General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

Produced by the NASA Center for Aerospace Information (CASI)

(NASA-TM-86491) NASA-VCOSS DYNAMIC TEST FACILITY (NASA) 21 p HC A02/MF A01 CSCL 14B
N85-18998
Unclas
G3/14 14345

NASA
Technical
Memorandum

NASA TM - 86491

NASA-VCOSS DYNAMIC TEST FACILITY

By Dr. Henry B. Waites, Dr. Sherman M. Seltzer,
and Dr. George B. Doane III

Systems Dynamics Laboratory

February 1985

MAR 1985
RECEIVED
NASA STI FACILITY
ACCESS DEPT.

National Aeronautics and
Space Administration
George C. Marshall Space Flight Center

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. NASA TM-86491	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE NASA-VCOSS Dynamic Test Facility		5. REPORT DATE February 1985
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Dr. Henry B. Waites, Dr. Sherman M. Seltzer,* and Dr. George B. Doane III*		8. PERFORMING ORGANIZATION REPORT #
9. PERFORMING ORGANIZATION NAME AND ADDRESS George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812		10. WORK UNIT NO.
		11. CONTRACT OR GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, D.C. 20546		13. TYPE OF REPORT & PERIOD COVERED Technical Memorandum
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

Prepared by Systems Dynamics Laboratory, Science and Engineering.

*Control Dynamics Company, Huntsville, Alabama.

16. ABSTRACT

This report describes the Large Space Structure Ground Test Facility under development at the NASA Marshall Space Flight Center in Huntsville, Alabama. It presents the status of the tests being performed and the present and proposed utilization of that facility by DOD. The Ground Test Facility was established initially to test experimentally the control system to be used on the Solar Array Flight Experiment. Further, the structural dynamics of the selected test article were to be investigated, including the fidelity of the associated mathematical model. It became apparent that many of the LSS objectives of NASA were similar to those of DARPA and the US Air Force. In particular, all three agencies are interested in a Government test facility that can accommodate large structures emulating actual space systems. The facility must permit the investigation of structural dynamics phenomena and be able to evaluate candidate attitude control and vibration suppression techniques.

17. KEY WORDS Large space structures Modal identification Hardware Ground test Controls Dynamics	18. DISTRIBUTION STATEMENT Unclassified — Unlimited

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	21	NTIS

MSFC - Form 3292 (May 1969)

For sale by National Technical Information Service, Springfield, Virginia 22151

TABLE OF CONTENTS

	Page
INTRODUCTION	1
LSS CONTROL VERIFICATION	4
LSS GROUND TEST FACILITY DESCRIPTION	6
GROUND TEST STATUS	8
A. Effectors	8
B. Control Computer	8
C. Sensors	9
D. Test Article	12
E. Support Structures	12
VCOSS II CONTROLS TESTING	14
A. Objective	14
B. VCOSS II MSFC Responsibilities	14
C. NASA VCOSS II Schedule	15
LSS GROUND TEST ISSUES	15
REFERENCES	16

LIST OF ILLUSTRATIONS

Figure	Title	Page
1.	First orbital experiment configuration	2
2.	Deployable antenna flight configuration	3
3.	Initial SAFE II flight experiment	3
4.	WBS breakdown tree	5
5.	NASA LSS ground test facility (GTF)	7
6.	Typical noise plot for KARS rate gyro	10
7.	Typical noise plot for ATM rate gyro	11
8.	Modified ground test verification experiment under consideration for future studies	13
9.	Log-log plot of the one-sided disturbance PSD for the CSDL No. 2 model	14

LIST OF TABLES

Table	Title	Page
1.	Set-Up State for Test of KARS Rate Gyro Resulting in Data of Figure 6	10
2.	Set-Up State for Test of ATM Gyro Resulting in Data of Figure 7	11

TECHNICAL MEMORANDUM

NASA-VCOSS DYNAMIC TEST FACILITY

INTRODUCTION

The development of a Large Space Structure (LSS) Ground Test Facility (GTF) at NASA/Marshall Space Flight Center (MSFC) found its incipience from a Center Director's discretionary fund project. The discretionary fund project, submitted by the Pointing Control Systems Branch in 1979, was entitled Large Space Structure Orbital Experiment (LASSOE). The primary goal for LASSOE was to develop a low cost flight experiment in which LSS control could be demonstrated. The detailed approach to achieve the LASSOE goal was as follows:

1) Select a candidate flight test structure.

2) Develop control systems based upon closed-loop eigenvalue placement to assure desired performance.

3) Investigate control system design techniques to isolate disturbance forces via active control.

4) Develop centralized, distributed, and decentralized controllers for the LASSOE test configuration.

5) Conduct trade study of centralized, distributed, and decentralized controllers with and without disturbance isolation.

6) Integrate control concepts to determine actual sensor and effector need for the LASSOE test configuration.

7) Establish a proof of concept (POC) ground demonstration test.

8) Develop a real time test procedure for control optimization.

9) Develop data reduction techniques to ferret out pertinent modeling techniques.

10) Verify modeling techniques.

11) Apply the design and control methodology to larger structures with various performance constraints.

12) Develop a shape control scope of work.

As can be seen, the items in the LASSOE approach are fairly comprehensive, but the main items of concern are the selection of a candidate flight test structure and the establishment of a proof of concept (POC) ground demonstration test. For a ground test, why is the selection of a flight test structure relevant? This is to show not only the evaluation of the flight candidate but to also show how the present ground test configuration was chosen. It must be remembered that the greatest determinant for the selection of the flight test articles and the ground test candidate was economics.

Several flight test articles were in the candidate evaluation. The first flight test candidate, shown in Figure 1, consisted of two deployable beam structures, the Skylab, and the Orbiter. One of the deployable beams was attached to the Orbiter and the Skylab, and the other beam was attached to another Skylab docking port. The beam lengths were selected so that the test candidate had the desired characteristics of an LSS. The Orbiter reaction control system was to be augmented with control moment gyros, and together with the Skylab control system, this configuration could provide centralized, distributed, and decentralized control both with and without disturbance isolation. History dictates why this configuration was not viable. It is also evident that a POC ground test for the Skylab configuration would have been very difficult to achieve because of the masses involved.

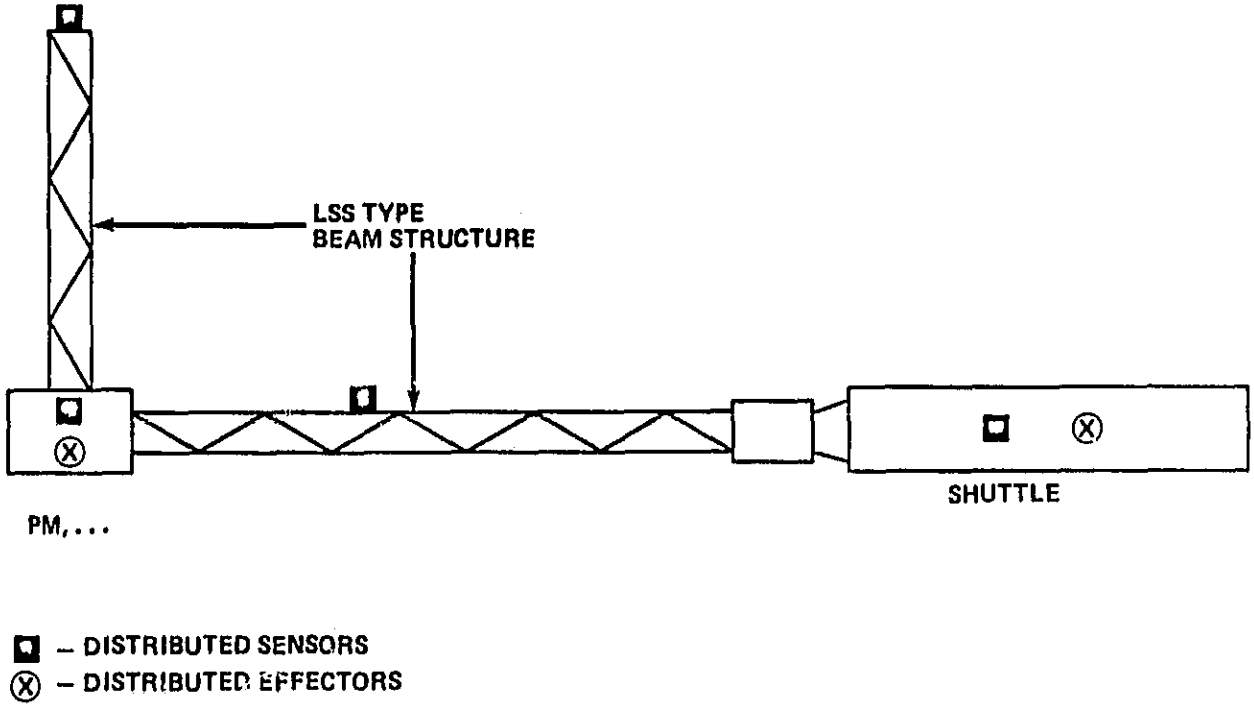


Figure 1. First orbital experiment configuration.

Since work was being done in the area of deployable antennae at MSFC, the next flight candidate, which is shown in Figure 2, consisted of an Orbiter and a deployable antenna. The antenna was connected to the Orbiter by means of a pointing mount. The pointing mount contained its own sensors, effectors, and control computer so that either centralized control could be provided by this unit, or in coordination with sensors and effectors located at the antenna hub other control configurations could be established. Because of the program costs and rescheduling, this configuration met its demise. Because of the antenna characteristics, the ground test for such a configuration is not as intractable as it seems. The present MSFC/GTF with suitable modifications, could entertain such a configuration.

The third alternate for a flight experiment is shown in Figure 3. It consists of the solar array, a pointing mount, reaction wheels, strain gauges, rate gyros, and accelerometers. With this experiment configuration, all of the previously mentioned control concepts could be implemented. However, the additional computer software for the distributed and decentralized control algorithms and the hardware interfaces

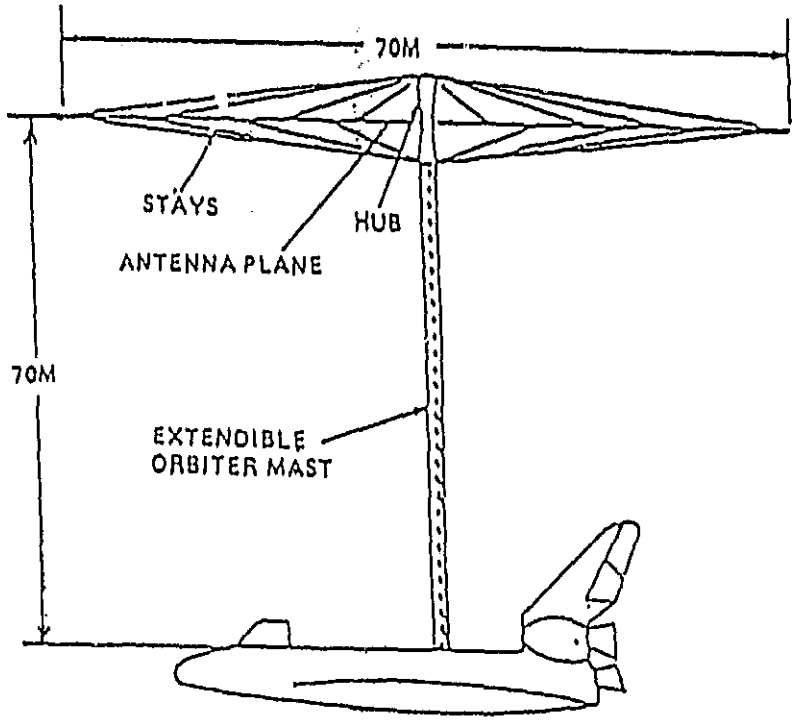


Figure 2. Deployable antenna flight configuration.

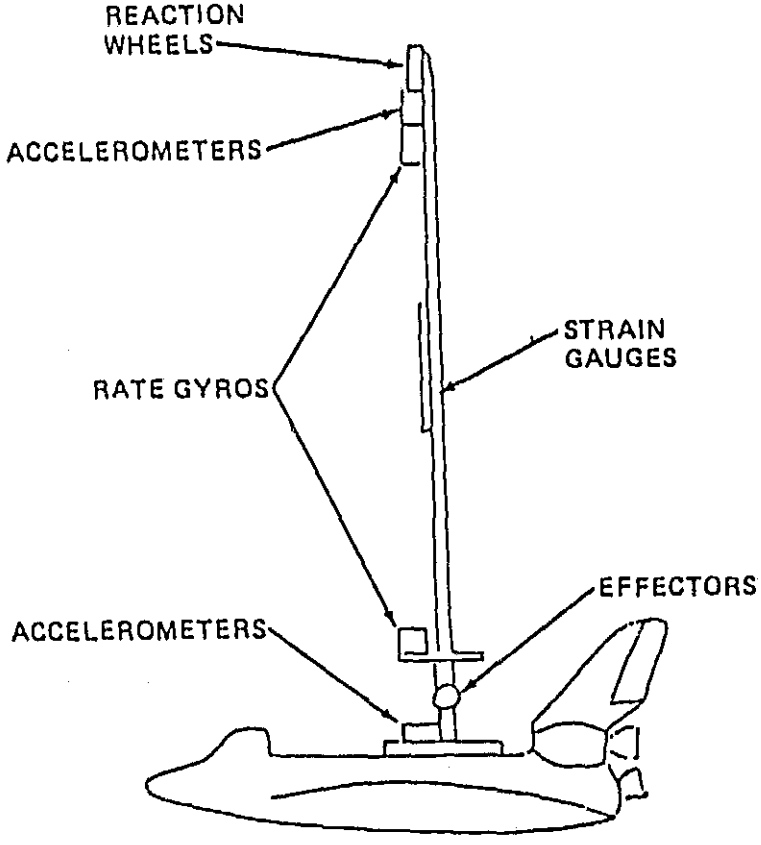


Figure 3. Initial SAFE II flight experiment.

for the strain gauges and the reaction wheels priced this configuration out of contention. Even though this flight configuration was too costly, it was used as a model for the POC ground test presently being developed at MSFC. This migration from configuration to configuration shows the flexible planning and effort that went into the LSS ground test facility.

LSS CONTROL VERIFICATION

Due to the economic nature of any flight experiment and especially a flight experiment for controls, the LSS control verification at MSFC has been partitioned into four interacting areas of work. The work areas are dynamic modeling, control synthesis, verification, and hardware flight system. The importance of these areas is clearly understood from a controls flight experiment. Each area interacts with the other from an initial experiment concept to hardware flight system. The personnel that work these areas are an integral part of the success of any verification program.

The personnel in the dynamic modeling area include the Structural Dynamics Division at MSFC, the Control Dynamics Company, Dr. R. Singh of Honeywell with consulting by Professor P. Likens at Lehigh University, the MSFC Structural Test Division and Dr. D. Brown at the University of Cincinnati. This group provides a wide range of capability in structural modeling, testing and identification. The Structural Dynamics Division and Control Dynamics Company provide the finite element modeling for the preliminary control synthesis and the structural verification. Dr. Singh and Professor Likens are developing a general purpose dynamics analysis computer program which analyzes a structure with a topological tree configuration. The program will be used to match the ground test data. Once the match is obtained, the program can be used to study LSS maneuvering. This capability should be extremely useful for military spacecraft dynamic and control analysis. The structural testing will be performed by the Structural Test Division under the auspices of Dr. Brown. This team provides the total spectrum in the area of dynamic modeling.

The control analysis and synthesis will be performed by the Pointing Control Systems Branch at MSFC and Control Dynamics Company. The responsibilities for this area include control literature reviews, personal interplay with other control personnel, evaluation of different control techniques, and the control system analysis, design, integration, and evaluation. The control system reviews and evaluation are focused upon the following areas:

1) High authority/low authority control [1].

2) Positivity control concepts [2].

3) Model reference adaptive techniques [3].

4) Eigenvalue placement schemes [4,5].

5) Various combinations of the previously mentioned schemes.

Since the control system is only as good as the structural and disturbance data, the areas of parameter and disturbance identification and of real time control optimization also fall in the control bailiwick. The model identification must also involve expertise in the dynamic modeling and testing domain because it is inclusive of every

aspect of system design. The same can be said of the disturbance identification and real time control optimization. The integration of these multi-disciplines ultimately ensures the success of the control system and consequently the success of the system design.

The LSS controls verification is the main area of concern at MSFC. All the personnel elements are involved in this task because it encompasses every previously mentioned area of analysis, design, integration, and testing. The MSFC Work Breakdown Structure (WBS), which is shown in Figure 4, is divided into four areas, and they are:

1) Project management.

2) Systems engineering and integration.

3) Design and development, hardware procurement, fabrication assembly, and coordination.

4) System assembly verification and use.

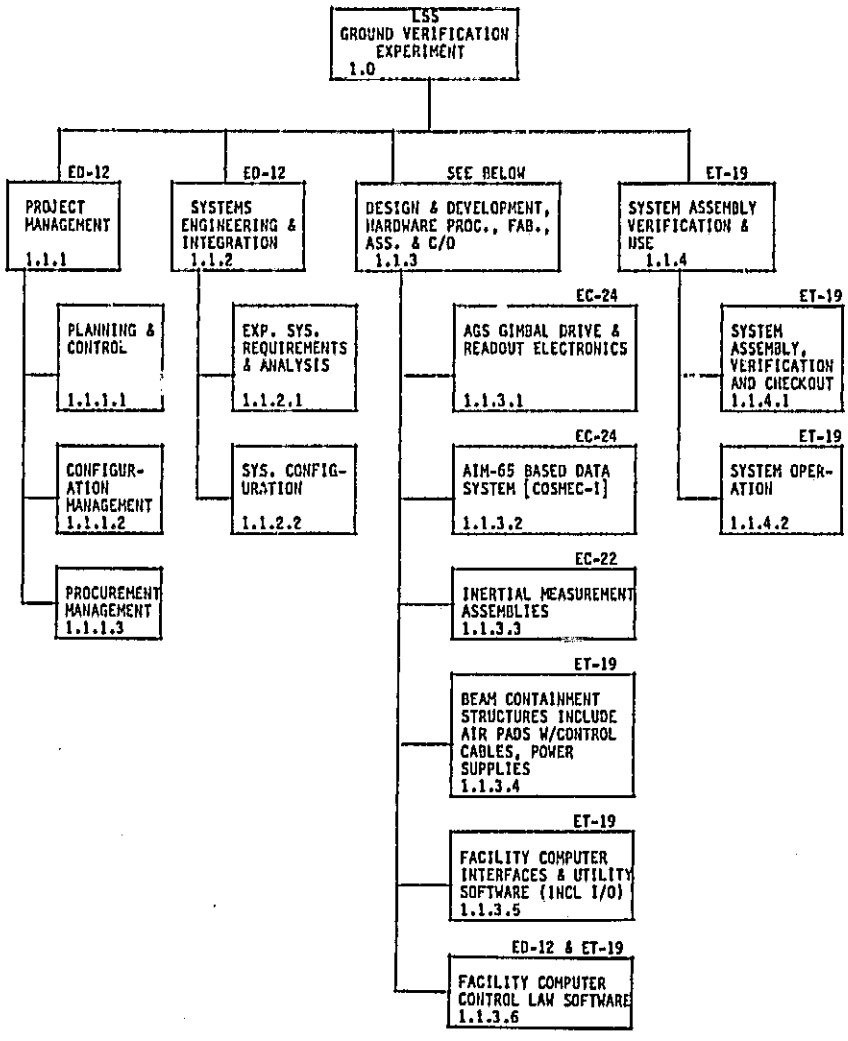


Figure 4. WBS breakdown tree.

The main purposes of the LSS ground verification effort are to design and build a ground facility that can verify control synthesis techniques and to have sufficient fidelity to support hardware flight article tests to reasonably ensure successful on-orbit operations. It is the responsibility of every personnel element to assure that every facet of the ground verification is integrated properly so that the main test goals are achieved.

The last but not least area in the LSS control verification is the flight experiment. This is an area in which NASA and the DOD are very much concerned. The chief reasons for concern are to develop a flight experiment which does not have parochial goals and to assess economic feasibility. This is one area in which all agencies should cooperate so that a flight experiment can be designed within a combined operating budget.

LSS GROUND TEST FACILITY DESCRIPTION

The Ground Test Verification (GTV) experiment for the NASA Research Technology Project (RTOP) is shown in Figure 5. The first test article is an ASTROMAST with a few structural modifications. The ASTROMAST has a weight of about 5 pounds, is approximately 45 feet in length and is composed of S-Glass. The structural modifications are to lower the ASTROMAST's fundamental frequency and to densely pack the modal vibrations. The test article and any ancillary equipment mounted to the test article are suspended by a constant tension cable connected to a tripod which is free to translate on air bearings.

The test article is mounted to the payload mounting plate of a modified Advanced Gimbal System (AGS) engineering model. The AGS modifications include the addition of a third gimbal and a sensor which provides closed loop control capability for the third gimbal. The third gimbal facilitates rotation of the test article about its center line so that different test setups can be achieved.

The AGS sits upon the base which is free to translate. Programmed disturbances to the base are effected by linear actuators and the disturbances are to include typical Orbiter attached inputs and a free flyer disturbance input.

Sensors are mounted to the AGS payload mounting plate and to the tip of the test article. Three Apollo Telescope Mount (ATM) rate gyros are located on the payload mounting plate and three Kearfott 2401 accelerometers are located at the AGS base. A Kearfott Attitude Reference System (KARS) along with three Kearfott 2407 accelerometers are located at the tip of the test article.

The signals from these sensors are read by the control computer and processed according to the control algorithm under study. The control computer provides torque information to the AGS as inputs to the test article.

The control computer interfaces with a Hewlett Packard 9845C computer which stores data as collected from the test run. The data is either transferred to a disk or a tape for off-line data reduction. The sensor and effector data is recorded at each sample period and off-loaded to the storage device.

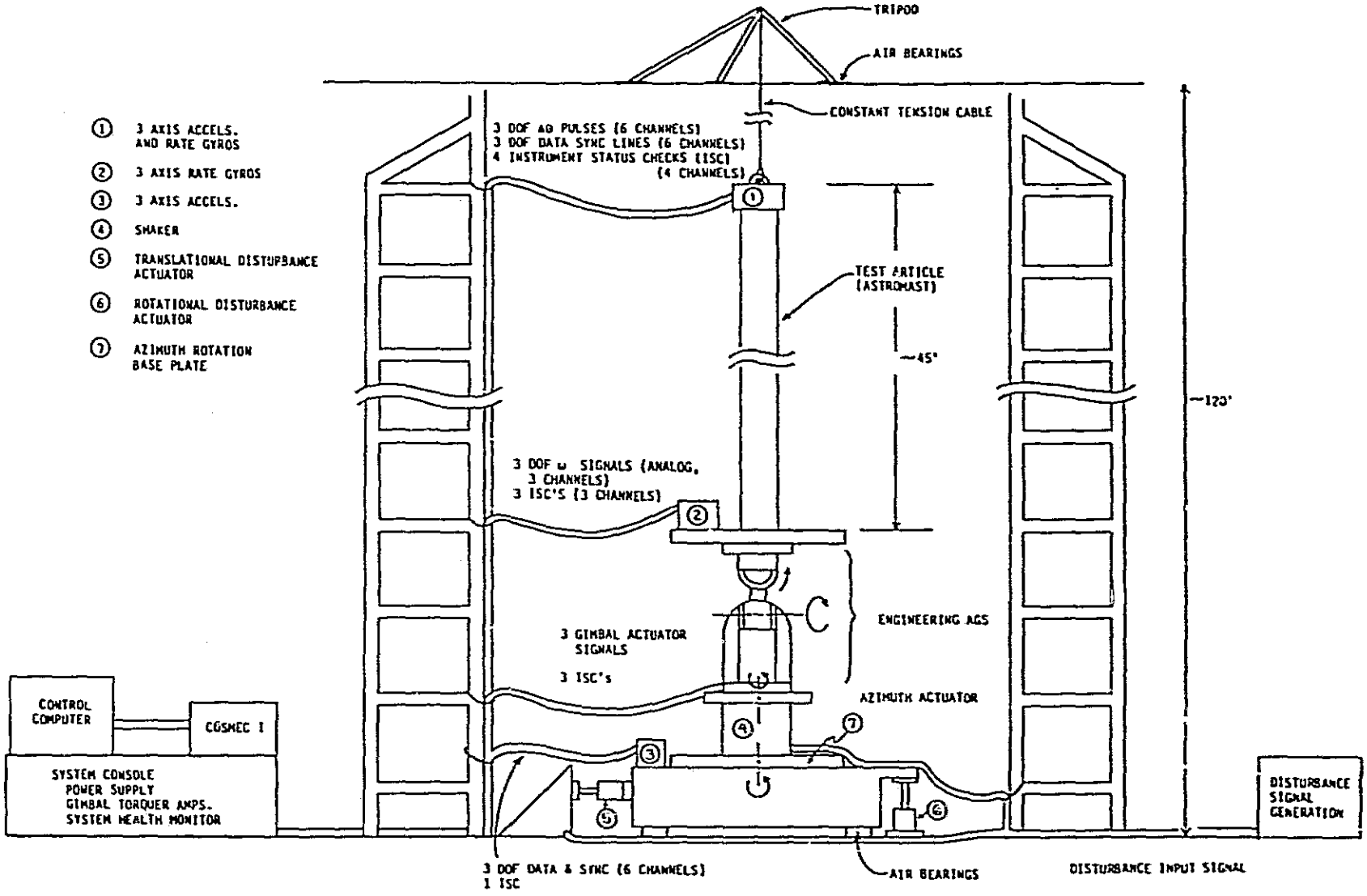


Figure 5. NASA LSS ground test facility (GTF).

GROUND TEST STATUS [6]

The LSS/GTV subsystems are currently in various stages of checkout and development at NASA/MSFC. Much of the functional data concerning the ground test system will be found in Reference 6. Each subsystem will be thoroughly checked out and integrated, where possible, to other subsystem elements for functional and dynamics verification. This test procedure will be used to ferret out as many hardware and software problems as possible so that complete assembly check out will be effected with great assurance.

A. Effectors

The modified AGS provides torque effector capability in three axes. The top two gimbals can generate up to 51.375 N-M of torque and the azimuth gimbal can generate up to 20 N-M of torque. The bandwidth limitation for the top two gimbals is 50 Hz and for the azimuth gimbal the bandwidth is 25 Hz. The torque resolution for the gimbals is yet to be determined but the test is scheduled for the immediate future.

B. Control Computer

1. System Aspects

The control computer is based upon an AIM 65 micro system. The AIM 65 micro system provides great flexibility at reasonable cost especially in hardware simulations. The main purposes of the control computer is to process the sensor input, to keep track of the lab coordinate system, to provide torque commands for the AGS, and to off-load control and sensor data to the Hewlett Packard system. All of this system data interaction is to have a 50 Hz sample rate with twelve sensor inputs and three torque outputs.

2. Hardware

The control computer is complete except for checkout and installation of 32 kbytes of RAM. Once this item is completed, a hardware requirements review will firm-up the general system needs. Finalizing the system needs will precipitate the packaging of the control computer for system integration testing. All of this is dependent upon the software development and check-out.

3. Software

The control computer has many jobs that must be worked. To initiate this work, software must be developed in the following areas:

1) Calibration

2) Alignment

3) Reference system tracking

4) Control

- Centralized control with and without disturbance isolation.

- Distributed sensor control with and without disturbance isolation.

The generic equations for the reference system tracking and the control algorithms have been derived. Also preliminary gains have been obtained for the centralized control system. The integration of the sensors, control computer, and effectors, which are dependent upon the software checkout, will occur on or about December 1983.

C. Sensors

1. Kearfott Altitude Reference System (KARS)

The KARS is an altitude reference system which includes three rate gyros and three accelerometers. This unit is mounted to the tip of the test article so that these sensors provide information for the distributed sensor control. The rate gyros have a resolution of approximately 50 arcsec/sec in two axes and 90 arcsec/sec in the third axis. The KARS rate gyro bandwidth is about 70 Hz. A typical noise plot 10 log $[(\text{deg/sec})^2/\text{hz}]$ versus frequency is shown in Figure 6. The set up state for Figure 6 is depicted in Table 1. Once the rate gyro resolutions are checked, the KARS unit will be ready for system integration-testing with the control computer and the effectors. This integration should also occur in December 1983.

2. ATM Rate Gyros

The ATM rate gyros are mounted to the AGS payload mounting plate. The minimum resolution for these gyros is approximately 2 arcsec/sec. The ATM gyros operate in a fine mode, which has a bandwidth of 12 Hz, and a coarse mode which has a bandwidth of 40 Hz. MSFC has a total of 15 units that could be used for the ground experiment, if required. A typical ATM gyro noise plot of 10 log $[(\text{deg/sec})^2/\text{hz}]$ versus frequency is shown in Figure 7 and the set-up state is depicted in Table 2. These units are ready for integration tests with the control computer and the effectors.

3. Accelerometers

Six Kearfott 2401 accelerometers will be used in the ground test. Three will be mounted to the effector base and three will be mounted to the tip of the test article. The minimum resolution for these units is 11 micro-g's but during quiescent testing each unit exhibited at least one count of noise. This one count of noise is equivalent to 11 micro-g's, so it appears that the resolution is approximately 22 micro-g's. The accelerometer bandwidth is 25 Hz and there are a total of twelve units available for use in the ground test.

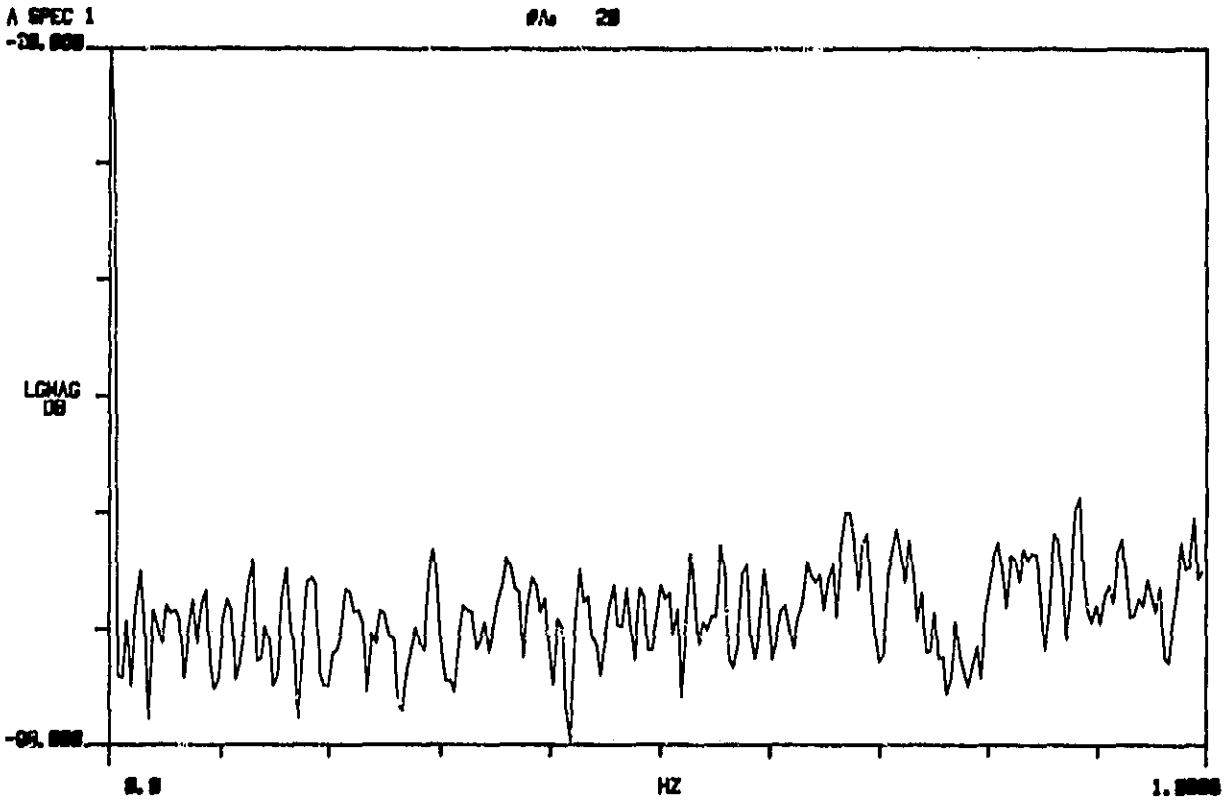


Figure 6. Typical noise plot for KARS rate gyro.

TABLE 1. SET-UP STATE FOR TEST OF KARS RATE GYRO RESULTING IN DATA OF FIGURE 6

MEASUREMENT : AUTO SPECTRUM

AVERAGE : 20 . STABLE

SIGNAL : RANDOM

TRIGGER : FREE RUN . CHNL 1

CENT FREQ : 0.0 HZ

BANDWIDTH : 1.00000 HZ

TIME LENGTH : 256.000 S

AF : 3.90625 mHZ AT : 250.000 mS

ADC CHNL.	RANGE	AC/DC	DELAY		CAL (C1/C2)
* 1	100 mV	AC	0.0 S	-2.05000	
2	10 V	DC	0.0 S	1.00000	

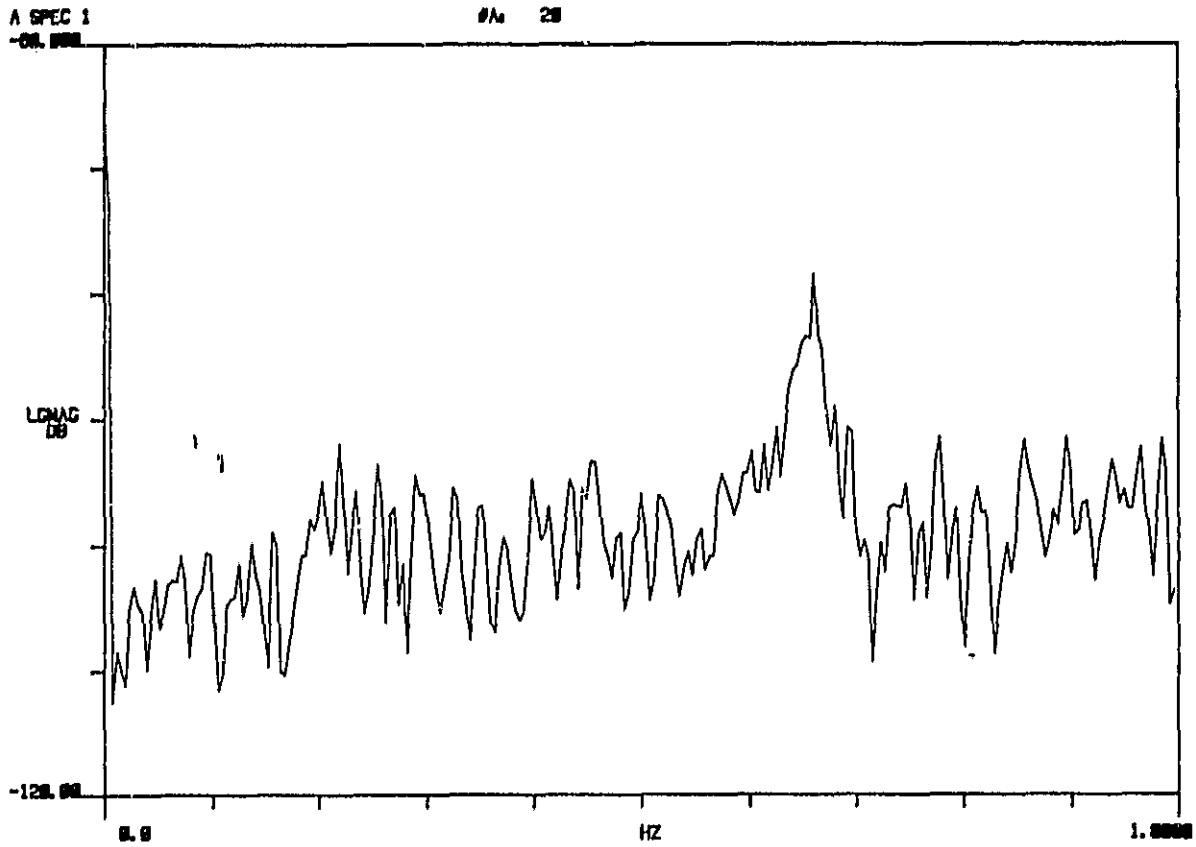


Figure 7. Typical noise plot for ATM rate gyro.

TABLE 2. SET-UP STATE FOR TEST OF ATM GYRO RESULTING IN DATA OF FIGURE 7.

MEASUREMENT :	AUTO SPECTRUM				
AVERAGE :	20	, STABLE			
SIGNAL :	RANDOM				
TRIGGER :	FREE RUN	, CHNL 1			
CENT FREQ :	0.0 HZ				
BANDWIDTH :	1.00000 HZ				
TIME LENGTH :	250.000 S				
ΔF :	3.90625 mHZ		ΔT :	250.000 mS	
ADC CHNL	RANGE	AC/DC		DELAY	CAL (C1/C2)
• 1	2.5 V	AC		0.0 S	22.2000 m
• 2	2.5 V	AC		0.0 S	22.2000 m

D. Test Article

1. Analytical Model

The test article for the GTV is an ASTROMAST. The ASTROMAST will be mounted to the AGS mounting plate and suspended by a constant tension cable. The analytical model predicted fundamental transverse vibrational modes of 0.6 Hz and a first torsional mode of 6 Hz. The second transverse mode was at 3.9 Hz while the second torsional mode was calculated to be 20 Hz. Clearly, the fundamental modes are too high and the frequency separation is too much. The objective is to lower the fundamental modes below 0.1 Hz and have at least five modes less than 0.5 Hz.

2. Unmodified Test Article Data

The Structural Test Division ran a modal survey of the ASTROMAST cantilevered from a base plate. The fundamental transverse modes were measured at 0.56 Hz and the first torsional mode was measured at 4 Hz. The second transverse mode was at 3.4 Hz while the second torsional mode was at 21 Hz. The agreement between the analytical model frequency values and the test data is at least 11 percent or better.

3. Modified Test Article Data

To achieve the structure goals mentioned in the Analytic Model section, a weight of 5 kg with an inertia about torsion of 1 kg-m^2 was clamped to the tip of the ASTROMAST. The modal survey showed the fundamental transverse vibrations to be 0.225 Hz while the first torsional mode was reduced to 0.5 Hz. The second transverse mode and the second torsional mode are not available because the modal survey has not been completed. The main point of contention is that a small structural modification yielded a considerable change in the fundamental frequencies.

Future LSS/GTV work may require more extensive modifications to the structure as shown in Figure 8.

E. Support Structures

1. Tip Support Mechanism

The tip support mechanism is used to off-load the weight of the test article and its ancillary equipment. The cable, which is attached to a tripod whose feet are on air bearings, will supply a constant tension to the test article. The translational capability of the tripod will allow the test article tip to translate almost unconstrained. This configuration along with the base mechanism will permit up to 5 rigid body modes.

2. Base Mechanism

The Base Mechanism will input disturbances of a prescribed characteristic to the test structure. Present plans for disturbances are two Orbiter attached inputs and one free flyer input. The Orbiter originated disturbances are an RCS thruster firing

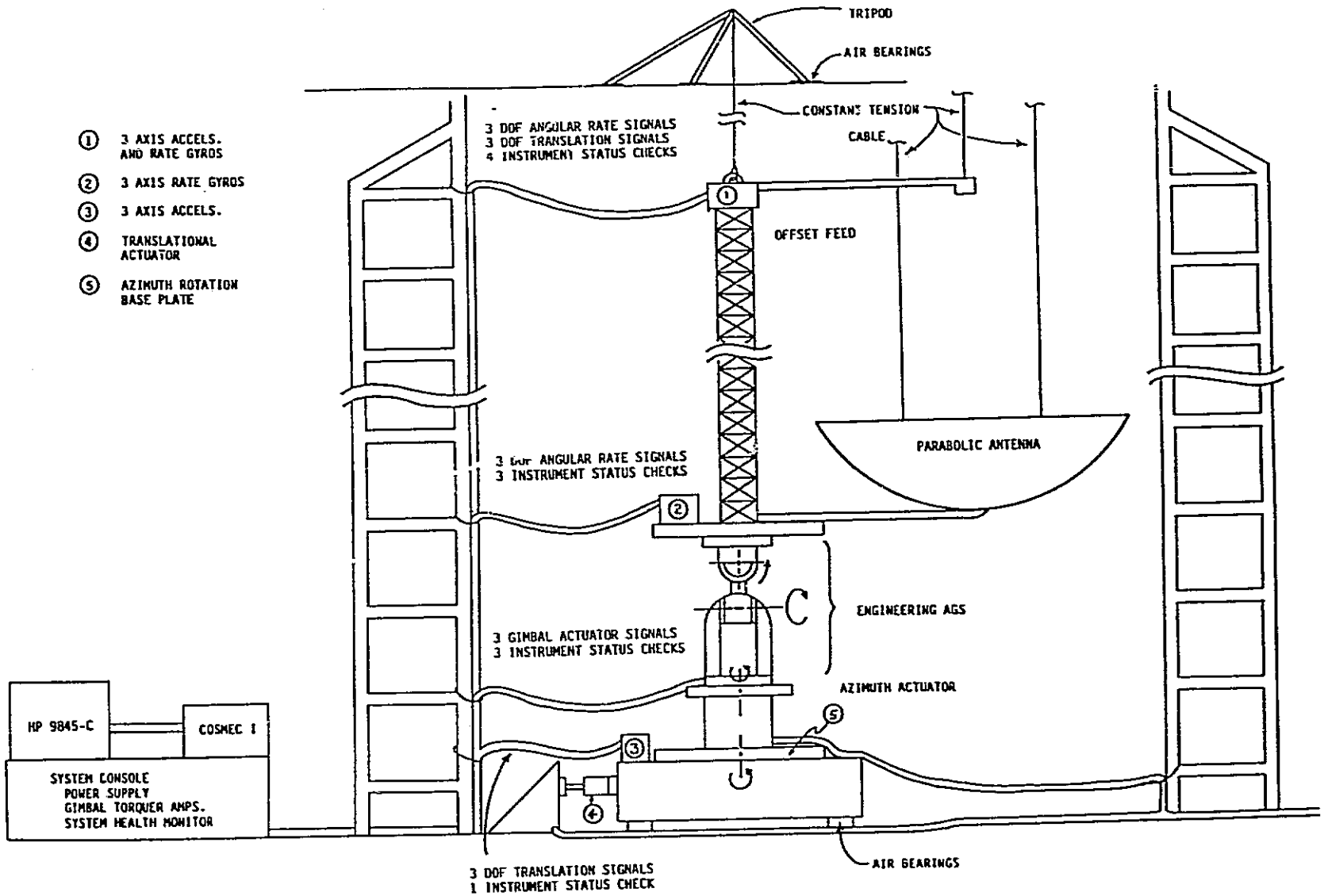
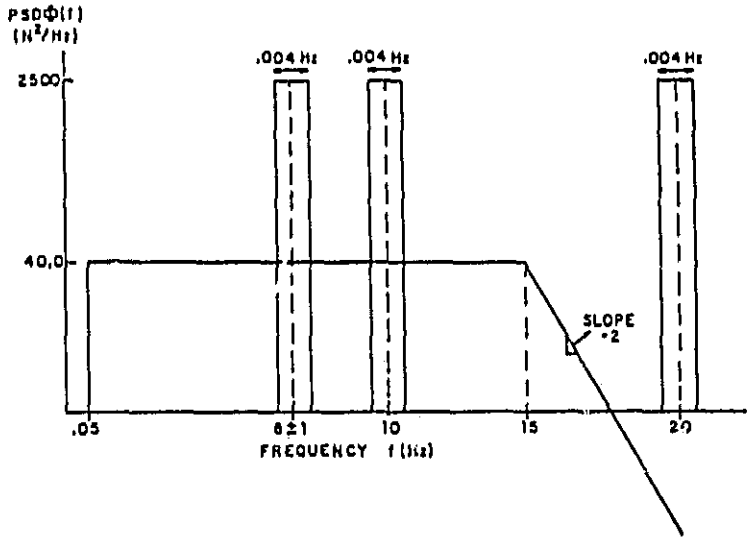


Figure 8. Modified ground test verification experiment under consideration for future studies.

(actual flight data taken from previous Orbiter telemetry) and a crew motion disturbance (actual flight data taken from Skylab). The free flyer disturbance is a PSD generated by the Riverside Research Institute which is shown in Figure 9. The ability of the base mechanism to generate an RCS thruster firing, a crew motion wall push-off and the free flyer disturbance will provide input base necessary to analyze LSS.



DEFINITIONS

PSD: $\Phi(f) = \int_{-\infty}^{\infty} \phi(t)\, e^{-i2\pi f t}\, dt$

AUTO-CORRELATION FUNCTION: $\phi(t) = \int_{-\infty}^{\infty} \Phi(f)\, e^{i2\pi f t}\, df$

Figure 9. Log-log plot of the one-sided disturbance PSD for the CSDL No. 2 model (not to scale).

VCOSS II CONTROLS TESTING

A. Objective

The main objective for the VCOSS II effort is to proof out the theories developed in the VCOSS I program. The VCOSS I theories show two approaches which actively control the vibrations of an LSS. Each technique requires special hardware to achieve the prescribed control goals. This hardware will be implemented into the NASA/MSFC GTV to provide a POC for the VCOSS I study.

B. VCOSS II MSFC Responsibilities

Without any unforeseen difficulties the NASA/MSFC GTV should be ready to start the VCOSS II test activities in April, 1984. However, the preliminary testing activity requires the completion of the following tasks:

1) Ground test facility description.

2) Preliminary description of modified structure.

3) Analysis and model of modified structure.

4) Simulation of modified structure.

5) Facility analysis and modification.

6) Integration plan of VCOSS II equipment.

7) VCOSS II inputs.

8) Preliminary Requirements Review (PRR) preparation.

These tasks are necessary to provide an orderly flow of information to and from the selected VCOSS II contractor. Once the task mechanisms are implemented, MSFC will install the VCOSS I control devices on the test article, run all prescribed tests, provide the test results, and provide access to the test facility, consultation, observation, and test assistance on a reasonable basis.

C. NASA VCOSS II Schedule

The starting times for the tasks outlined in the previous section are based upon the VCOSS II contract initiation. The facility description, the conceptual models, and the VCOSS-II inputs all start at contract initiation and run concurrently for a two month period. The analysis and model task and the PRR preparation begin one month after contract start. The PRR preparation runs for one month while the duration of the analysis and model task is four months. The facility analysis and model task starts after the PRR preparation and runs for three months. The simulation task and the installation of VCOSS II equipment plan start three months after the contract initiation. The installation plan task is a three month activity while the simulation task is a five month activity. The scheduling for the remaining tasks will be based upon the PRR.

LSS GROUND TEST ISSUES

The main LSS GTV objective for FY-84 and FY-85 is to set up a facility in which advanced control concepts can be demonstrated and LSS modeling techniques can be verified. The advanced control issues that will be addressed are structural vibration suppression, disturbance isolation, attitude control, evolutional control, remote sensing control, figure control, and image motion compensation. The modeling areas will include systems identification and the parameters obtained from the identification to verify and up-grade the modeling process. Once these issues are addressed in the LSS/GTV facility, a cogent plan for a flight experiment can be developed.

REFERENCES

1. Lyons, M. G., Aubrun, J. N., Margulies, G., Gupta, N. K., et al.: ACOSS Three (Active Control of Space Structure) Phase 1. RADC-TR-80-131, May 1980.

2. Iwens, R. P.: Challenges in Stable and Robust Control Systems Design for Large Space Structures. Conference on Decision and Control, Albuquerque, NM, December 10-12, 1980.

3. Benhabib, R. J., Iwens, R. P., Jackson, R. L.: Adaptive Control for Large Space Structures. 18th IEEE Conference on Decision and Control, Fort Lauderdale, Florida, December 12-14, 1979.

4. Davison, E. J., and Wang, S.: On Pole Assignment in Linear Multivariable Systems Using Output Feedback. IEEE Transactions on Automatic Control, August 1975.

5. Kimura, H.: A Further Result on the Problem of Pole Assignment by Output Feedback. IEEE Transactions on Automatic Control, June 1977.

6. Waites, H. R., Doane, G. B., and Tollison, D. K.: Definition of Ground Test for Large Space Structure (LSS) Control Verification. AIAA Guidance and Control Conference, Gatlinburg, TN, August 15-17, 1983.

APPROVAL

NASA-VCOSS DYNAMIC TEST FACILITY

By Dr. Henry B. Waites, Dr. Sherman M. Seltzer,
and Dr. George B. Doane III

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

G. F. McDONOUGH
Director, Systems Dynamics Laboratory

☆U.S. GOVERNMENT PRINTING OFFICE 1985–544-048/10103