NASA Contractor Report 195041

Development of a Model Protection and Dynamic Response Monitoring System for the National Transonic Facility

Clarence P. Young, Jr.
North Carolina State University, Raleigh, North Carolina

S. Balakrishna
ViGYAN, Inc., Hampton, Virginia

W. Allen Kilgore
Calspan Corporation, Hampton, Virginia

Cooperative Agreement NCC1-141

February 1995

National Aeronautics and
Space Administration
Langley Research Center
Hampton, Virginia 23681-0001

TABLE OF CONTENTS

LIST OF FIGURES

SUMMARY

A computer-based model protection and dynamic response monitoring system has been developed for use at the National Transonic Facility located at the NASA Langley Research Center. The state-of-the-art system was custom designed for protecting model systems from possible structural failure due to dynamic overload and to provide a powerful, on-line dynamic measurements, monitoring and analysis capability. The system is assembled and installed in the National Transonic Facility control room. The system description, capabilities and example applications are presented. Recommendations for system upgrades to improve graphics, data analysis performance and user interfaces are provided.

INTRODUCTION

The National Transonic Facility (NTF) located at the NASA Langley Research Center (LaRC) is a cryogenic wind tunnel which provides a Reynolds Number capability of 140 million per foot at Mach 1.0 (see ref. 1). The nature of testing at high Reynolds number, high dynamic pressure (up to 7000 psf), cryogenic conditions (-300° F) and high angle of attack can result in unexpected and undesirable vibrations, unsteady loads, and testing to minimum margins on aeroelastic stability. Test envelopes have been limited for a number of models due to unacceptably high vibration loads experienced by the model force balance and/or model structure. Such oscillatory loads can result in model or model component loss which could render major damage to the facility.

Since the NTF does not have a catcher screen, the Model Protection and Shutdown Systems (MPSS) is relied upon to protect against loss of model due to structural failure. The force balance loads are monitored by a Balance Dynamic Display Unit (BDDU) with balance load interlock protection provided by a Critical Point Analyzer (CPA) system. See reference 2 for a description of the BDDU and CPA.

The need for model protection and dynamic testing capability at the NTF has long been recognized (see ref. 3). More recently, model vibrations have raised issues relative to effects on aerodynamic data quality and effects on inertial model attitude measurement devices (see refs. 4 and 5). Model vibration problems are not unique to the NTF but become more severe due to testing at high dynamic pressures. The MPSS was designed to be a portable system and can be used at other wind-tunnel facilities or dynamic test sites.

The objectives of this paper are to describe the system development, architecture, capabilities, functions, and performance and to present recent applications of the MPSS to vibration problems encountered at the NTF.

SYSTEM DESCRIPTION

A schematic of the NTF Model Protection and Shutdown System (MPSS) is represented in figure 1. A photograph of the system is provided as figure 2. The MPSS collects information on the tunnel flow conditions, model attitude, and model dynamic loads which are then analyzed in real-time. Based on this real-time analysis the MPSS can command the tunnel to return to a safe condition by sending a trip command to the tunnel interlocks. The MPSS consists of three distinct components. These are the MPSS System Rack, the MPSS display, and the keyboard/mouse as shown in figure 3. Figures 4(a) and 4(b) show detailed front and back views of the equipment in the MPSS System Rack. This rack contains the integrated components of the MPSS. These components are the Precision 6000, the VME Card Cage, and the Sun Sparc2 Workstation. Figure 5 shows a schematic of the integrated hardware architecture of the MPSS. The details of each component are discussed below. General specifications are provided in appendix A.

Precision 6000

The Precision 6000 provides the signal connections for the 24 channel inputs from the NTF transducer signals (viz., six model balance loads, model wing tip accelerations, and the wing root/tip accelerations). The details of the Precision 6000 as shown in figure 6, consists of six 4-channel filter amplifiers. The signals are first brought to the pre-gain amplifier as floating input with 60 dB Common Mode Rejection Ratio. The inputs can be AC/DC coupled with a zero offset feature. The first 16 channels have gain capability from 1 mV to 10 V full scale, while the remaining eight have gain capability of 0.1 V to 10 V. A 4 pole time delay filter set for 285 Hz for the first 16 channels and 10 Hz for the remaining 8 channels functions as the anti-aliasing filter. This filter is located between the pre-gain and post-gain amplifiers. The pre-gain amplifiers are capable of 1, 2, 4, 8, 16, 32, 64 or 128 for the first 16 channels and only 1 for the next 8 channels. The post-gain amplifier can be varied from 0.100 through 10.000 with a resolution of 0.001 for all the channels. Figure 6 shows the connection between the Precision 6000 output and the VME card cage mounted Pentek Analog to Digital Converter (ADC). The Precision 6000 is configured for floating inputs through twin axial BNC connectors to prevent ground loops.

VME Card Cage

A VME card cage is shown in figures 3, 4(a), and 4(b). This card cage contains the following cards:

1) Pentek 4248, 12-bit simultaneous sample and hold ADC operating at a 4 kHz sampling rate. Attached to the Pentek 4248 is a Pentek 4283 Digital Signal Processor (DSP) and 4 MB DRAM acting as shared memory. The DSP processor is a TMS320C30.

2) Bit3 VME-SBus communication card, which provides interface between VME Bus which is used in the card cage and the SBus which is used in the Sun Sparc2 Workstation.

3) VMIVME 2200 Relay Card, provides 32 channel relay output to interface the MPSS with the NTF sequencer.

Sun Sparc2 Workstation

The MPSS central processing unit is a Sun Sparc2 Workstation which is located in the MPSS Rack as shown in figures 4(a), 4(b), and 5. This workstation includes:

Internal hard disk (425 MB)
3.5" internal floppy drive
32 MB RAM
2 Serial ports
TechSource Gxtra Graphics Accelerator Card
19" color display monitor, (1280x1024)
Keyboard and mouse
2 Data Shuttle 1000 hard disks (1 GB each)
Exabyte 8 mm tape drive (2.3 GB)
QIC 1/4" tape drive (150 MB)
CDROM
Ethernet connection
Bit3 Communications Card (SBus - VMEBus)

The MPSS uses custom developed application software which are C based programs developed around canned graphics packages of Motif, X11, X-Designer, and XRT/graph. The DSP real-time program is based on TI assembly language routines.

SYSTEM OPERATION AND CAPABILITIES

Detailed information on operation of the MPSS is provided in a "Descriptive Manual" and a "Users Manual" which are kept with the system at the National Transonic Facility. The "Statement of Work" (revised 1/2/92) which documents the technical requirements was used as the basis for the system development, design and operation and is available at the NTF library.

This section provides an overview of the general capabilities and functions of the system. The MPSS was designed and developed during the 1992–1993 time period. MPSS is designed to monitor dynamic response of the model system from the onboard force balance and other sensors such as inertial angle-of-attack sensors, accelerometers and strain gages. The setup for acquisition of signals from onboard instrumentation for the MPSS is illustrated in figure 7. The bandwidth 0–256 Hz was chosen initially to encompass all expected model system structural vibration modes of concern during tunnel operation. Recent experience suggests that reducing the bandwidth to 0–128 Hz should be sufficient to cover all vibration modes of concern for model systems tested to date in the NTF. The system is a powerful tool for analyzing model dynamic response in both the time and frequency domain. The sample rate of 4000 Hz per channel simultaneously for 16 channels provides a time domain signal resolution within 5 percent of peak values. Fast Fourier Transforms are computed for 16 channels simultaneously in 10–20 milliseconds over a bandwidth of 256 Hz with a frequency resolution of approximately 1 Hz.

Monitoring Dynamic Response

The system calibration and configuration information is set forth in the "Users" and "Descriptive" manuals. The system can be configured to monitor 16 channels of dynamic data at a sample rate of 4000 Hz per channel simultaneously. A spreadsheet display is used to configure channels as illustrated in figure 8. The configuration shown in the figure is set up for the six components of the force balance only. The six balance channels are assigned to channels 1 through 6. Other dynamic data from onboard sensors are assigned to channels 7 through 16. The tunnel parameter data, i.e., pressure, Mach number, temperature, etc., are assigned to channels 17 through 23. The tunnel status data are quasi-static with a 10 Hz sample rate.

The MPSS displays consist of both time domain and frequency domain data, as well as the tunnel parameters which display the tunnel status. Time domain plots are available in 1, 2, 4 and 6 channel configurations for up to 4 seconds of data. Peak time domain displays are available in 2 and 4 channel configurations. These displays provide a bar type of plot showing peak amplitudes of the signal versus time. Frequency domain displays can be configured for either 0–256 Hz or 0–128 Hz with choices of 1, 2, and 4 channel displays. Also, the frequency domain displays both the on-line, quasi-real time values for the Fast Fourier Transform (FFT) versus frequency plus the peak-hold values over the total time of interest. Capability for interchanging displays during data acquisition and monitoring is provided. All time domain and frequency domain data are stored on the 1.0 Gbyte hard disk including tunnel status data. Instant record and replay capability is provided using an on-screen display menu which displays record time in minutes. Configuration names and configuration files must correspond during the record/replay process. Tape drives include an 8 mm tape with 2.3 GB storage and 1/4" tape with 150 MB storage for saving compressed files.

The graphics displays provide the user with the capability for observing and analyzing dynamic response characteristics during the actual wind tunnel test. Such data can be used for making risk decisions during the test and for obtaining dynamic response records for later analysis. Since the MPSS can generate 15 to 20 MB of data per minute, the hard disk storage can be flooded easily unless judiciously used. Experience to date suggest that sample rates can be reduced significantly (from 4000 to 1000 samples/second) without adversely affecting signal quality or MPSS performance for 0–128 Hz bandwidth. Reduction of sample rate and frequency bandwidth is expected to improve graphics speed as well as provide approximately 4 times as much storage. See the section on proposed system upgrades.

Safety Trip Algorithms

The MPSS is custom designed to prevent model system failure by analyzing dynamic data from onboard sensors. The system is designed to generate a trip command which will in turn energize a relay card which in turn commands the NTF logic sequencer to unload the aerodynamic model in the test section. The time required to trigger the trip relay is approximately 10 milliseconds (ms). That is computation, comparison and trip initiation is accomplished within a 10 ms window.

The NTF relay/sequencer can be made to pitch the model home (e.g., to zero angle of attack) or unload the inlet guide vanes (IGV) which rapidly drops the dynamic pressure in the test section. Both pitch home and IGV unload can be initiated simultaneously. Also the compressor fan can be tripped if desired, however this tends to unload the model slowly and is inefficient from an operational point of view. The NTF shutdown strategy is not dependent on the MPSS.

In order to implement to trip limit capability, the limits for the data channels used are configured using the Trip Limits display illustrated in figure 9. The example display in figure 9 is configured for six force balance channels only. Note from figure 9 that entries are required for amplitude limit, trip count limit (number of times the limit amplitude can be exceeded), the rate of change limit and time to double limit. Thus, three trip algorithms are provided for the user. Any combination of algorithms can be used. The available algorithms are described in the following sections. It should be noted that not all of the algorithms are not operational at the present time.

Limit Amplitude: The amplitude limit algorithm computes the maximum value in sixteen samples, which is memorized as a local peak value. The peak value of the next sixteen samples of the new array is calculated and compared with the previous value. If the new value of the peak is higher than the previous peak value, this becomes the new peak value. This logic is continued with peak values being compared with the pre-set limit value. If the limit value is exceeded by the preset number of counts, the tunnel trip relay will be initiated. The number of counts (i.e., number of exceedances before trip) is preset by the operator. The number of counts is used to avoid a situation where one or two spikes in the data signal can trip the tunnel. By allowing limit values to exceed pre-set values for a number of counts (say 6–9) provides a more realistic measure of sustained dynamic motion justifying tunnel shutdown and unloading the model. This algorithm is probably best used for buffet type oscillations in which the amplitude is varying significantly with tunnel conditions, the motion is expected to be limit cycle in nature, or for making risk decisions relative to limiting amplitude for a high risk type of test, i.e., maintain a safe margin against dynamic overload.

Rate of Change Limit: This algorithm determines the rate of change for peak amplitudes in the time domain based on the time interval between peak values. Since this algorithm looks at the growth rate of the amplitude (slope) of the signal peaks, it can detect potentially unstable dynamic response trends associated with model vibration. Instabilities of principal concern for model systems are aeroelastic divergence, stall buffet, buffet flutter and classical flutter. At present, this algorithm is suppressed due to potential problems during system switching and channel switching.

Time to Double: The time to double algorithm is based on detecting exponential growth of peak amplitudes of the time domain signal based on harmonic motion. Time to double is a measure of dynamic oscillations which have a divergent time response. The time to double is specified in the trip limit configuration. This algorithm is best used when guarding against model system dynamic/aeroelastic instabilities, such as divergence, flutter, etc. At the present time this algorithm is suppressed but can be implemented with additional software upgrades.

DISCUSSION

Although the MPSS was designed primarily for model protection and monitoring model system dynamic response during wind tunnel testing, the system has been used for other applications as well. Applications of the system, performance, status and proposed future system upgrades are discussed in this section.

NTF Applications

The system has been used as a dynamic data acquisition and analysis tool as well as for wind tunnel on-line operation. Initial application of the system occurred during an NTF wind tunnel test in which severe unexpected yaw vibrations of a High Speed Research (HSR) model at high Reynolds number, high dynamic pressure (2900 psf) resulted in the test envelope being drastically reduced. At the time of the event, the MPSS was in the NTF control room for initial interface checks. The system was then utilized to acquire the force balance dynamic signals in order to analyze the nature of the yaw vibration. The test showed a strong 29–31 mode response on the lateral force and moment components. In order to isolate the problem to forcing in the yaw plane, data were acquired for 0° and 90° model roll angle orientations. MPSS frequency spectra showing the pitch and yaw moment peak hold amplitudes are provided in figures 10 and 11. Spectra for a wind tunnel run at high dynamic pressure, cryogenic conditions at 0° and 30° roll angle are also displayed in figures 12 and 13. Initial results indicated that the yaw vibration was a forced response associated with vibration of the model support system. The system was subsequently used for a forced response test which confirmed that a model system yaw mode was in resonance with a model support system yaw mode at 30 Hz. See reference 6 for details on this particular application of MPSS.

A third application involved an experimental study of a wind-tunnel model inertial angle of attack sensor response to a simulated dynamic environment. In this application the filtered and unfiltered angle of attack (AOA) sensor signals along the unfiltered six component balance signals were acquired, recorded and analyzed by the MPSS. A schematic of the test setup is shown in figure 14. An example of an MPSS display illustrating the AOA device static and dynamic response with applied sinusoidal yaw moment as a function of time is shown in figure 15. Note from the figure that for a yaw moment peak amplitude of 12000 in.-lb., the AOA output gives a bias of -0.14 degrees. Also from the figure note that as the yaw moment amplitude begins to decrease asymptotically, the AOA static value begins to follow the moment decrease and approaches zero as the load (yaw moment) approaches zero. This occurs because the inertial device cannot distinguish between the gravity vector and the centrifugal accelerations associated with model system vibrations, see reference 5 for a discussion of this problem. This application of the MPSS quantified, for the first time, AOA bias errors associated with an actual wind-tunnel model system vibration. As a result of the application, which showed the potential for bias errors of 0.5 degrees which greatly exceeded the AOA accuracy criterion of 0.01 degrees, an inter-group team was formed to address the problem as well as to develop more advanced systems for measuring model attitude in a dynamic environment. The MPSS can, in fact, be programmed to acquire AOA data and calculate the bias error associated with vibration in a real-time or post-test mode. This application further demonstrated the versatility, portability, dynamic monitoring, and diagnostic capability of the system.

Since assembly and installation of MPSS in the NTF control room in January, 1994, the system has been used to monitor the dynamic response of model systems through June of 1994. Most significant among the models tested was the re-entry test of the HSR model. During recent tests, the MPSS was used to monitor and record dynamic response data for a special wind tunnel test proposed by the previously mentioned inter-group AOA team. Real time data acquisition for this test allowed instant observation of dynamic response levels as well as vibration mode participation, whereas the data acquisition system used by the AOA team did not have capability for recording and viewing the real time data simultaneously. Surprisingly, the MPSS revealed vibration levels much lower than expected, which was later attributed to attenuated vibrations of the model support system. This attenuation is believed to be the result of jammed and damaged bearing support pads. The damaged bearing pads detuned the model support structure yaw vibration modes from the model system yaw vibration mode, and doubled the structural damping in the system.

Utilizing the data obtained with MPSS, a proposed test plan has been developed for doubling the Reynolds number at which the HSR model can be tested at a much higher dynamic pressure (2700 $lb./ft.^2$ versus 1800 $lb./ft.^2$). If the plan is used, the MPSS can be used to monitor the HSR model dynamic loads in order to minimize the risk of model overload and tripping the tunnel interlocks.

Potential Commercial Applications

Although the system was custom designed for wind-tunnel model testing applications, the MPSS can be used as a diagnostic tool for identifying and characterizing dynamic response of any structural and/or dynamic systems. Some of the potential commercial uses of the system are: (1) wind tunnel flutter/buffet testing, (2) forced structural vibration testing, (3) monitoring/analysis of rotating systems, (4) monitoring/analysis of equipment vibration, and (5) as a safety system for protection against exceedance of displacement/amplitude or stability limits for dynamic systems.

The above list of potential applications is not all inclusive. Also, the packaging of the system in a portable cabinet makes it ideal for off-site dynamic testing applications.

System Status

The MPSS was installed in the NTF control room in January, 1994. Interface checks have been done to assure that the MPSS is buffered sufficiently to preclude any effect on wind tunnel data acquisition systems. As previously mentioned, the system has been used primarily as a monitoring and data acquisition and analysis system. Although developed primarily for protection against model loss, the connections to the wind tunnel interlocks have not been made. Also, the trip algorithms have not been checked out in an actual wind tunnel test situation.

Future Upgrades

Since the NTF does not have a catcher screen and continuing model vibrations are expected to restrict test envelopes, it is imperative that the system be upgraded to meet the technical specifications and commissioned for routine use at the NTF and/or other wind tunnel facilities.

The system was designed to very stringent specifications and utilized state-of-the-art technology. At present, the system does not meet performance specifications in the areas of graphics display update rates, user interfaces and reliable performance. Some debugging will be required to obtain the reliability needed for on-line, high risk testing situations. However, as with any developmental program which pushes the state-of-the-art technology, such problems are expected to arise. Delineating the upgrade requirements is beyond the scope of this report. However, it is strongly recommended that the system upgrade and continued development of the system be accomplished as soon as possible. Although the system has provided a high return on investment in terms of dynamic testing knowledge for applications other than wind tunnel testing, the system offers a dynamic testing capability far beyond most wind tunnel test facilities in the world. Future development and application of the system is truly needed for a world class facility such as the NTF.

CONCLUDING REMARKS AND RECOMMENDATIONS

A state-of-the-art, computerized model protection and dynamic response monitoring system has been developed for the NASA Langley National Transonic Facility. This report describes the development of the model protection and shutdown system (MPSS). A technical description of the system is given along with discussions on operation and capabilities of the system. Applications of the system to vibration problems are presented to demonstrate the system capabilities, typical applications, versatility, and investment research return derived from the system to date. The system was custom designed for the NTF but can be used at other facilities or for other dynamic measurement/diagnostic applications. Potential commercial uses of the system are described. System capability has been demonstrated for forced response testing and for characterizing and quantifying bias errors for onboard inertial model attitude measurement devices. The system is installed in the National Transonic Facility control room and has been used successfully for monitoring, recording and analyzing the dynamic response of several model systems tested in the NTF.

It is recommended that the necessary system upgrades be implemented to meet technical performance specifications and that the wind tunnel interlock interface checkout be completed. Although not discussed in this report, strong consideration should be given to future implementation of algorithms originally developed in the statement of work for application to buffet and flutter testing.

REFERENCES

1. Fuller, D. E.: *Guide to Users of the National Transonic Facility.* NASA TM 83124, July 1981.

2. Ferris, Alice T.; and White, William C.: *Monitoring Dynamic Loads on Wind Tunnel Force Balances.* ISA Paper 89–0021, 1989.

3. Glass, Blair B.: *Future Experimental Needs to Support Applied Aerodynamics: A Transonic Perspective.* AIAA Paper 92–0156, January 1992.

4. Finley, T.; and Ching, P.: *Model Attitude Measurements at NASA Langley Research Center.* AIAA Paper 92–0763, January 1992.

5. Young, Clarence P., Jr.; Buehrle, Ralph D.; Balakrishna, S.; and Kilgore, W. Allen: *Effects of Vibration on Inertial Wind-Tunnel Model Attitude Measurement Devices.* NASA TM 109083, July 1994.

6. Buehrle, R. D.; Young, C. P., Jr.; Balakrishna, S.; and Kilgore, W. A.: *Experimental Study of Dynamic Interaction Between Model Support Structure and a High Speed Research Model in the National Transonic Facility.* AIAA Paper 94–1623, April 1994.

APPENDIX A

Model Protection and Shutdown System Specifications

General Specifications for the MPSS are provided below:

Number of Signals	16 dynamic signals (channels), 285 Hz bandwidth 8 quasi static signals (channels), 10 Hz bandwidth
Input Signals	0–1 mV to 0–10 V full scale, 0–300 Hz bandwidth Floating inputs with 60 dB CMRR 10 MΩ with 10 pf input impedance
Signal Conditioning	24 signal (channel) Precision 6000 System AC/DC coupling, zero offset capability Pre-gain 1, 2, 4, 8, 16, 32, 64, and 128 (ch 1–16) 285 Hz low pass 4 pole time delay type filter (ch 1–16) 10 Hz low pass 4 pole time delay type filter (ch 17–24) Post-gain 0.1 to 10
Signal Processing	Pentek 4248 Analog Digital Conversion (32 Ch. Max.) Pentek 4283 Array Processing DSP (TMS320C30) 12-bit resolution Simultaneous Sample and Hold 4096 Hz sampling rate 2 pole software filter for ADC noise 4 seconds data/FFT in shared memory level crossing/amplitude trip algorithms 16 channel, 512 point FFT
CPU System	SUN Sparc2 Workstation 19" Color monitor, 1280x1024 TechSource Gxtra 1280/2 Graphics Accelerator Card 32 MB RAM Internal hard disk (425 MB) 2 Data Shuttle hard disk (1 GB each) CDROM 1/4" Tape (150 MB) 8 mm Tape (2.3 GB) Ethernet connection Bit3 Communication, SBus-VME
Development Software	SunOS 4.1.3, XRT/graph, X-Designer, SEMS, Fortan77, C, Motif 1.2, X11R5, TI Swift

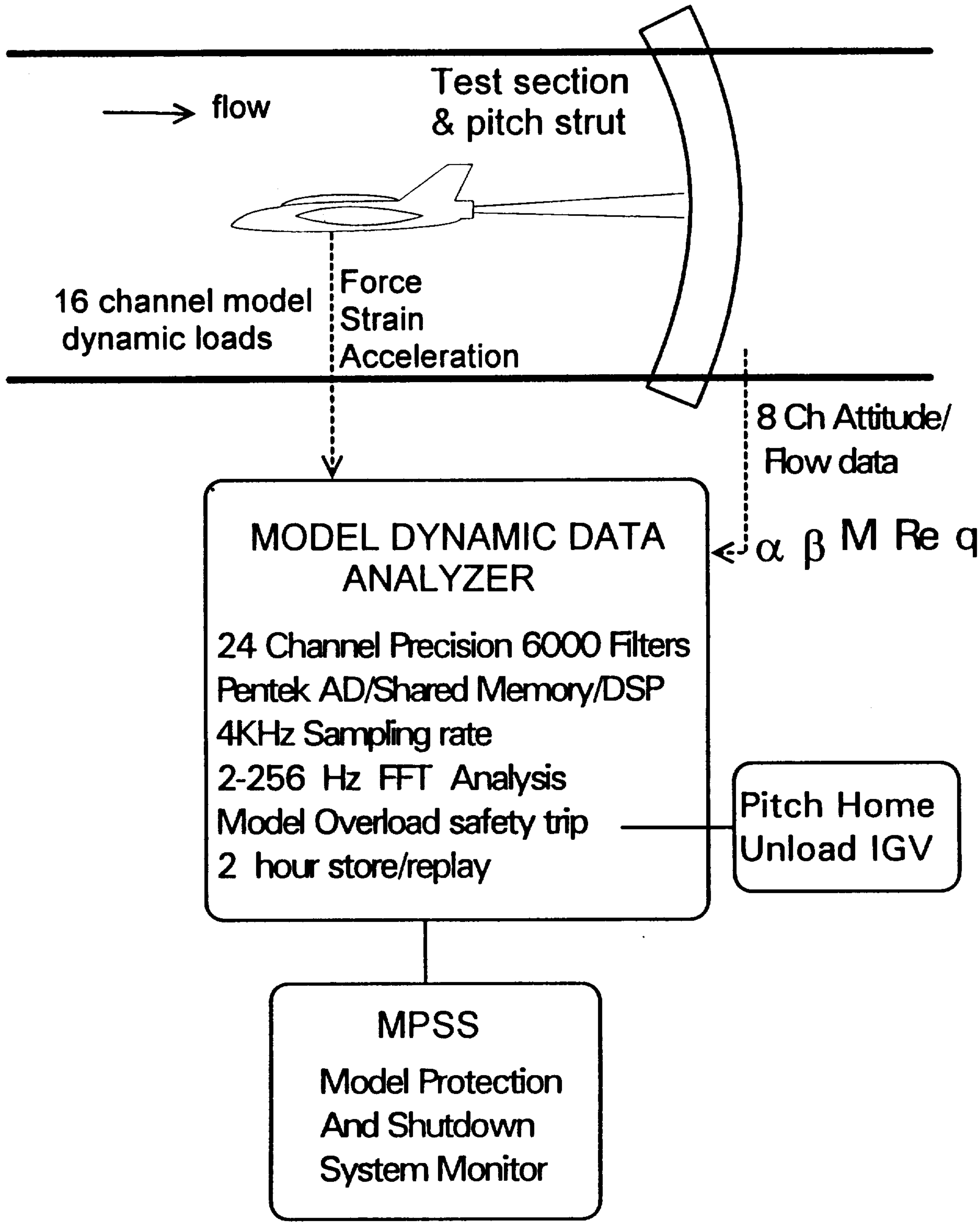

Figure 1:Schematic of the NTF Model Protection and Shutdown System

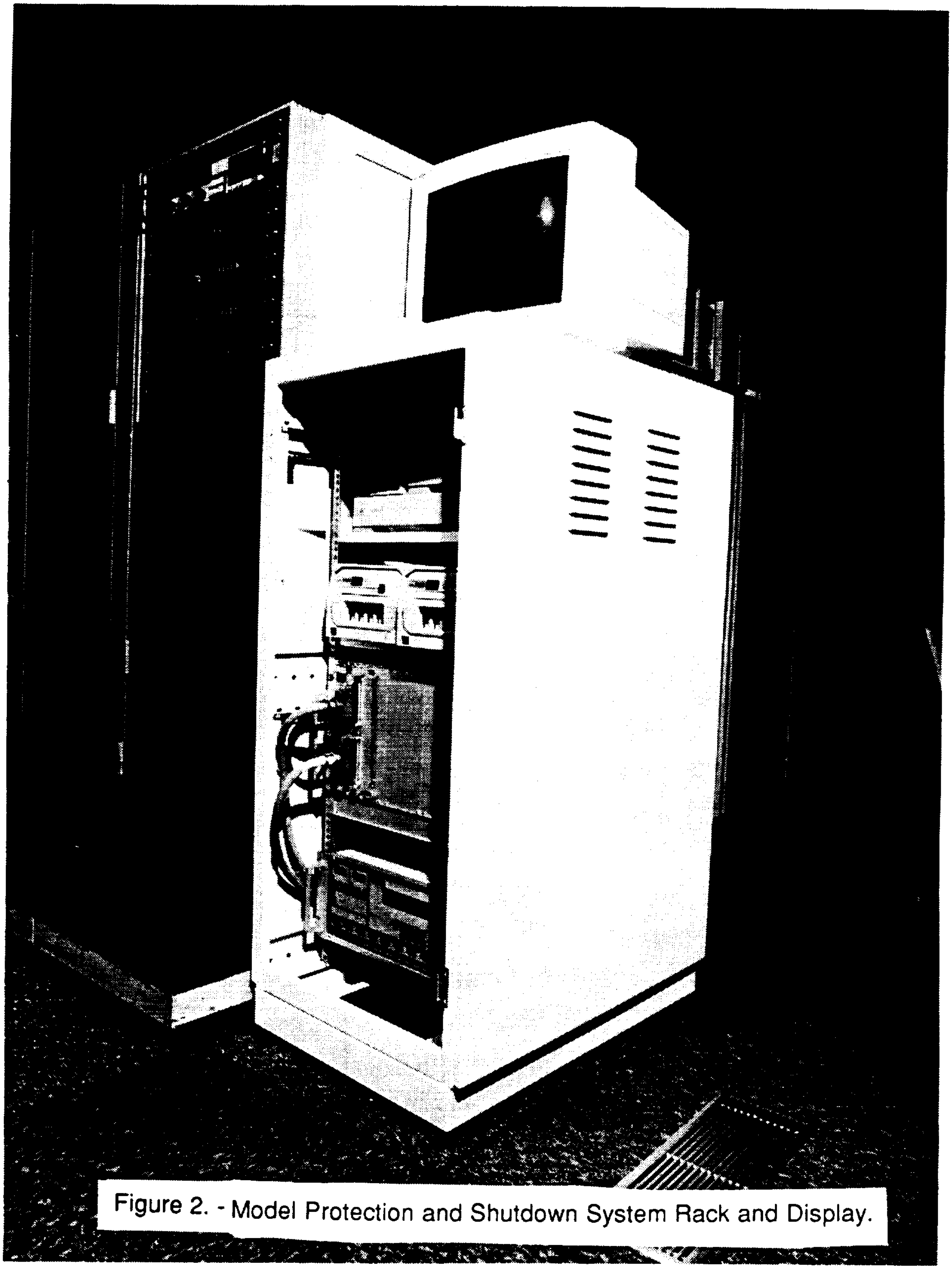

Figure 2. - Model Protection and Shutdown System Rack and Display.

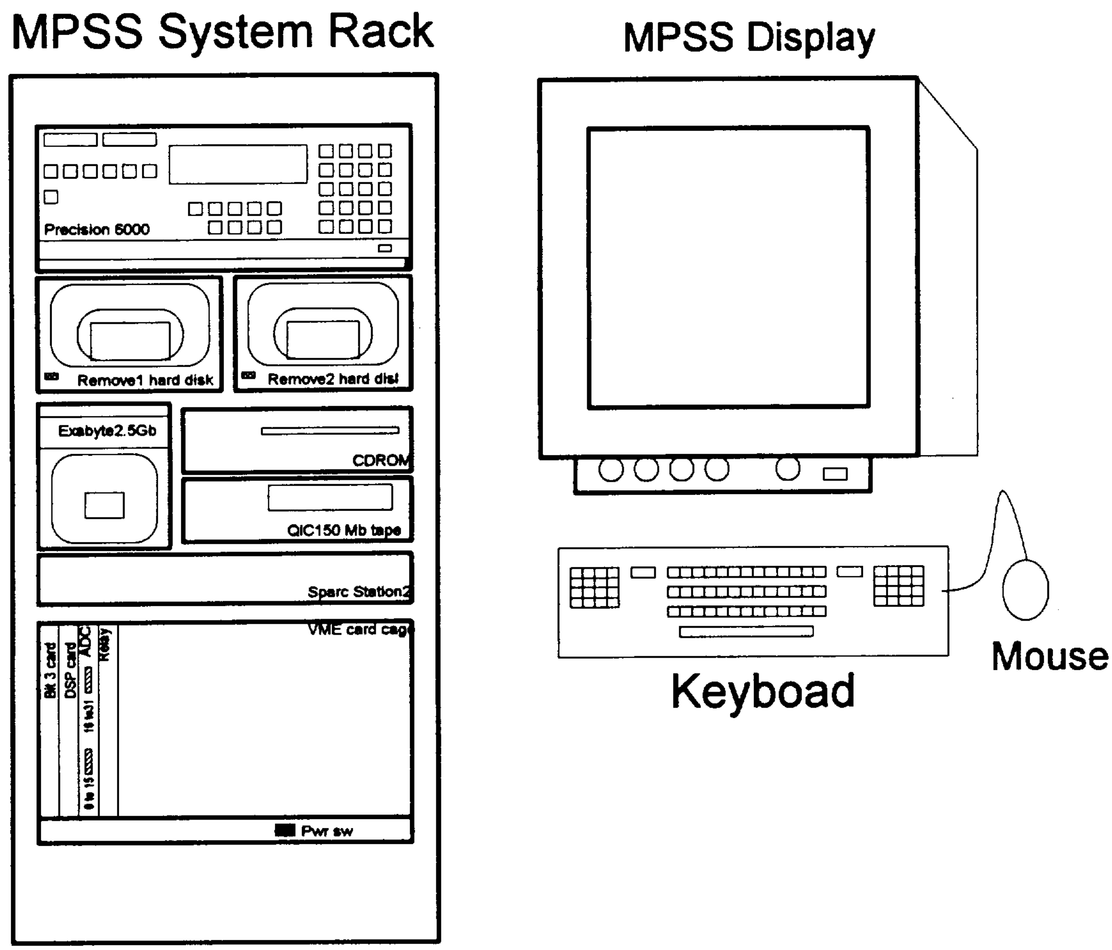

Figure 3: Model Protection & Shutdown System Rack and Display

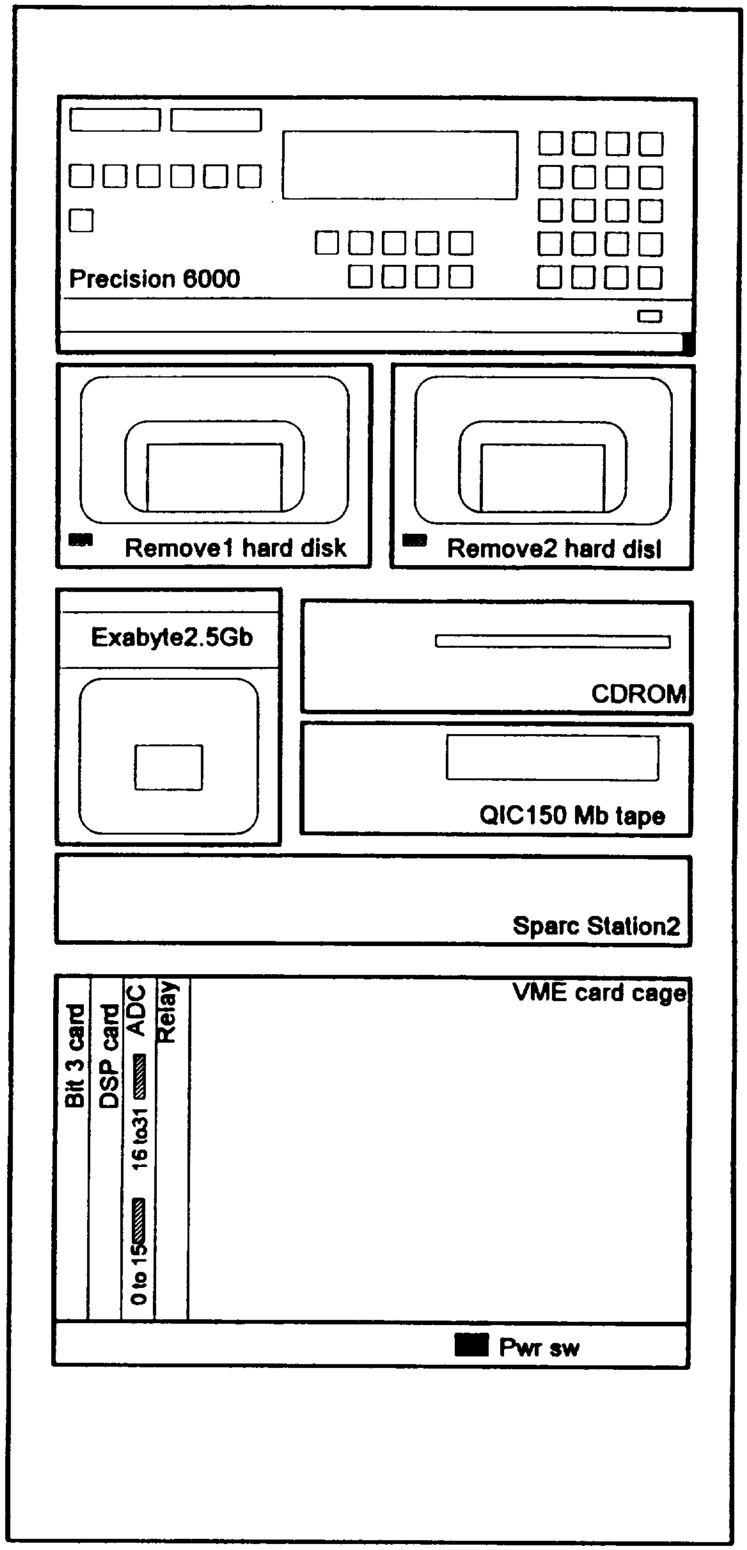

Figure 4a: Front View of MPSS Rack

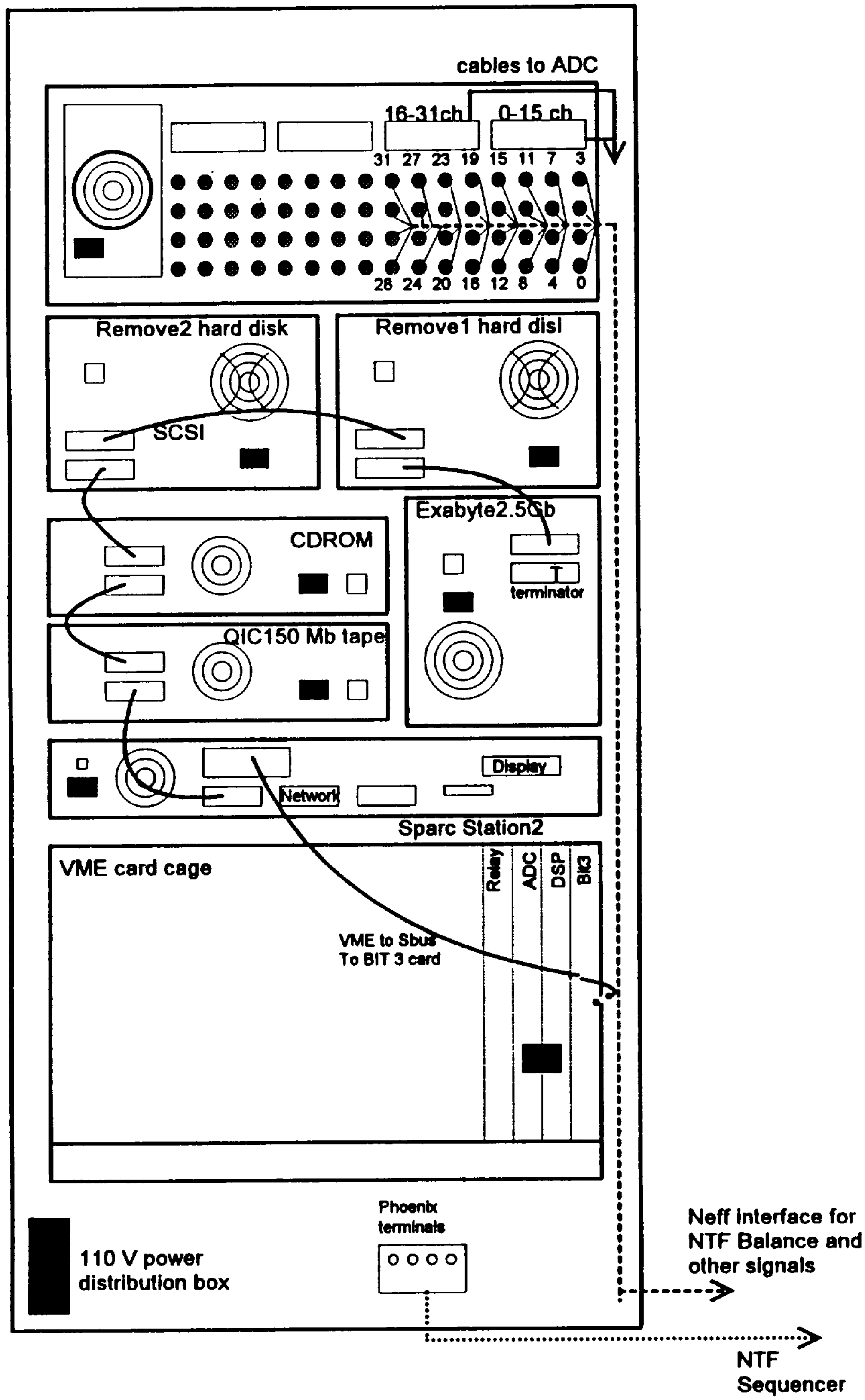

Figure 4b: Rear View of MPSS Rack

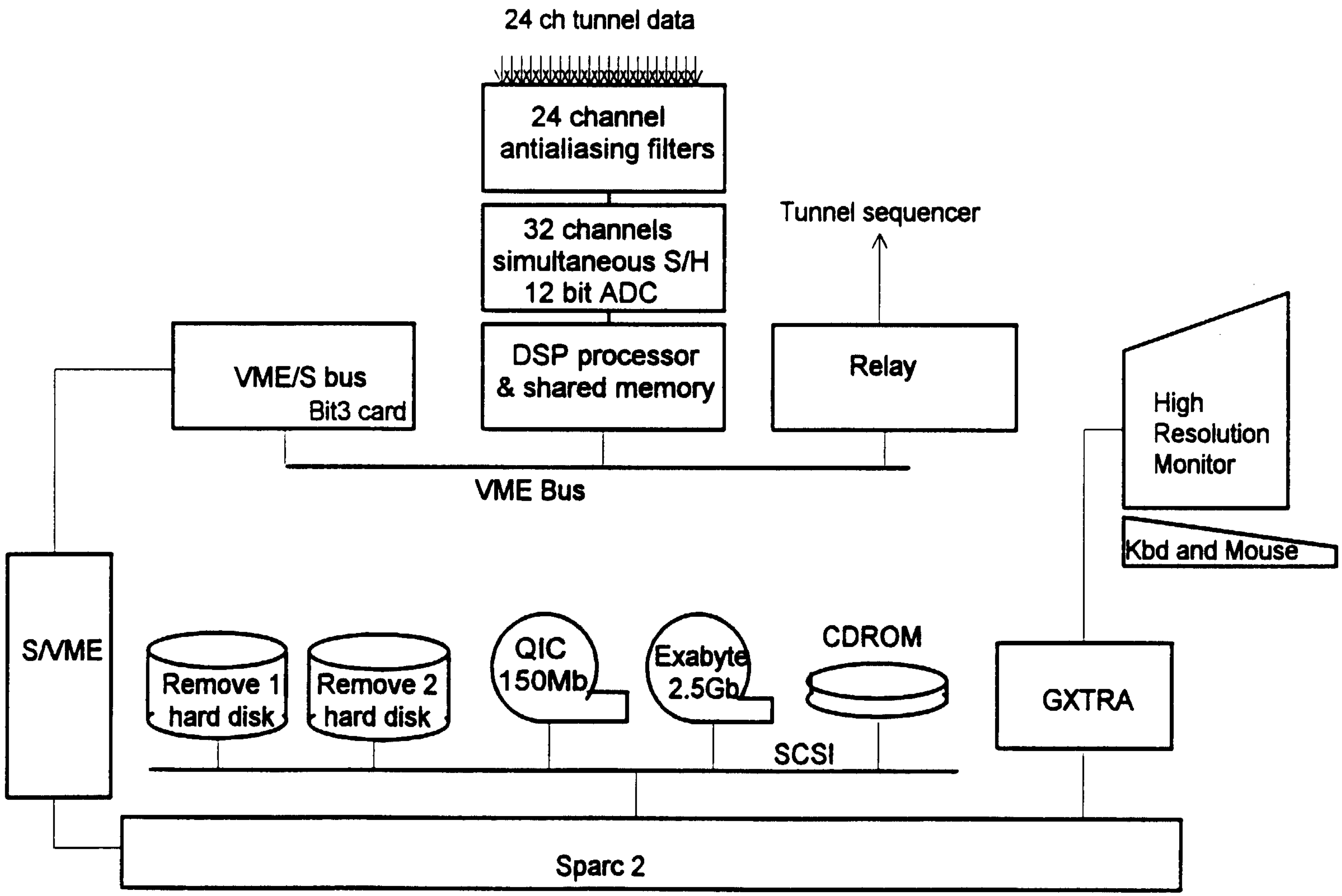

Figure 5: Hardware Architecture of M P S S

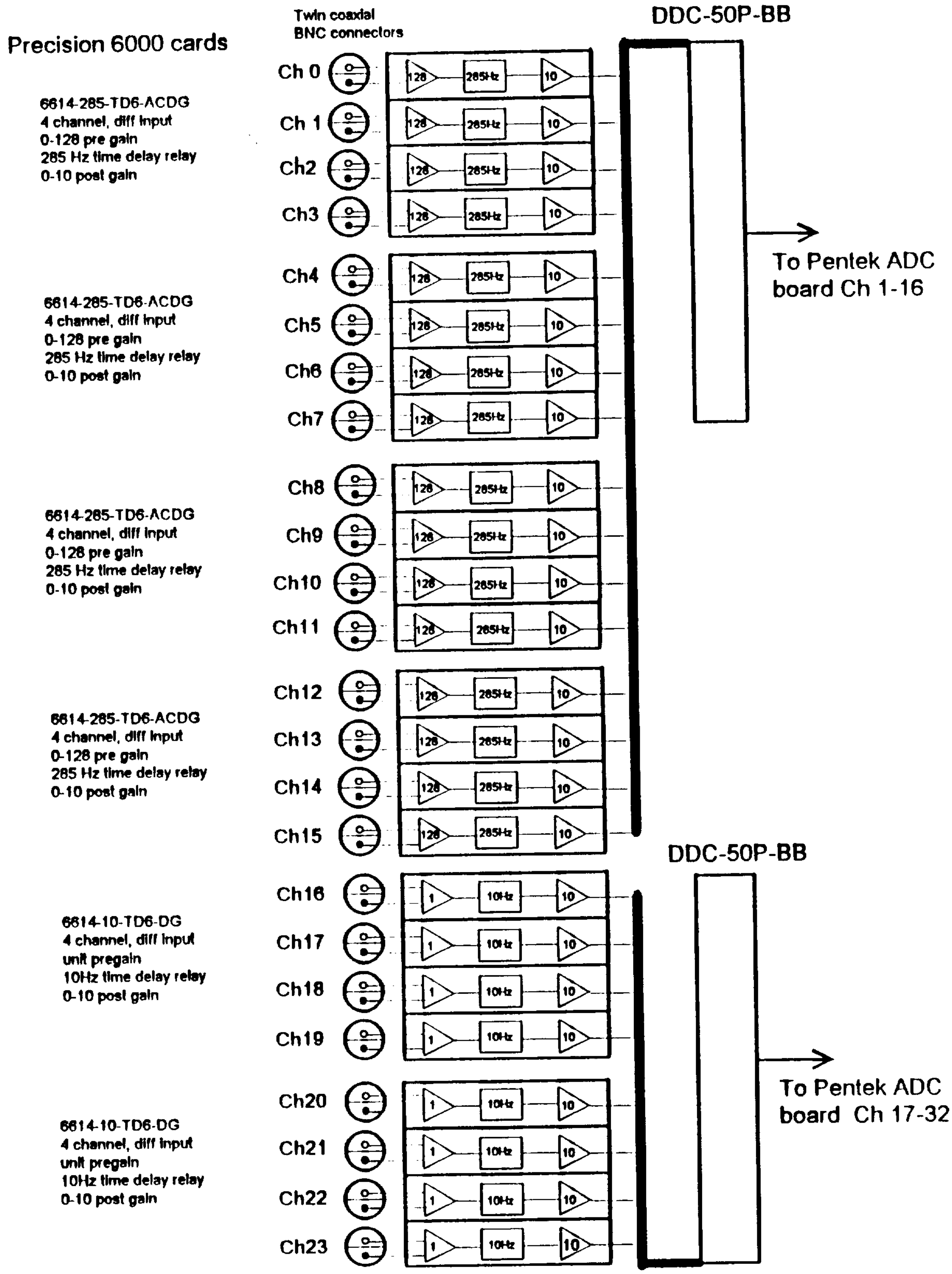

Figure 6 :Precision 6000 System wiring to Pentek ADC

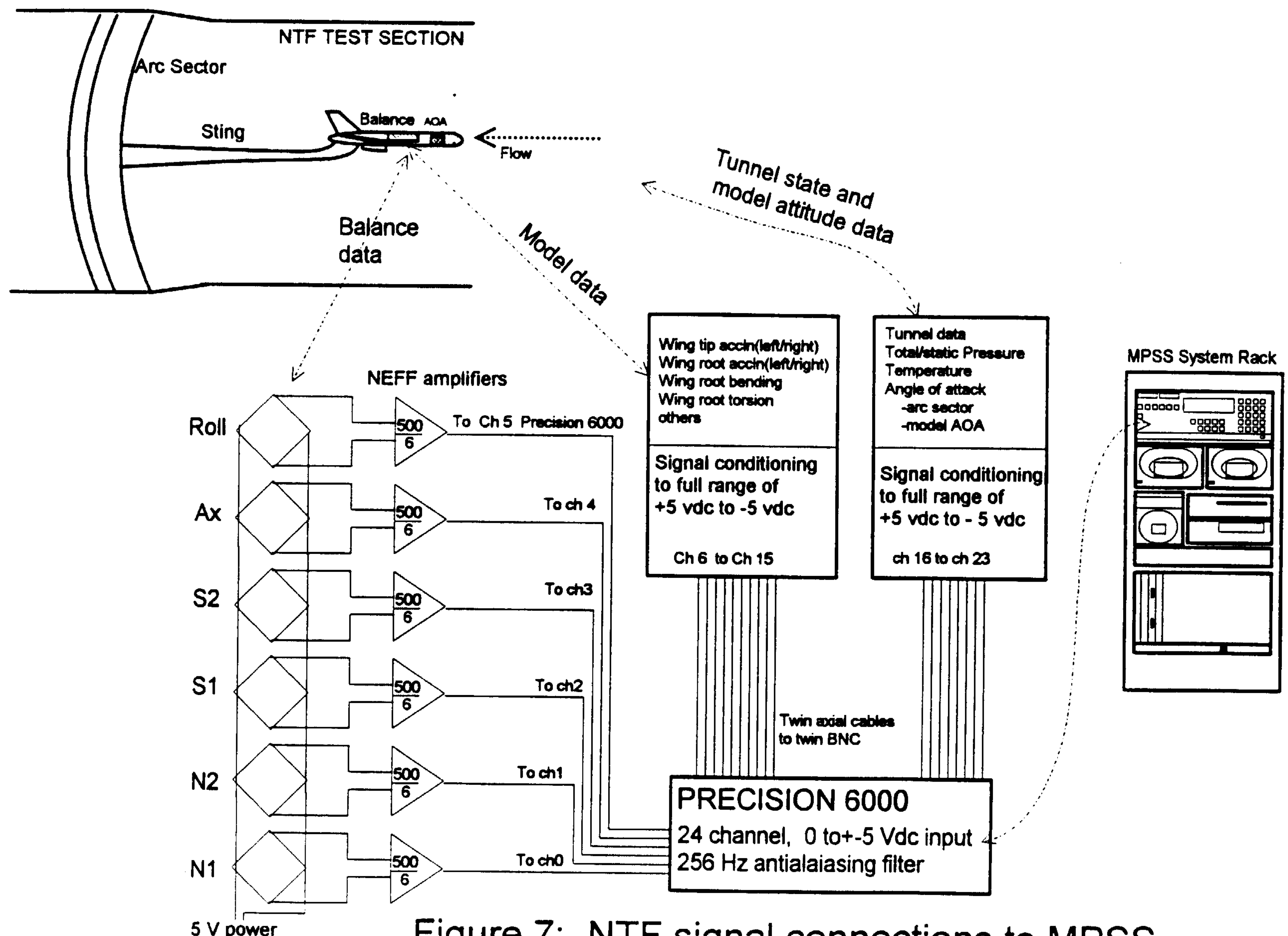

Figure 7: NTF signal connections to MPSS

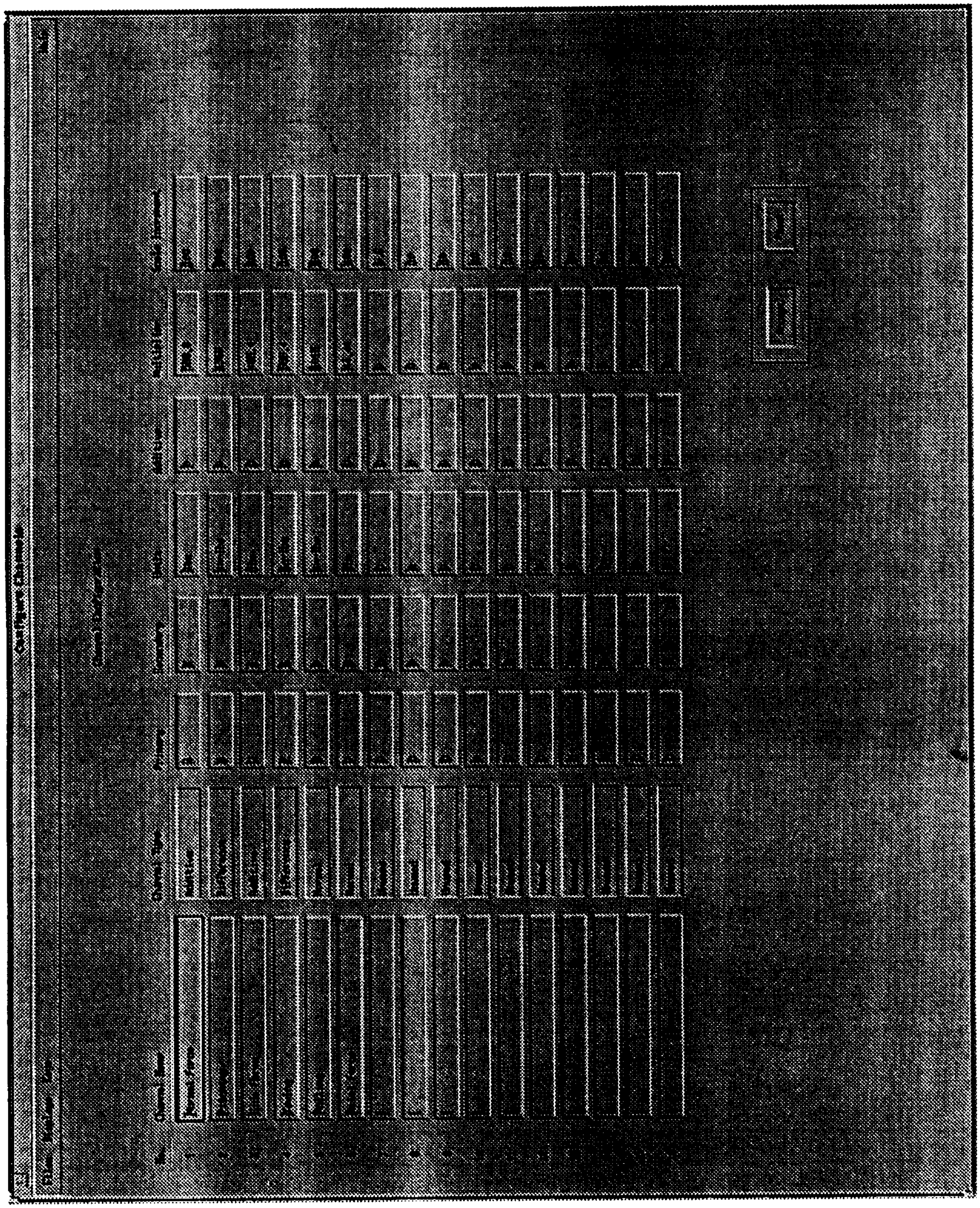

Figure 8. - Configure Channels Display.

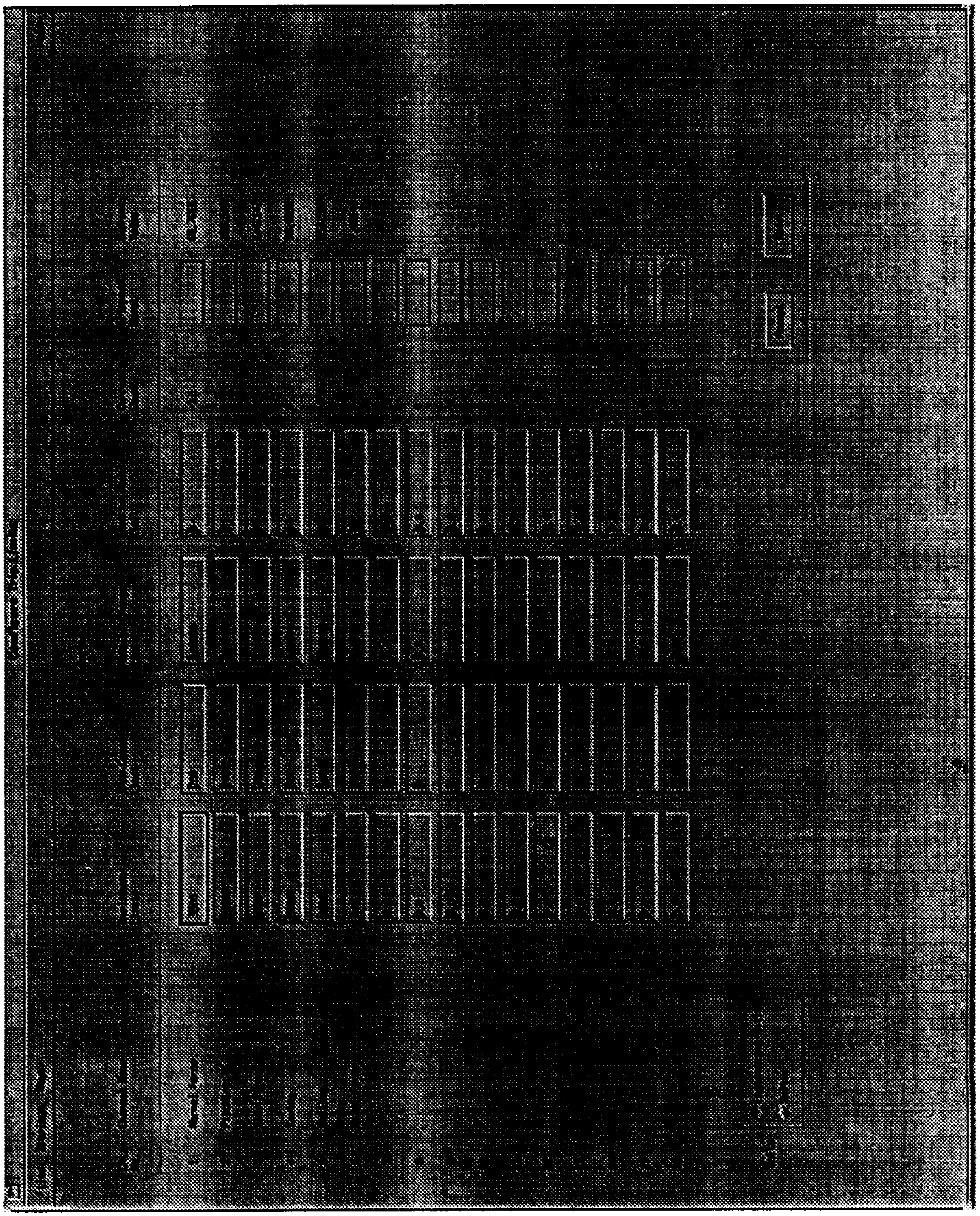

Figure 9. - Configure Trip Limits Display.

ORIGINAL PAGE IS
OF POOR QUALITY

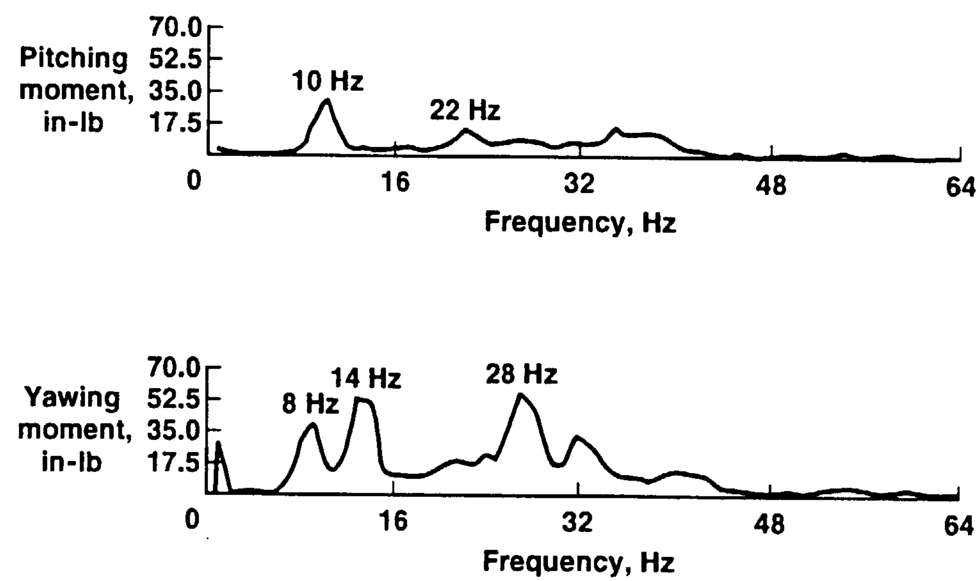

Figure 10. MPSS Peak Hold Spectra for HSR Model During Warm-up, Zero Roll Angle.

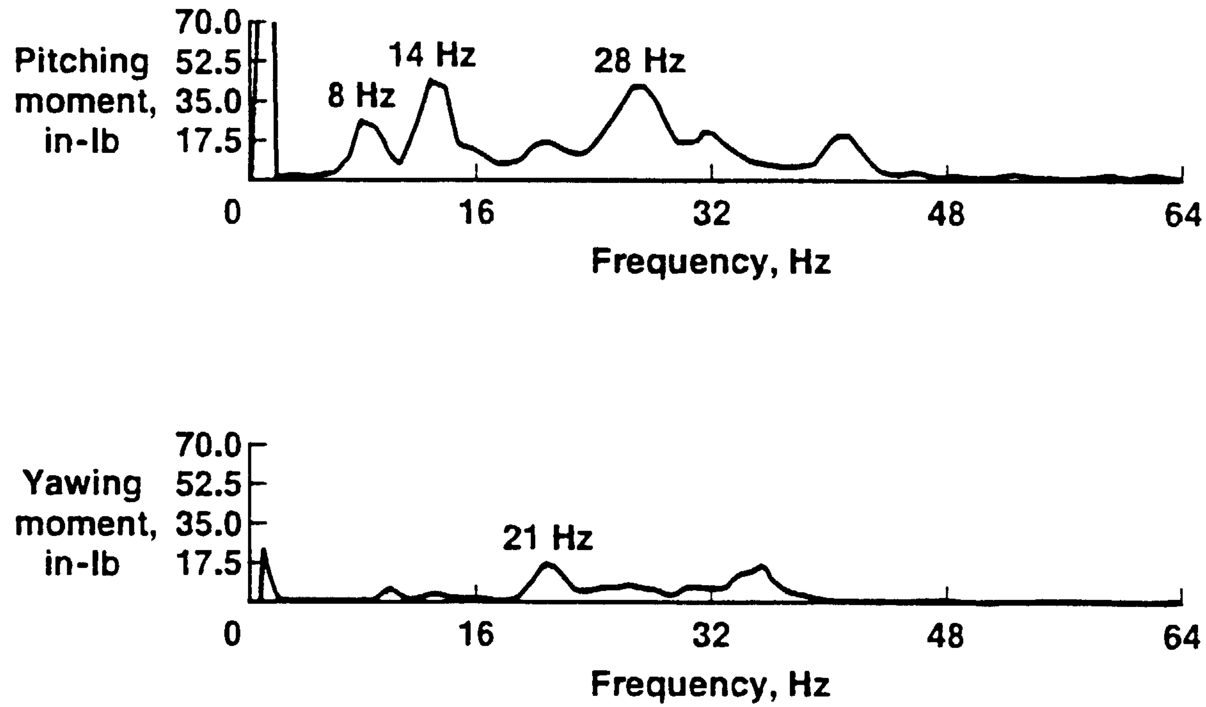

Figure 11. - MPSS Peak Hold Spectra for HSR Model During Warmup, 90° Roll Angle.

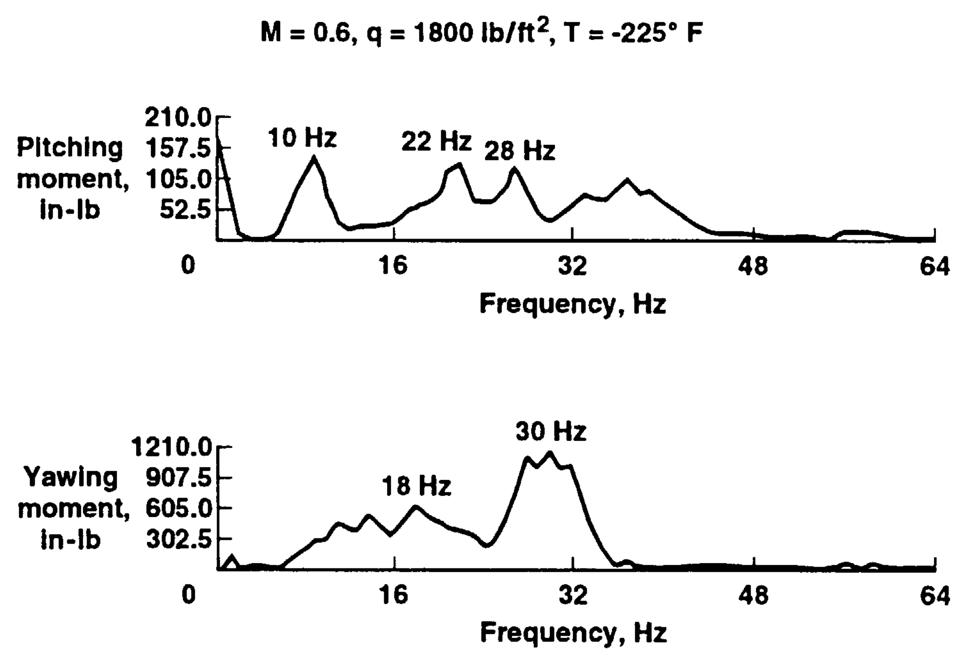

Figure 12. MPSS Peak Hold Spectra for HSR Model at Cryogenic Conditions, Zero Roll Angle.

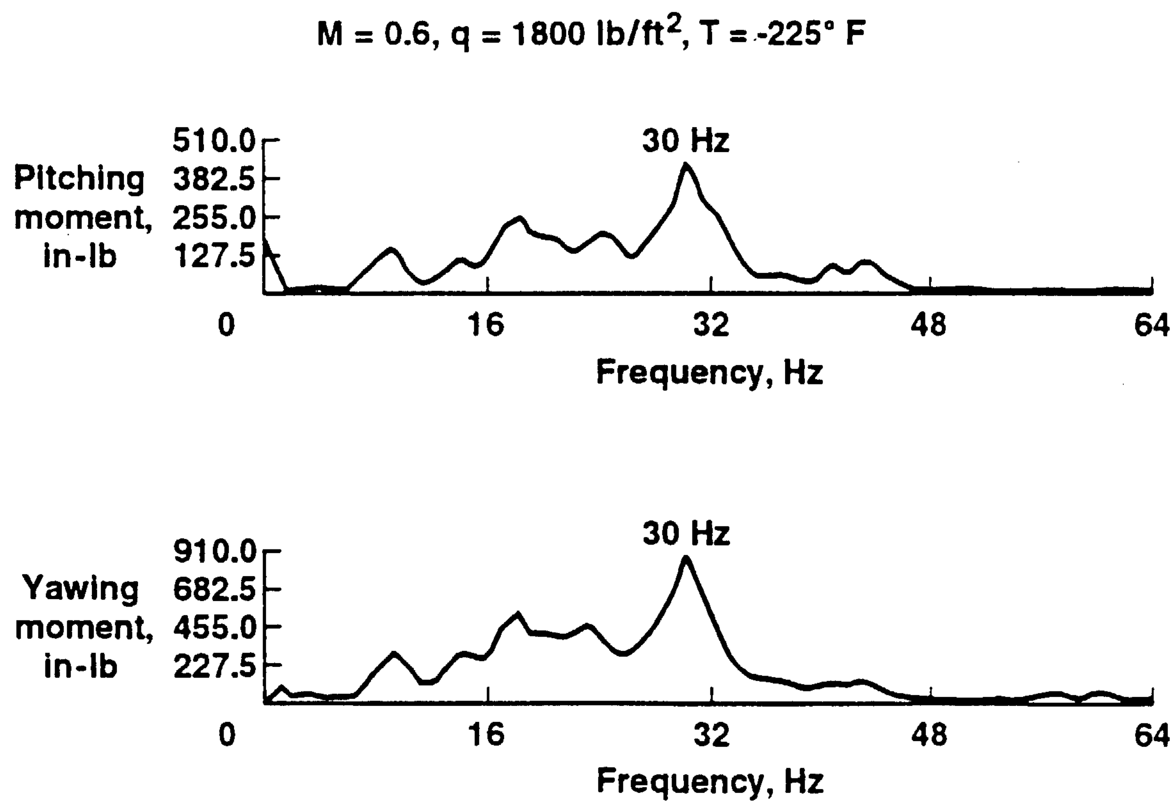

Figure 13. - MPSS Peak Hold Spectra for HSR Model at Cryogenic Conditions, 30° Roll Angle.

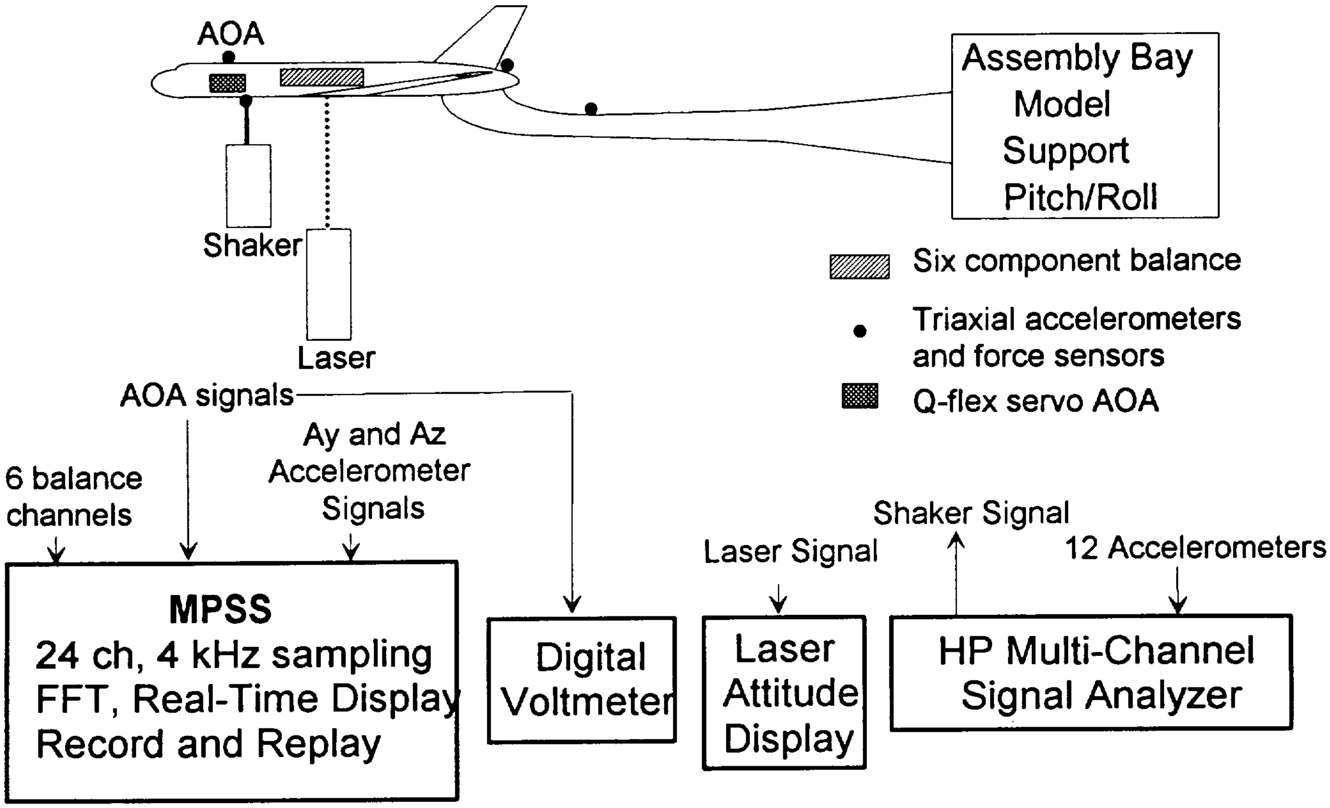

Figure 14: Schematic Showing Instrumentation for Model AOA Dynamic Tests

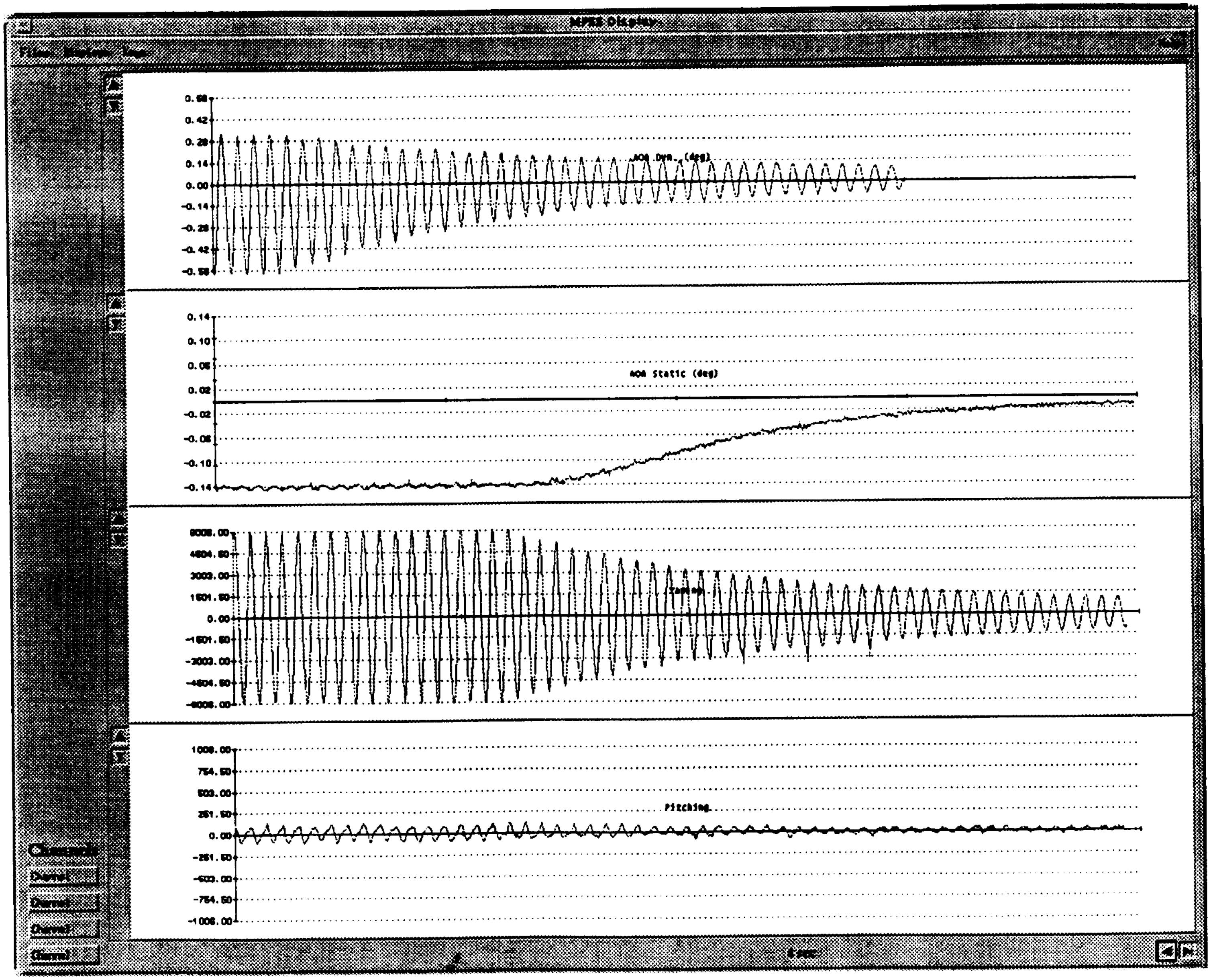

Figure 15. - MPSS Display Illustrating AOA Device Static and Dynamic Response With Yaw Moment (Due to 14 HZ Execution) as a Function of Time.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	February 1995	Contractor Report

4. TITLE AND SUBTITLE
Development of a Model Protection and Dynamic Response Monitoring System for the National Transonic Facility

5. FUNDING NUMBERS
CA NCC1-141
WU 505-59-85-01

6. AUTHOR(S)
Clarence P. Young, Jr.; S. Balakrishna; and W. Allen Kilgore

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
North Carolina State University
Raleigh, NC 27607
Calspan Corporation
Hampton, VA 23681
ViGYAN, Inc.
Hampton, VA 23666

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Langley Research Center
Hampton, VA 23681-0001

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
NASA CR-195041

11. SUPPLEMENTARY NOTES
Young, North Carolina State University, Raleigh, NC; Balakrishna, ViGYAN, Inc., Hampton, VA; Kilgore, Calspan Corporation, Hampton, VA
Langley Technical Monitor: Lawrence E. Putnam

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Unclassified - Unlimited

Subject Category 09

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

A state-of-the-art, computerized mode protection and dynamic response monitoring system has been developed for the NASA Langley Research Center National Transonic Facility (NTF). This report describes the development of the model protection and shutdown system (MPSS). A technical description of the system is given along with discussions on operation and capabilities of the system. Applications of the system to vibration problems are presented to demonstrate the system capabilities, typical applications, versatility, and investment research return derived from the system to date. The system was custom designed for the NTF but can be used at other facilities or for other dynamic measurement/diagnostic applications. Potential commercial uses of the system are described. System capability has been demonstrated for forced response testing and for characterizing and quantifying bias errors for onboard inertial model attitude measurement devices. The system is installed in the NTF control room and has been used successfully for monitoring, recording and analyzing the dynamic response of several model systems tested in the NTF.

14. SUBJECT TERMS
Dynamic Signal Processing, wind tunnel, dynamic response monitoring, model protection, National Transonic Facility (NTF).

15. NUMBER OF PAGES
29

16. PRICE CODE
A03

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	