238800-2-T (Vol. II)

Interim Design Review

NASA GODDARD SPACE FLIGHT CENTER ROBOTIC PROCESSING SYSTEM PROGRAM AUTOMATION SYSTEMS

M.E. DOBBS

OCTOBER 1991

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

Contract No. NAG 5-1517

SpARC
Space Automation
& Robotics Center

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Ann Arbor, MI 48113-4001

Interim Design Review

NASA Goddard Space Flight Center
Robotic Material Processing System Program
Automation Systems

18 October 1991

prepared by

Environmental Research Institute of Michigan
Space Automation and Robotics Center
P.O. Box 134001
Ann Arbor, Michigan 48113-4001

RoMPS General Mission Requirements

- Rapid Thermal Annealing (RTA) in Microgravity
  - Microgravity material processing
  - High temperature annealing furnace
  - Automated RTA processing and sample change

- STS Hitchkiker Payload
  - GAS canister and HH avionics mounting plate
  - Class D payload classification
  - Serial command and telemetry

- Mission Characteristics
  - Operates during STS disturbance free "quiet" periods
  - Operational changes expected
    - reschedule operations to meet STS constraints
    - modification of RTA processing parameters

Office of Commercial Programs Requirements

- Infrastructure - Enable Low Cost Space Manufacturing
  - new technology - patents, license, product sales
  - reduced cost-per-pound
    - reduce non-recurring engineering cost
    - use industrial practices and products
    - carrier independent systems
    - experiment independent systems
  - system architecture for manufacturing facility

- Closely Related OCP Infrastructure CCDS Flight Programs at SpARC
  - Autonomous Rendezvous & Docking
    - Autonomous Experiment Mangement System (AEMS)
  - Wake Shield Facility
    - Autonomous Experiment Mangement System (AEMS)
    - Robotic Substrate Servicing System
    - Satellite Servicing System
    - EPOP Control and Data System (AEMS)
  - LABS
    - Autonomous Experiment Mangement System (AEMS)
    - Material Handling Automation

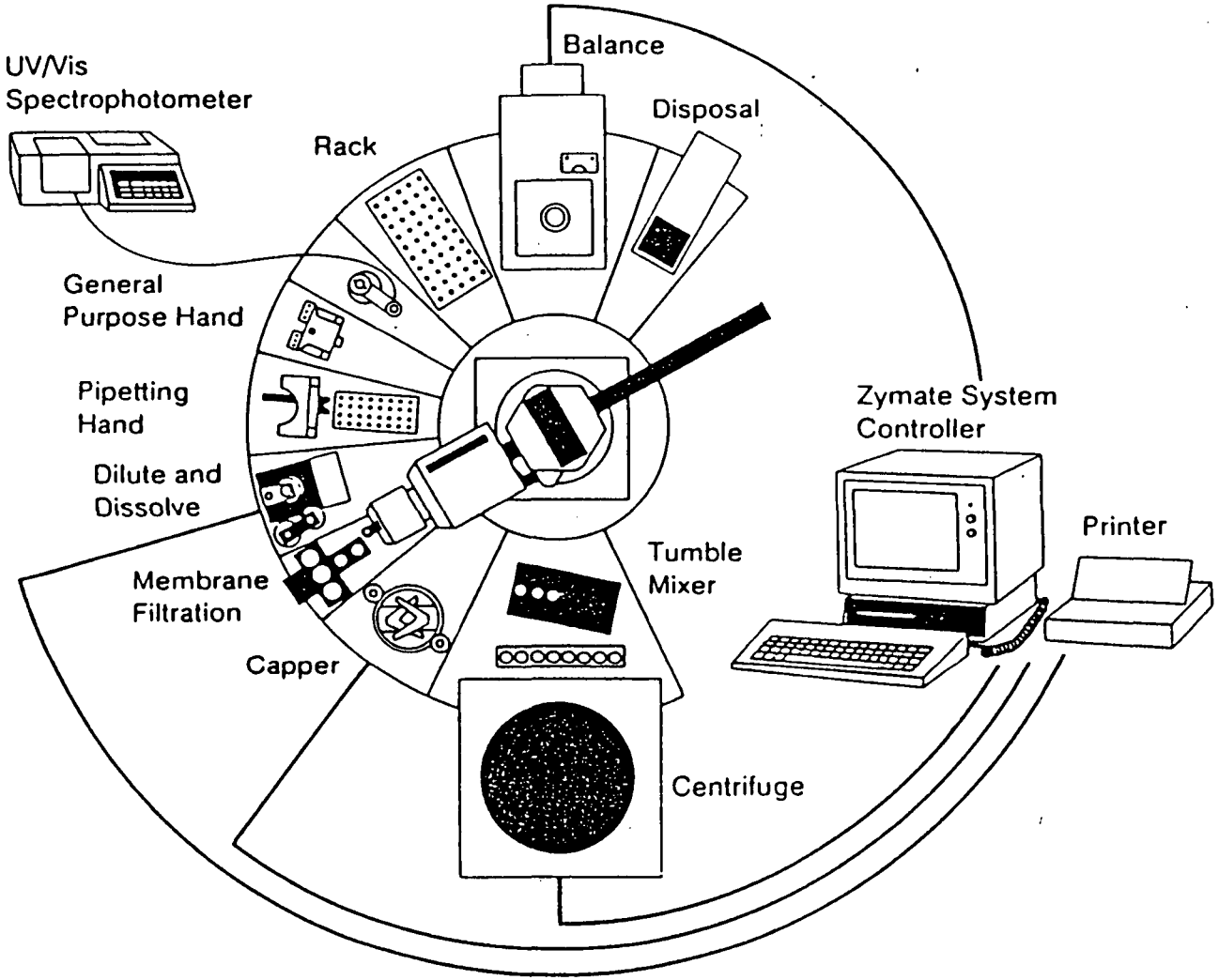
Automation Management System

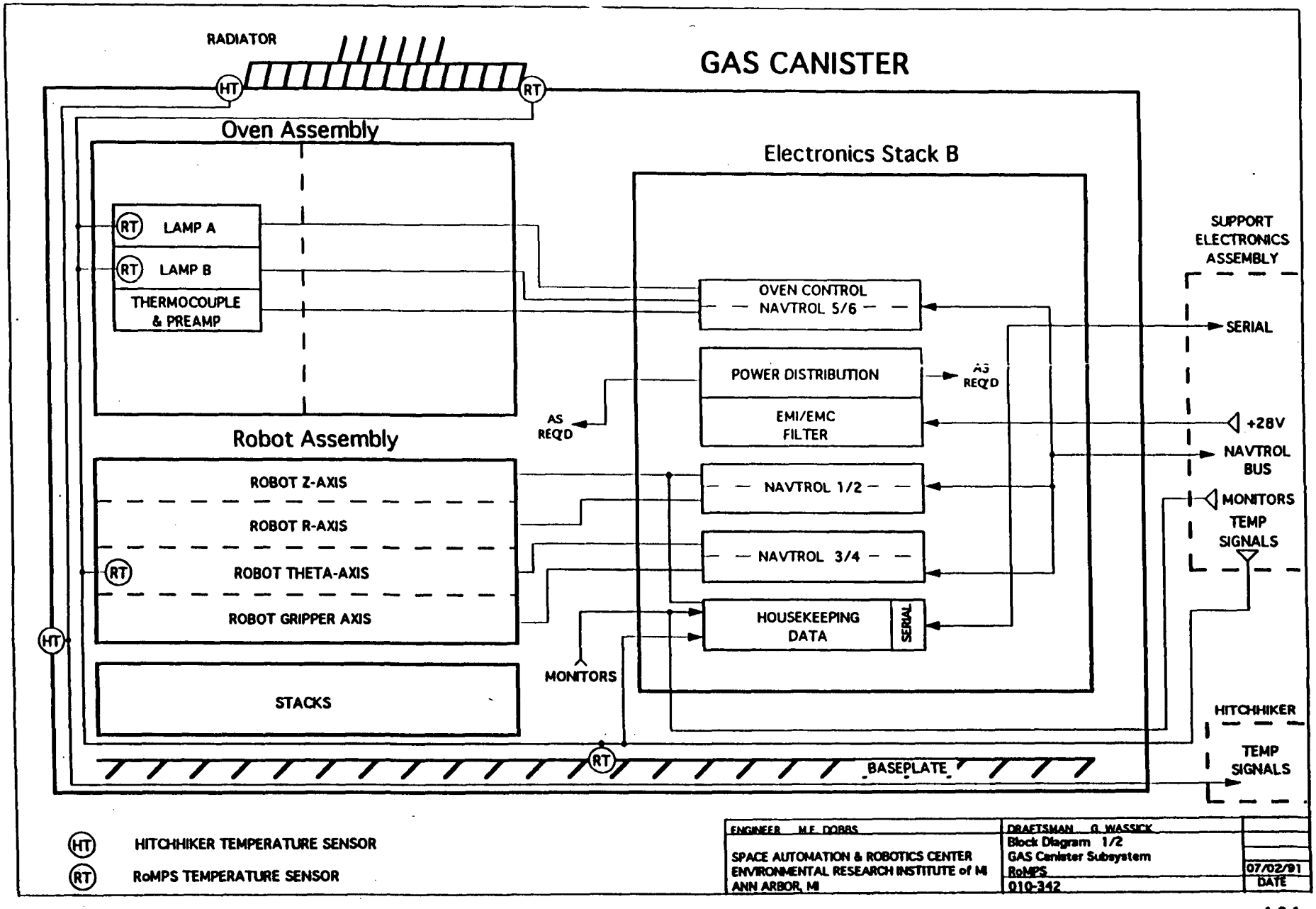
- Schedule Scripts
  - STS operational timeline changes
  - Investigator sample priority changes

- Processing Scripts
  - process methodology changes
  - process parameter changes

- High Level Language User Interface
  - industry proven
  - put PI in the drivers seat
  - attempt transparent environment from laboratory to flight

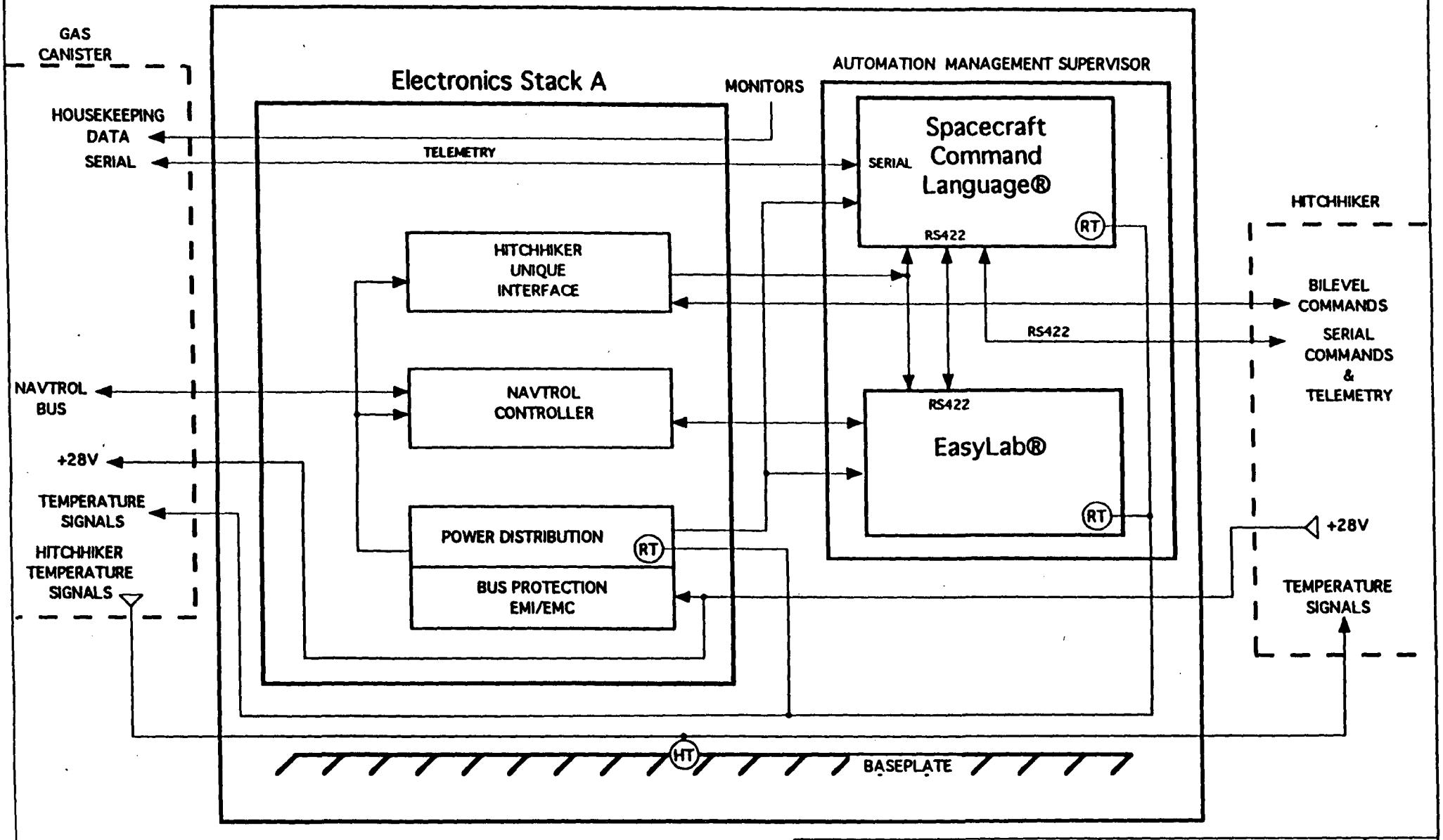
- Automatic Control
  - automatic sample change
  - automatic process control
  - rule based error detection and resolution


UV/Vis
Spectrophotometer
Balance
Disposal
Rack
General
Purpose Hand
Pipetting
Hand
Dilute and
Dissolve
Membrane
Filtration
Capper
Tumble
Mixer
Zymate System
Controller
Printer
Centrifuge


RADIATOR
GAS CANISTER
HT
RT
Oven Assembly
RT LAMP A
RT LAMP B
THERMOCOUPLE & PREAMP
Electronics Stack B
OVEN CONTROL NAVTROL 5/6
POWER DISTRIBUTION
EMI/EMC FILTER
NAVTROL 1/2
NAVTROL 3/4
HOUSEKEEPING DATA
SERIAL
AS REQ'D
AS REQ'D
Robot Assembly
ROBOT Z-AXIS
ROBOT R-AXIS
RT ROBOT THETA-AXIS
ROBOT GRIPPER AXIS
STACKS
MONITORS
SUPPORT ELECTRONICS ASSEMBLY
SERIAL
+28V
NAVTROL BUS
MONITORS
TEMP SIGNALS
HITCHHIKER
TEMP SIGNALS
HT
RT
BASEPLATE
HT HITCHHIKER TEMPERATURE SENSOR
RT RoMPS TEMPERATURE SENSOR
ENGINEER M.F. DOBBS
SPACE AUTOMATION & ROBOTICS CENTER
ENVIRONMENTAL RESEARCH INSTITUTE of MI
ANN ARBOR, MI
DRAFTSMAN G. WASSICK
Block Diagram 1/2
GAS Canister Subsystem
RoMPS
010-342
07/02/91
DATE

1.2.1

HITCHHIKER AVIONICS PLATE



(HT) HITCHHIKER TEMPERATURE SENSOR

(RT) RoMPS TEMPERATURE SENSOR

ENGINEER M.F. DOBBS	DRAFTSMAN G. WASSICK	
	Block Diagram 2/2	
SPACE AUTOMATION & ROBOTICS CENTER	SEA Subsystem	
ENVIRONMENTAL RESEARCH INSTITUTE of MI	RoMPS	07/02/91
ANN ARBOR, MI	010-339	DATE

Experiment Spreadsheet

	A	B	C	D	E	F	G	H	I
1	Run	Sample	Rack	Rack Index	Temperature 1	Time 1	Temperature 2	Time 2	Processed
2	1	1	1	1	410	90	410	90	N
3	2	2	1	2	410	90	410	90	N
4	3	3	1	3	410	90	410	90	N
5	4	4	1	4	410	90	410	90	N
6	5	5	1	5	410	90	410	90	N
7	6	6	1	6	410	90	410	90	N
8	7	7	1	7	350	90	350	90	N
9		...	...	...	...	...	...	...	...
10		...	...	...	...	...	...	...	...
11		...	...	...	...	...	...	...	...
12		...	...	...	...	...	...	...	...
13	141	141	6	5	400	30	400	30	N
14	142	142	6	6	200	30	200	30	N
15	143	143	6	7	400	5	400	5	N
16	144	144	6	8	400	15	400	15	N

```
-- SCL Scenario Script
--
-- Function Defines processing scenario for do_processing
-- script.

script  experiment_scenario

run                         = 1
gSample[run]                = 1
gRack[run]                  = 1
gRack_Index[run]            = 1
gTemperature1[run]          = 410
gTime1[run]                 = 90
gTemperature2[run]          = 410
gTime2[run]                 = 90

run                         = 2
gSample[run]                = 2
gRack[run]                  = 1
gRack_Index[run]            = 2
gTemperature1[run]          = 410
gTime1[run]                 = 90
gTemperature2[run]          = 410
gTime2[run]                 = 90

     ...

     ...
run                         = 144
gSample[run]                = 144
gRack[run]                  = 6
gRack_Index[run]            = 8
gTemperature1[run]          = 200
gTime1[run]                 = 30
gTemperature2[run]          = 200
gTime2[run]                 = 30

end  experiment_scenario
```

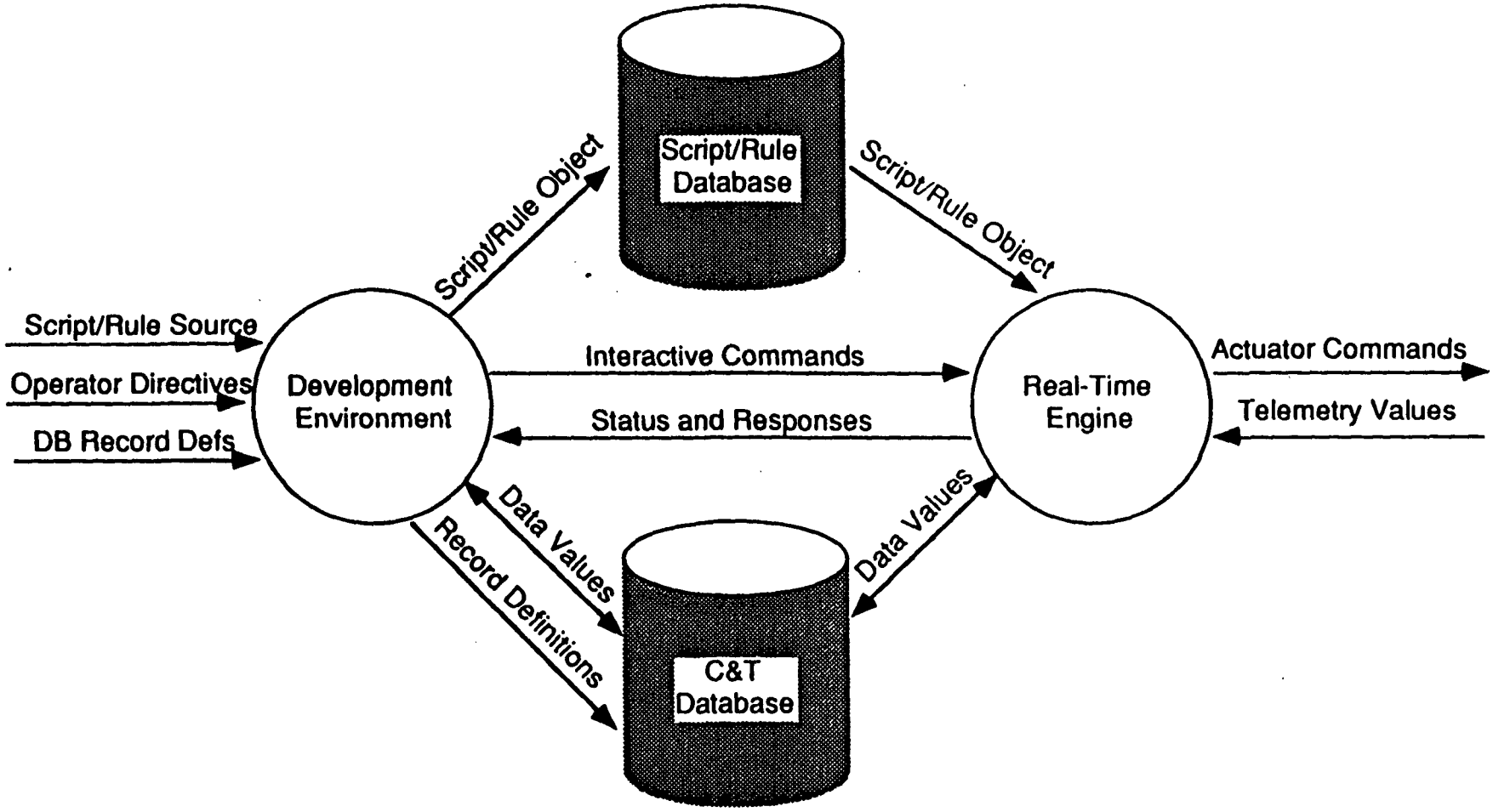
SCL Scripts

- SCL scripts are similar to tasks or other stand alone programs.
- Scripts can be executed immediately by command directive.
- Scripts can also be scheduled for deferred execution. SCL supports:
  - Absolute execution times.
  - Relative execution times.
- Scripts can be scheduled for cyclic execution (repetitive execution).

SCL Software Components

- The SCL software system is divided into 3 major components:
  - The Development Environment. The development environment provides tools for developing and maintaining scripts and rules and for controlling the operation of the system
  - The Real-Time Database. The database defines the SCL software's operating environment.
  - The Real-Time Engine (RTE). Executes the SCL scripts, rules, and command directives.

SCL Software Data Flows



SCL Real-Time Engine

- The Real-Time Engine (RTE) executes SCL scripts, rules and command directives.
- The RTE is portable:
  - Written in C and Ada
  - Application specific I/O and system service calls have been isolated and "abstracted" out the SCL software.
- The RTE is generic/reusable. SCL scripts and rules are used to tailor the system to a specific application.
- The RTE is dynamic. Scripts and rules can be added or deleted without changing the RTE and its underlying interface routines.

RoMPS EasyLab Command &Variable Summary for Rack Stations

RACK.INDEX	EasyLab variable used by RoMPS PyTechnology to determine the current sample for robot to manipulate. Initial Value is 1.
GET.FROM.RACK	Get sample RACK.INDEX from its home rack and slot.
PUT.INTO.RACK	Move the currently held sample into the home rack and slot of RACK.INDEX.

RoMPS EasyLab Command &Variable Summary for Annealer Module

ANNEALER.TEMPERATURE	Output Command Variable used to set the target temperature for the next annealing initiated by ANNEALER.ON and ANNEALER.TIMED.RUN. Initial Value TBD.
ANNEALER.TIME	Output Command Variable used to set the annealing time for the next annealing initiated by ANNEALER.TIMED.RUN. Initial Value TBD.
ANNEALER.RATE	Output Command Variable used to set the heating rate for the next annealing initiated by ANNEALER.ON and ANNEALER.TIMED.RUN. Initial Value TBD.
ANNEALER.ACTIVE.OVEN	EasyLab variable used by the Annealer robot movent commands, to determine position to put and get samples.
MOVE.UNDER.ANNEALER	Move Robot Gripper Under Sample, Lined up to allow pallet to be inserted into annealer.
PUT.INTO.ANNEALER	Move sample up into Annealer After a MOVE.UNDER.ANNEALER command.
ANNEALER.ON	Initiate an untimed run of the Annealer.
ANNEALER.OFF	Terminate an untimed run of the Annealer.
ANNEALER.TIMED.RUN	Initiate a timed run of the Annealer.

Automation Management System

- Architecture Demonstrated at SpARC on 4 October 1991

  SC4 #1 with SCL implements
  - generic - scheduler
  - specific - carrier i/o

  SC4 #2 with EASYLAB implements
  - generic - sample handling, processing
  - specific - robot geometry

  Electronics
  - generic - servos, housekeeping
  - specific - interfaces

- Status
  - MOU's in place
  - License agreements outlined
  - DFD's prepared
  - Elements to be designed have models to work from

- Long Term Architecture
  - Multiple robot and process space manufacturing facility

- Minimize Lifecycle Costs
  - Industrial development, support, maintenance and documentation

RoMPS Electronics Assemblies

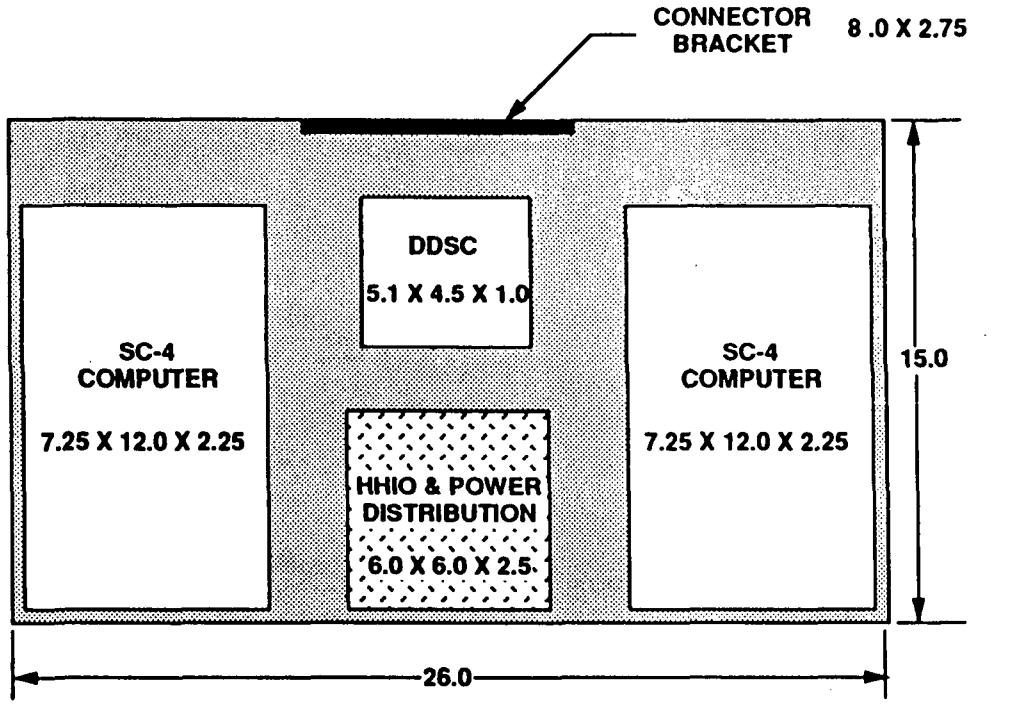
- Support Electronics Assembly

  Mounted to Hitchhiker Adapter Plate
  Integrated assembly with common support plate and cover
    - Connector Bracket
    - Power Distribution
    - SwRI SC4 Computer #1
    - SwRI SC4 Computer #2
    - Navtrol DDSC Master

- GAS Electronics Assembly

  Mounted inside 5" GAS Extension
  Integrated assembly with common support plate
    - Connector Brackets
    - Power Distribution
    - Navtrol DDSC Slave #1
    - Navtrol DDSC Slave #2
    - Navtrol DDSC Slave #3
    - Thermocouple Signal Conditioning
    - Data Acquisition

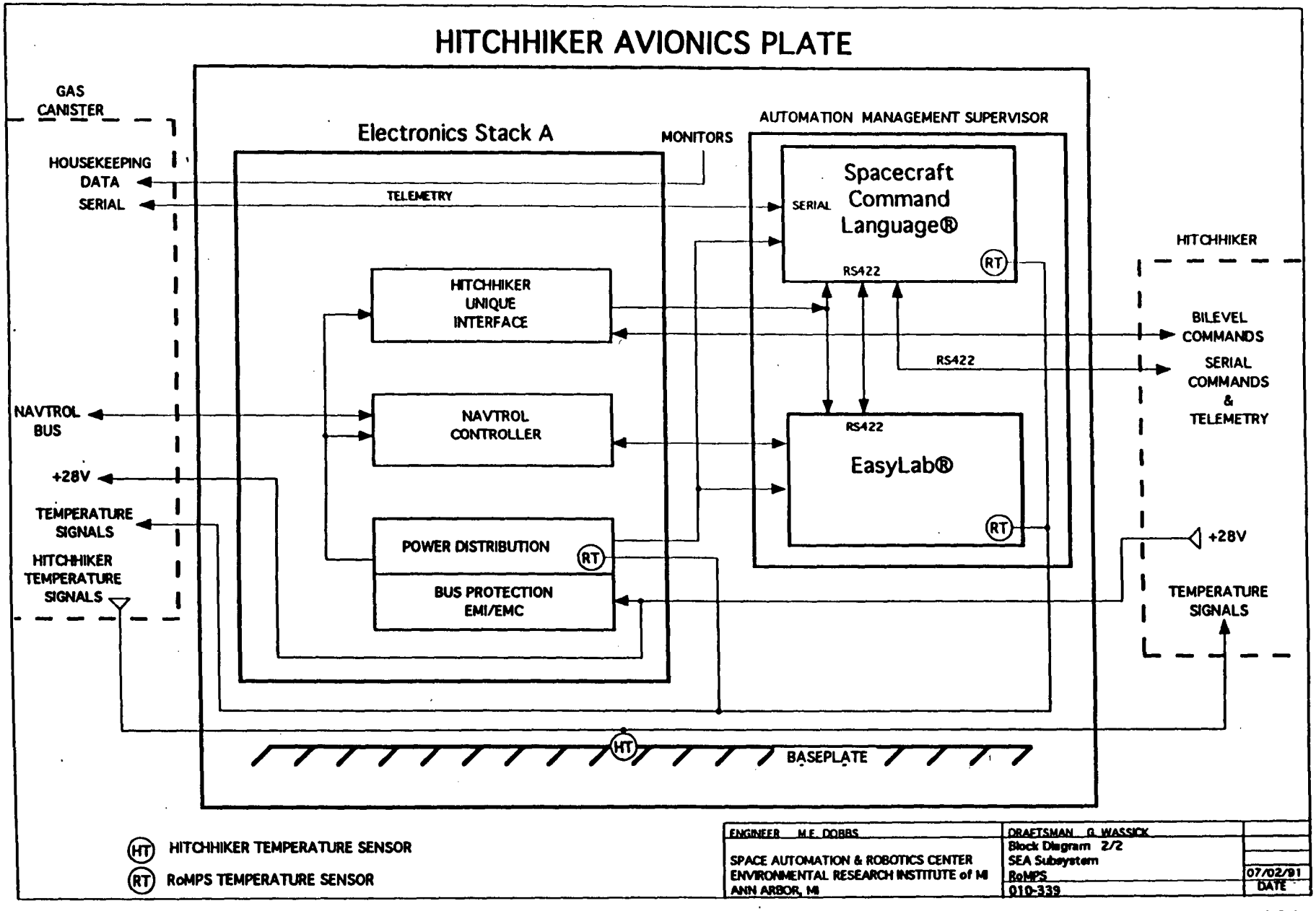
SUPPORT ELECTRONICS ASSEMBLY



ENGINEER R.E. QUADA	DRAFTSMAN S.J. CARR	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	LAYOUT SUPPORT ELECTRONICS ASSEMBLY ROMPR	10/09/91 DATE

RoMPS Elec Weight & Power

	A	B	C	D	E	F	G	H
1	RoMPS Weight & Power							
2	Assembly	Subassembly	Mfgr	Size LWH in	Mass lbs	Avg Pwr	Peak Pwr	Comments
3								
4	Support Elect	mount plate	GSFC		tbd			
5	Assembly	emi cover	GSFC		tbd			
6		SC-4	SwRI	7.25x12.25x2	3.7	5	5	
7		SC-4	SwRI	7.25x12.25x2	3.7	5	5	
8		HH I/O	ERIM	7 x 7 x 0.75	1.1	1	1	
9		HH PWR	ERIM	7 x 7 x 1.25	1.1	0	0	
10		DDSC Master	Navtrol	4.5x5.1x1	2	3.7	3.7	
11		connec. brack	ERIM		tbd			
12		harness	ERIM		tbd			
13		hardware			tbd			
14								
15		SUBTOTAL			11.6	14.7		
16								
17	GAS Eectroni	mount plate	GSFC	17.5 dia	tbd			
18	Assembly	DDSC	Navtrol	4.5x5.1x1	2	3.7	269	9.6a worst ca
19		DDSC	Navtrol	4.5x5.1x1	2	3.7		one axis only
20		DDSC	Navtrol	4.5x5.1x1	2	3.7		one axis only
21		Housekeeping	ERIM	7x7x0.75	1.1	3	5	logic
22		Housekeeping	ERIM	7x7x0.75	1.1	2	5	analog
23		Power Dist	ERIM	7x7x1.25	2.2	2	2	converter los
24		connec.bracke	ERIM		tbd			
25		harness	ERIM		tbd			
26		hardware			tbd			
27								
28		SUBTOTAL			10.4	18.1		
29								
30		TOTAL			22	32.8		

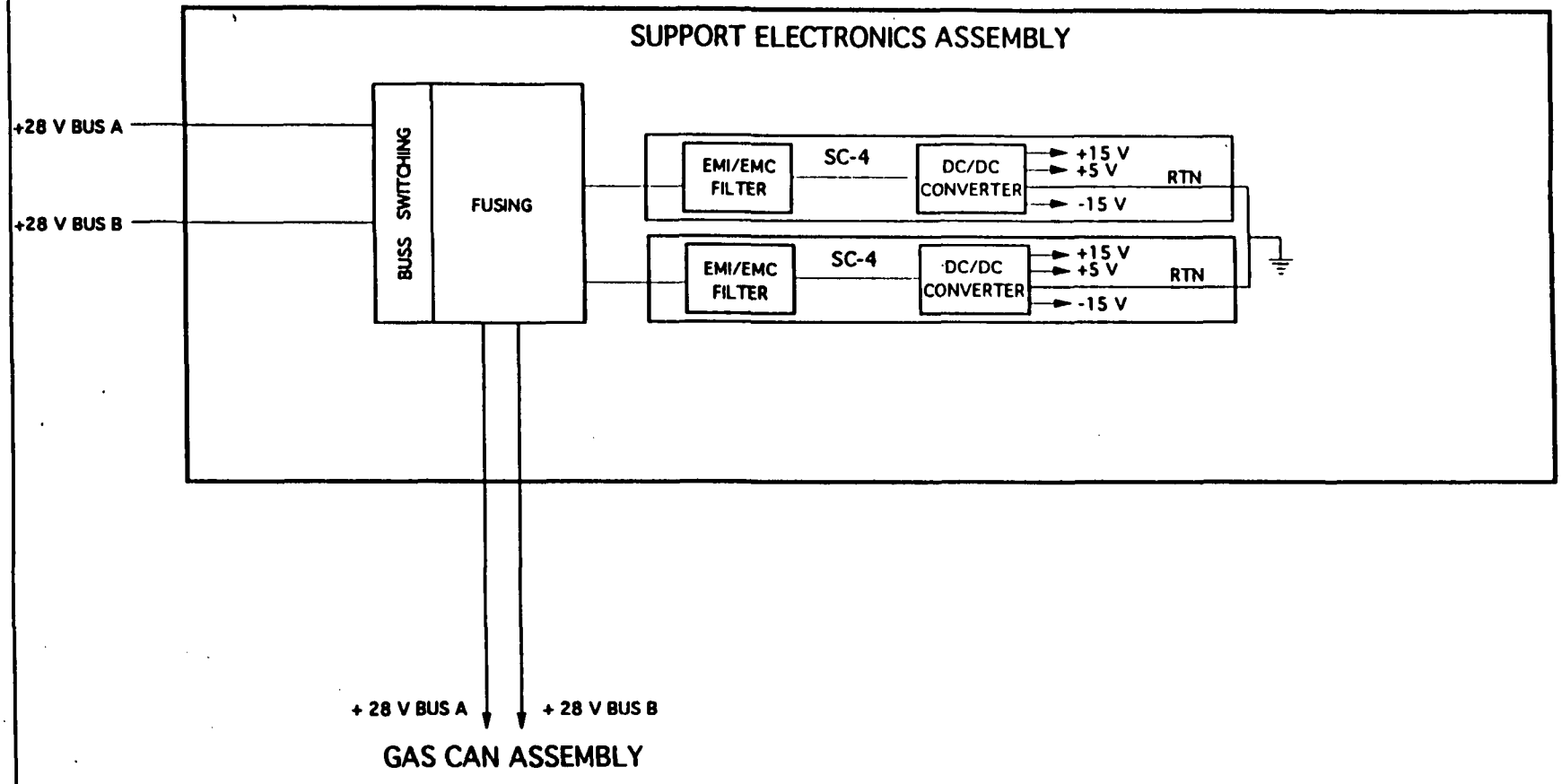

HITCHHIKER AVIONICS PLATE
GAS CANISTER
HOUSEKEEPING DATA SERIAL
NAVTROL BUS
+28V
TEMPERATURE SIGNALS
HITCHHIKER TEMPERATURE SIGNALS
Electronics Stack A
MONITORS
TELEMETRY
HITCHHIKER UNIQUE INTERFACE
NAVTROL CONTROLLER
POWER DISTRIBUTION
RT
BUS PROTECTION EMI/EMC
AUTOMATION MANAGEMENT SUPERVISOR
SERIAL
Spacecraft Command Language®
RS422
RT
RS422
RS422
EasyLab®
RT
HITCHHIKER
BILEVEL COMMANDS
SERIAL COMMANDS & TELEMETRY
+28V
TEMPERATURE SIGNALS
HT
BASEPLATE
HT HITCHHIKER TEMPERATURE SENSOR
RT RoMPS TEMPERATURE SENSOR
ENGINEER M.F. DOBBS
SPACE AUTOMATION & ROBOTICS CENTER
ENVIRONMENTAL RESEARCH INSTITUTE of MI
ANN ARBOR, MI
DRAFTSMAN G. WASSICK
Block Diagram 2/2
SEA Subsystem
RoMPS
010-339
07/02/91
DATE

1.2.2

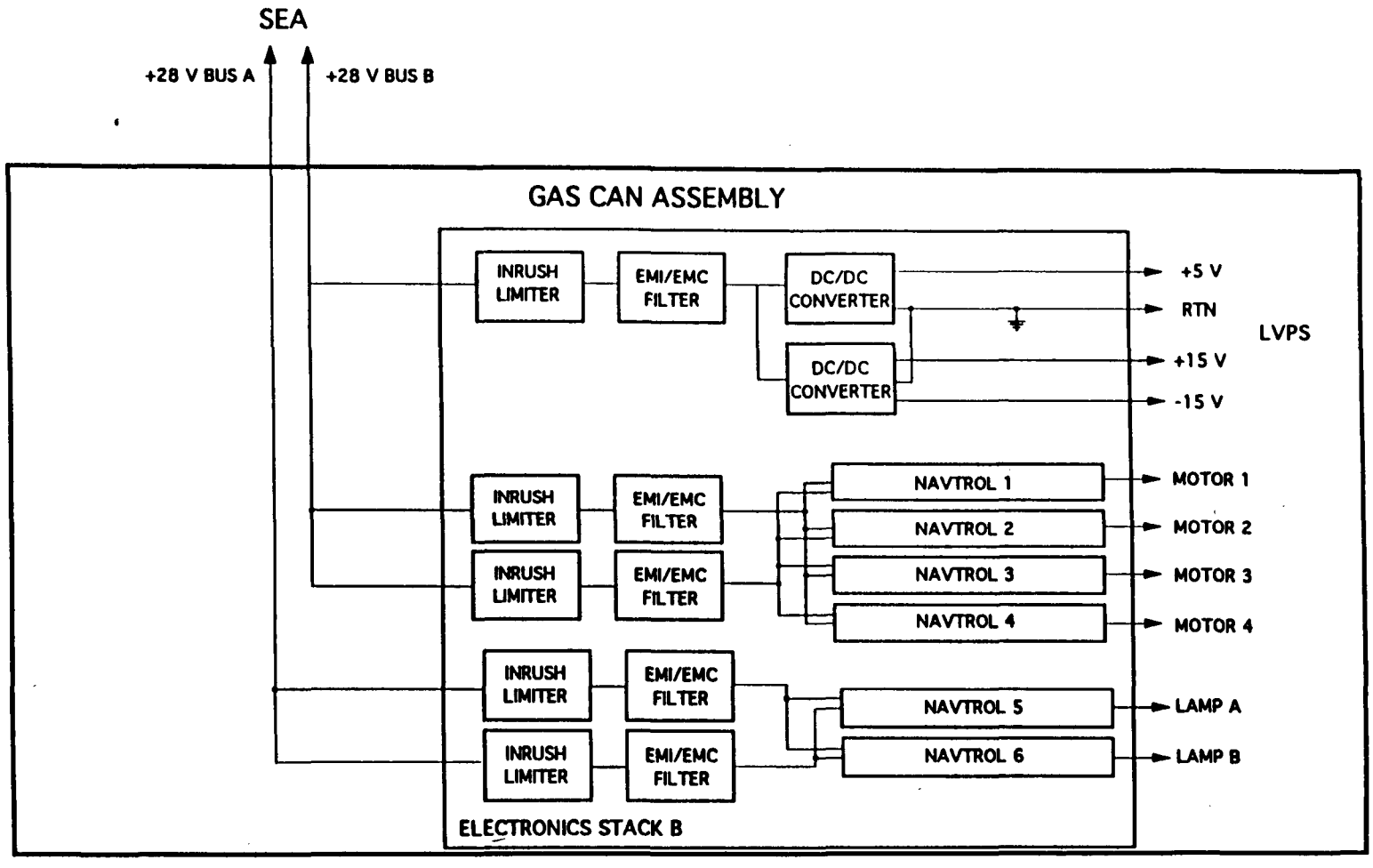
Hitchhiker Interface Subsystem

- Flight Hardware
  - power switching and bus protection
  - serial interface receivers and drivers
  - HH command packet protocol processing
  - telemetry packet generation
  - health and safety monitors

- Ground Support Equipment & Operations Console
  - customer ground support equipment
    - command generation
      - script development
      - process development
    - telemetry processing
      - archiving
      - engineering unit conversion
      - parameter limit checking
  - investigator operations console



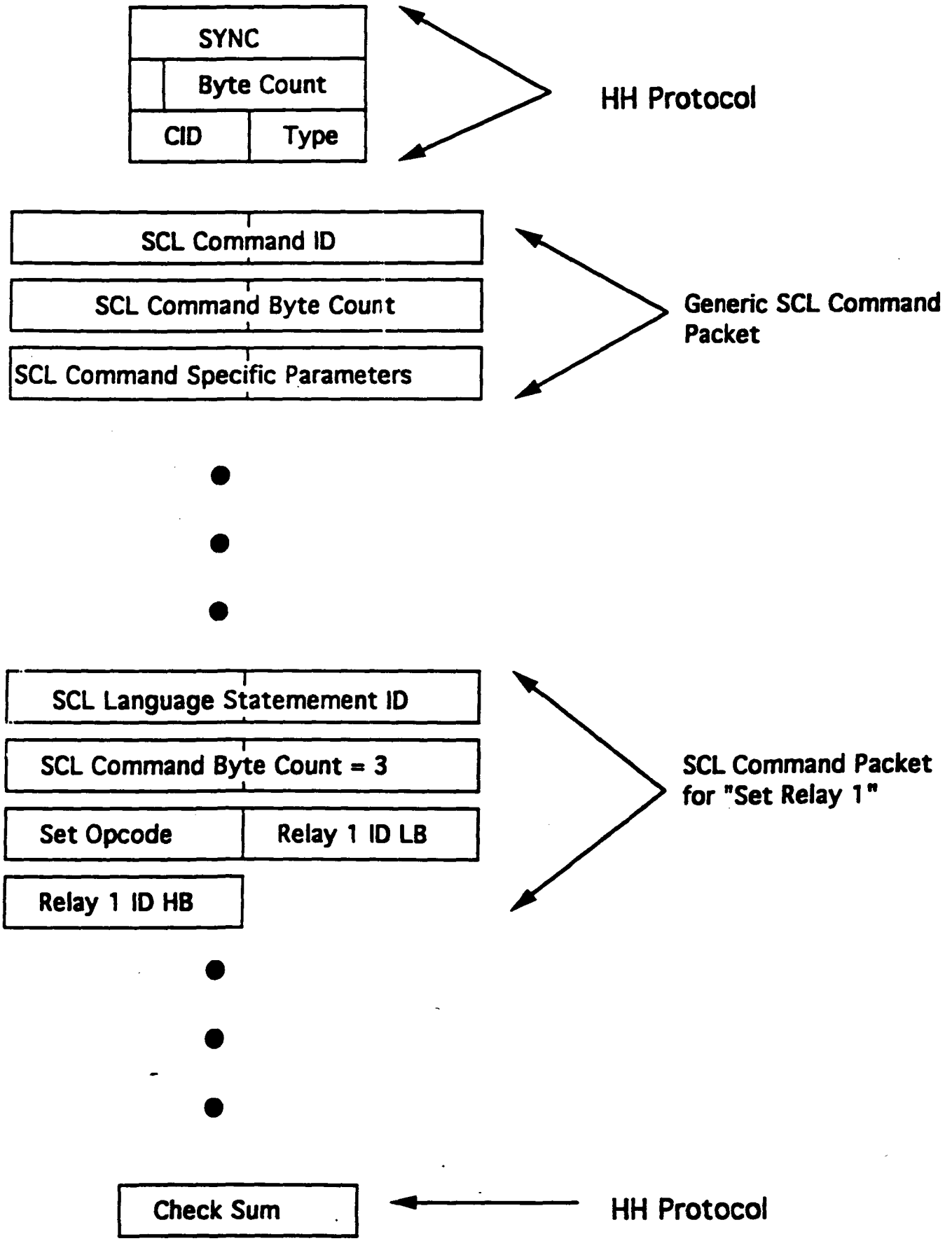
ENGINEER M. E. Dobbs	DRAFTSMAN	
	SEA	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	Power Distribution Block Diagram ROMPS 010-341	10/10/91 05/14/91 DATE



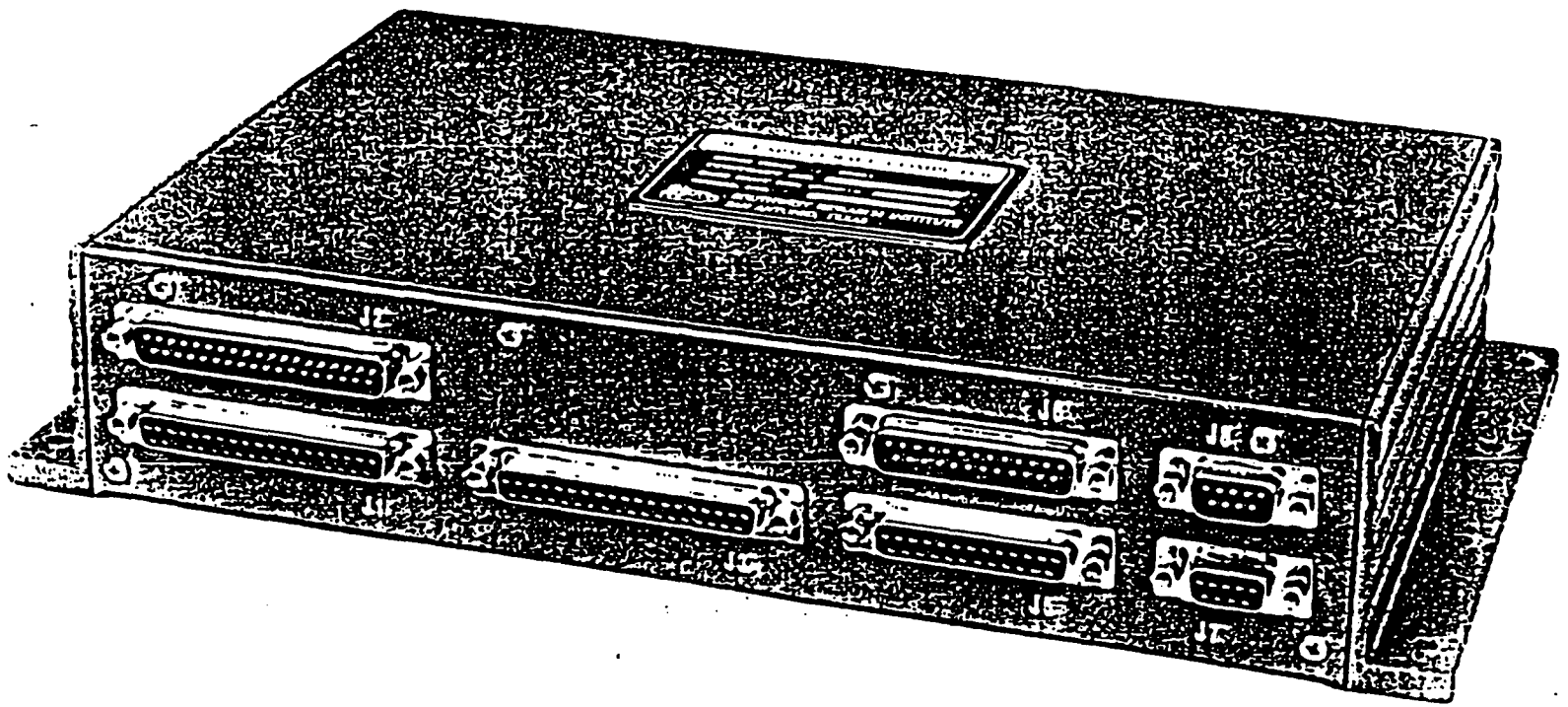
ENGINEER M.F. DOBBS	DRAFTSMAN	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	GAS Can Assembly Power Distribution Block Diagram RoMPS 010-345	10/10/92 07/17/91 DATE

17.0.2

SCL Uplink Packet Definition



	A	B	C	D	E
1	RoMPS Telemetry				
2	Function	Description	Length	Rate	Comment
3					
4	Frame Header	sync	2	1	
5		sync/id	2	1	
6					
7	RTE Packet	id, etc	2	1	
8		rte state	2	1	
9		agenda status	2	1	
10		script status	10	1	
11		script status	10	1	
12					
13	DUMP Packet	id/len	4	1	
14		sample id	2	1	
15		process id	2	1	
16		sample temp	2	1	
17		lamp intensit	2	1	
18		lamp intensit	2	1	
19		lamp intensit	2	1	
20		lamp intensit	2	1	
21		lamp current	2	1	
22		elevation	2	1	
23		theta	2	1	
24		radial	2	1	
25		grip	2	1	
26		force	2	1	
27		exp. current	2	1	
28		eot status	2	1	
29		error reports	10	1	5 maximum
30		housekeeping	16	1	8 maximum
31					
32	TOTAL		90		
33	BUDGET		120		1200 baud



ENGINEER	DRAFTSMAN	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	010-132	08/08/91 DATE

TABLE 1.2.2-1

Preliminary Specification
SC-4 Single Board Spacecraft Computer

Central Processor	80C186/80C187 16 Bit
Clock Frequency	10 MHz
Operating System	MS-DOS and VRTX Compatible
Onboard Memory	
RAM	512K Bytes w/EDC
EEPROM	256K Bytes w/EDC
UVPROM	640K Bytes w/EDC
Hardware Vectored Interrupts	16 User Configurable
Timer/Event Counters	8, Software Configurable, 120 ns Granularity
Input/Output Capability	
Parallel I/O	16 Input, 16 Output
Analog Input	32 Channels, 12-bit Resolution
Analog Output	4 Channels, 12-bit Resolution
RS-422 Serial I/O	2 Channels
SCSI Interface	1 Port
Software Controlled Power Switch	4 Each
Mass Storage	24M Bytes, Read/Write Non-volatile with Additional Battery
Expansion	Internal Daughterboard Connector
Size	7.25 X 12 X 2.25 in
Weight	3.7 Lb (Approximate)
Power	28v @ 5w (Approximate)

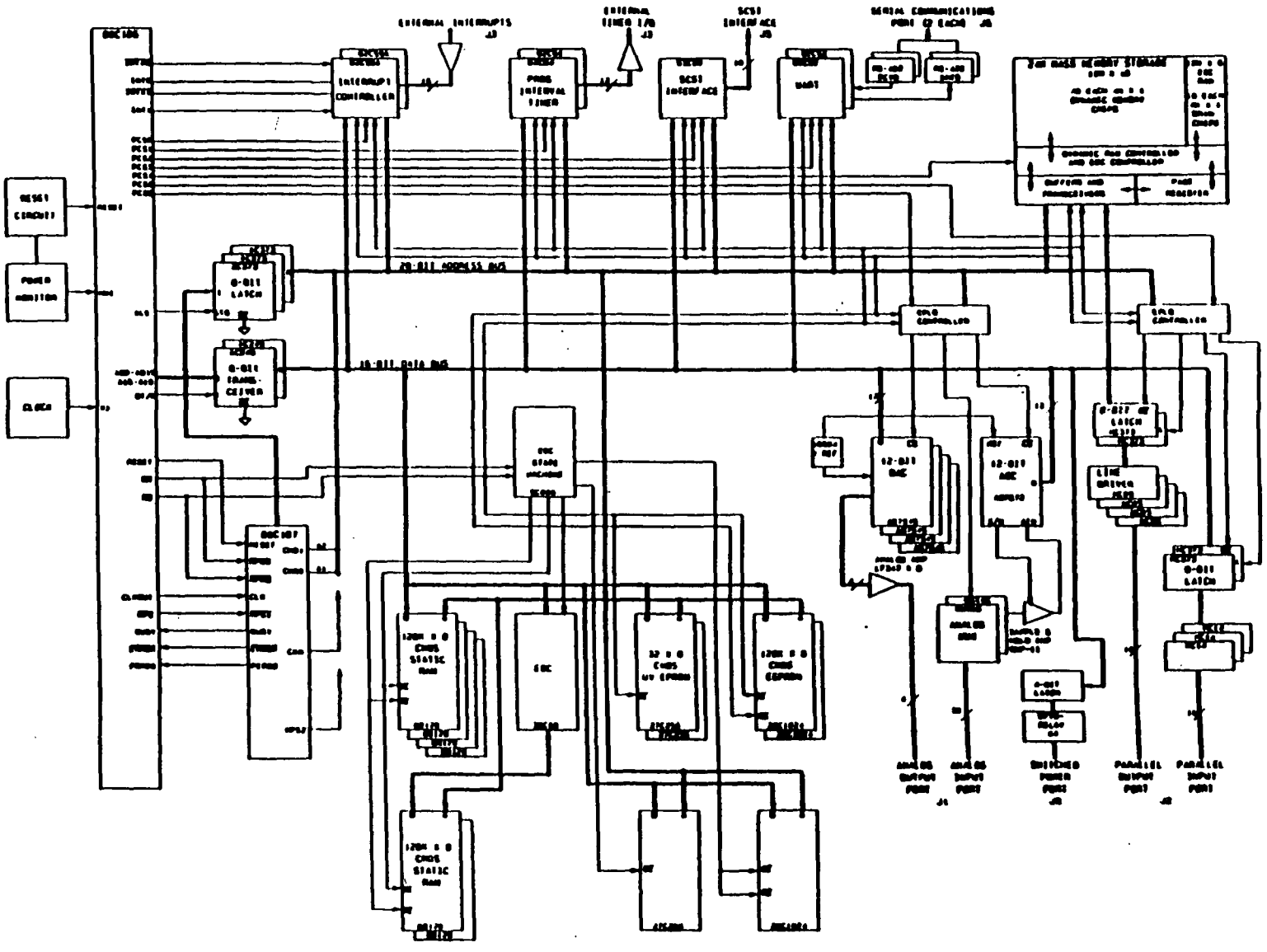


Figure 3.2-1 SC-4 Single Board Spacecraft Computer Block Diagram

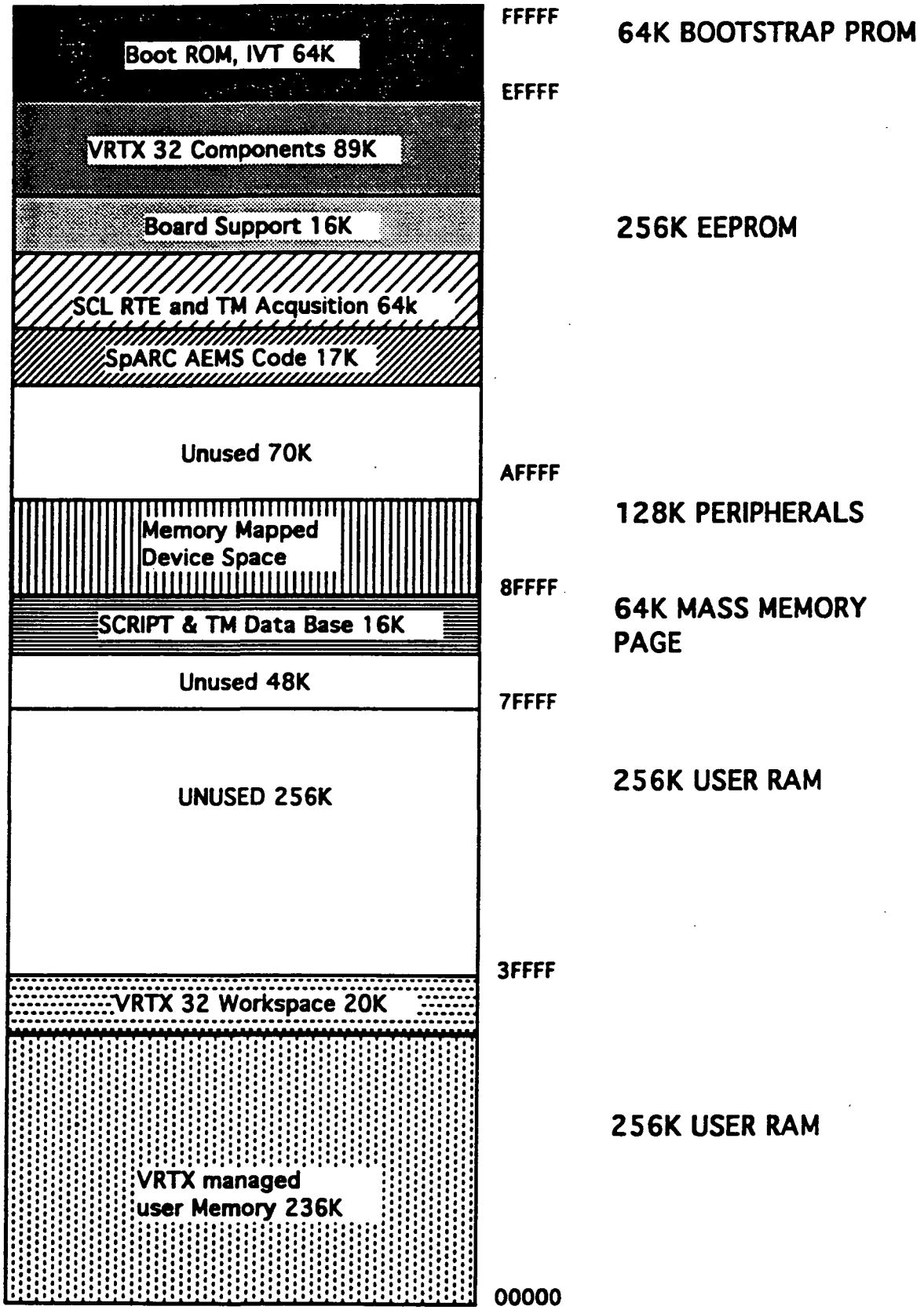
RoMPS AMS Software Summary

MODULE	VENDOR	FUNCTION	LANGUAGE
VRTX-32	Ready Systems	Real Time Executive	"C", Assembler
RTL/86 VRTX-32	Ready Systems	"C" Reentrent Run Time Library Interface	"C", Assembler
RT-SCOPE	Ready Systems	System Monitor, Debugger	"C", Assembler
RTL/86 RT-SCOPE	Ready Systems	"C" Language Interface to RT-SCOPE	"C", Assembler
SC-4 Board Support Package	ICS/SpARC	Interface Between VRTX and SC-4 Devices	"C", Assembler
Command Input	SpARC	Get Command Packets from HH Avionics	"C"
Zymate Interface	SpARC	SCL to Zymate Interface	"C"
Telemetry Acquistion	SpARC	Acquire the Data of the Telemetry Items and forward to Telemetry Reduction	"C"
Telemetry Output	SpARC	Format and send telemetry	"C"

RoMPS AMS Software Summary

MODULE	VENDOR	FUNCTION	LANGUAGE
SCL RTE	ICS	SCL Command Interpreter and Rules evaluation	"C"
Telemetry Reduction	ICS	Monitor Telemetry and post detected changes	"C"
Processing Scheduler	SpARC	Scheduled execution of scripts initiating EasyLab processing programs	SCL
Initiate Sample Processing	SpARC	Sends the EasyLab commands initiating sample processing	SCL
Initialize / Shutdown EasyLab	SpARC	Sends the EasyLab commands initiating/shutting down EasyLab	SCL
Send EasyLab Commnad	SpARC	Send an EasyLab Command	SCL

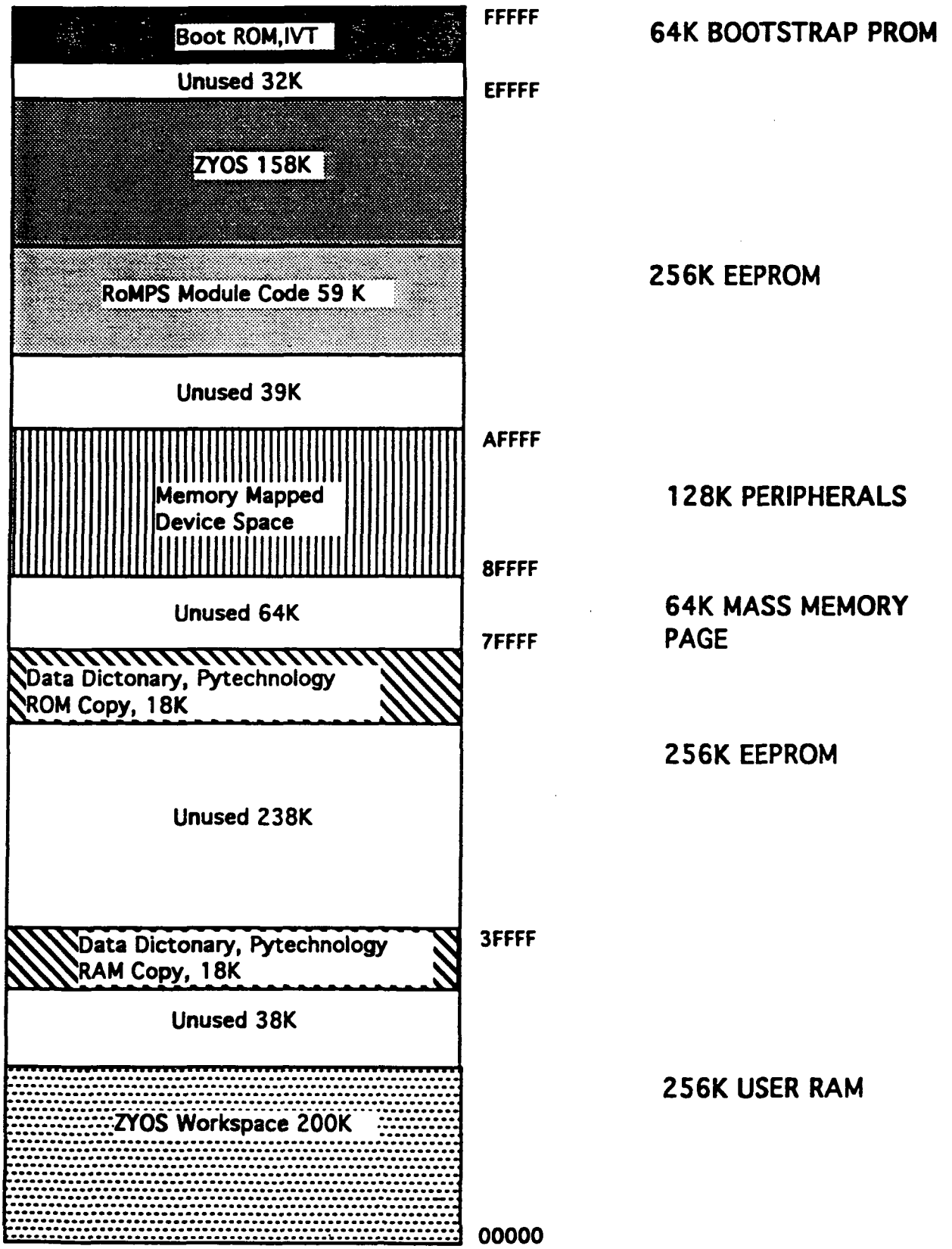
AMS Memory Map



RoMPS SC-4 EasyLab Software Summary

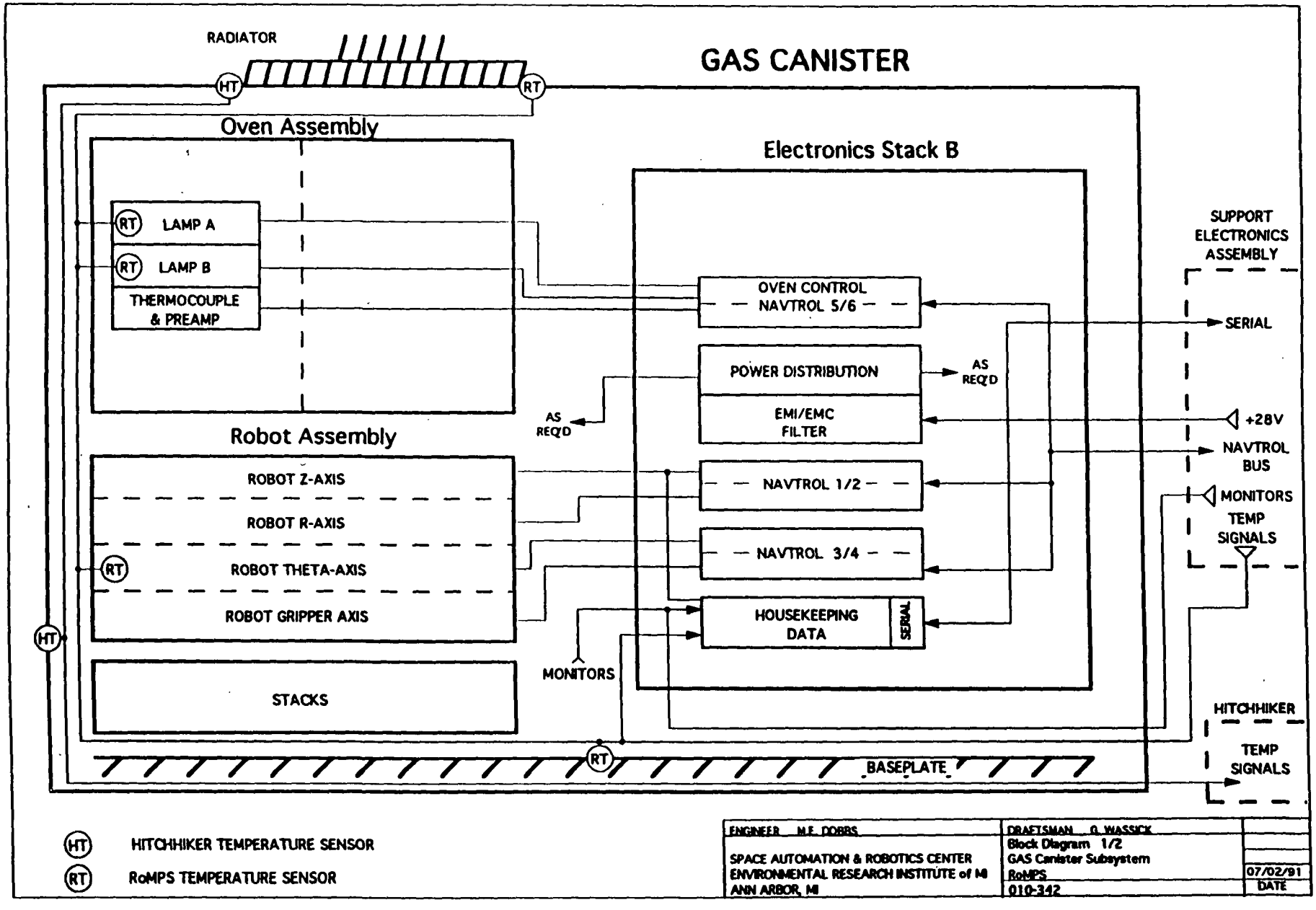
MODULE	VENDOR	FUNCTION	LANGUAGE
ZYOS	Zymark	Zymate Operating System	"C", PLM 86
Boot ROM	Zymark	Operating System Initialization	"C", PLM 86
Robot Module	SpARC	High level robot controller and servo interface	"C"
Annealer Module	SpARC	Oven controller interface	"C"
Annealer PyTechnology	SpARC	Annealer control variables and navigation routines	EasyLab
Rack Pytechnology	SpARC	Rack navigation routines and variables	EasyLab
Robot PyTechnology	SpARC	Robot control and navigation variables	EasyLab

SC-4 EasyLab System Memory Map



Processor Utilization

- RoMPS sample thruput limited by annealing time
- Spacecraft Command Language
  Compiled script 300 lines/second
- EasyLab
  Interpreted procedure 10 lines/second
- Memory Margin 37 %


GAS CANISTER
RADIATOR
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Oven Assembly
LAMP A
LAMP B
THERMOCOUPLE & PREAMP
Electronics Stack B
OVEN CONTROL NAVTROL 5/6
POWER DISTRIBUTION
EMI/EMC FILTER
NAVTROL 1/2
NAVTROL 3/4
HOUSEKEEPING DATA
SERIAL
AS REQ'D
AS REQ'D
Robot Assembly
ROBOT Z-AXIS
ROBOT R-AXIS
ROBOT THETA-AXIS
ROBOT GRIPPER AXIS
STACKS
MONITORS
SUPPORT ELECTRONICS ASSEMBLY
SERIAL
+28V
NAVTROL BUS
MONITORS
TEMP SIGNALS
HITCHHIKER
TEMP SIGNALS
BASEPLATE
HT HITCHHIKER TEMPERATURE SENSOR
RT RoMPS TEMPERATURE SENSOR
ENGINEER M.E. DOBBS
SPACE AUTOMATION & ROBOTICS CENTER
ENVIRONMENTAL RESEARCH INSTITUTE of MI
ANN ARBOR, MI
DRAFTSMAN G. WASSICK
Block Diagram 1/2
GAS Canister Subsystem
RoMPS
010-342
07/02/91
DATE

Robot Control Subsystems

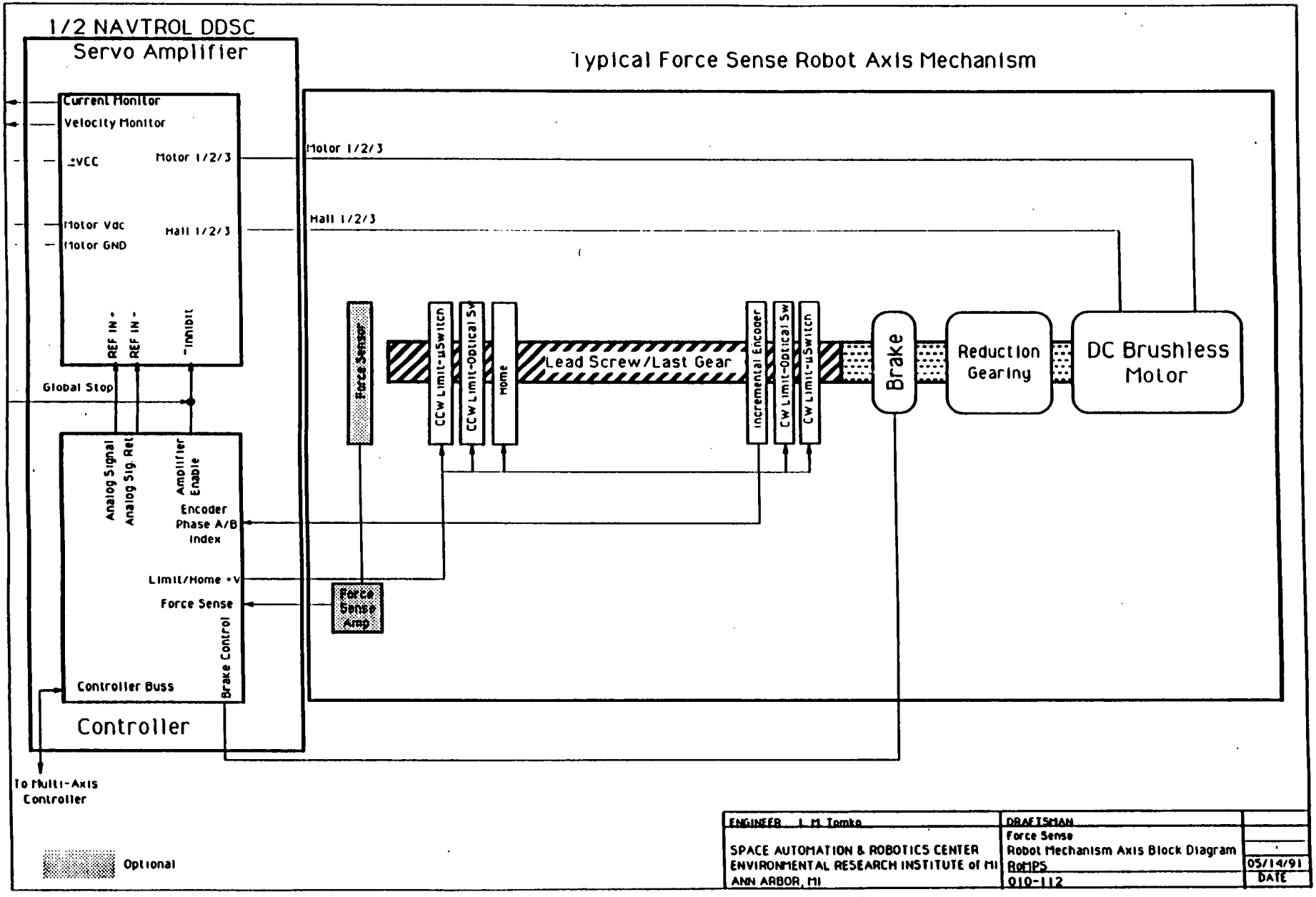
- 4 Degree-Of-Freedom Material Processing Robot
  - elevation, azimuth, reach, gripper axis
    - brushless dc motors
    - hall effect commutation
    - normally-on electrical brakes
    - quadrature output incremental position encoders
    - end-of-travel fiducials
    - current or force limited
    - compliant gripper
  - sequential operation

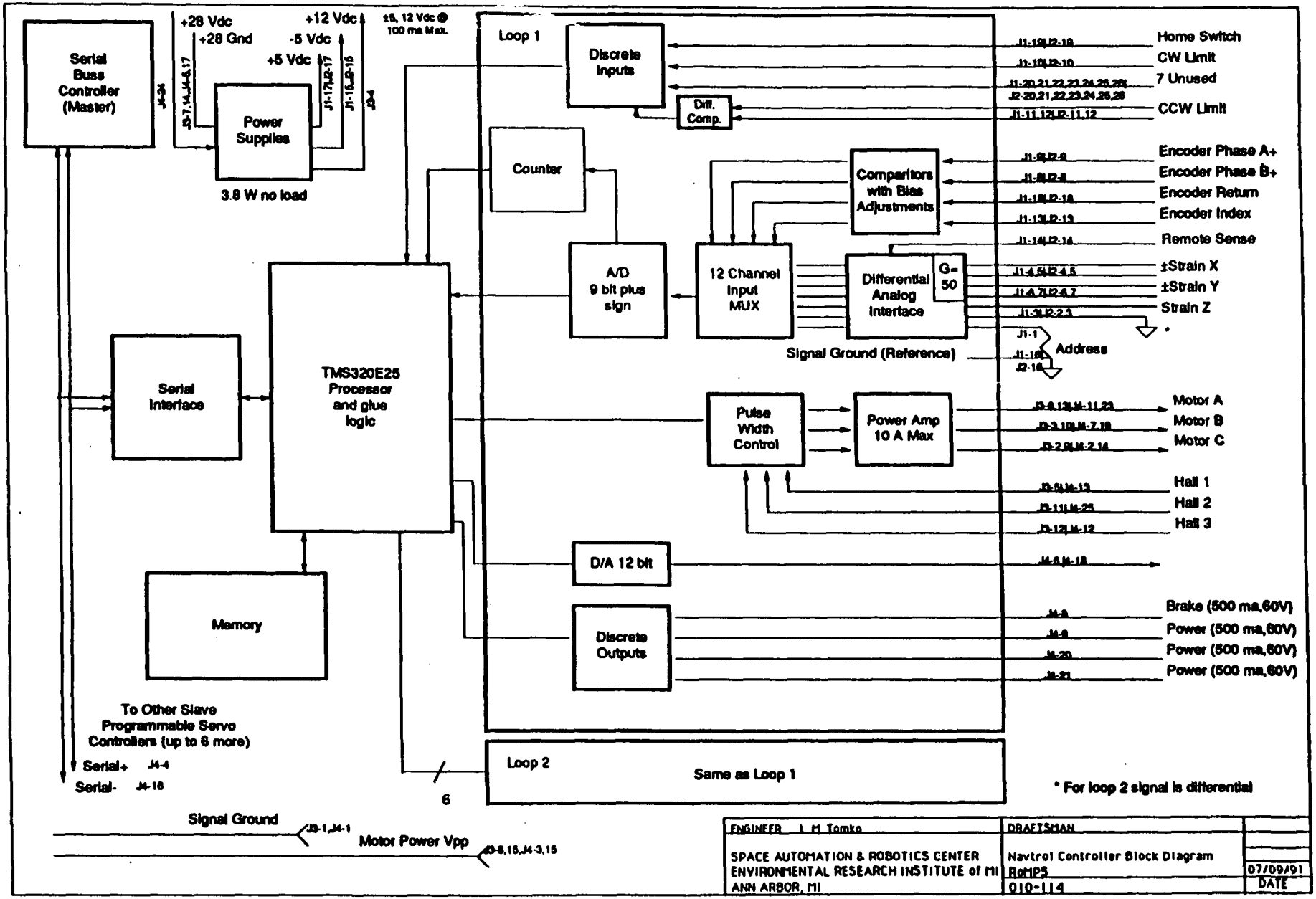
- Digital Servo Position Control

positioning accuracy	+- 0.025 inch
velocity range	0.1 to 2.0 inches/sec
force limiting	+- 1 lbf

  - Proportional-Integral-Deriviative algorithm
  - <5 msec control loop cycle time

- PWM Drive Amplifier
  - chassis isolated output stage
  - 32 volt maximum phase voltage
  - 10 amp maximum phase current
  - fold-back current limiting
  - over-temperature protection
  - output inhibit



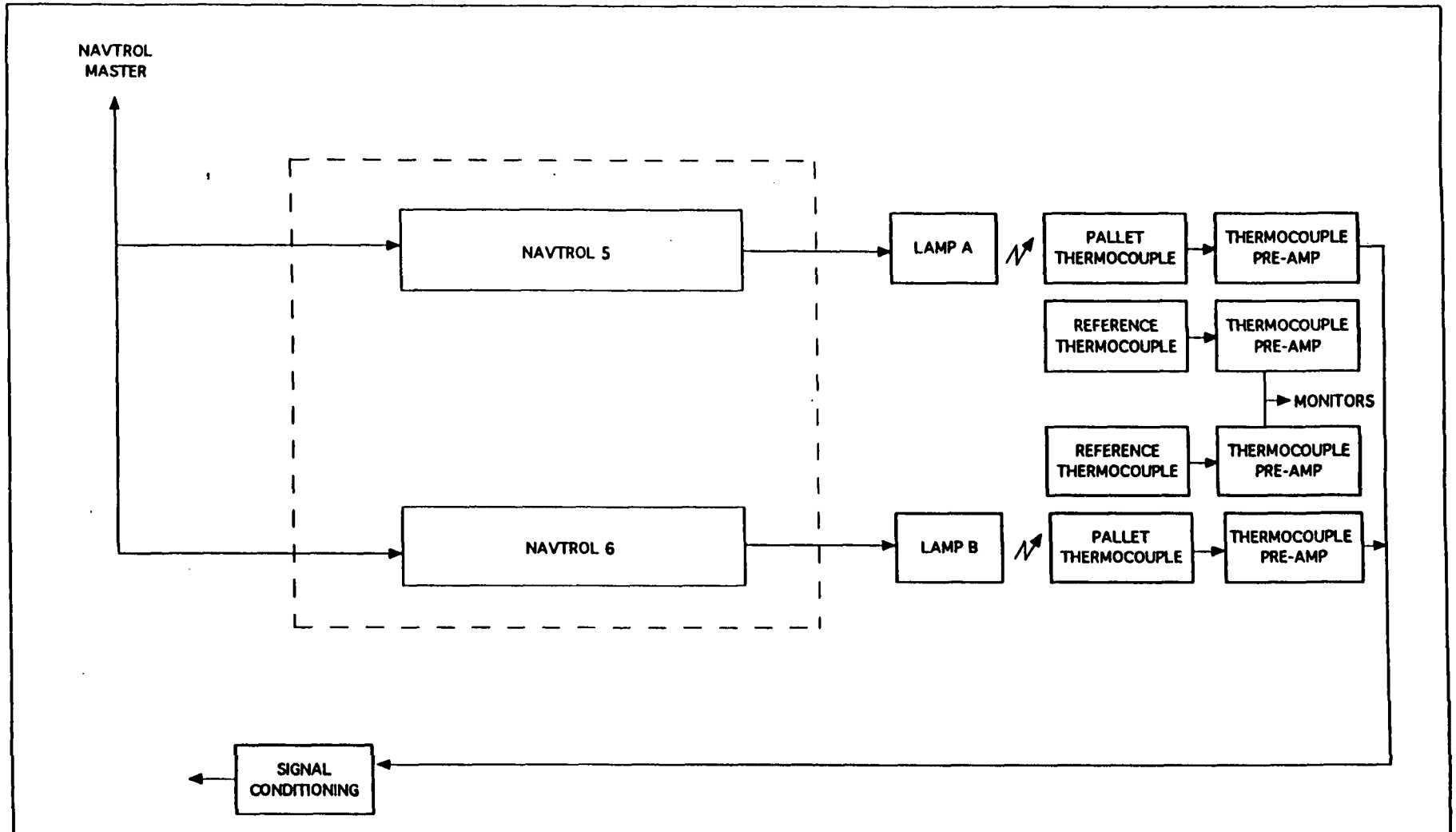


Servo Axis Control Logic Suppliers

Functional Characteristic	Navtrol	Zymark	Industrial	uC
control algorithm	custom	custom	pid	pid
control loop rate	1.6 ms	5 ms	5 ms	5ms
number of channels/unit	2	6	1	1
commandable pid parameters	no, ucode	rom'd	yes	yes
traje	ctory mode	yes	no	no
cpu	32020	80186	several	NEC
embedded code rom'd	no	yes	yes	yes
edc ram	no	no	no	no
position detection	pot,incr	pot+incr	incr.	incr.
auxilary inputs/outputs	yes/yes	yes/no	yes/yes	yes/no
standard functions	no	yes	yes	yes
interface library	no	yes	yes	yes
host i/o	AT bus	rs422	rs422	parallel
printed circuit board	smc	dip	dip	smc
temperature range	industrial	industrial	industrial	industrial
883	no	no	no	no
883 available 1:1	no	yes	no	no
industrial heritage	no	1800 units	yes	yes
flight heritage	pending	no	no	no
industrial cost	5k	tbd	2.5k	0.25k
mil-spec cost	na	na	na	na
883B cost	>200k	>50k?	na	na

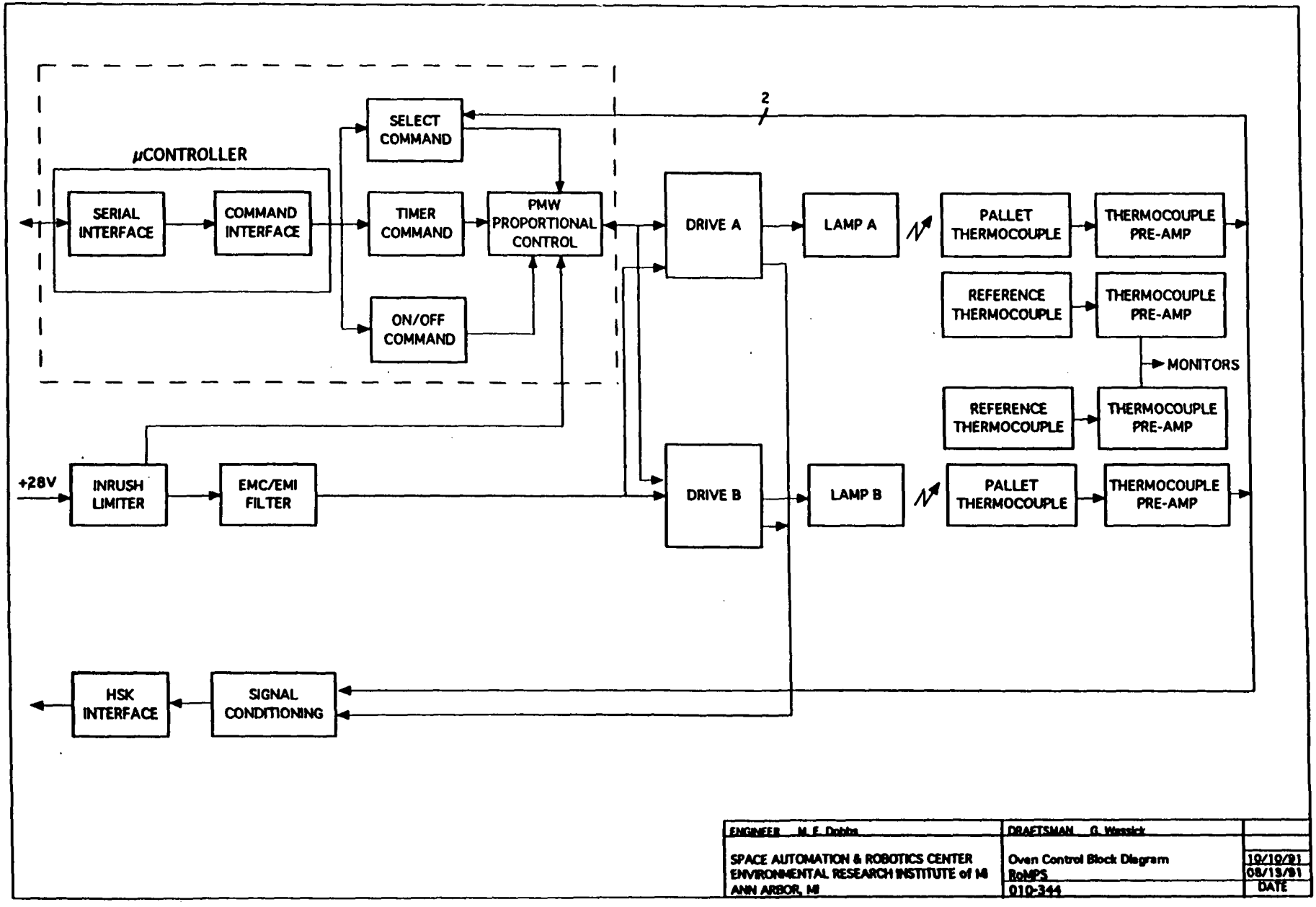
Annealing Oven Control Subsystem

- Interfaces
  - Control — serial interface
  - Feedback — conditioned thermcouple output
  - Output — quartz halogen filament lamp
  - Protection — filament inrush protection
- Power Requirements
  - Voltage — 24 volt rated lamp
  - Current — 10 amp maximum
- Temperature Set Point
  - Range — 350°C to 1500°C
  - Resolution — +- 2% of setpoint (6 bits)
  - Repeatability — +- 2% of setpoint (6 bits)
- Time Set Point
  - Range — 3 to 7200 seconds
  - Resolution — +- 1 second (software controlled)
- Response Time
  - limited by thermal coupling to sample
- Time Profile
  - 2 step time-temperature profile
    - 1) preheat, 2) melt



ENGINEER M. F. Dobbs	DRAFTSMAN G. Wassick	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	Oven Control Block Diagram RoMPS 010-343	08/13/91 DATE

15.0A

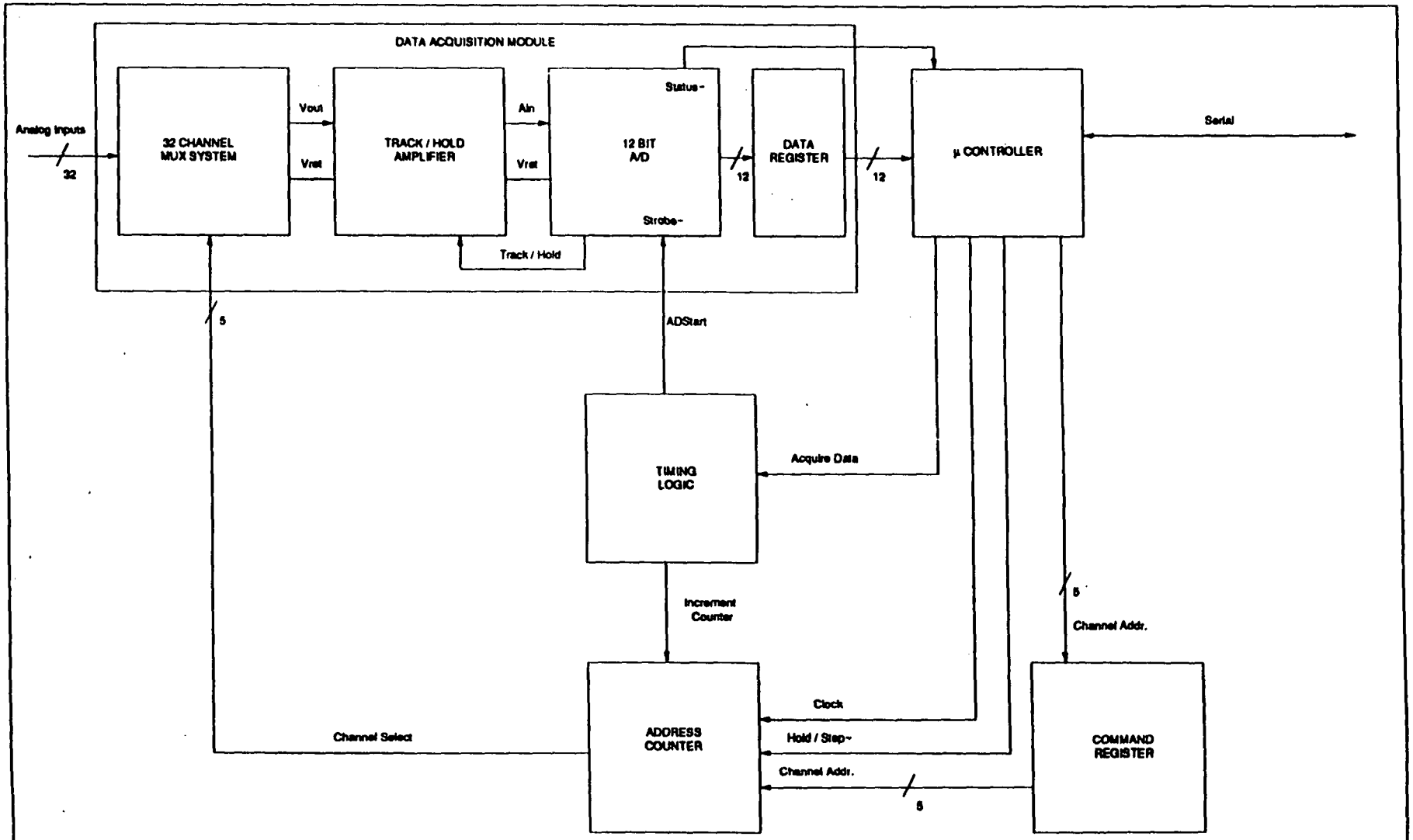


ENGINEER M. F. Dobbs	DRAFTSMAN G. Wenstick	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	Oven Control Block Diagram RoMPS 010-344	10/19/91 08/13/91 DATE

15.0B

Experiment Data Acquisition Subsystem

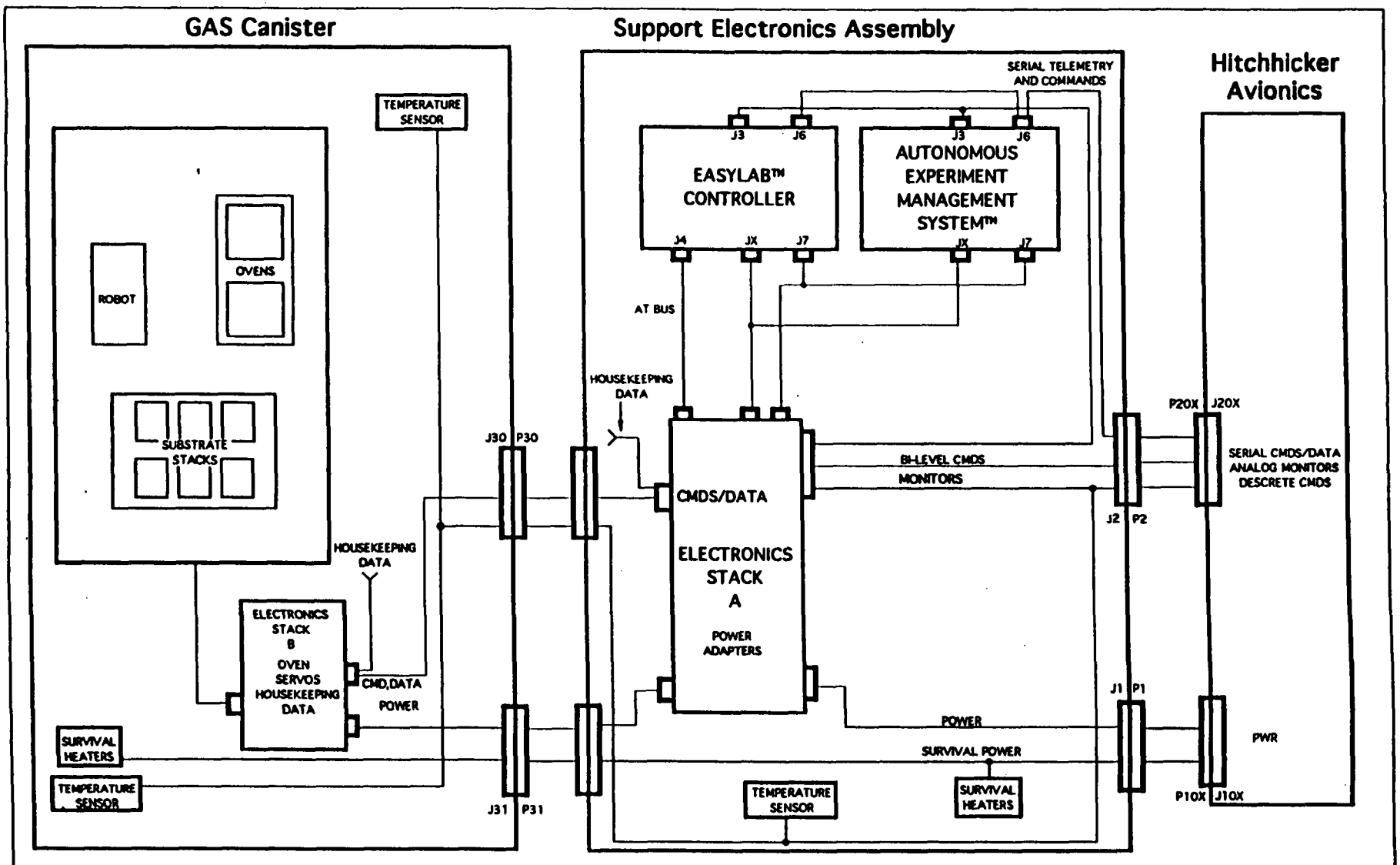
- RTA process monitor
  thermocouple lamp flux monitors
- Oven Status
  lamp current
- Robot Status
  4 axis position
  1 axis force
  EOT fiducials
  overtemp, current limit indicators
- Computer Status
  executive status
  script status
  rule evalutation
- Health and Safety Monitors
  radiator
  oven
  robot
  electronics stacks
  power supplies



ENGINEER I. M. Tomko	DRAFTSMAN	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	Housekeeping Data Acquisition Block Diagram RoMPS 010-338	10/10/91 07/16/91 DATE

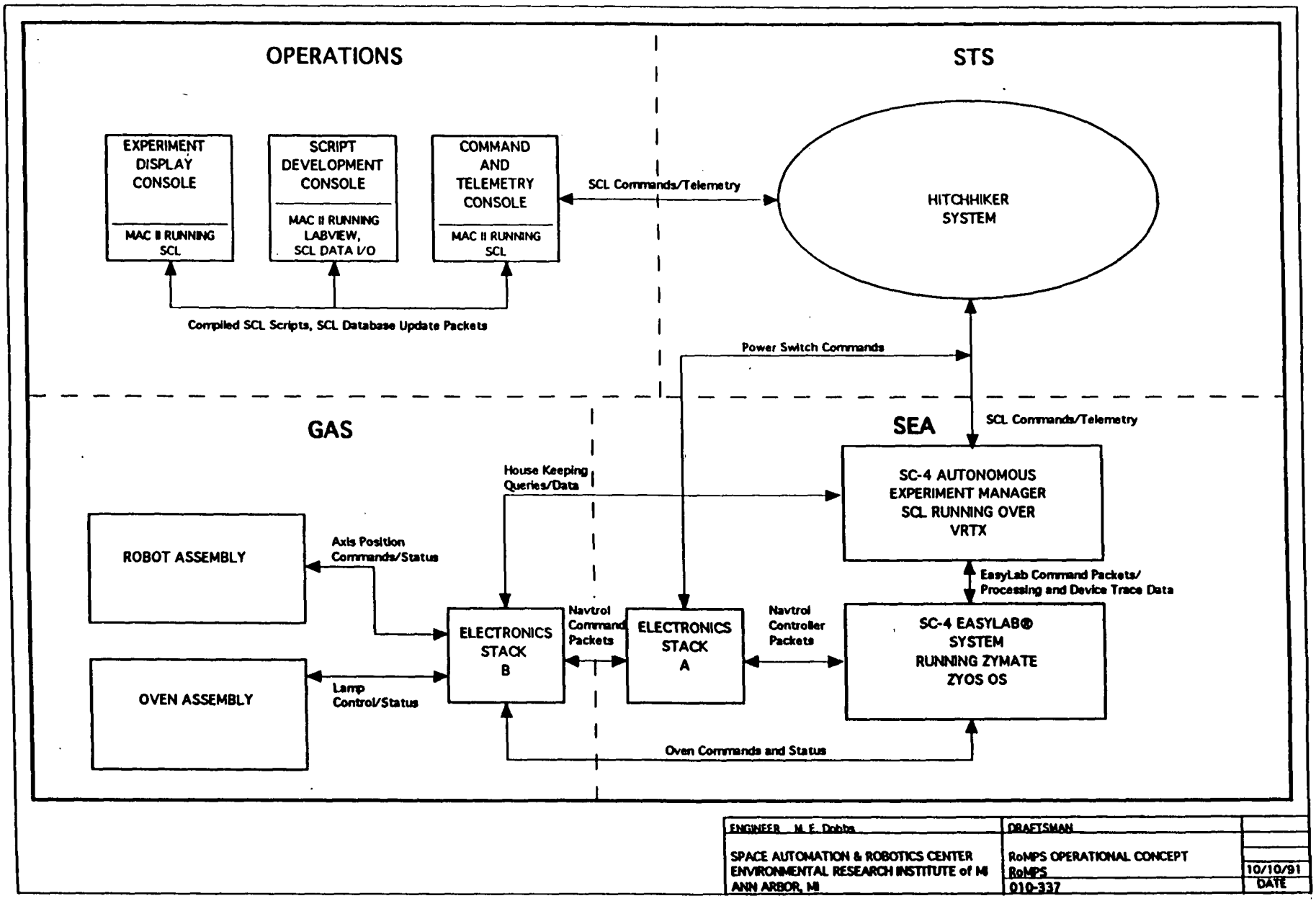
16.0.2

	A	B	C	D	E
1	RoMPS Data Acquisition				
2	Function	Description	Length	Rate	Comment
3					
4		sample temp	2	1	process
5		flux intensity	2	1	
6		flux intensity	2	1	
7		flux intensity	2	1	
8		flux intensity	2	1	
9		lamp current	2	1	
10		force	2	1	robot
11		eot status	2	1	
12		exp. current	2	1	engineering
13		elec temp	2	1	
14		elec temp	2	1	
15		radiator temp	2	1	
16		oven temp	2	1	
17		oven temp	2	1	
18		robot temp	2	1	
19					
20					
21					
22					
23					
24	TOTAL		30		



Note: The designation "P" means this connector is on the end of a cable.
The designation "J" means this connector is on a chassis mount connector.
PLUG JX IS 1553 OR nRS422

ENGINEER I. M. Tomko	DRAFTSMAN	
SPACE AUTOMATION & ROBOTICS CENTER	Interface Connectors	
ENVIRONMENTAL RESEARCH INSTITUTE of MI	Harnessing	10/10/91
ANN ARBOR, MI	RoMPS	06/07/91
	010-140	DATE



ENGINEER M. F. Dobbs	DRAFTSMAN	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	RoMPS OPERATIONAL CONCEPT RoMPS 010-337	10/10/91 DATE