②

-TR-91-3038

AD-A238 776

WRIGHT LABORATORY

DEL BOURNE DATA MANAGEMENT SYSTEM FOR WIND TUNNEL TESTING

e F. Webster
ger Davis
rry L. Bradford

DTIC
ELECTE
JUL 22 1991
S D
D

SCO, Inc.
5 S. Jackson Street
llahoma, TN 37388

ne 1991

nal Report for the Period July 1990 - February 1991

proved for public release; distribution unlimited.

91-05603

IGHT DYNAMICS DIRECTORATE
IGHT LABORATORY
R FORCE SYSTEMS COMMAND
IGHT-PATTERSON AIR FORCE BASE, OHIO 45433-6553

91 7 19 020

NOTICE

This report is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

James R. Hayes
JAMES R. HAYES
Project Engineer
High Speed Aero Performance Branch

Valentine Dahlem
VALENTINE DAHLEM
Chief
High Speed Aero Performance Branch

FOR THE COMMANDER

David R Selegan
DAVID R. SELEGAN
Acting Chief
Aeromechanics Division
Flight Dynamics Directorate

If your address has changed, if you wish to be removed from our mailing list, or if the addressee is no longer employed by your organization please notify WL/FIMG , WPAFB, OH 45433-6553 to help us maintain a current mailing list.

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

1b. RESTRICTIVE MARKINGS
N/A

2a. SECURITY CLASSIFICATION AUTHORITY

2b. DECLASSIFICATION / DOWNGRADING SCHEDULE

3. DISTRIBUTION / AVAILABILITY OF REPORT
Approved for public release; distribution is unlimited.

4. PERFORMING ORGANIZATION REPORT NUMBER(S)
TeSCO-TR-91-1

5. MONITORING ORGANIZATION REPORT NUMBER(S)
WL-TR-91-3038

6a. NAME OF PERFORMING ORGANIZATION
TeSCO, Inc.

6b. OFFICE SYMBOL *(If applicable)*

7a. NAME OF MONITORING ORGANIZATION
Flight Dynamics Dir (WL/FIMG)
Wright Laboratory

6c. ADDRESS *(City, State, and ZIP Code)*
305 S. Jackson Street
Tullahoma TN 37388

7b. ADDRESS *(City, State, and ZIP Code)*
Wright-Patterson AFB OH
45433-6553

8a. NAME OF FUNDING / SPONSORING ORGANIZATION
Flight Dynamics Directorate

8b. OFFICE SYMBOL *(If applicable)*
WL/FIMG

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
F33615-90-C-3006

8c. ADDRESS *(City, State, and ZIP Code)*
Wright-Patterson AFB OH 45433-6553

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
62201F	3005	40	90

11. TITLE *(Include Security Classification)*
Model Bourne Data Management System for Wind Tunnel Testing

12. PERSONAL AUTHOR(S)
Webster, Lee F., Davis, R., Bradford, T.

13a. TYPE OF REPORT
Final

13b. TIME COVERED
FROM 90/7 TO 91/2

14. DATE OF REPORT *(Year, Month, Day)*
91/06

15. PAGE COUNT
33

16. SUPPLEMENTARY NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP
14	02	
14	03	

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
Wind Tunnel Data Systems. Model Mounted Processors. Optical Data Transmission. "On Line" Data Processing.

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

This report covers the preliminary design of a modern wind tunnel data processing system capable of producing immediate test results in engineering units by employing an on board model mounted data multiplexing and signal processing unit communicating through a minimum of through sting wiring to its own personal computer based data acquisition and processing system. Up to 1000 channnels of data can be acquired at speeds up to 83K samples per second. Since the system is modular it can be fitted to a wind range of models with a minimum of hardware modification. Also, since gains and sampling rate & sequence are computer controlled, needed adjustments to data processing can be made from a keyboard, without hardware changes, even while a test is in progress. The work accomplished in this project included all circuit design, component selection, circuit board design and breadboarding and verification of the overall design operability. At this point, the design has proceeded to the point where it is ready to be prototyped during a Phase II effort. During the proposed follow on work, the system prototype will be tested to verify its performance during bench and wind tunnel testing following installation in a suitable model. At the completion of this work, the system will be ready

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION
UNCLASSIFIED

22a. NAME OF RESPONSIBLE INDIVIDUAL
JAMES R. HAYES

22b. TELEPHONE *(Include Area Code)*
(513) 255-3439

22c. OFFICE SYMBOL
WL/FIMG

DD Form 1473, JUN 86 *Previous editions are obsolete.*

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

ABSTRACT (CONT.) (BLOCK 19)

for commercial application.

TABLE OF CONTENTS

PAGE NO.

LIST OF FIGURES

INTRODUCTION

The development cost of new aerodynamic vehicles is largely influenced by the costs of acquiring the wind tunnel information needed to validate design performance predictions. This can be a long and costly process for each new vehicle design. The application of modern developments in electronics, technical hardware miniaturization, and high speed personal computers has made possible a new wind tunnel data management concept which has the promise of reducing development cycle time and costs. A Phase I SBIR contract on topic AF90-102 titled Model-Bourne Data Management System was issued by Wright-Patterson AFB in July 1990 for the conceptual development of a system capable of realizing these savings.

Current Aircraft Design Practice

State of the art, conceptual aircraft design practice is to use mathematical representations of the aerodynamics of new aircraft models generated by Computational Fluid Dynamic (CFD) techniques employing modern super-computers. These mathematical models aid in the preliminary designs of the aircraft, but the CFD models still require experimental validation before design decisions can be made on actual aircraft shapes and loads. This validation process requires that physical, aerodynamic subscale models of the aircraft be tested in various wind tunnels to produce data from which the CFD algorithms can be verified. The data needs for such validation requires high quality measurements of pressures, temperatures, forces, and moments. Data acquisition techniques for obtaining these measurements have not kept pace with the increasingly demanding requirements of modern aircraft design and have not taken advantage of the new electronic technology available to the wind tunnel model designer. It is in this area that the work reported herein is concentrated.

Wind Tunnel Testing

Current wind tunnel testing practice is to interface the output of model mounted sensors to the wind tunnel facility data acquisition and data reduction computer system. The model with its sensors is usually prepared by the organization desiring the test information. When the instrumented model is received at the wind tunnel facility, it is adapted to interface with the wind tunnel facility signal processing and data acquisitioning equipment and software. After the test has been completed, and the data collected, the data are massaged (checked, manipulated, corrected, reviewed, and often modified) by the wind tunnel personnel and finally made available to the user originally requesting the test. Since each wind tunnel facility has different testing capabilities (Reynolds number, Mach number, altitude, and temperature simulation) the same model or another similar model will have to be subjected to the same test procedure described above at a number of different wind tunnels in order to obtain data over the complete flight envelope. The assembly of these diverse bits of data into a coherent set of design information is a difficult and time consuming process that can not be completed until all the data is collected. It is on this information package that design decisions are based. Obviously, the earlier this information is available, the shorter the development cycle time. If the overall process can be shortened, great savings in development costs are possible.

Also, many organizations have contributed to the process, each with its own interpretation and biases. This data screening activity can alter the data, slightly changing its information content. Clearly, the sponsoring organization has lost a measure of control over its own information gathering process as is illustrated in Figure 1A. As a consequence of the messy distribution of the task responsibility to the many organizations involved in the wind tunnel test process, fragmentation of Management Control occurs. If a procedure can be developed which would eliminate the management fragmentation inherent in the current approach to wind tunnel testing, the initiating organization could regain control of and responsibility for the development process. This would eliminate much of the potential for mistakes, surprises, and expensive compromises which currently are encountered routinely.

Budgetary Aspects

Contract cost rates for new aircraft design projects are often in excess of 1 million dollars per day. If development time can be shortened by 30 days, then savings of more than 30 million dollars may be possible. Considering today's budget limitations, such cost reductions may make the difference as to whether a new development is affordable or not.

Current Needs

Since the science of aerodynamics is expanding, the needs for measurement information also increases with time. Current wind tunnel programs require an ever increasing number of measurements of pressure, temperature, force, heat transfer, and moments in a given wind tunnel model test. Also, the new aircraft designs require testing in hypersonic facilities which involve very high pressures, flow rates, and temperatures. Consequently, facility acquisition and operational costs are high. In an effort to keep test costs within reason, these facilities employ small test sections and short run times, often much less than one second in duration. The need is then to get the required large number of diverse measurements on a single small model during short tunnel run times in a hostile environment and to record, process, and analyze the data in near real time to provide information content to the development organization in a timely manner at the end of the test.

The past decade has produced significant technical progress in the development of advanced electronic systems such as very capable personal computer systems, advance computational software, micro miniature solid state electronics, fiber optic data transmission, and advanced solid state sensor devices. In the meantime, wind tunnel testing, even after taking full advantage of fluid dynamic computational procedures, has continued to grow more expensive. A large part of the blame for this cost increase lies with an ever expanding flight envelope. Facilities designed to provide data at high mach numbers are very expensive to build and operate. Also, test durations remain very short, thus putting a premium on high data rates and the number of measurements per data run. Another cost driver is the time required to process the data to a format from which engineering design decisions can be made. By providing timely information, the direction of a given test can be guided so as to maximize the amount of information gained as well as allowing the engineering design of a new vehicle to proceed on an expeditious schedule. To reduce the high cost of wind tunnel testing, it is clear that new concepts must be developed to increase productivity. It is toward this end that the Modular Data Acquisition and Recording System (MDARS) has been conceived.

THE MDARS APPROACH

The approach presented herein is to obtain immediate test data in useable engineering form by employing an "on board" model bourne data multiplexing and signal processing system communicating through a minimum of "through sting wiring" to its "own" modern portable personal computer for data acquisition and processing located in the wind tunnel test control room. Since modern models are small, maximum use of miniaturization of electronic components is required. Such miniature designs must also be durable enough to withstand operation in a high temperature and high vibration environment. Also, since a large number of channels are needed ($\approx$1000), high speed data acquisition and processing must be provided. Also, a system is desired that will permit test measurement flexibility, i.e. one that will allow variations in the quantity and type of sensors used (pressure, temperature, and force), the rate of data sampling, and the order of sampling without mechanically modifying the model hardware.

Self-Contained System Advantages

The use of modern electronic devices and recent micro-miniature packaging techniques are required to provide a model bourne data acquisition unit communicating with its "own" portable PC data control, recording, and reduction unit. This approach will put the total wind tunnel model and data system into the hands of the development organization. The same MDARS will stay with the model as it is moved from one facility to another keeping consistent data calibrations and operating software. The model and its measurement sensors and data processing, reduction and analysis systems can be validated end-to-end before the model is shipped from one wind tunnel facility to another affording drastically reduced model installation and checkout time. With the miniature model bourne system, it is also possible to measure force, temperature, heat transfer, and pressures in the same tunnel entry thus reducing model hardware costs, lengthy tunnel test times, and difficult post test data correlation. Since reduced data are available in near real time, the user may analyze data between test runs and make testing decisions while the model is still installed in the tunnel, a technique which will allow maximum test information in a given scheduled time. With this system, when the test user leaves the wind tunnel facility, all the model test data may be carried off for immediate in-depth analysis and design decision making. The user also has a model data system combination that is unchanged from "test to test" to ship to another wind tunnel. The MDARS wind tunnel test approach, as planned, is illustrated in Figure 1B. Figures 1A and 1B show how the MDARS shifts the model data system efforts away from the wind tunnel test facility back to the user, who has the ultimate responsibility for the results of the model's success.

Previous "On Board" Data Acquisition Systems

Early efforts to produce a model bourne data processing system have resulted in hardware small enough to be mounted in the average hypersonic model but only capable of handling 200 to 400 measurement channels. Sampling speeds were high enough to produce good results even in test durations of one second or less. The system easily withstood the wind tunnel environment, although the desirability of an active temperature control system became evident when testing at high tunnel stagnation temperatures. While these designs were promising, operational problems were encountered which limited their overall usability. The design efforts addressed in this report are devoted to the development of concepts which will allow these early systems to become practical data acquisition systems for wind tunnel testing.

PROJECT OBJECTIVE

The technical objective of this SBIR project is to design, package, and fabricate a prototype of a modern, cost effective, commercially available model bourne data acquisition system for wind tunnel testing, meeting all the requirements stated above. This system includes a miniaturized model mounted unit to provide signal conditioning, multiplexing, and digitizing of model instrumentation outputs, interfaced to a remote personal computer to simultaneously provide the acquisition, data storage system, and an analysis capability for wind tunnel data. Phase I of the project is to complete the conceptual design while Phase II is to build and test a prototype in an actual wind tunnel test. This system is shown schematically in Figure 2.

Phase I Studies

Phase I objectives were to first study current wind tunnel testing techniques to ascertain those areas in which improvements were needed to reduce cost and to speed the entire information gathering sequence. To accomplish this, the industries needs for wind tunnel data were examined to acquire an estimate of the ranges of measurements needed, the frequency content of such measurements, the accuracies, the calibration processes, the state of the art of sensor design, and the technology of model design, set up and wind tunnel operational aspects. Once these factors were well in hand, a set of specifications for the system was established. At this point, the design of the circuitry required to meet these specifications began. Each circuit design was then built up in a "breadboard" configuration and tested to ensure that the circuit design and the chosen solid state components would meet the design goals. When this step was complete, packaging proceeded with the design of the actual printed circuit boards and the connectorization required to make the system work in the model and wind tunnel environment.

System Specification

The following specifications were derived from a review of the overall requirements for data from a wide range of wind tunnel model tests. Any practical data acquisition system should have the capability to handle pressure tests, heat transfer tests, and force testing as a minimum. Generally, expeditious testing will require a mix of sensors which involve all of the above, plus specialized measurements of strains (i.e., hinge moments), gas or liquid flows, and acceleration. In most cases, the frequency response of the measurement system will be dictated by a combination of the tunnel operational characteristics and the model configuration. Hence, the data system should accommodate low frequency inputs (such as pressure measurements which employ long sensing tubes or slow moving temperatures) to rapidly changing sensor outputs such as strain gauge and rate of heat transfer measurements in high enthalpy flows. All of the above dictates that a practical system must have the capability to accommodate a wide range of sampling speeds, amplification factors, and flexibility in sampling sequence.

The system in many cases will be used to obtain information on classified vehicles. Hence, some consideration has been given to meeting "tempest" requirements. To this end, the device should be digital and employ optical data transmission techniques.

Finally, to have universal applicability, the basic hardware must be small enough to allow it to fit readily in most models without expensive rework. This means maximum utilization of available space inside a model. In turn, this requires that electrical components be mounted in dense fashion so that no board space is wasted. The smallest solid-state electrical components available commercially must be used. This helps to reduce self heating since it reduces current requirements. Careful attention to component heating is required to provide heat dissipation which not only prevents operating temperatures from exceeding operating limits but also eliminates calibration shifts resulting from varying hardware temperatures.

Connectorization is a critical aspect of the design, since the volume occupied by these devices becomes one of the most significant users of space. Yet, durability can not be sacrificed for miniaturization since during the course of a models test life time such connections are broken and re-established many times.

The hardware must be capable of rapid reconfiguration to interface with new models and new test conditions without or with only minor mechanical modification. Consequently, a modular building block system is required which will allow the wind tunnel user to quickly build up the hardware configuration required for a specific test. Control and data acquisition software must be developed which can accommodate such configuration changes without modification. This approach also makes it possible to accelerate system trouble shooting. Since each module is a low cost item in itself and spares are easily affordable, a suspected module can be changed out quickly if found to be defective. Such a trouble shooting capability can be of major importance in holding to a test schedule during test operations.

Phase I Progress

Phase I design studies have resulted in circuit designs using advanced solid-state micro-miniature surface mounted components laid out in a modular arrangement using complex, advanced circuit design concepts. The model electronics design utilizes multi-layer printed circuit boards with components on both sides mounted in "plug in" modules which are in turn installed in a temperature conditioning box designed to protect the equipment from facility vibration and heating affects. This concept is illustrated schematically in Figure 3.

These designs have been incorporated into a packaging concept which will allow needed configuration versatility to adapt the system to the specific requirements for a given model and test objective while retaining a size small enough to fit into very small models. The versatile modular design utilizes a buss system into which control modules and data modules can be interconnected. By selection of appropriate "plug-in" modules, the mix of measurement channels can be configured to match test requirements, affording the model designer testing flexibility and lower cost. The buss approach also allows signal conditioning modules to be remotely located using a cable adapter to optimize usage of model space or to minimize model wiring or pressure measurement tubulation.

Figure 4 shows a representation of the printed circuit board design for the control module. The ten layer board, approximately 1.8 inches square, is typical of the modules which have been designed in Phase I. The Phase I design allows acquisition of up to 1024 channels of data at rates of up to 83K samples per second in a physical volume of about 20 cubic inches. "Through sting" connection requirements are reduced to 3, 22 AWG wires required to provide power to the "on board" systems and 2 fiber optic data cables required to provide control inputs and data outputs from the *digital data recording system, as shown in Figure 5.*

The MDARS system provides for real time alteration of channel scan sequence, gains, and settling times by keyboard control to optimize the recording of the desired measurements. Measurement sensitivity (channel gain) can be adjusted as test conditions demand and critical, fast response channels can be super commutated to increase their effective scan rate. These scan alterations occur in real time and require no physical access to the model bourne system since they are electrically communicated from scan menus in the personal computer used for data recording and display.

The required computer interface hardware has also been designed and successfully "breadboard" tested in Phase I. This interface hardware and software provides the capability to adjust the measurement gains, scan sequences, settling time, and acquisition speed on a channel by channel basis. Such adjustments will be keyboard programmable making fine tuning of acquisition procedures possible between test points during a wind tunnel test program.

When the Phase I technical effort was considered complete, a proposal was prepared for a Phase II SBIR contract in which it is planned to actually construct a prototype of the system, bench test the system, fit it into a model and demonstrate its performance during an actual wind tunnel test.

Phase II Approach

Prototyping of the actual hardware and software requires Phase II funding. During Phase II, the Phase I designed system will be constructed, tested, debugged, and used to demonstrate expected performance. Once the fabricated system has demonstrated satisfactory operation during bench testing, it is desirable to proof test the hardware and software in an actual wind tunnel environment. Therefore, it is proposed that the system be installed in an existing model and tested in a suitable government provided wind tunnel. During these later tests, procedures and techniques are to be developed to provide the guidelines for future government and commercial users of the new system to ensure that maximum benefit will accrue from these new concepts.

Phase II Work Plan

A Phase II proposal was prepared and submitted in November of 1990 proposing the building of a prototype of the complete MDARS system, bench testing that prototype, correcting any shortcomings and then installation of the system in a suitable wind tunnel model. After bench checking of the model installation the complete package would be installed in a selected wind tunnel and tested to demonstrate the system performance and readiness for production and use by the industry.

Phase II efforts are scheduled to cover about 18 months. However, prototyping will take approximately 6 months, followed by bench tests at the environmental extremes expected in use i.e., temperatures and vibrations. While these tests are in progress, the items required for installation of the system in a selected model will be designed and constructed. Once the tests are complete, the entire system will be installed in the model, calibrated and prepared for test. These preparations will include the generation of all data reduction software required for near real time data acquisition, data validation, and model performance definition.

At about the 12th month, the model and data system will be ready for test in a wind tunnel. The exact schedule will depend on tunnel availability. However, it is expected that the test can be scheduled, run, and the results evaluated and reported in a 6 month period.

Possible Additional Areas of Study

Connector design remains a major development area. While the MDARS calls for compact sensor and module connectors using 0.050 inch pin spacing, a major reduction in system size could result from the development of connectors for model bourne systems with 0.025 inch pin spacing. While connectors with this pin spacing are becoming commercially available, most are not in configurations that are useful for wind tunnel applications. Continued development of connector designs is of major importance to future further reductions in the size of MDARS.

Evaluation of the use of data reduction techniques to compensate for the drift in ESP modules rather than attempting to hold the ESP at a constant temperature with an electrical heater will require further study. This would eliminate the bulky heater and the large power requirement now required to temperature condition the ESP modules.

MDARS HARDWARE DESIGN DESCRIPTION

The following is a brief description of the design concepts for the various MDARS subassemblies.

18 Slot Buss Module

The buss module distributes power, addresses, and signals throughout the model bourne unit and provides the mechanical supports for the individual modules. The buss module has been electrically and mechanically designed and successfully breadboarded. However, a form, fit, and function prototype will be fabricated and proof tested in Phase II.

Control Module

The control module, shown in Figure 6 in block diagram form, provides analog to digital conversion, channel selection, selectable gain, and final multiplexing of the data signals from each individual data module installed on the buss. The circuit design was breadboarded and tested and artwork for the fabrication of the control module was developed in Phase I. The control module measures approximately 2 x 2 x 1/2 inches. A prototype of the control module will be fabricated, assembled, and tested during Phase II.

ESP Interface Module

The ESP interface module, shown in Figure 7 in block diagram form, provides an interface to address up to 16 remotely located 48 channel ESP units and multiplex their analog output data into the control module for amplification, multiplexing, and analog to digital conversion. The circuit was designed and artwork for the fabrication of the ESP interface module was developed in Phase I. The module measures approximately 1 x 1.5 x 1/2 inches. ESP operational power requirements and ESP heater control for ESP environmental temperature control will be contained in an "in line" module located at the connector of each individual ESP module. This is to reduce the power routed through the basic MDARS buss system. ESP's and their respective heaters require a relatively large amount of current to operate. Therefore, it is desirable to confine the self heating which results from this power consumption to the ESP proper. This "in line" module will be designed and developed in Phase II and a prototype of the ESP interface module and the "in line" ESP module will be fabricated, assembled, and tested during Phase II.

To further improve operating efficiency and reduce test complexity, studies will be conducted in Phase II to evaluate the feasibility of adjusting the ESP data output voltages to compensate for measured temperature variances of the ESP units via the data recording software. With this approach, the current practice of maintaining constant sensor temperature with a high power consumption ESP heater could be eliminated thus reducing MDARS complexity and power requirements. If this approach is proven workable, only the "in line" connector module hardware will require redesigning to incorporate this feature.

Multi Input/Output Module

The Multi I/O module, shown in Figure 8 in block diagram form, supplies the on-board regulated power, transmits and receives the data over the power cables or optional fiber optic cables, and supplies the system calibration voltage. The circuit for the multi I/O module was designed and breadboard tested in Phase I. Artwork for the mechanical design is also complete resulting in a module measuring approximately 1 x 1.5 x 1/2 inches. A prototype of this module will be fabricated, assembled, and tested in Phase II.

Thermocouple Interface Module

The thermocouple sensor module, shown in Figure 9 in block diagram form, is designed to scan 48 temperature channels. Three channels out of each 48 are dedicated to calibration, zero, and thermocouple reference junction measurements. The zero and calibration voltage are used to establish the gain and offset of each set of 48 channels. The circuit design for the thermocouple interface module was developed and breadboard tested in Phase I. Artwork was also completed resulting in a module measuring approximately 2 x 2 x 1/2 inches. A prototype of this module will be assembled or tested during Phase II.

Strain Gage Interface Module

The strain gage interface module will excite, monitor, and calibrate up to 24 individual 6 wire bridge networks per module. The excitation voltage will be routed to the bridges and voltage level will be measured for data reduction. The resulting module should measure approximately 2 x 2 x 1/2 inches. During Phase I, the thermocouple module was used as a strain gage interface module with an external excitation voltage since the circuitry is almost identical. Because of funding limitation, the actual circuit design was not "breadboarded" during Phase I. The unit needs to be breadboard tested and a prototype built during Phase II.

Remote PC Computer System

The remote PC computer system, as shown in Figure 10 in block diagram form, provides real time control of each channel's scan rate, amplification, and settling time through a custom designed interface board designed and breadboarded in Phase I. During acquisition of data, the computer will store data in extended RAM and processes selected measurements in engineering units for screen display. After a data acquisition sequence, the computer copies the acquired data in the desired units to removable hard disk media for storage. (A second copy of the data can be retained by the wind tunnel facility if desired for analysis work.) The computer is capable of test data reduction and graphical analysis and presentation of both on the screen and on a printer or plotter as required between data acquisition cycles.

To provide real time measurement of tunnel conditions, the computer also contains an internal 16 channel data multiplexer and analog to digital converter. The tunnel data conditions are multiplexed into the model data stream and recorded for data reduction purposes.

The computer hardware consists of a high speed 80386, 32 bit CPU with a clock speed of at least 20 MHz. High speed extended memory is used to temporarily store the data during fast data acquisition. Eight megabytes of memory is required to allow for continuous data recording at the maximum data rate. Acquisition control is designed to allow software selection of data rates from as low as 1 channel per second to a maximum of 83,000 channels per second.

A two bay removable media hard disk is required to provide portability and storage of the large amounts of data that will be recorded in a test matrix. A 16 channel, 16 bit A/D converter is used to process record pertinent tunnel conditions synchronously with the model data. The VGA monitor, 80386 math co-processor, and laser printer allow high quality rapid post test data reduction and reporting. The VGA screen and laser printer provides tabular and plotted data and allows the test user rapid review of the acquired data between tunnel operations.

Custom data acquisition software will provide for acquisition of data. All recorded data will be acquired in the computers electronic memory and then downloaded to removable disk cartridges at the completion of each data acquisition cycle. Standard data reduction routines for pressure, temperature, and force will be added in Phase II. Diagnostic routines and operation interface software to be provided in Phase II will be required to provide monitoring of the status of the system and pretest checkout.

PC Interface Card

The data stream to and from the model bourne electronics package is controlled by the computer through an interface card. The received data is decoded and provided for interrupt driven transfer to the memory of the computer. The card contains the hard wire and fiber optic interfaces for the model bourne electronics. The circuit design for the fabrication of the PC interface card has been developed and breadboard tested in Phase I. Printed circuit board artwork along with a prototype will be developed, fabricated, assembled, and tested in Phase II. A block diagram of this system is shown in Figure 11.

PC Computer System Operational Software

The interface software has been developed in Phase I. It is written in Microsoft C and uses DMA techniques to achieve the required throughput.

The data acquisition, display, and control software, as shown in Figure 12, will be coded in Microsoft C in Phase II to afford speed and close connection to the interface software. The completion of this software is an extensive effort, but will afford the ability to totally automate all wind tunnel data acquisition and bring test control to the test user.

Subsequent data analysis software will also be needed which would afford post test or between test run data evaluation and reporting. Although this software is generally test specific, many generic modules could be developed to expedite this specialized task. This data reduction software should be written in a language more appropriate to the scientific community such as ADA or FORTRAN. The portions of this software needed for the Phase II testing will be developed in Phase II.

MDARS Breadboard Testing Set-Up

The individual modules were breadboard tested with a 80386 computer to ensure that proper operational goals were achieved. A photograph of this set up is included in Figure 13. Individual channel selection, gain selection, module selection, data transmittal rates, and calibration circuitry was validated through this process.

MDARS Wooden Mock-Up

A wooden mock-up of the "on-board" portion of the MDARS system was manufactured to aid in the design of the individual modules. This mock-up has proven to be invaluable in determining logistical problems in MDARS model bourne cabling and instrumentation. A photograph of the mock-up is included as Figure 14.

MARKETABILITY

Because of the cost savings in aerodynamic testing afforded by the MDARS and the diversity of potential applications, a large market for this product is anticipated. The modular design approach and innovative engineering concepts for application to specific wind tunnel models will result in an ever growing market share of the data acquisition, recording, and analysis applications.

The proposed Phase II research will lead to the development of a commercially supplied data acquisition system which can be used repeatedly in different test models in different test facilities with complete end-to-end system checkout before the model arrives at the test facility. The system will reduce the data between test runs so the user can make engineering decisions while the model is still in the tunnel instead of months after the test is complete. Tunnel installation times should be reduced and the amount of data from a single tunnel entry will increase. This will substantially increase the amount of data delivered for every test dollar spent and revolutionize wind tunnel testing as we currently know it.

It is expected that the MDARS will have applications outside of wind tunnel testing. For example, it would be an ideal small facility data acquisition system and could also be integrated into a facility control system. The small size and ruggedness of the system should make it usable for flight test applications. The unit could be located at remote locations throughout the test aircraft with the only connections being fiber optic cabling to a central recorder and processing data system.

Another flight application would be as a monitor for in flight engine health monitoring. In this application, an adaptation of the model mounted section would be permanently attached to the turbine engine. In this position, it would collect engine performance data from sensors on the engine which measures RPM, pressure ratio, selected air and bearing temperatures, and engine vibration levels. These data could be recorded on the aircraft or by telemetry sent to ground recording stations. When equipped with suitable software, the computer system would continuously analyze the basic health of the engine. Although health monitoring systems exist, the MDARS system will be lighter, more compact and durable than present systems. Also, present systems suffer from the same fragmentation of operational responsibility problems which are present in current wind tunnel operations. The use of a version of MDARS will allow maintenance personnel to acquire a complete picture of the current health status of the entire fleet at any instant in time. Such a system should be attractive to military organizations as well as the airlines.

Another use of the modular buss system would be for monitoring the performance of large industrial operations such as machine shops and manufacturing facilities. The modular set up will allow the proper mix of sensors and data processing to be applied to each monitored process. Again, at the computer center, not only machine operational health can be monitored, but also the output of machines or production lines.

TeSCO, Inc. has been involved in analyzing the potential market for an MDAR's for the last 2 years. During that time, many contacts with various aerospace organizations involved in wind tunnel testing have been made. These marketing efforts have always been received with great interest and have resulted in an earlier version of the Data System being used to acquire data during a major test series on the NASP program with good results. Further direct sales to that company and others are expected in the future once the MDARS performance is demonstrated. Also, interest has been shown by a number of firms engaged in the marketing of instrumentation and computer systems in securing marketing rights to the system. TeSCO, Inc. would plan to manufacture and service the systems with marketing being handled by the marketing firm. Once Phase II is in place, negotiations will proceed toward establishing such agreements.

SUMMARY OF RESULTS

The design of all the major subcomponents of the MDARS has been completed. Wiring schematics of all the model bourne modules have been prepared and updated to include any changes due to breadboard results. The computer interface circuitry and the operational concepts and software have been laid out schematically and tested. All of these systems are now ready to support Phase II actively.

All systems were set up on the bench in a "breadboard" configuration and tested to prove the design concept and to demonstrate system performance potential. When limitation in the design were identified, the changes required to solve the designs limits were factored back into the circuit or software designs.

When the component designs were proved, the actual hardware design was undertaken. This effort included the design of the multi layer circuit boards and the connectorization required. All the hardware systems required for proto type testing have been designed and are ready for fabrication pending Phase II go ahead.

Analysis of the overall system indicates that all performance specifications will be met. Considerable flexibility in operating configuration will exist. Hence, the system can be set up to support pressure tests with up to 1000 channels or combination of pressure, force, temperature, vibration with the combined channel count of 1000. Also, gains, scan sequence, and scan rate will be adjustable within specification limits from the control PC keyboard during test set up or during actual test. It was not planned during Phase I to write the detailed operating software, hence, this task remains to be accomplished early in Phase II. However, the operational procedures for this software have been demonstrated and no difficulty in programming is anticipated. The results of the Phase I studies indicate that the MDARS will be a "stand alone" data system capable of supporting all standard wind tunnel tests. It will handle all model generated data acquisition and data reduction. It will also handle near real time data analysis to the extent that the computer system is provided with appropriate data reduction software. Generation of such software was not part of the Phase I effort but is included to a degree in the Phase II proof tests with an actual wind tunnel test of a selected model.

This capability allows the organization seeking the test data to minimize the delays currently experienced in acquiring the information content of the data. It allows the test sponsor and user to control the progress of the test results as the test proceeds and to make the data immediately available for design purposes.

Customer's Responsibilities	
Hardware	**Tasks**
Model Model Instrumentation	Model Design Model Construction Instrumentation Selection Ship to Facility Monitor Testing Evaluate Final Data
Facility Responsibilities	
Hardware	**Tasks**
Sting and Balance Hardware Wind Tunnel Facility Data Acquisition Computer Data Reduction Computer Signal Conditioning	Model Installation Calibration System End to End Checkout Tunnel Operation CFD Verification Software Validation Data Acquisition Software
Disadvantages	
* Repeat Entire Hardware and Software Setup at Each Wind Tunnel Test Facility * Up to 6 Months to Receive Final Data From Each Facility * High Facility Installation Cost * High Facility Data Reduction Cost	

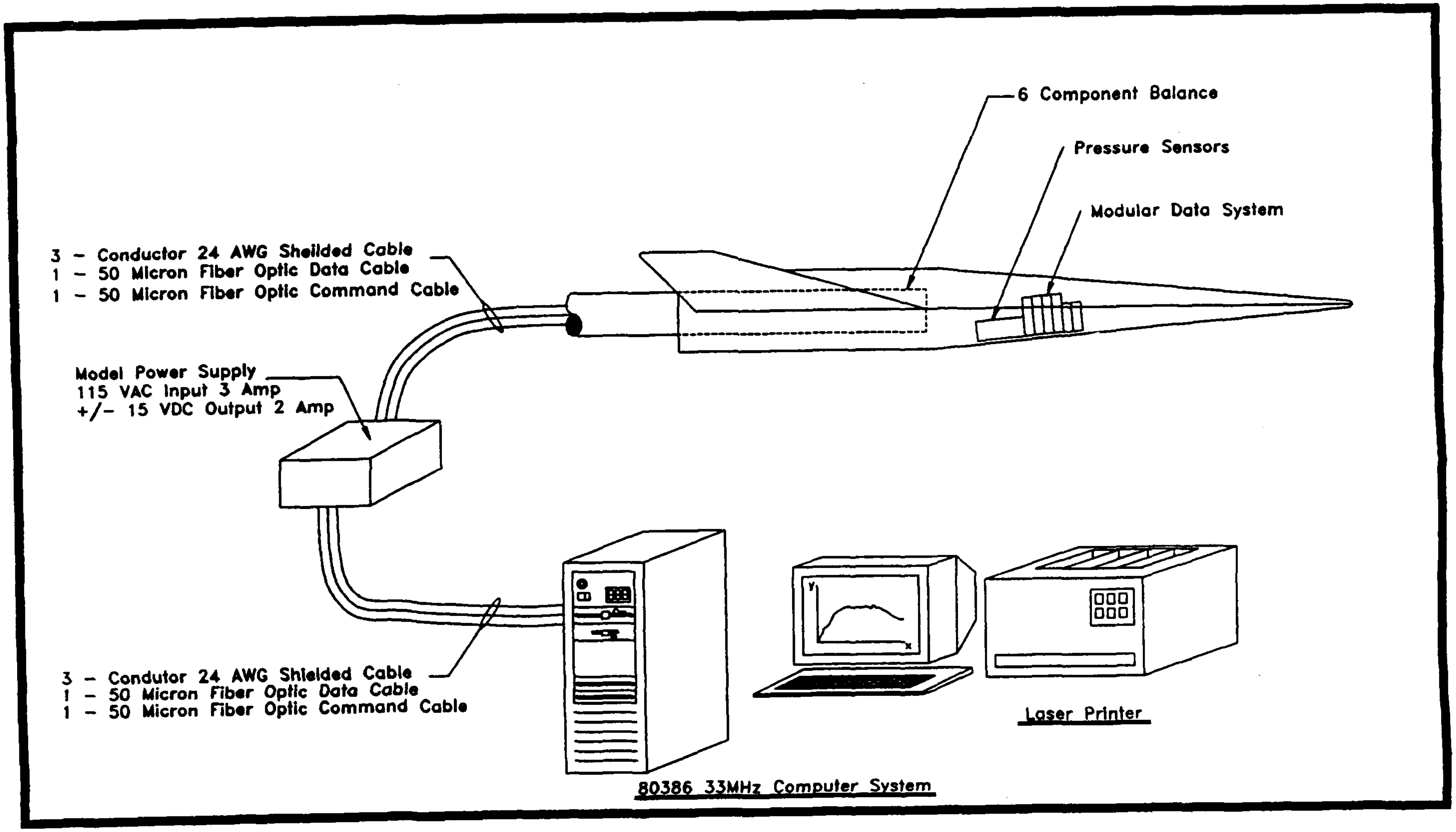
CURRENT TEST PROCEDURE

Figure 1-A

Customer's Responsibilities	
Hardware	**Tasks**
Model MDARS Computer MDARS Model Package (Signal Conditioning) Model Instrumentation Balance Hardware	Model Design Model Construction Instrumentation Selection Software Validation Calibration End to End Checkout Ship to Facility Monitor Testing CFD Verification Evaluate Final Data MDARS Software
Facility Responsibilities	
Hardware	**Tasks**
Sting Hardware Wind Tunnel Facility	Model Installation Tunnel Operation
Advantages	
* Model Pre-Configured for Test Facilities * Immediate Access to Reduced Data * Lower Facility Installation Costs * No Facility Data Reduction Costs * User Reponsible for Everything Except Test Conditions	

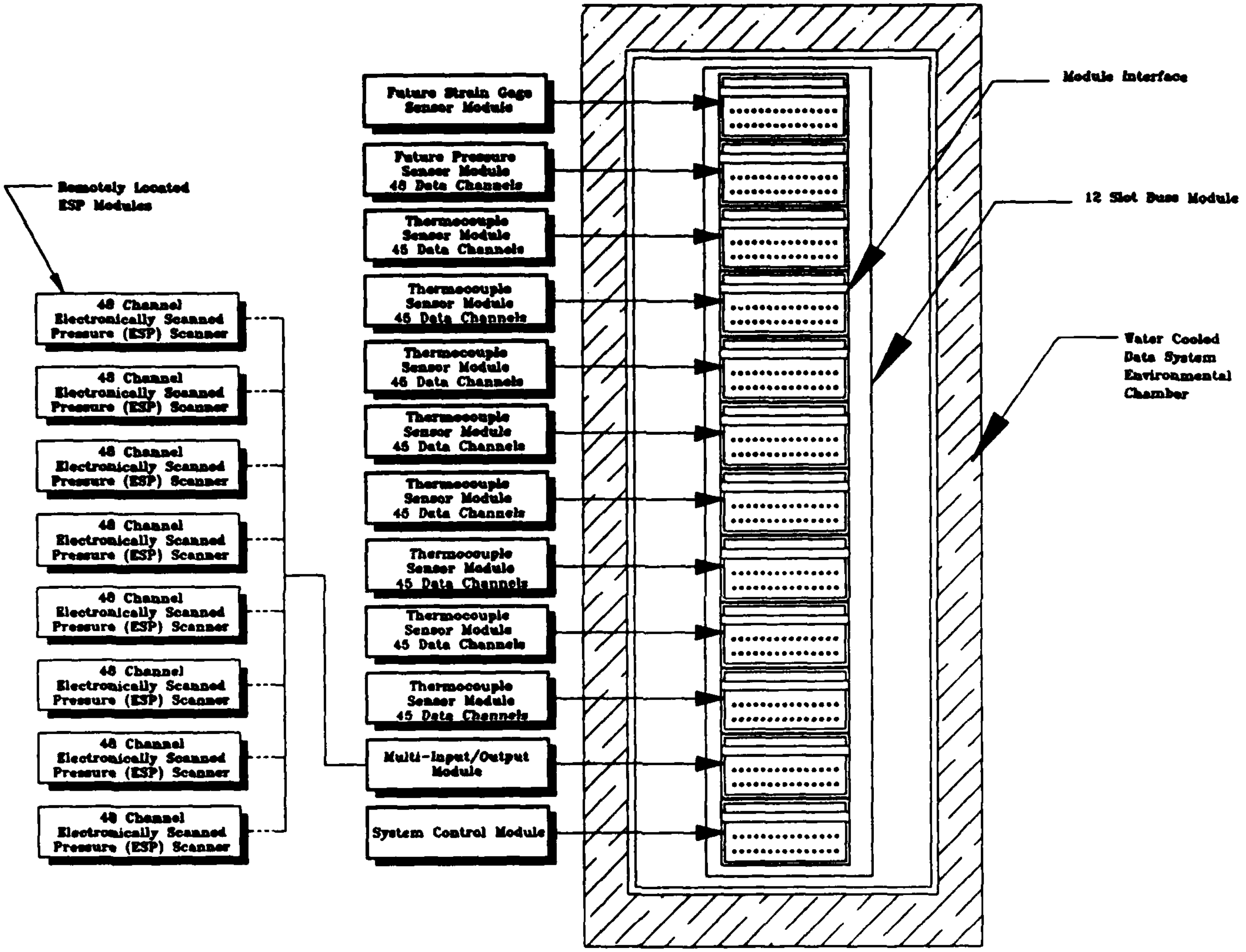
MDARS TEST PROCEDURE

Figure 1-B



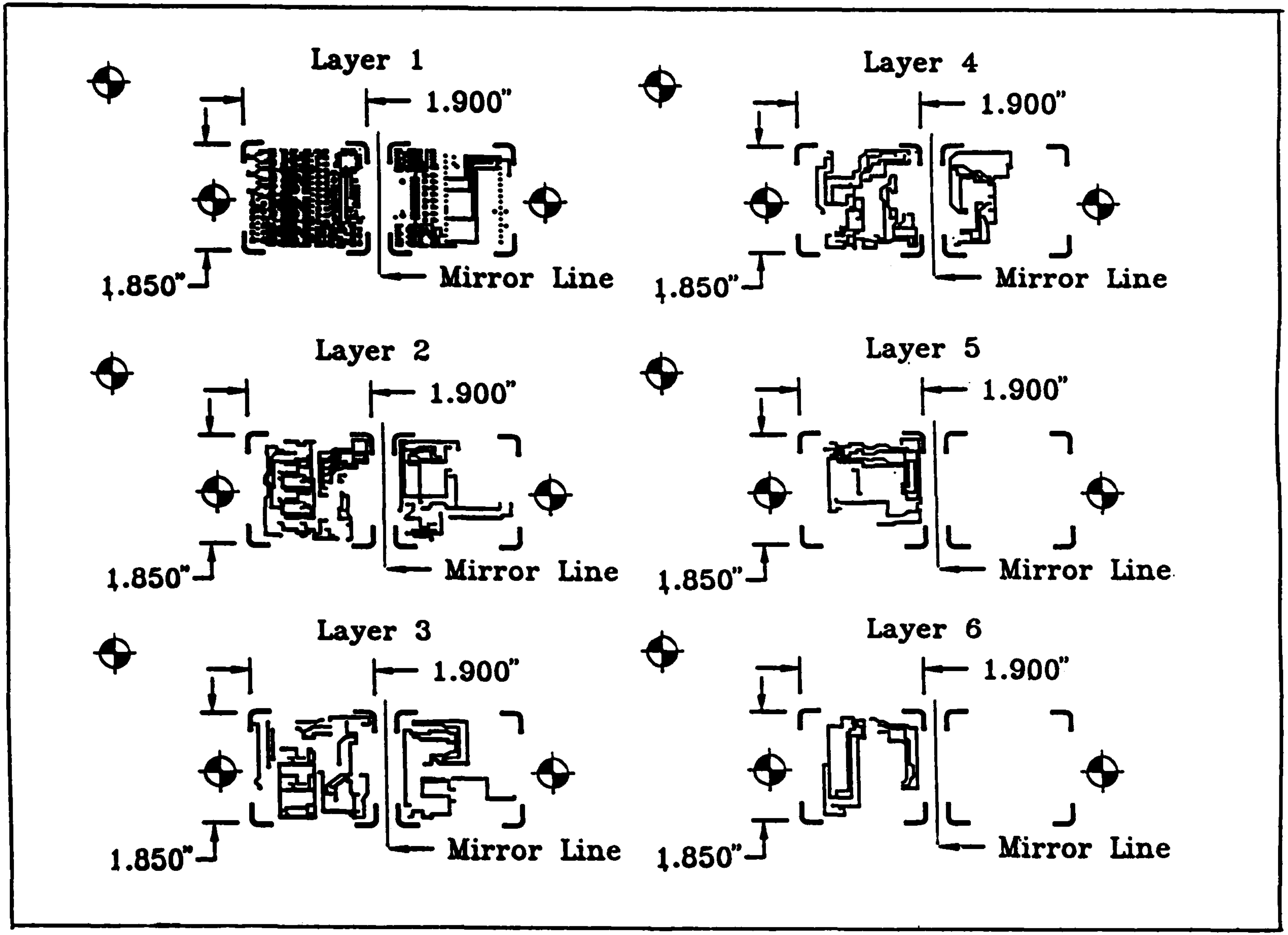
MODULAR DATA ACQUISITION SYSTEM CONCEPT

Figure 2



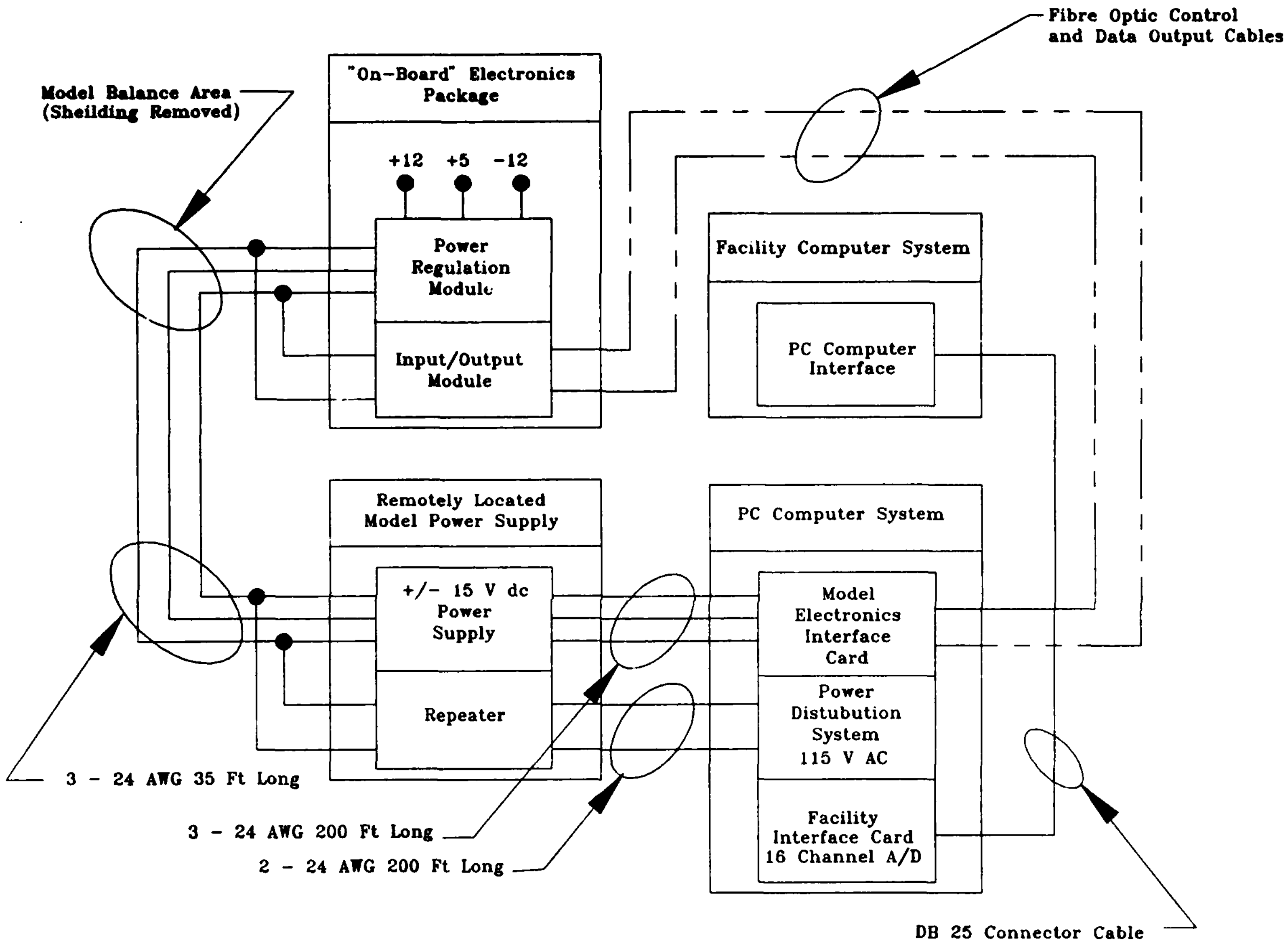
MINIATURE MODEL BOURNE UNIT (828 CHANNEL CONFIGURATION)

Figure 3



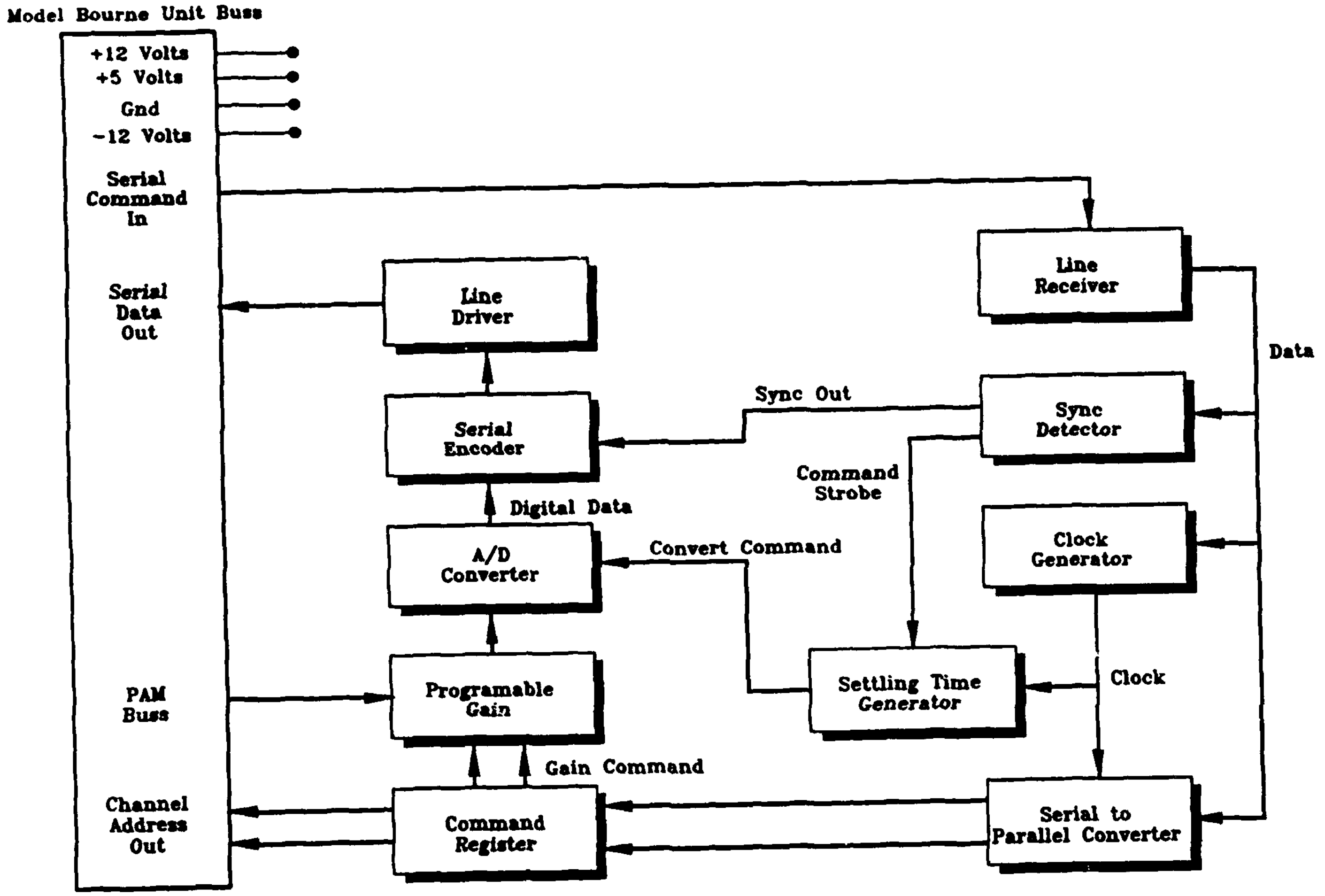
CONTROL MODULE PC BOARD LAYOUT (SUBSCALE)
TYPICAL MULTI-LAYER MDARS PC BOARD DESIGN

Figure 4



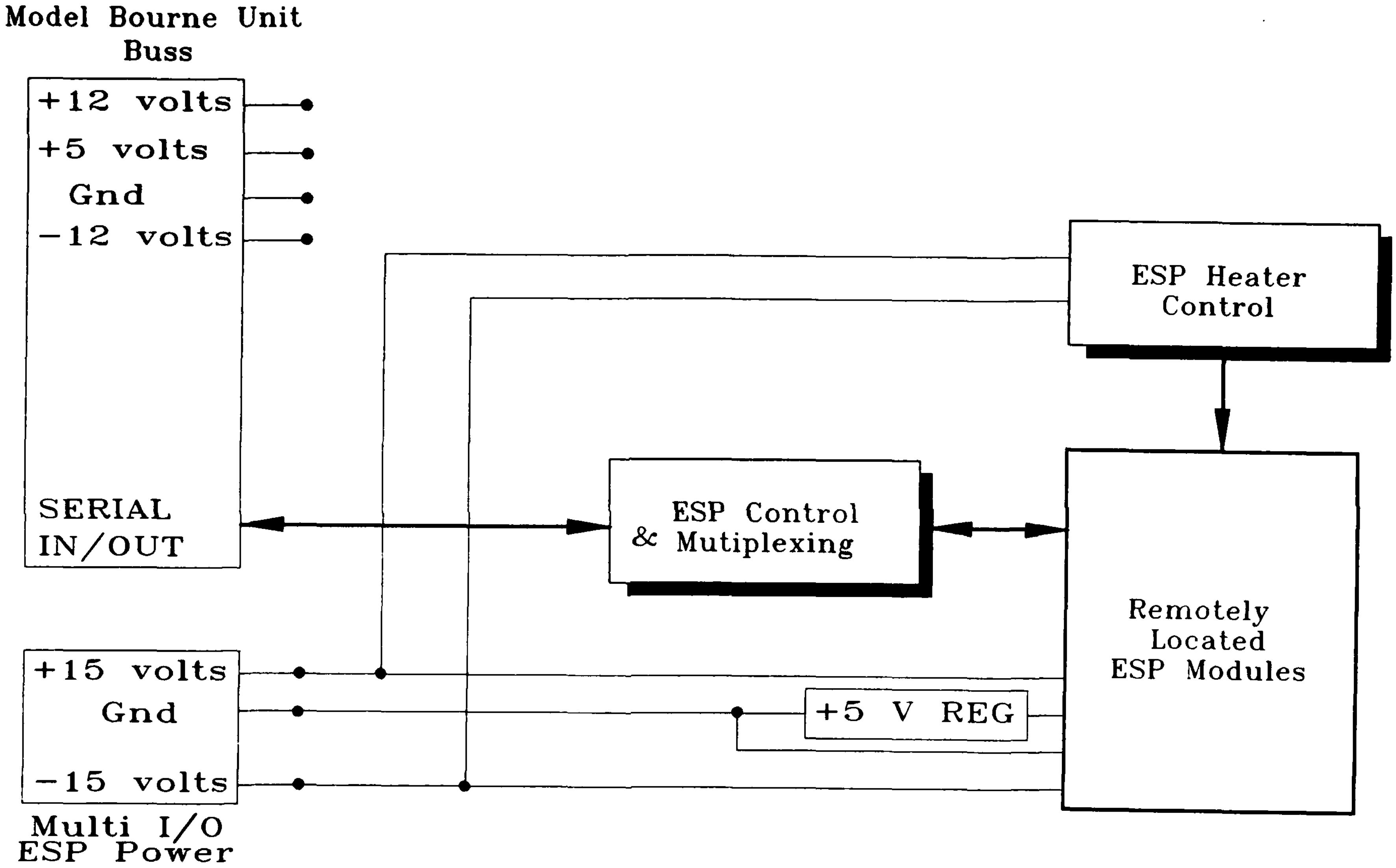
INPUT/OUTPUT CABLE FOR MDARS POWER/DATA TRANSMISSION SYSTEM

Figure 5



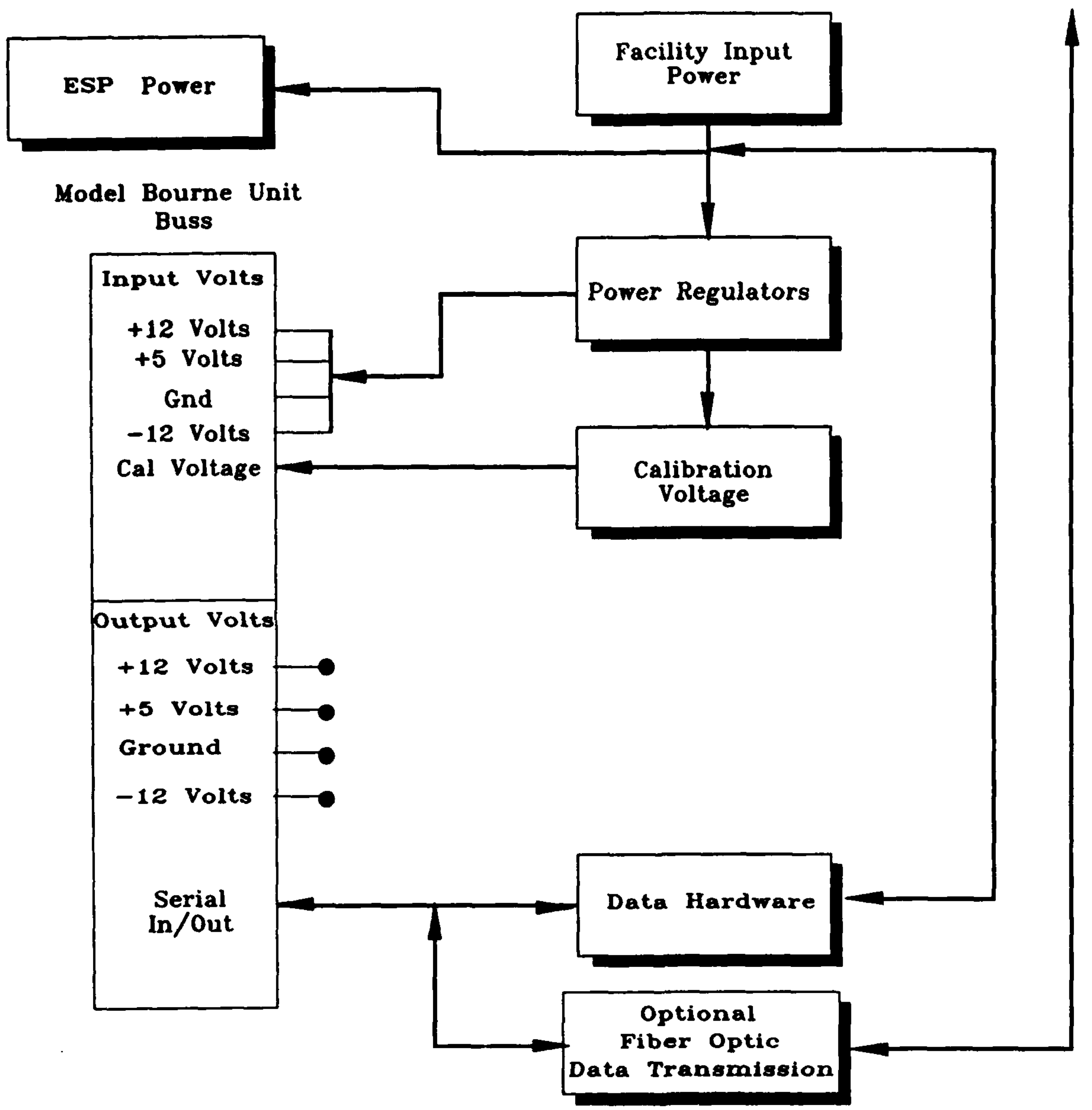
CONTROL MODULE BLOCK DIAGRAM

Figure 6



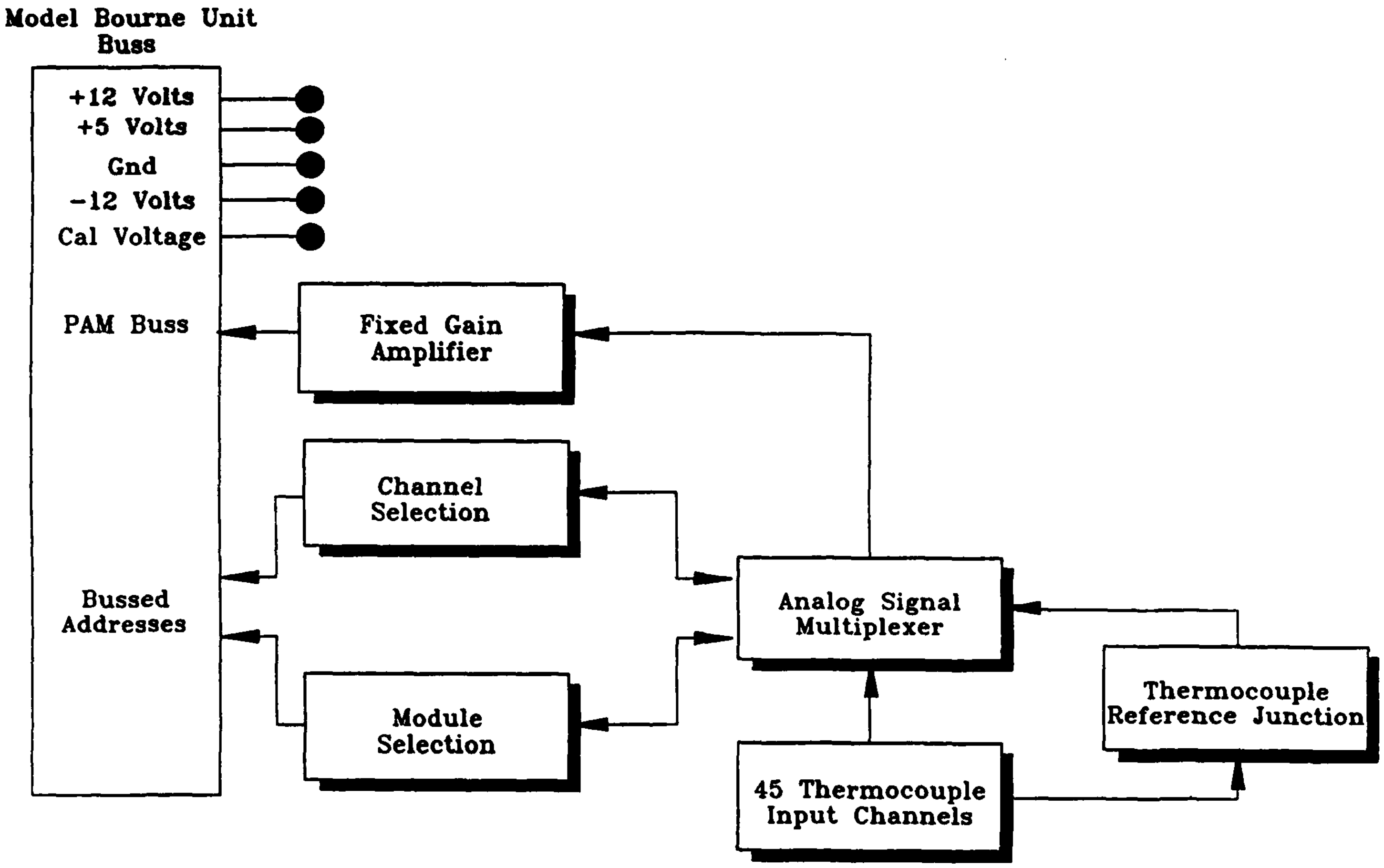
ESP MODULE BLOCK DIAGRAM

Figure 7



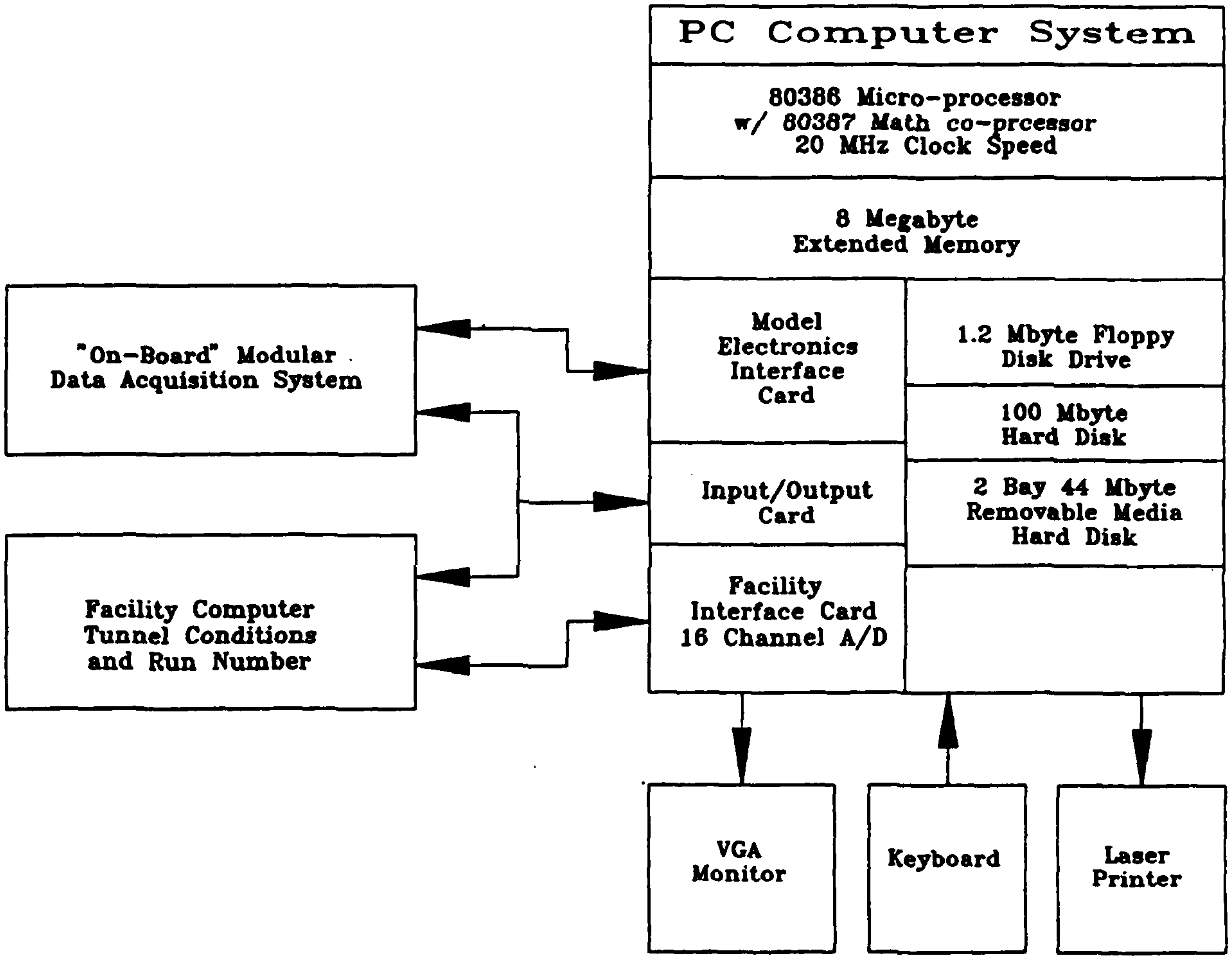
MULTI-INPUT/OUTPUT MODULE BLOCK DIAGRAM

Figure 8



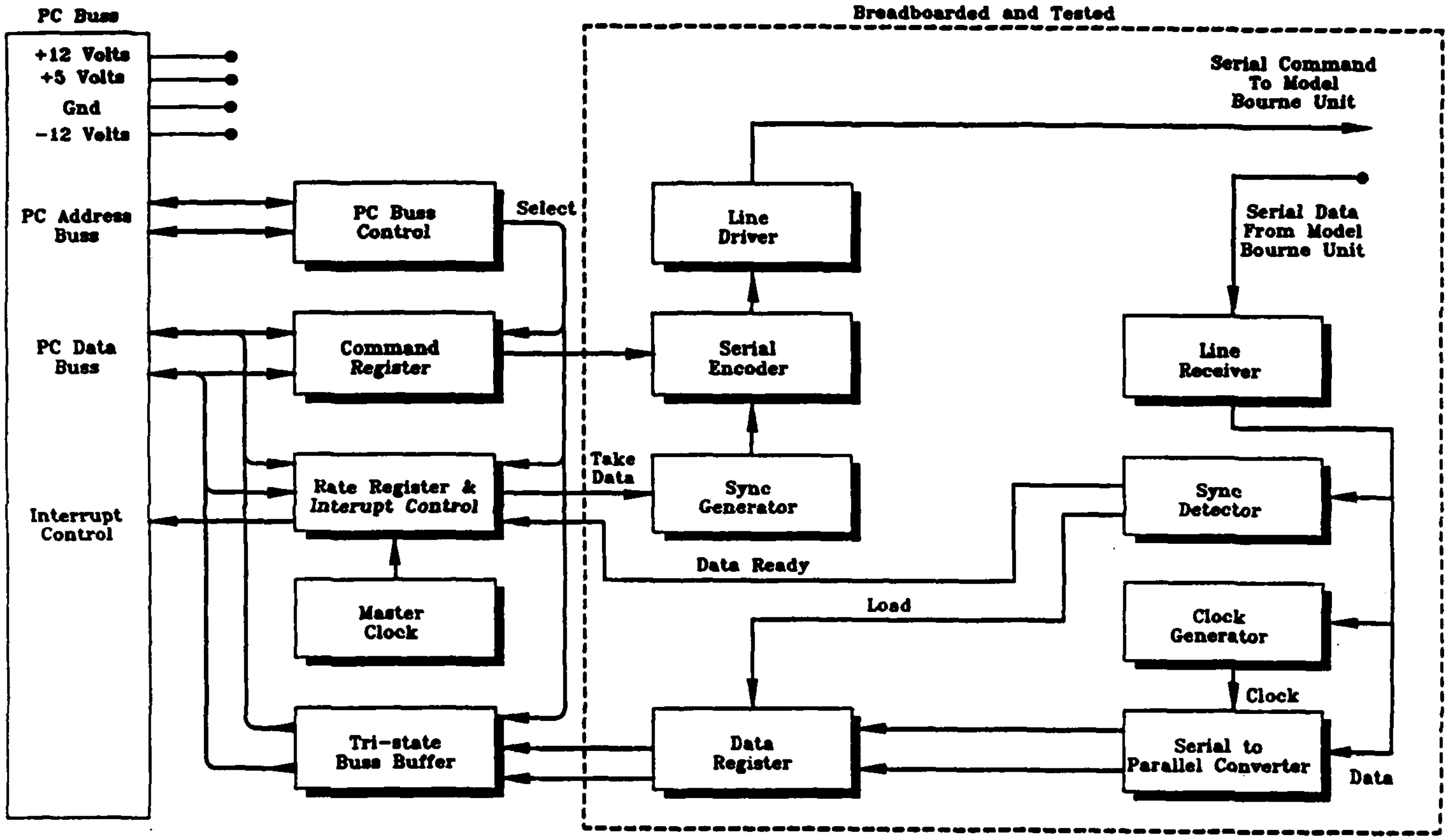
THERMOCOUPLE INTERFACE MODULE BLOCK DIAGRAM

Figure 9



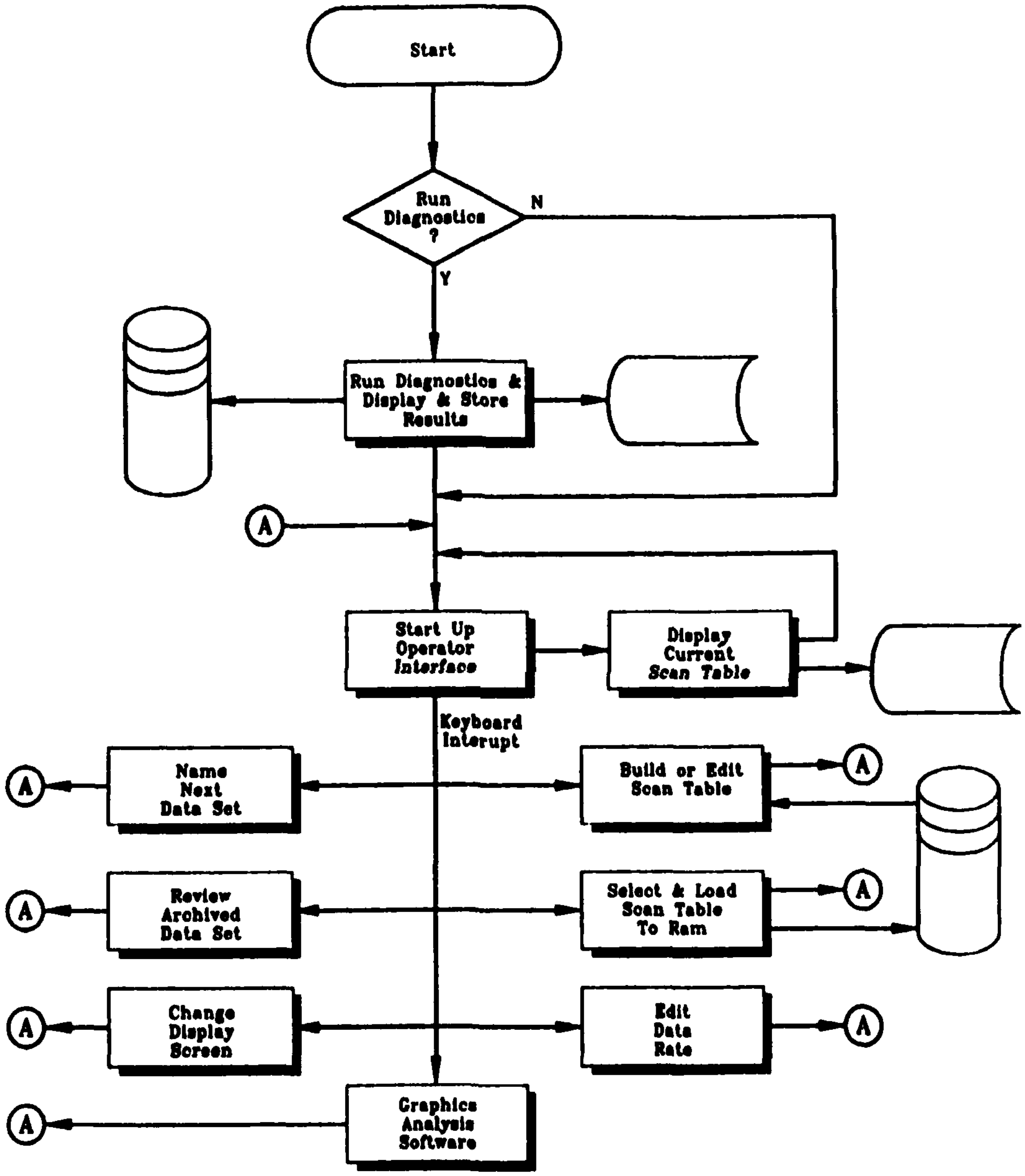
MICRO-COMPUTER BASED DATA ACQUISITION AND RECORDING SYSTEM

Figure 10



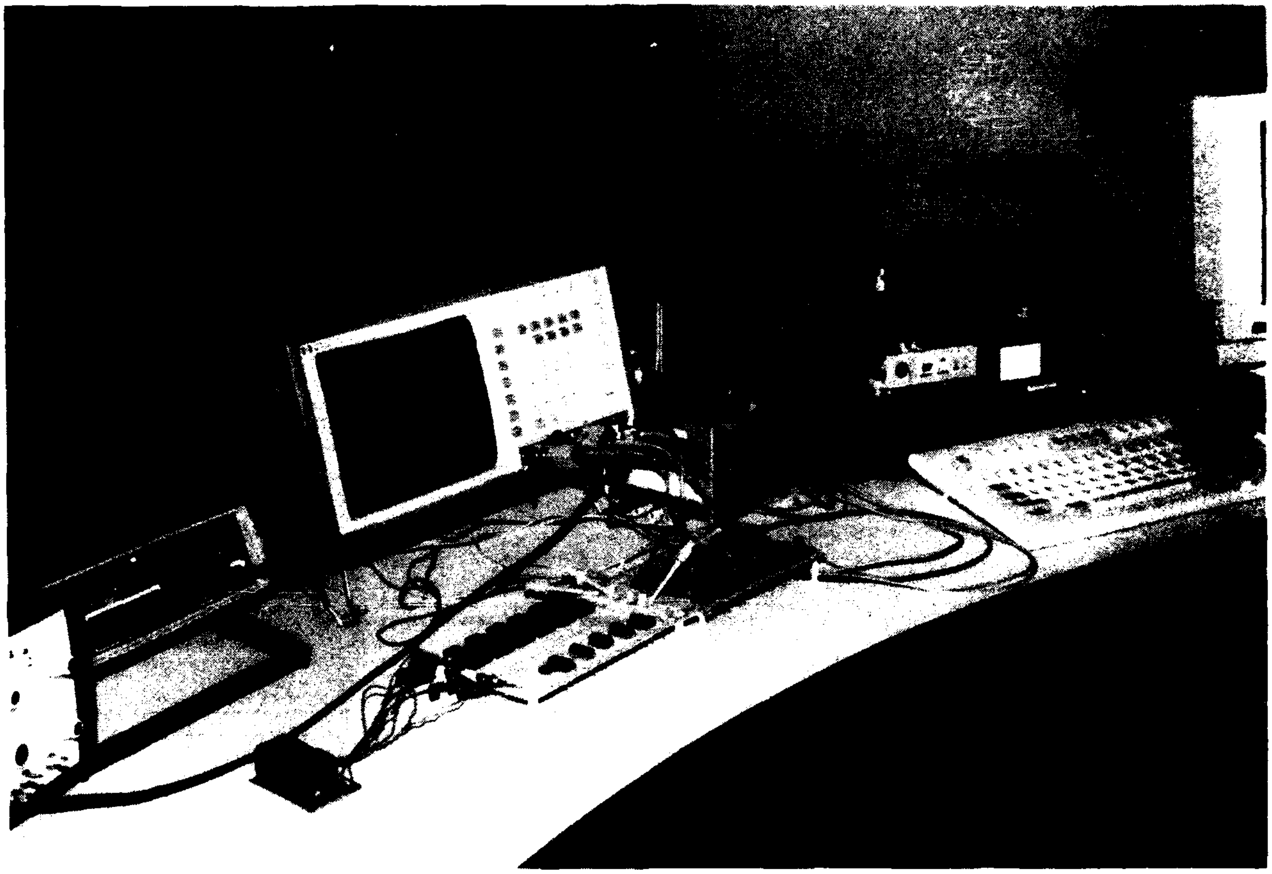
COMPUTER INTERFACE UNIT BLOCK DIAGRAM

Figure 11



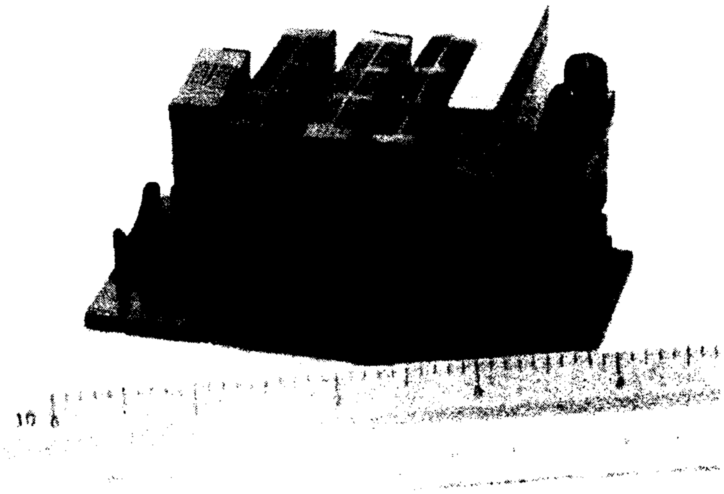
DATA CONTROL SOFTWARE DIAGRAM

Figure 12



MDARS BREADBOARD TESTING SET-UP

Figure 13



MDARS MOCK-UP

Figure 14

U.S. Government Printing Office 548-076