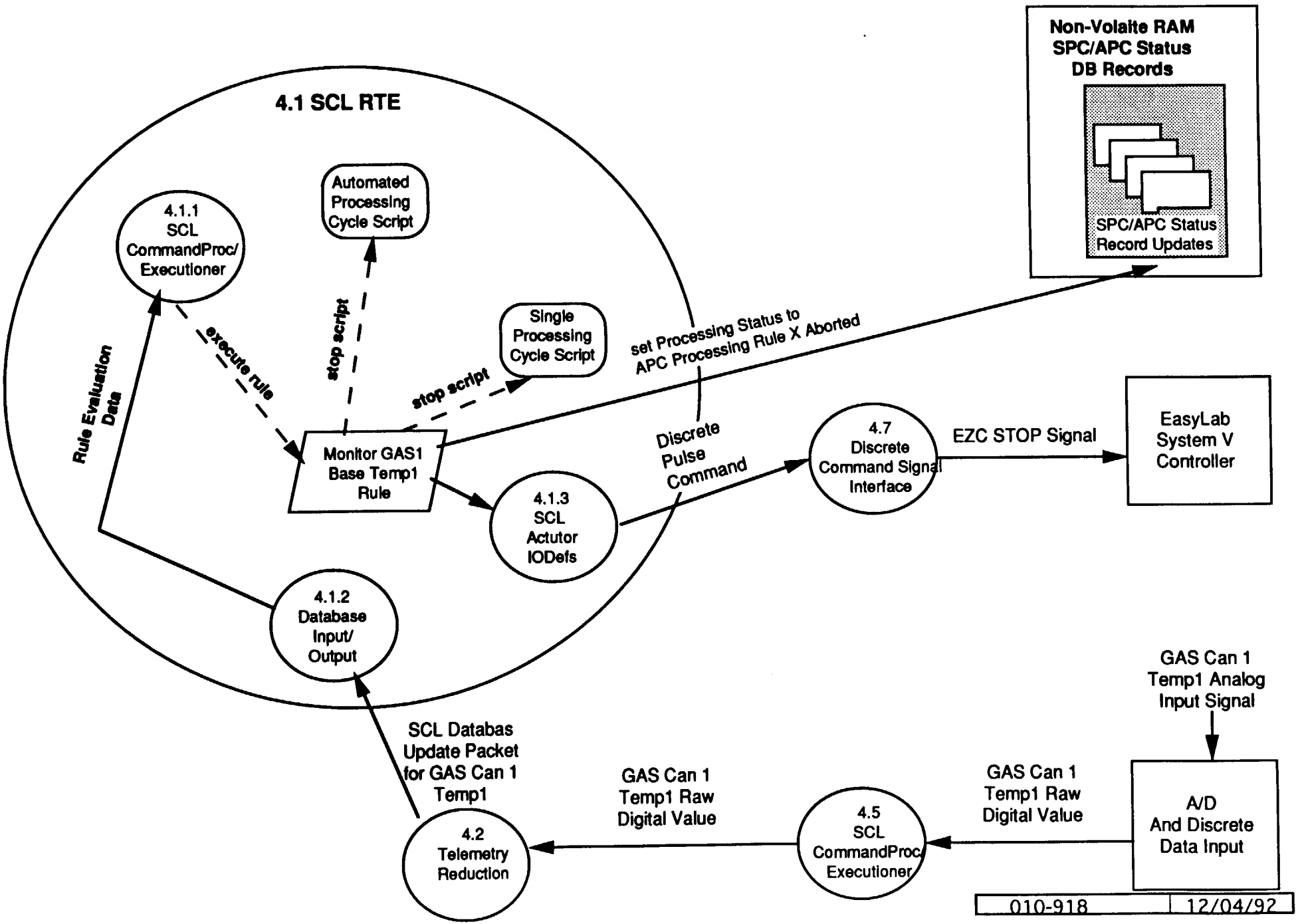
End Loop

SCL Script Automated Sample Processing Overview



010-922	11/24/92

Rule Based Automated Process..ıg Script Shutdown Overview



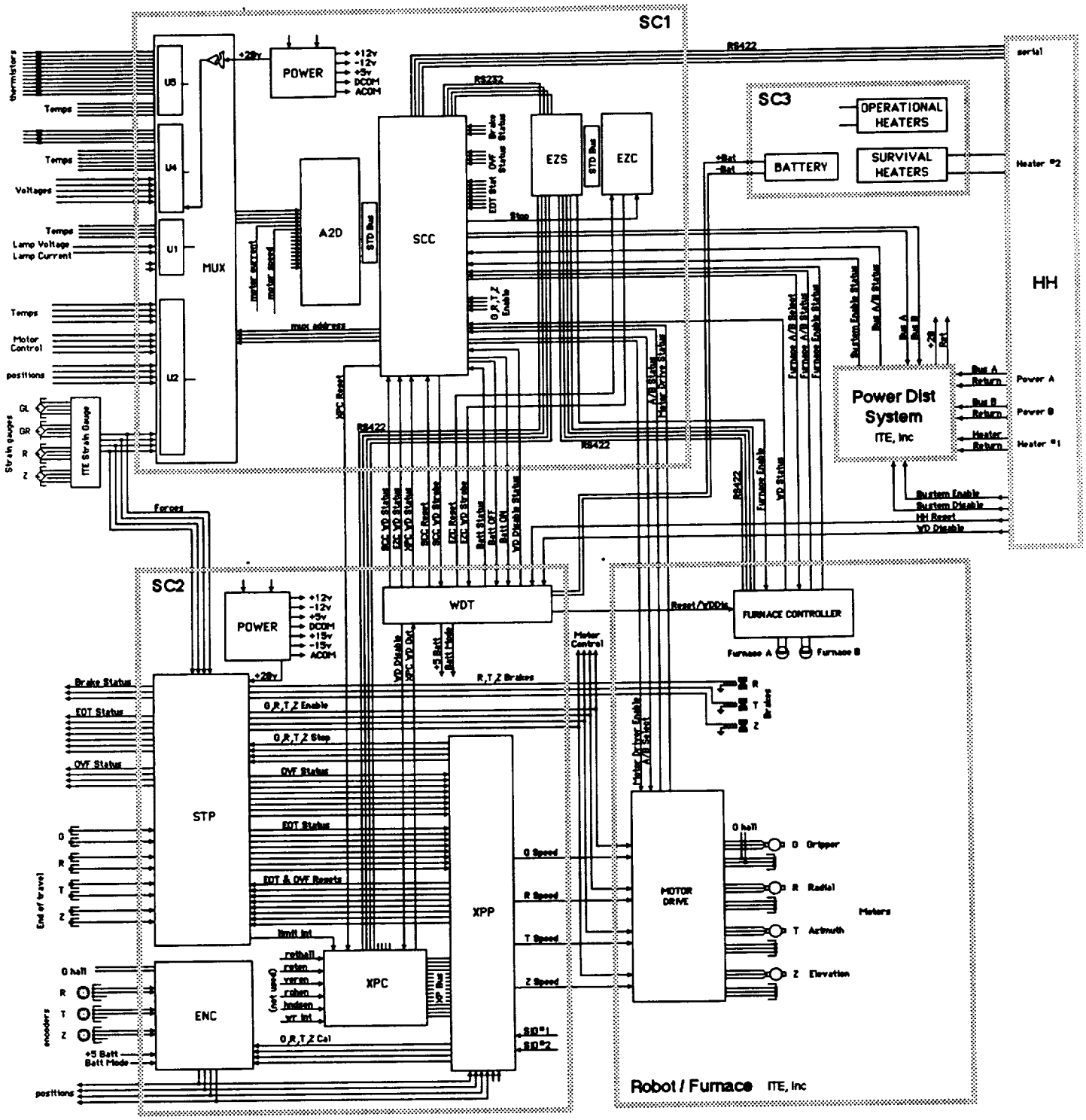
Monitor_GAS1_Base_Temp1 Rule

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

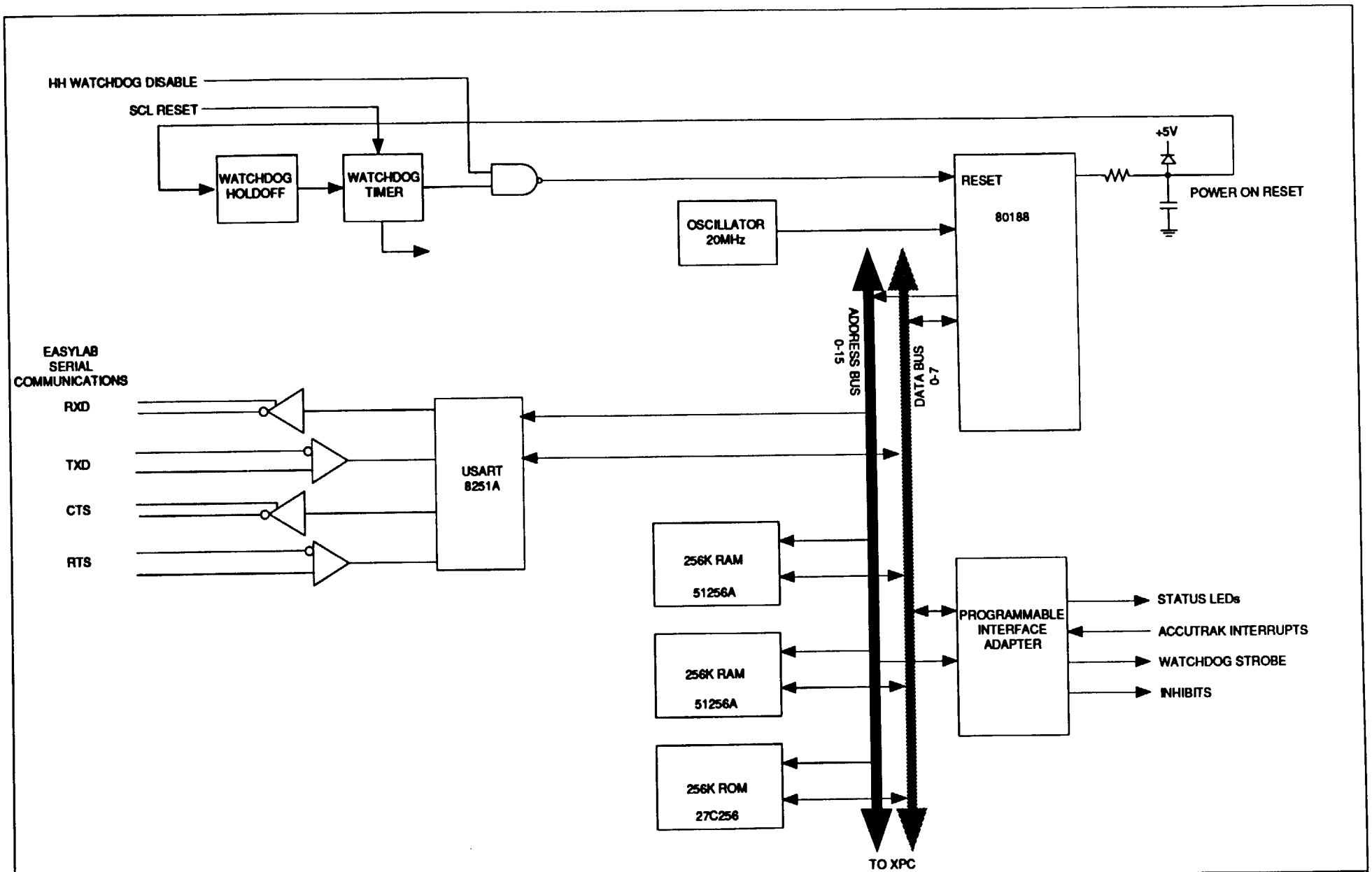
```
rule          Monitor_GAS1_BaseTemp1
subsystem     SYS
priority      15                        -- This rule preamble determines
activation    yes                       -- how and when this rule
continuous    yes                       -- is evaluated by Run Time Engine

If  GAS1_BaseTemp1 > MAX_GAS1_BASE_TEMP then
        stop APC
        stop SPC
        if (SPC_ProcessingStatus <> COMPLETE) then
                set SPC_ProcessingStatus to GAS1_BASETEMP1_SHUTDOWN
        endif
endif


end Monitor_GAS1_BaseTemp1
```

RoMPS Connection Diagram

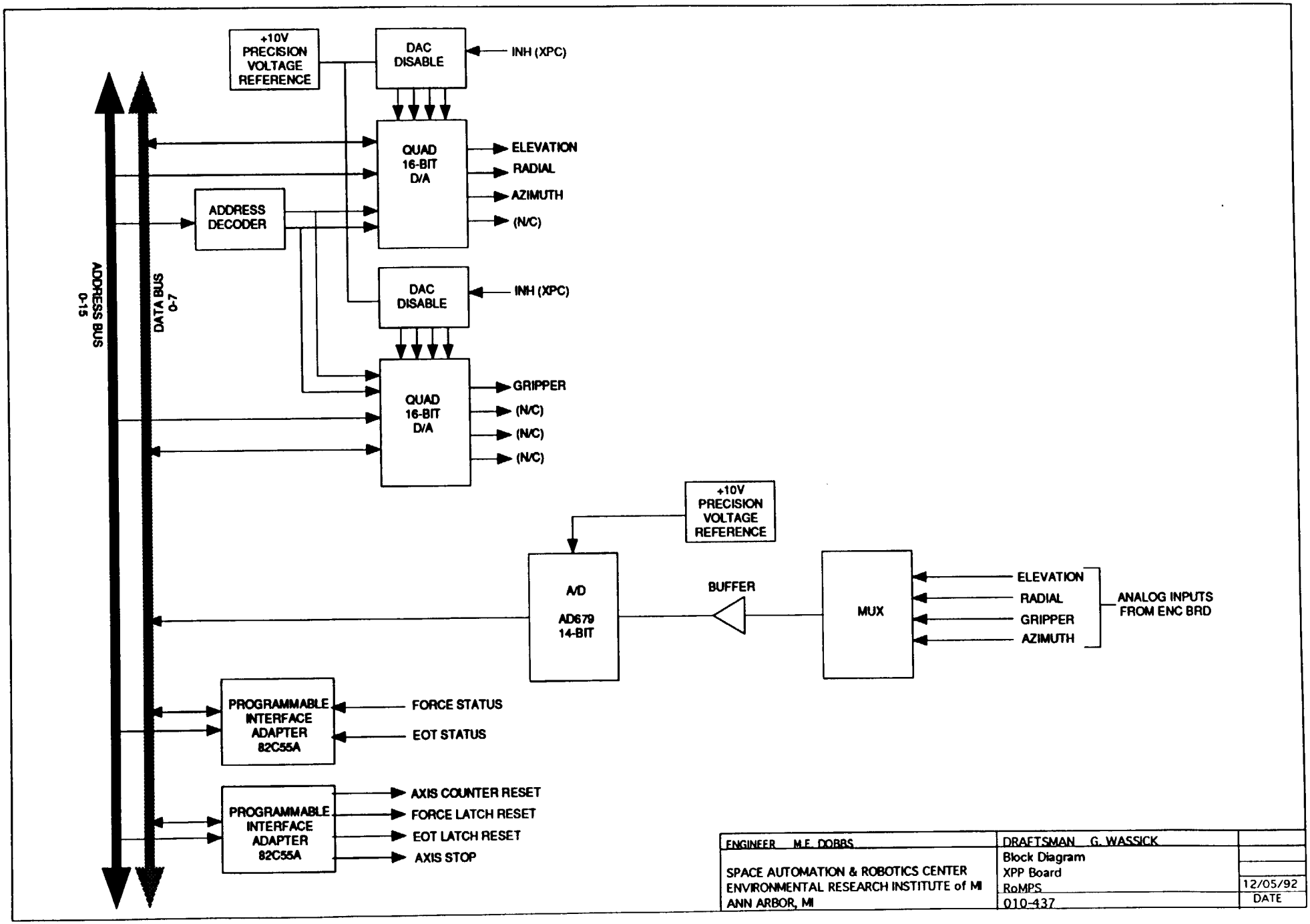
12/5/92 GD rev C



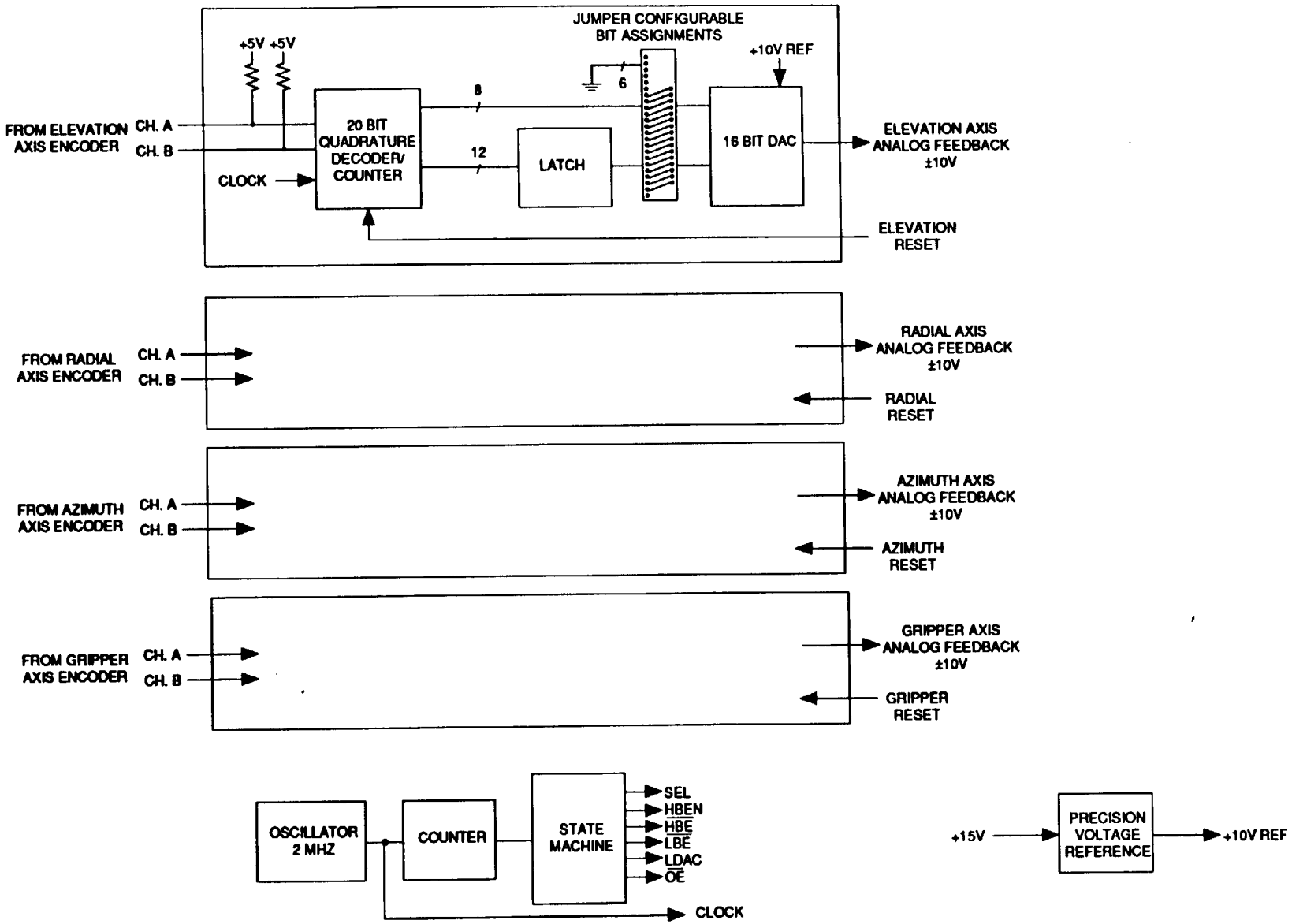
010-814 rev C	12/5/92



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

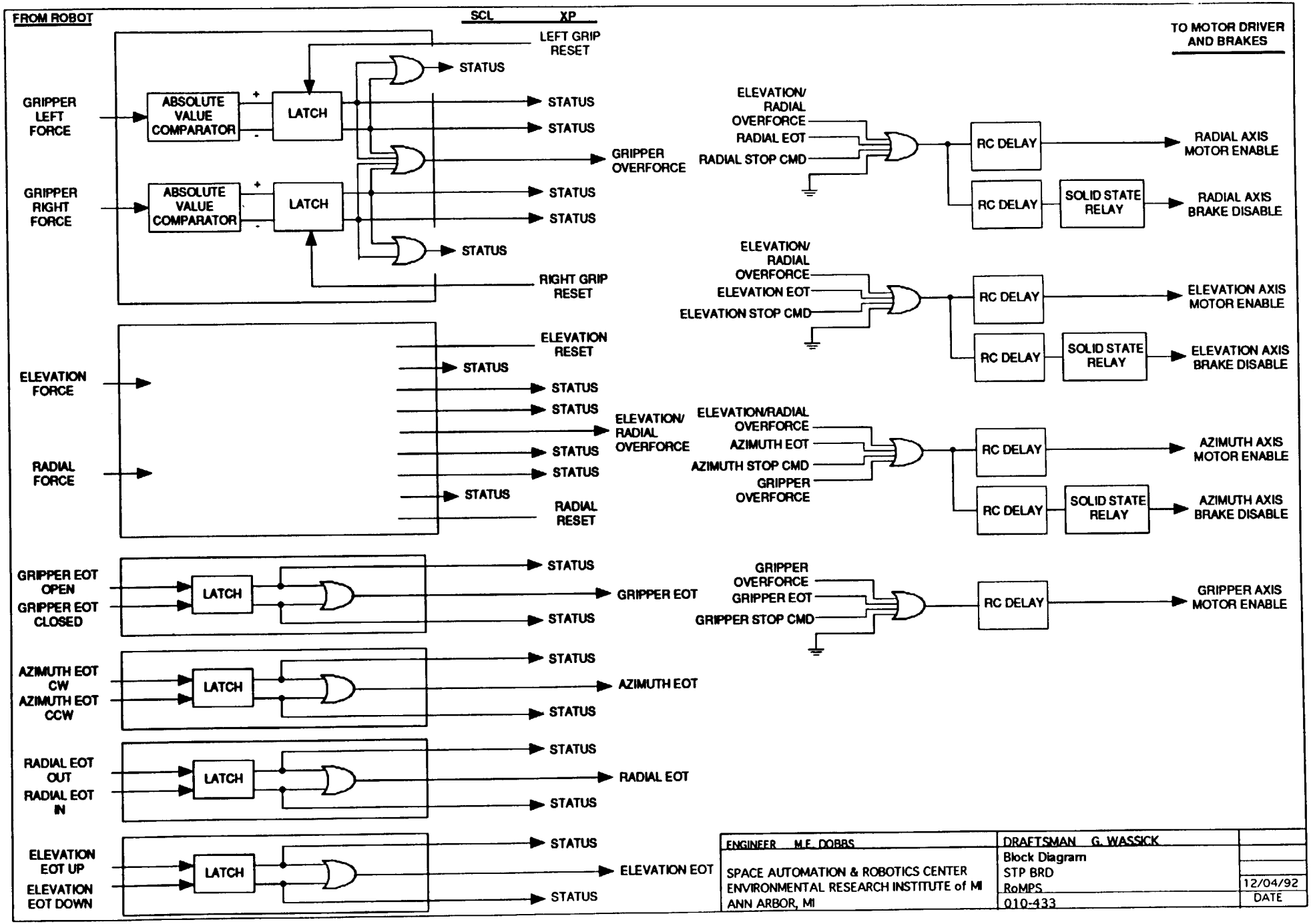


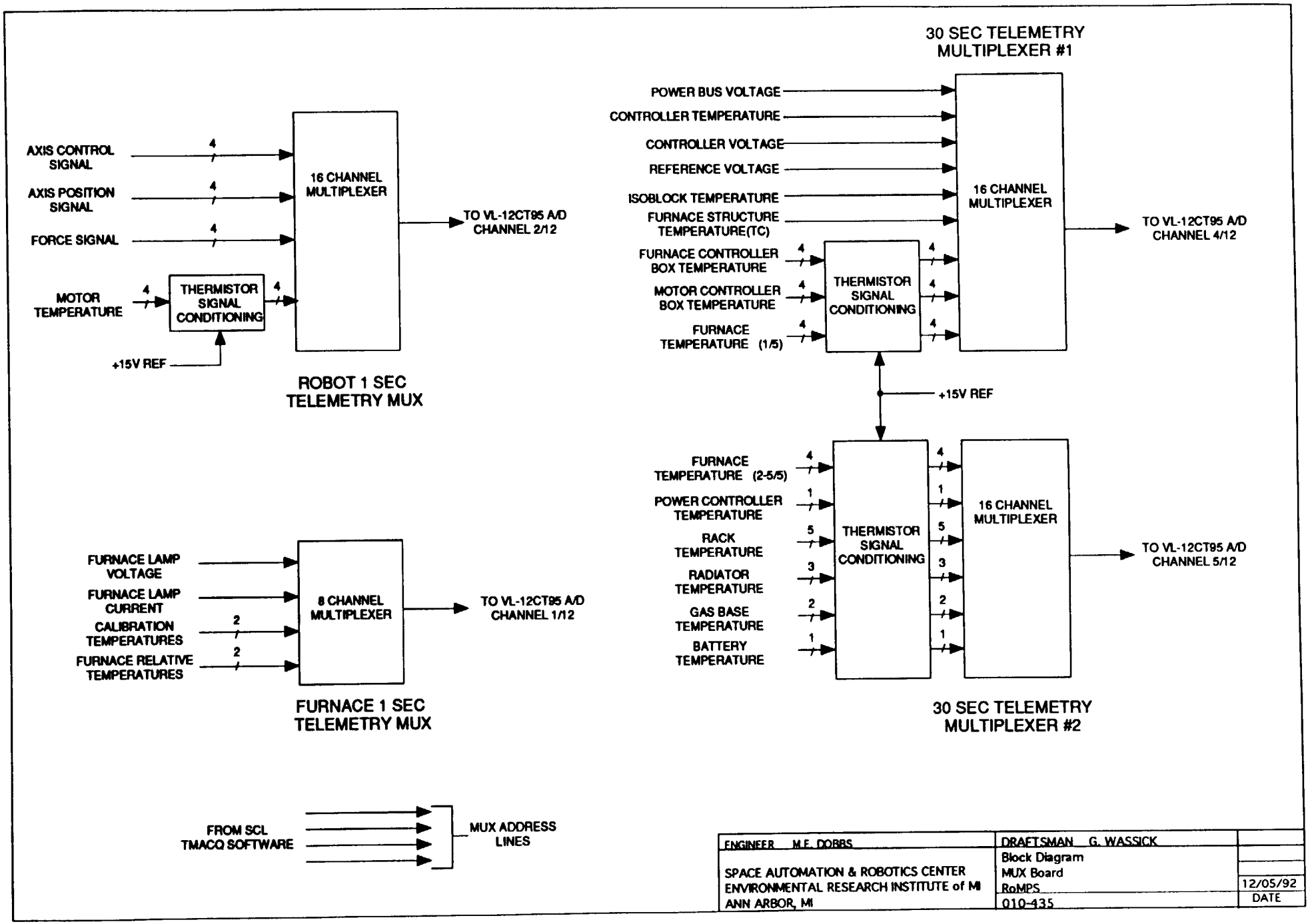
ENGINEER M.E. DOBBS	DRAFTSMAN G. WASSICK	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	Block Diagram XPP Board RoMPS 010-437	12/05/92 DATE



MAX COUNT RATE = 14MHz
UPDATE RATE = 8μSec

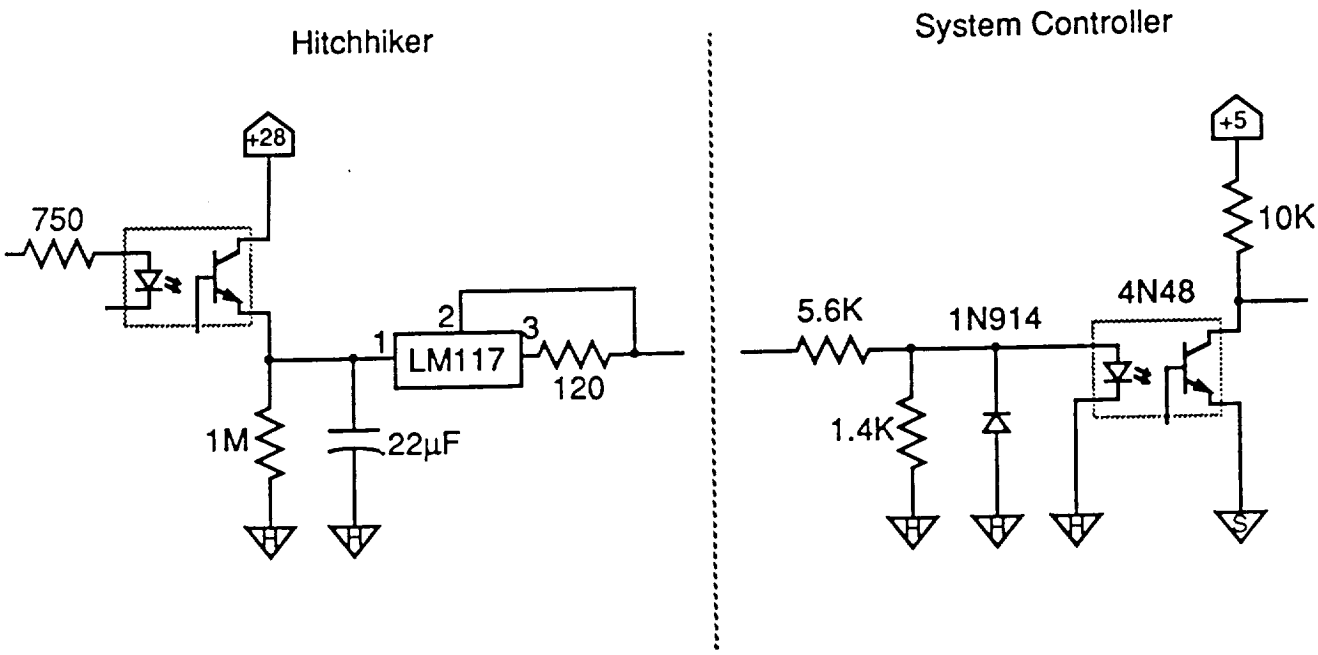
ENGINEER M.E. DOBBS	DRAFTSMAN G. WASSICK	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	Block Diagram ENC Board RoMPS 010-434	12/04/92 DATE


FROM ROBOT
SCL
XP
TO MOTOR DRIVER AND BRAKES
LEFT GRIP RESET
STATUS
GRIPPER LEFT FORCE
ABSOLUTE VALUE COMPARATOR
LATCH
GRIPPER OVERFORCE
GRIPPER RIGHT FORCE
RIGHT GRIP RESET
ELEVATION/ RADIAL OVERFORCE
RADIAL EOT
RADIAL STOP CMD
RC DELAY
SOLID STATE RELAY
RADIAL AXIS MOTOR ENABLE
RADIAL AXIS BRAKE DISABLE
ELEVATION EOT
ELEVATION STOP CMD
ELEVATION AXIS MOTOR ENABLE
ELEVATION AXIS BRAKE DISABLE
ELEVATION RESET
ELEVATION FORCE
RADIAL FORCE
RADIAL RESET
ELEVATION/RADIAL OVERFORCE
AZIMUTH EOT
AZIMUTH STOP CMD
GRIPPER OVERFORCE
AZIMUTH AXIS MOTOR ENABLE
AZIMUTH AXIS BRAKE DISABLE
GRIPPER EOT OPEN
GRIPPER EOT CLOSED
GRIPPER EOT
GRIPPER STOP CMD
GRIPPER AXIS MOTOR ENABLE
AZIMUTH EOT CW
AZIMUTH EOT CCW
AZIMUTH EOT
RADIAL EOT OUT
RADIAL EOT IN
RADIAL EOT
ELEVATION EOT UP
ELEVATION EOT DOWN
ELEVATION EOT
ENGINEER M.F. DOBBS
SPACE AUTOMATION & ROBOTICS CENTER
ENVIRONMENTAL RESEARCH INSTITUTE of MI
ANN ARBOR, MI
DRAFTSMAN G. WASSICK
Block Diagram
STP BRD
RoMPS
010-433
12/04/92
DATE

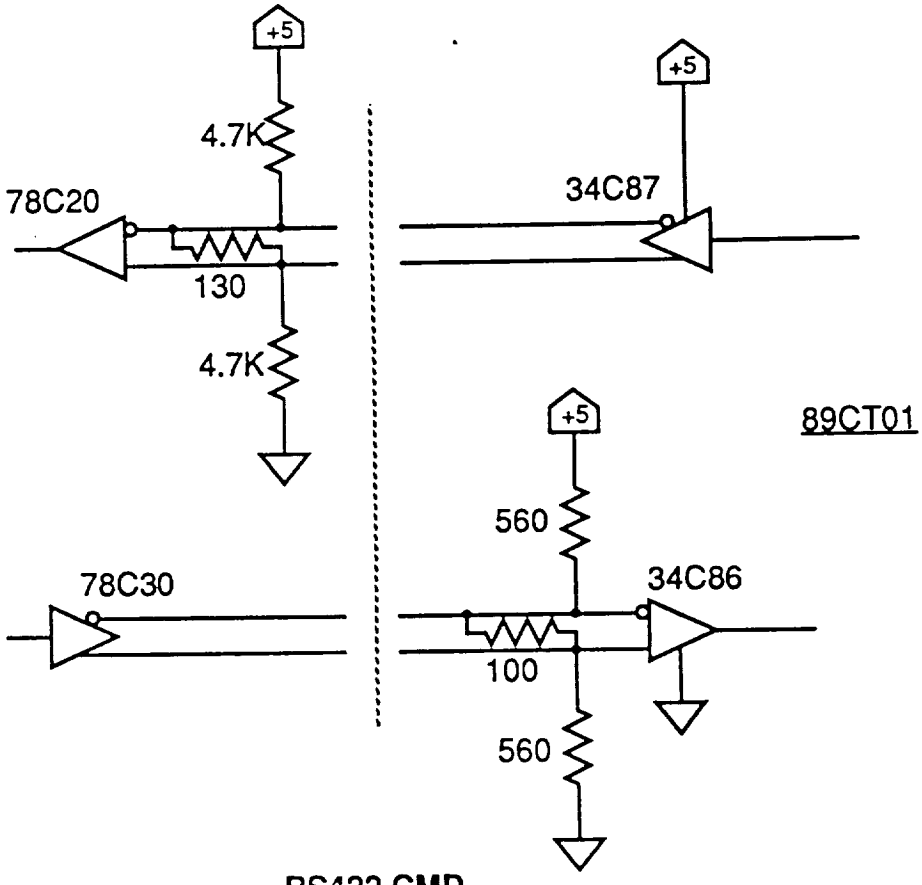


ENGINEER M.E. DOBBS	DRAFTSMAN G. WASSICK	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	Block Diagram MUX Board RoMPS 010-435	12/05/92 DATE

ROMPS Hitchhiker/System Controller Interfaces



BILEVEL CMD



RS422 CMD

12/7/92 GD rev C

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

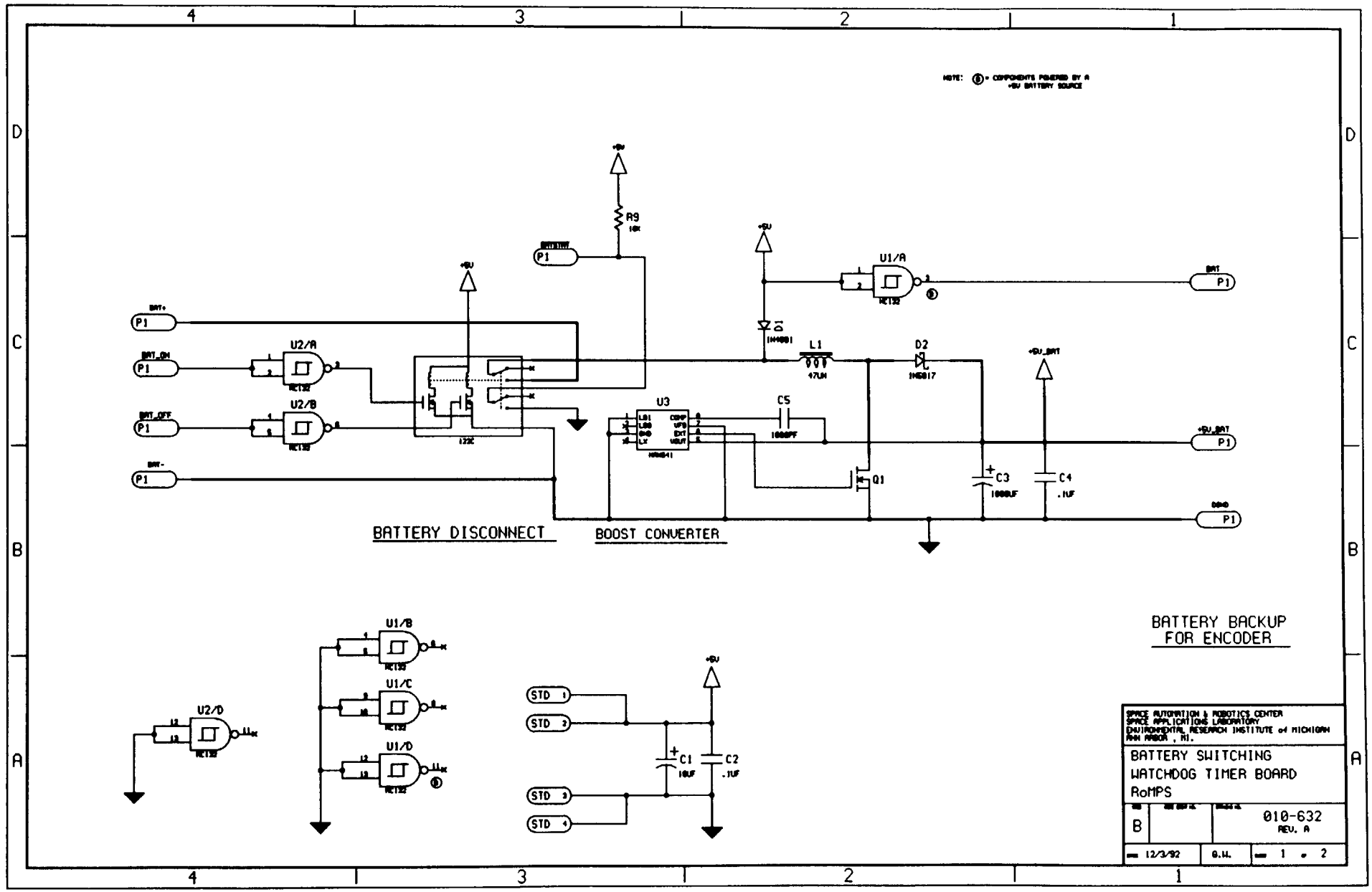
OP MODE	Constant Current @ 110 uAmps Intermittent Duty - Static Memory Backup
CAP	est @ 800 mAh at final integration and test
OP TIME	> 8,45 hours with single cell cell capacity at EOL
PROTECTION	Two Fault Tolerant hot side current limiting resistor hot side diodes
SHORT CKT	30mA ~ (3.6-0.3) / 100 @BOL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

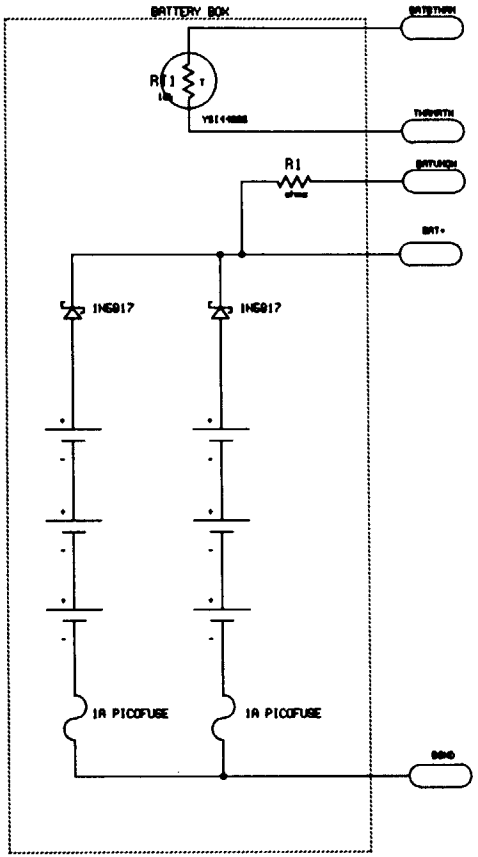
ALKALINE-MANGANESE DIOXIDE BATTERY

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 watthours

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 cell capacity at EOL current requirement
PROTECTION	Two Fault Tolerant ground leg fuse hot side diodes
SHORT CKT	14 amp ~ ((3*1.5)-0.4) / (3*0.1) BOL 1 amp ~ ((3*0.8)-0.4) / (3*0.8) EOL
FUSE	2 Amp Fuse is ~3X Load at EOL


NOTE: ⓑ = COMPONENTS POWERED BY A +5V BATTERY SOURCE
R9
U1/A
U2/A
U2/B
U3
L1
D2
C5
C3
C4
Q1
BATTERY DISCONNECT
BOOST CONVERTER
U1/B
U1/C
U1/D
U2/D
C1
C2
BATTERY BACKUP FOR ENCODER
SPACE AUTOMATION & ROBOTICS CENTER
SPACE APPLICATIONS LABORATORY
ENVIRONMENTAL RESEARCH INSTITUTE of MICHIGAN
ANN ARBOR, MI.
BATTERY SWITCHING
WATCHDOG TIMER BOARD
RoMPS
B
010-632
REV. A
12/3/92
G.W.
1 of 2



CELL:

MFGR: DURACELL
MODEL: SIZE D
SPEC: ANSI 13A
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: -20C to +54C
STOR TEMP: -40C to +64C
SHELF LIFE: 4% Loss per Year
INT RES: 0.1 Ohm
SHORT CKT: est @ 15A w/o Protection
PRESCREENED FOR LEAKAGE

SPACE AUTOMATION & ROBOTICS CENTER
SPACE APPLICATIONS LABORATORY
ENVIRONMENTAL RESEARCH INSTITUTE of MICHIGAN
ANN ARBOR , MI.

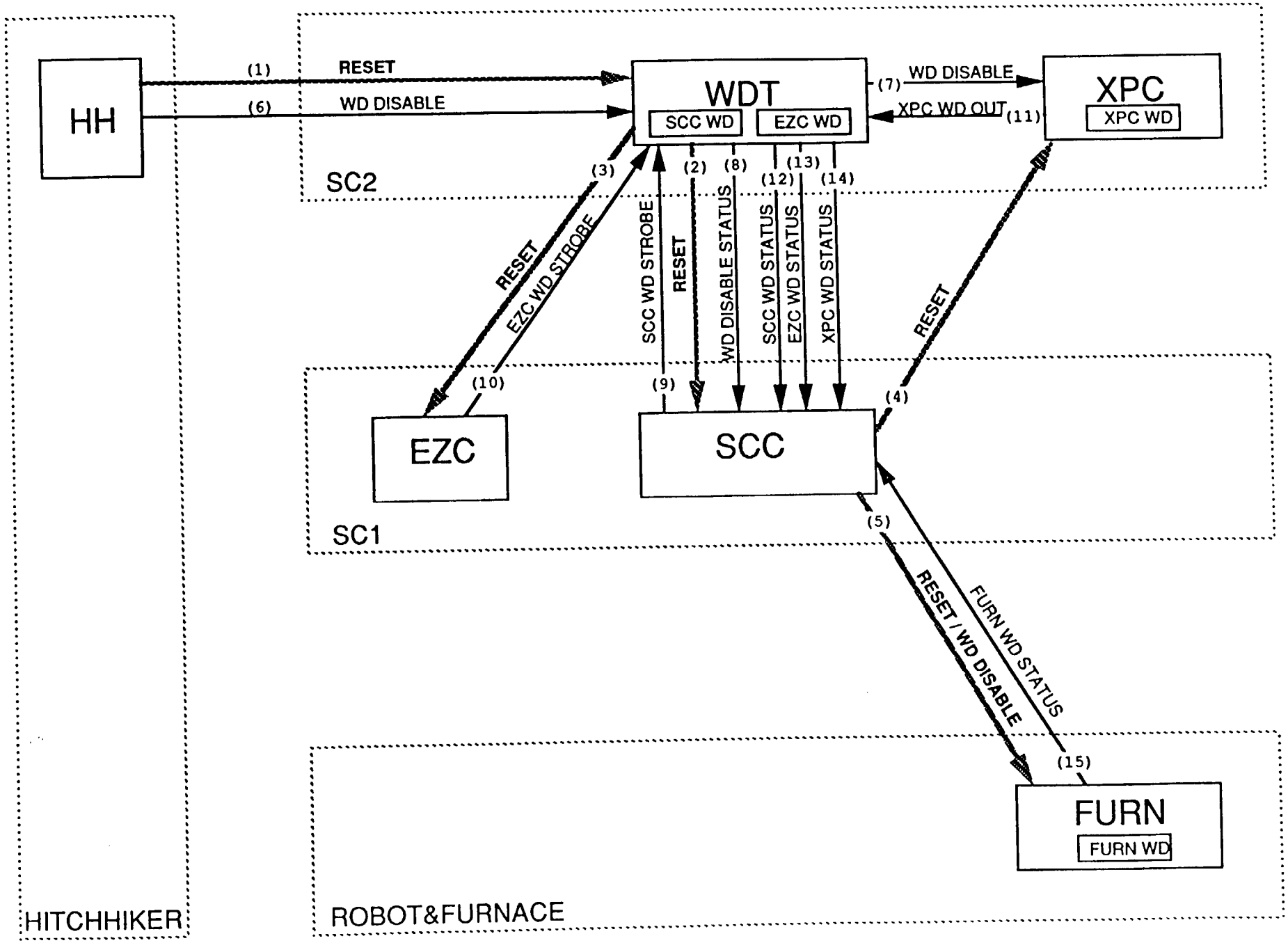
BATTERY SOURCE
BATTERY BOX
RoMPS

010-638
REV. B

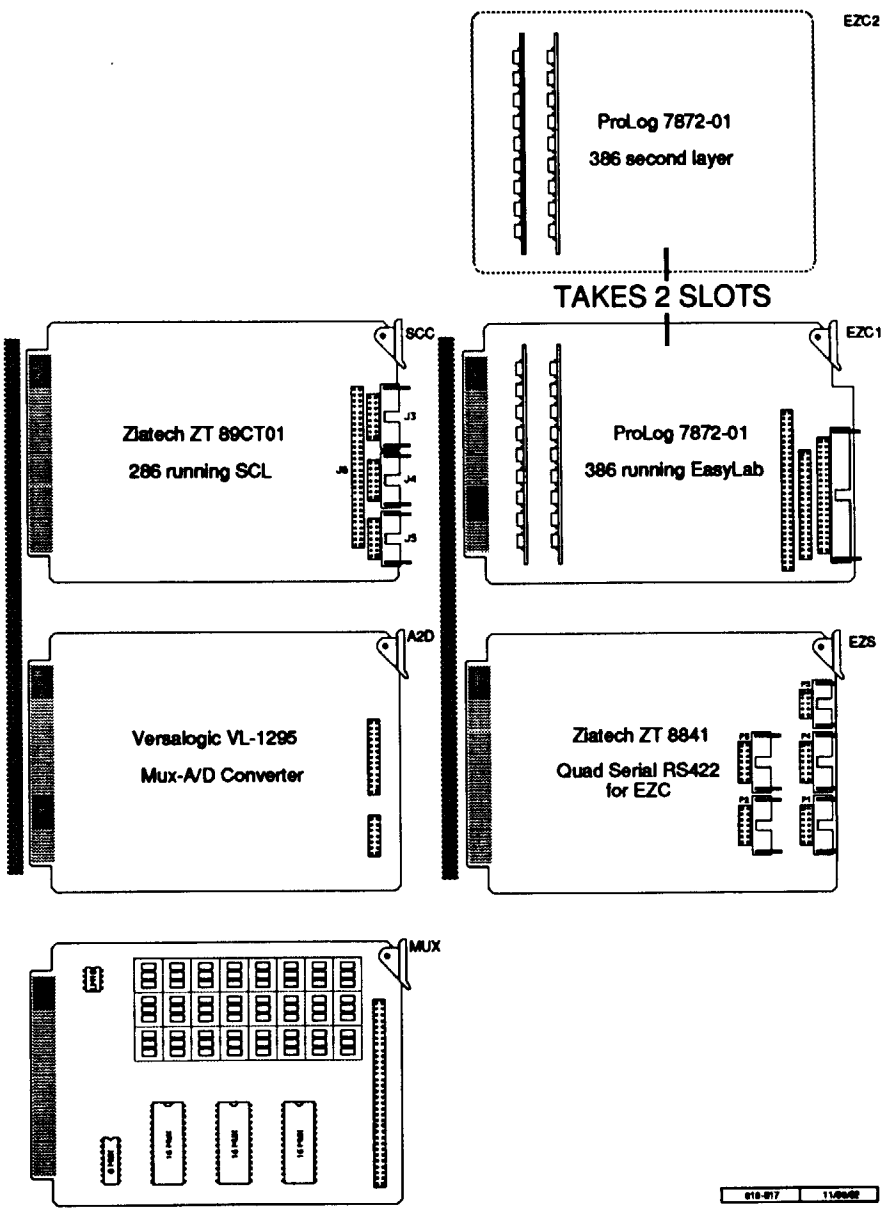
12/7/92 | G.W. | 1 of 1

ROMPS Reset and Watchdog Timer Signals

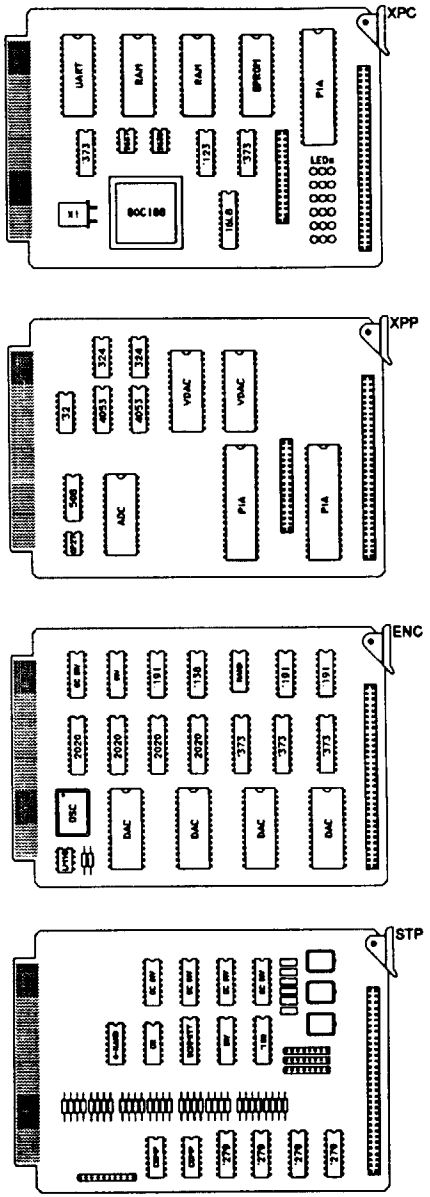
12/5/92 GD Rev B

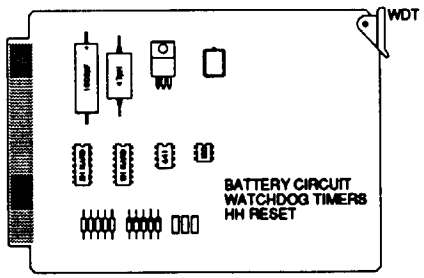


SC1 Boards



SC2 Boards

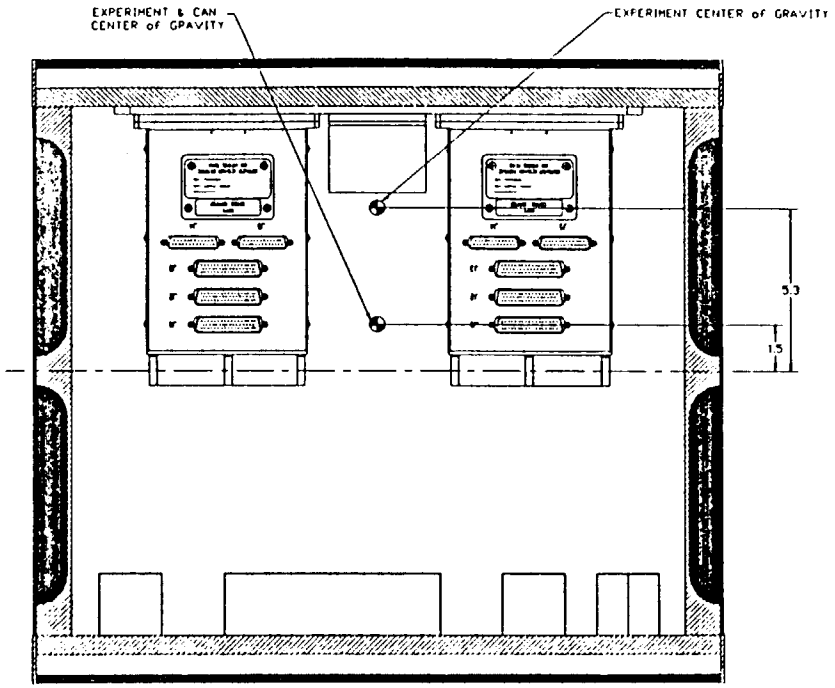


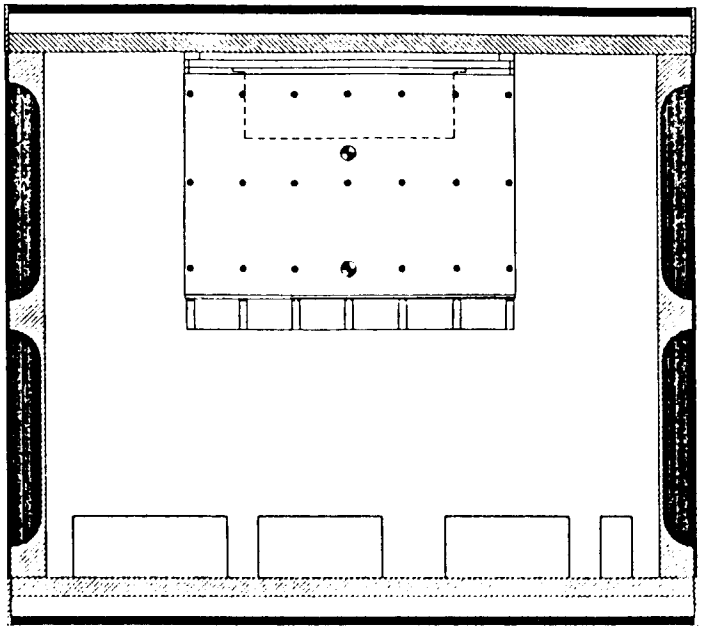


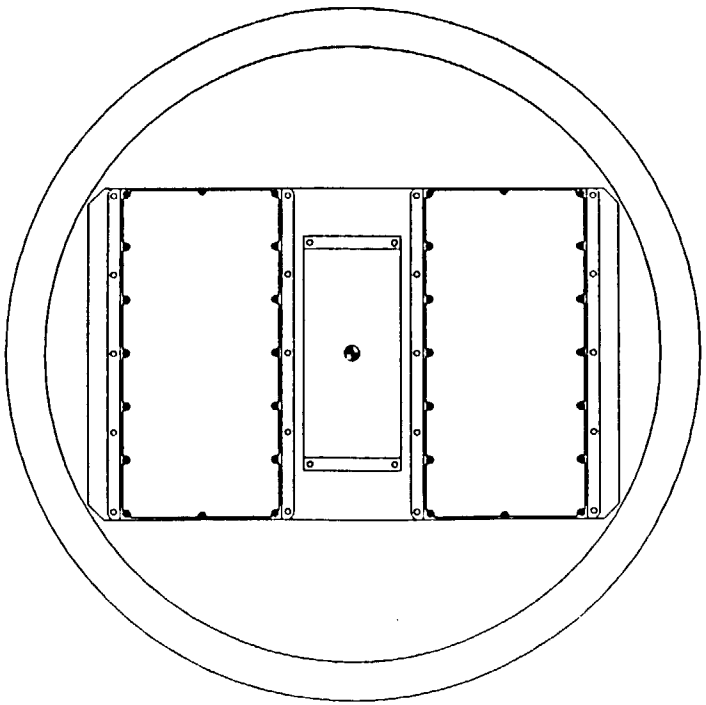
SpARC
Space Automation
& Robotics Center

CONTROL SYSTEM DESIGN
WEIGHT & POWER SUMMARY

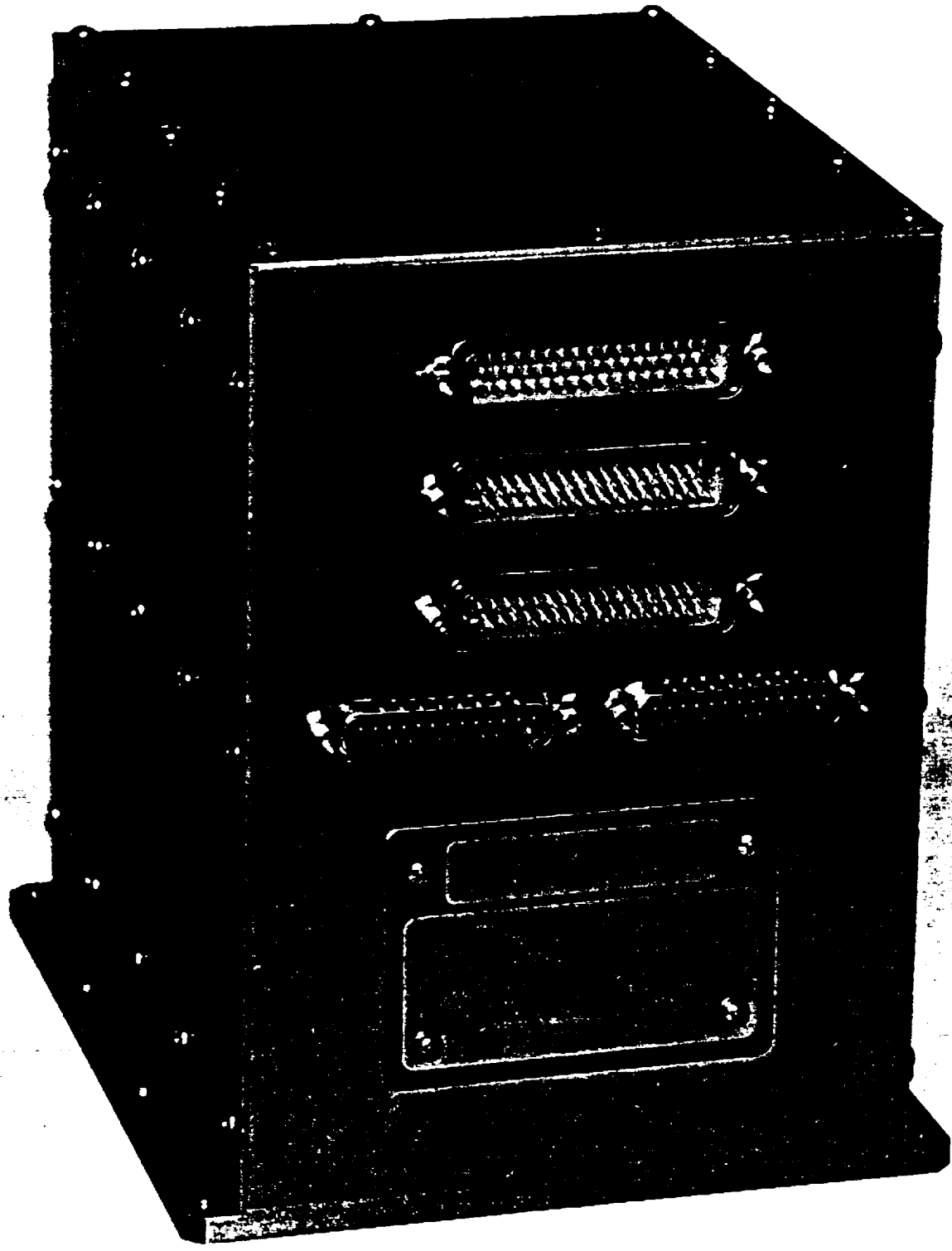
ITEM	SIZE	MASS	POWER
SUBASSEMBLY A	10.4 X 5.8 X 8.6	10 LBS	9.4 AVG
SCC PROCESSOR			
A2D ANALOG TO DIGITAL CONVERTER			
MUX SINGLE CONDITIONING			
EZC PROCESSOR			
SUBASSEMBLY B	10.4 X 5.8 X 8.6	10 LBS	12.0 AVG
XPC PROCESSOR			
ENC ENCODER INTERFACE			
XPP OUTPUT INTERFACE			
STP STOP CONTROL			
WATCHDOG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

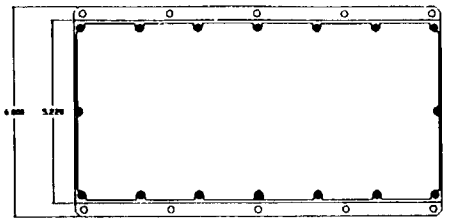


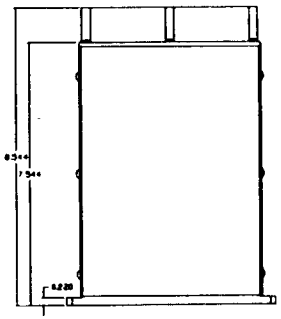


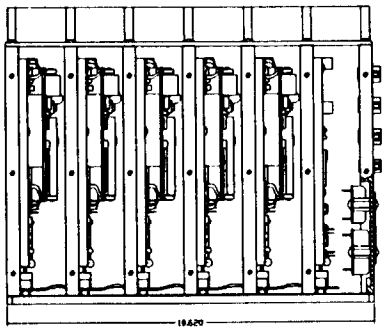


ENGINEER R.E. QUADA	DRAFTPERSON N.J. THOMAS	UNITS: INCHES	
	EXPERIMENT LAYOUT	TOLERANCES	
SPACE AUTOMATION & ROBOTICS CENTER	& CENTER OF GRAVITY	UNLESS SPECIFIED:	
ENVIRONMENTAL RESEARCH INSTITUTE of MI	ROMPS	± 0.005"	12/04/92
ANN ARBOR, MI	010-257	± 30 MINUTES	DATE

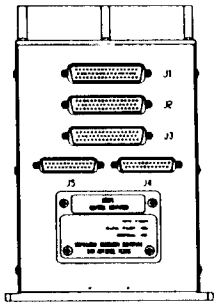


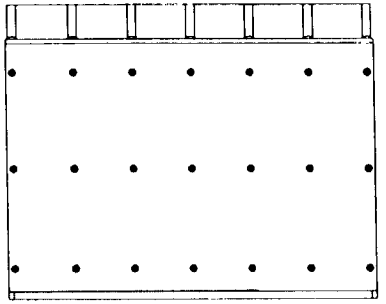


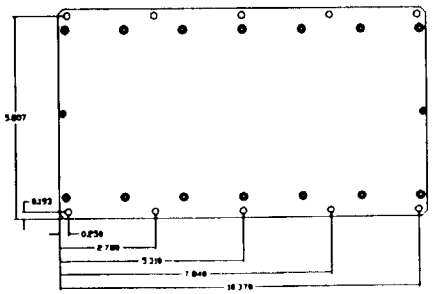




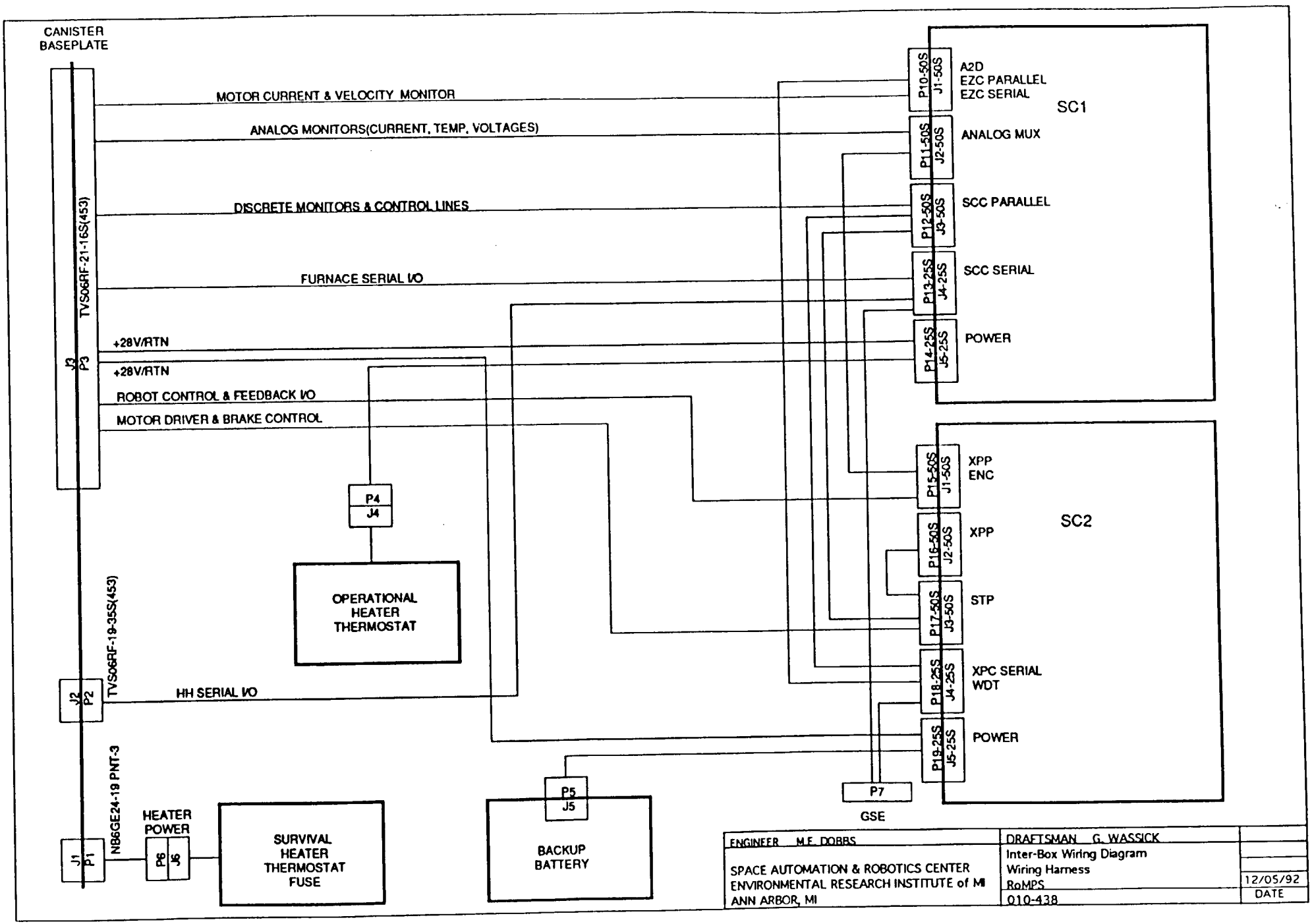
SIDE PANEL REMOVED FOR CLARITY

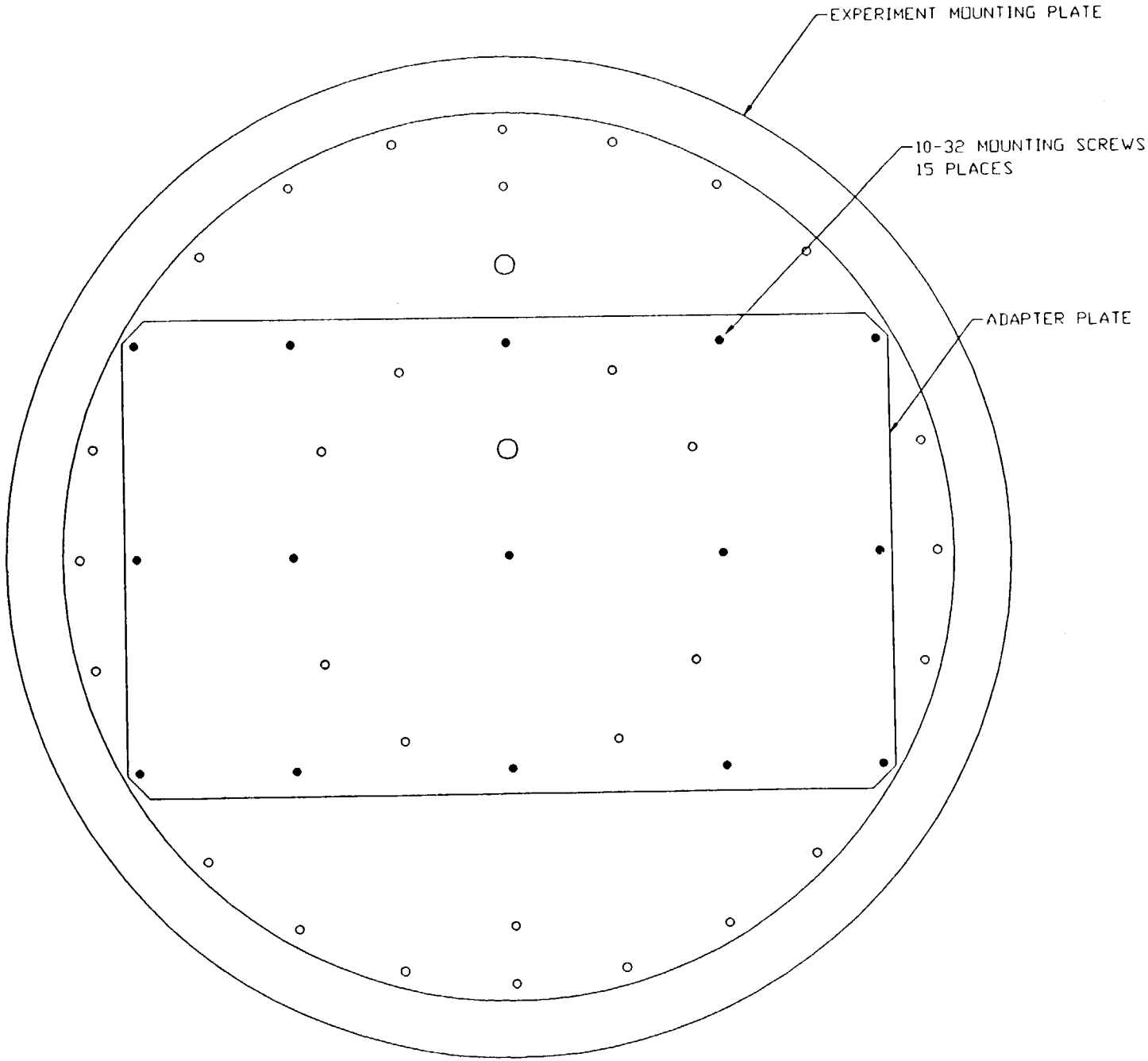






ENGINEER R.E. QUADA	DRAFTPERSON N.J. THOMAS	UNITS: INCHES	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	PAYLOAD CONTROLLER ROMPS 010-	TOLERANCES UNLESS SPECIFIED: ±0.005" ±30 MINUTES	10/30/92 DATE


CANISTER BASEPLATE
MOTOR CURRENT & VELOCITY MONITOR
ANALOG MONITORS(CURRENT, TEMP, VOLTAGES)
DISCRETE MONITORS & CONTROL LINES
FURNACE SERIAL I/O
+28V/RTN
+28V/RTN
ROBOT CONTROL & FEEDBACK I/O
MOTOR DRIVER & BRAKE CONTROL
HH SERIAL I/O
TVS06RF-21-16S(453)
J3 P3
TVS06RF-19-35S(453)
J2 P2
NB6GE24-19 PNT-3
J1 P1
HEATER POWER
P6 J6
P4 J4
OPERATIONAL HEATER THERMOSTAT
SURVIVAL HEATER THERMOSTAT FUSE
P5 J5
BACKUP BATTERY
P7
GSE
SC1
P10-50S J1-50S
A2D
EZC PARALLEL
EZC SERIAL
P11-50S J2-50S
ANALOG MUX
P12-50S J3-50S
SCC PARALLEL
P13-25S J4-25S
SCC SERIAL
P14-25S J5-25S
POWER
SC2
P15-50S J1-50S
XPP
ENC
P16-50S J2-50S
XPP
P17-50S J3-50S
STP
P18-25S J4-25S
XPC SERIAL
WDT
P19-25S J5-25S
POWER
ENGINEER M.F. DOBBS
SPACE AUTOMATION & ROBOTICS CENTER
ENVIRONMENTAL RESEARCH INSTITUTE of MI
ANN ARBOR, MI
DRAFTSMAN G. WASSICK
Inter-Box Wiring Diagram
Wiring Harness
RoMPS
010-438
12/05/92
DATE



ENGINEER R.E. QUADA	DRAFTPERSON N.J. THOMAS	UNITS INCHES	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	ADAPTER PLATE/INSTRUMENT PLATE INTERFACE ROMPS 010-258	TOLERANCES UNLESS SPECIFIED ± 0.005" ± 30 MINUTES	12/04/92 DATE

Control System Thermal Design

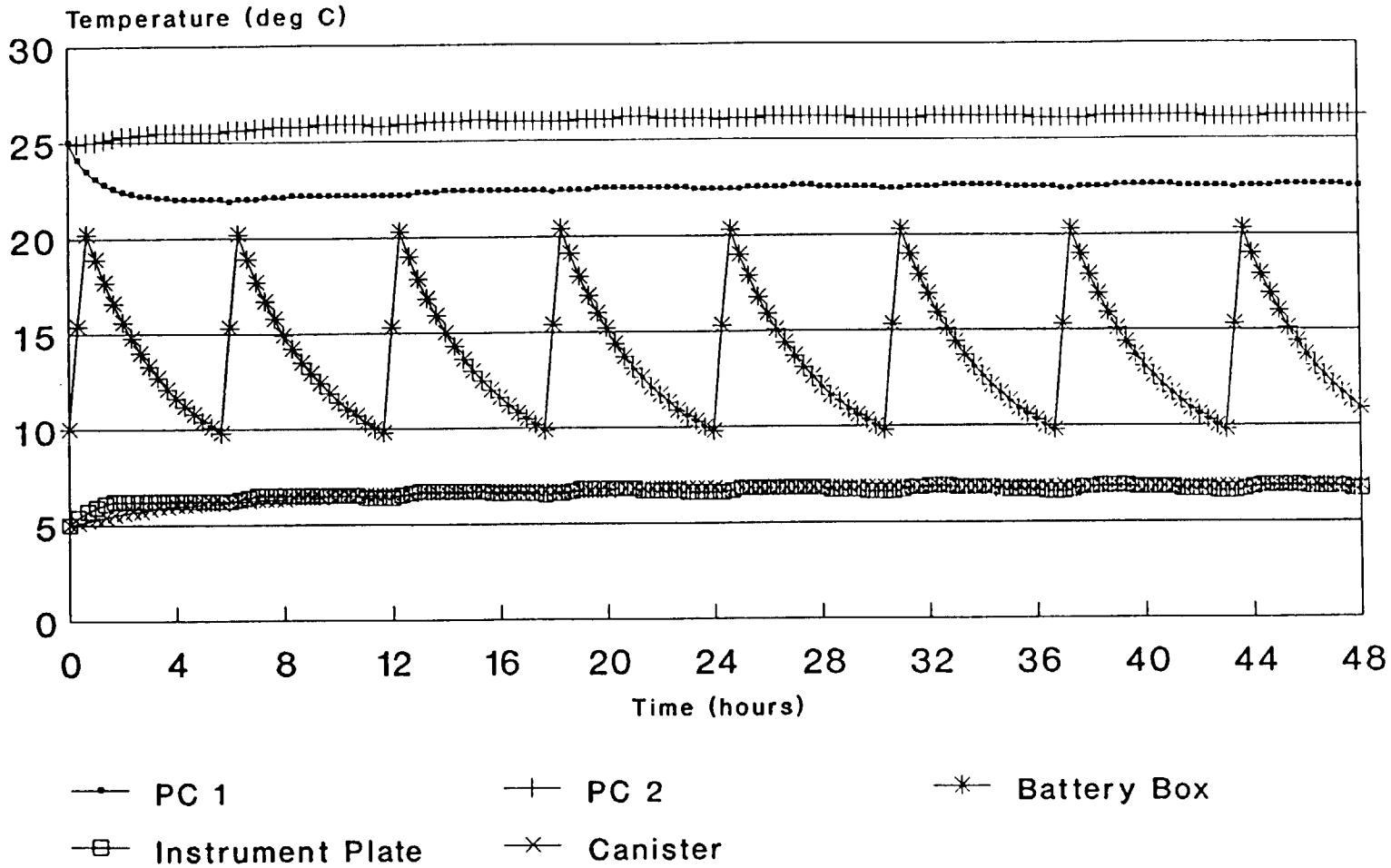
- 2.5 cu. ft. container without insulated endcap
- 1/4" G-10 spacers under payload controllers and battery box
- Payload controller and battery box external surfaces iridite
- Thermostatically controlled survival heaters on payload controllers and battery box
- Thermostatically controlled operational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

Control System Temperature Predictions
Operation

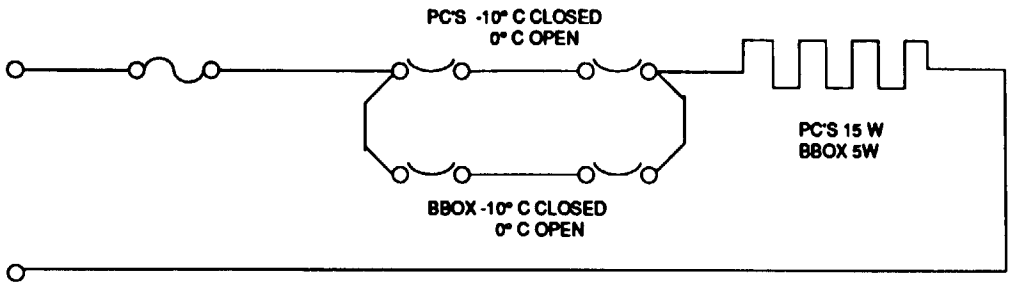
	Temperature			Avg. Heater Power		
Case	PC 1	PC 2	B.B.	PC 1	PC 2	B.B.
Hot	----------		N.A.	----------		
Moderate	31 °C	34 °C	16 °C	0.0 W	0.0 W	0.0 W
Earth view	23	26	10/20	0.0	0.0	1.0
Mod. cold	0/10	3	10/20	3.0	0.0	5.0
Cold	0/10	0/10	10/20	9.0	6.0	6.0

Control System Transient Response

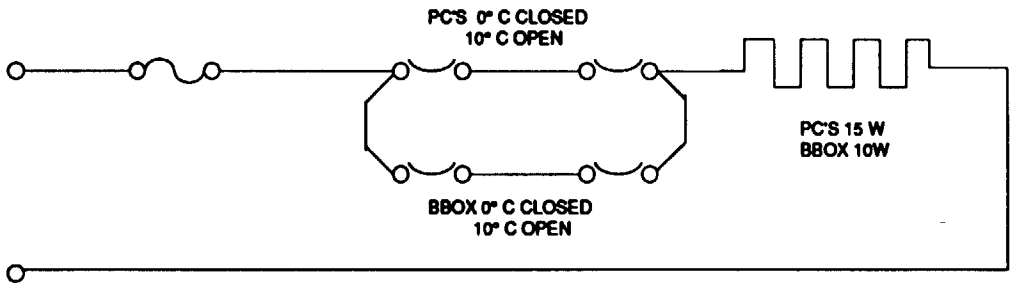
Earth Viewing; Instrument On



SURVIVAL HEATERS



OPERATIONAL HEATERS



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

Control System Mechanical Design

- Payload contoller 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

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

Fault Conditions and Responses

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

Fault Conditions and Responses

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

Fault Conditions and Responses

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

Fault Conditions and Responses

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

Fault Conditions and Responses

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

Fault Conditions and Responses

Fault	STP	XPC	EZC	SCC
XPC WatchDog	**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
EZC WatchDog	**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
SCC WatchDog	**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.

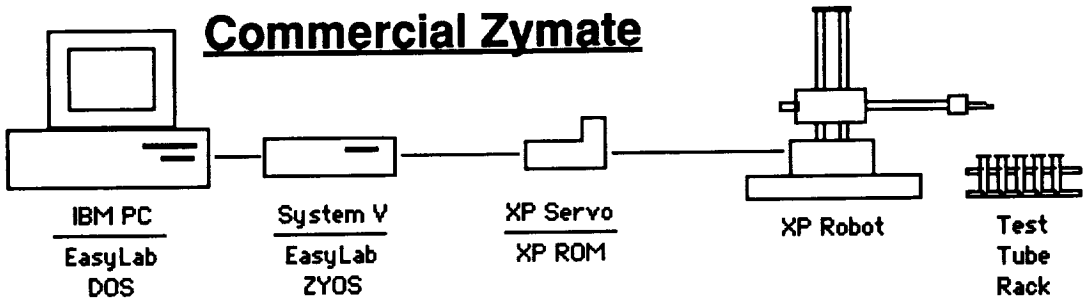
Fault Conditions and Responses

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

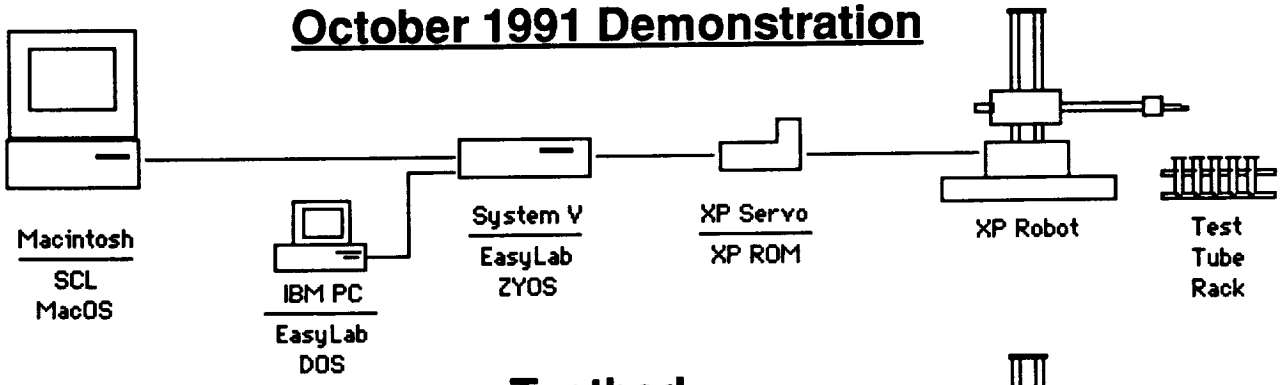
CONTROL SYSTEM ELEMENT	HARDWARE STATUS	SOFTWARE STATUS	BREADBOARD STATUS	DESIGN HERITAGE
SCC Processor				
Realtime Engine	COTS	COTS	BrBd 100%	OCP, ARD pgm
HH serial i/o	Des 100%	Oper by 12/31	planned	OCP, ARD pgm
command	na	Oper by 12/31		OCP, ARD pgm
telemetry	na	Des 100%		OCP, ARD pgm
a/d	COTS	COTS		OCP, ARD pgm
mux	Des 100%	Des 80%		OCP, FHPE pgm
EZC Processor				
EASYLAB	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
SERVO Controller				
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%	
MECHANICAL	Des 100%	na		SwRI, Qual'd to 17grms
THERMAL	Des 100%			COSMOS, Sinda, Traysis

Evolution from Zymate to ROMPS

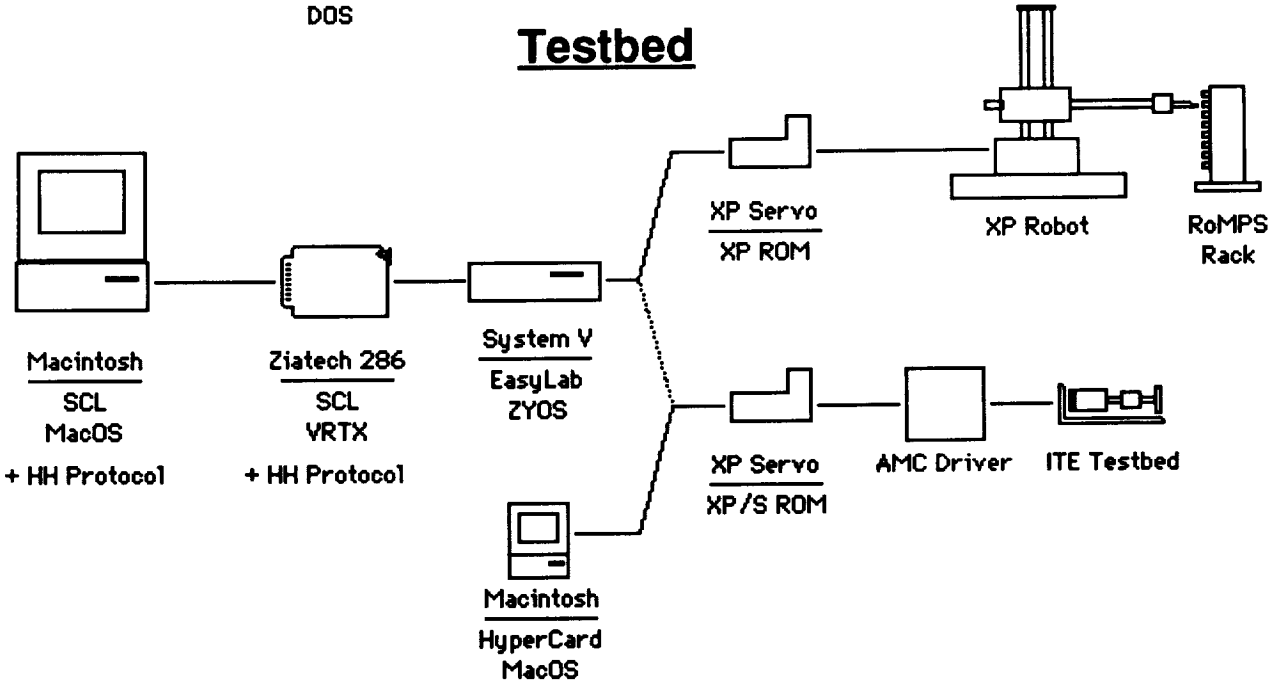
Commercial Zymate



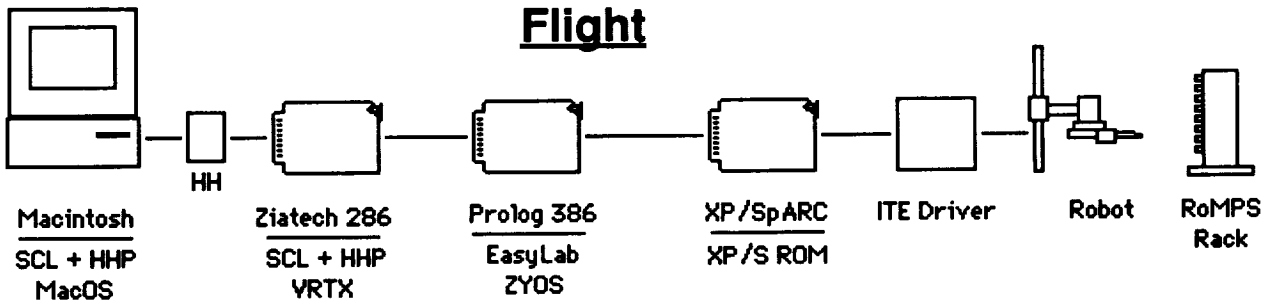
October 1991 Demonstration



Testbed



Flight



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