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FACILITY TO STUDY THE CONTROL OF FLEXIBLE SPACE STRUCTURES

TEST PLAN (PRELIMINARY)

[DOC-CR-SP-83-025]

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C. H. Hersom

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SPACE PROGRAM

TITLE: FACILITY TO STUDY THE CONTROL OF FLEXIBLE SPACE STRUCTURES

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SUMMARY and PREFACE

In order to focus on experimental objectives and procedures in connection with the facility under development to study the control of flexible space structures, a test plan is desirable. A series of discussions has been convened between Dynacon (represented by P. C. Hughes and G. B. Sincarsin) and HERSOM Engineering Services (represented by C. H. Hersom) in order to combine the technical goals of the facility (formulated by Dynacon) with proper technical procedures (formulated by HERSOM).

This document is only the first iteration in this process of collaboration — which accounts for the cautionary word "preliminary" in its title. As the detailed design proceeds; as the hardware becomes available; and as the familiarity with this facility becomes more mature; — the test plan(s) will become more complete. At such time, a subsequent edition of this report will be issued.

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LIST OF FIGURES

1.0 SCOPE

1.1 General

This integration and test plan establishes the sequence and methods of integration for the control systems laboratory demonstration, including the inspection of the control components, the staged integration and response testing of the control system, and the evaluation of algorithms for control of the structure.

1.2 Objectives

The integration and testing outlined herein will provide confidence that the demonstration facility can be successfully utilized to evaluate control laws for large space structures using typical control sensors and actuators.

2.0 APPLICABLE DOCUMENTS

The following documents will be useful during the integration and operation of the test facility.

1. Specification for the Reaction Wheel
2. Specification for the Angle Encoder
3. Specification for the Angular Rate Sensor
4. Specification for the Accelerometer
5. Specification for the Displacement Transducer
6. Specification for the Linear Actuator
7. Assembly Drawings for the Demo Structure
8. Operation Manuals for the Processing Computer
9. Operation Manuals for the Interface Computer

3.0 EQUIPMENT DESCRIPTIONS

3.1 Demonstration Structure

The structure that is used for the demonstration is similar to a relector of an antenna system. It is three meters in diameter and consists of a rigid hub, eighteen rigid ribs connected to the hub by soft negator springs. The periphery points of the ribs are connected to each other by peripheral mass/spring elements. The structure is supported by a rigid superstructure and is allowed to move in two axes (pitch and roll) by gimbals, but is restrained in yaw. See Figure 3-1 for a sketch of the test facility and Figure 3-2 for a sketch showing the components of the structure.

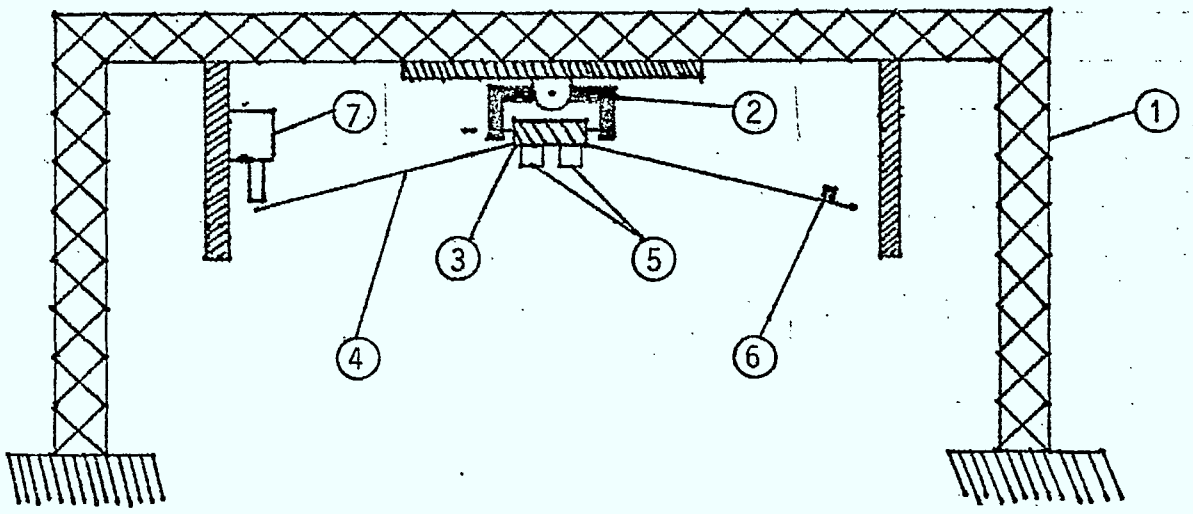
Two angle encoders and two angular rate sensors are located in the gimbals and two reaction wheels are mounted in the hub to control and measure the pitch and roll motion. Accelerometers may be mounted anywhere on the structure and displacement transducers and linear actuators may be positioned to measure and/or control the motion of the periphery.

3.2 Control Sensors

The sensors used to detect error consist of two sets: 1) the angle encoders and angular rate sensors mounted at the hub, and 2) the accelerometers and displacement transducers mounted on the ribs and/or periphery. The hub set is typical of the devices used in a space application, likely augmented by the accelerometers of the rib set. The displacement transducers are used to measure dynamic response to evaluate the quality of the control algorithm.

3.3 Control Actuators

The actuators used to correct error also fall into two sets: 1) the reaction wheels mounted in the hub, and 2) the linear actuators mounted at the periphery or elsewhere. The reaction wheels are typical of the devices used in space whereas the linear actuators are used to introduce disturbahce in order to evaluate the control system.



1. Superstructure
2. Gimbals--including Angle Encoders
   Angular Rate Sensors
   in each axis.
3. Hub
4. Ribs
5. Reaction Wheels
6. Accelerometers
7. Displacement Transducers
   and/or Linear Actuators

Figure 3-1 Sketch of Test Facility

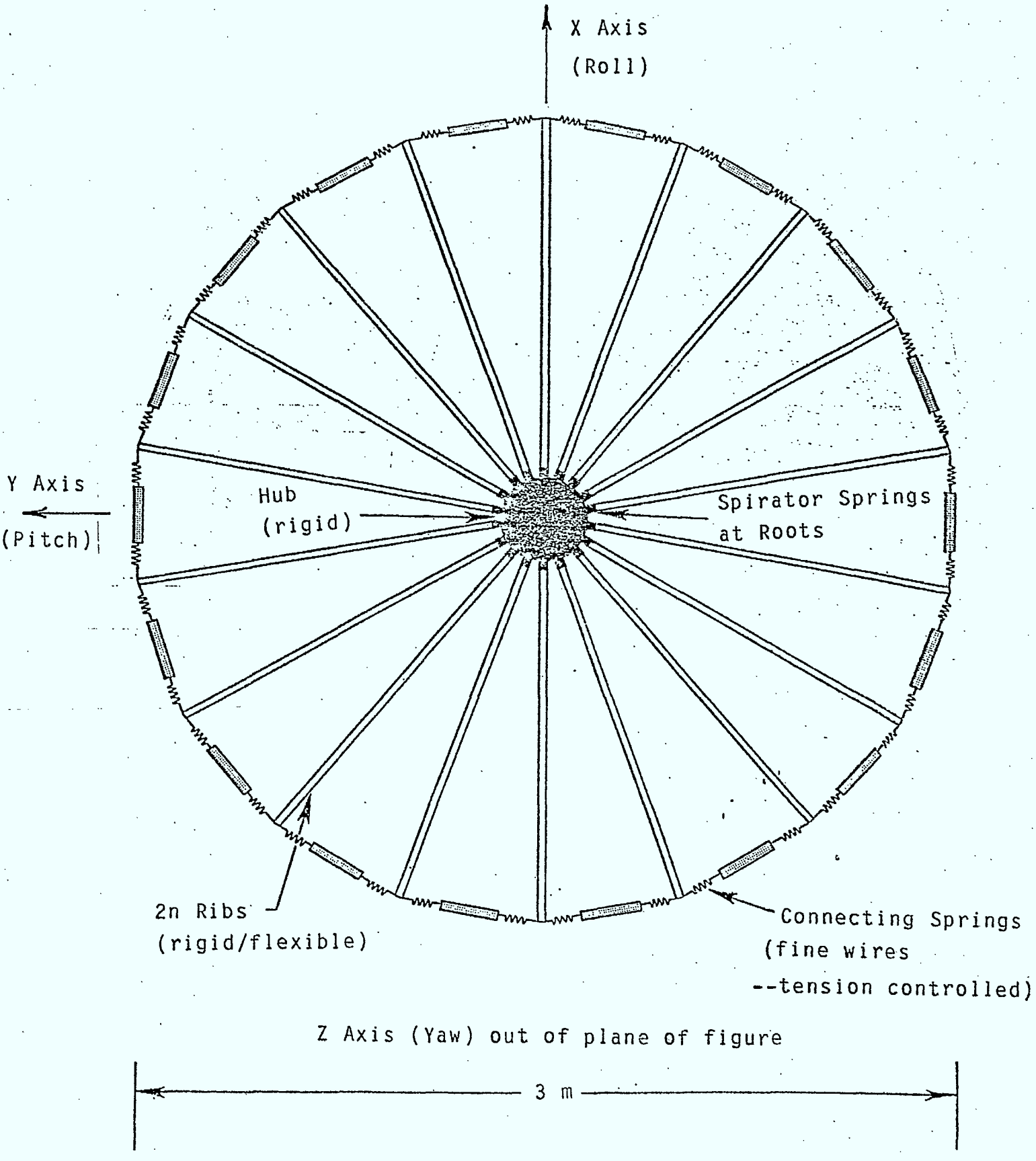


Figure 3-2 Components of the Demo Structure

3.4 Computer Facility

Two computers are used in the test facility. A block diagram of the facility is presented in Figure 3-3. One of the computers is used to interface with the control sensors, providing data acquisition, reduction and recording, and provides formatted data to the processing computer. In addition, this computer interfaces with the control actuators, providing appropriate commands to these devices based on outputs of the processing computer.

The processing computer receives sensor output data and uses it as input to the control algorithm under test. Control outputs from the algorithm are passed to the control actuators via the interfacing computer.

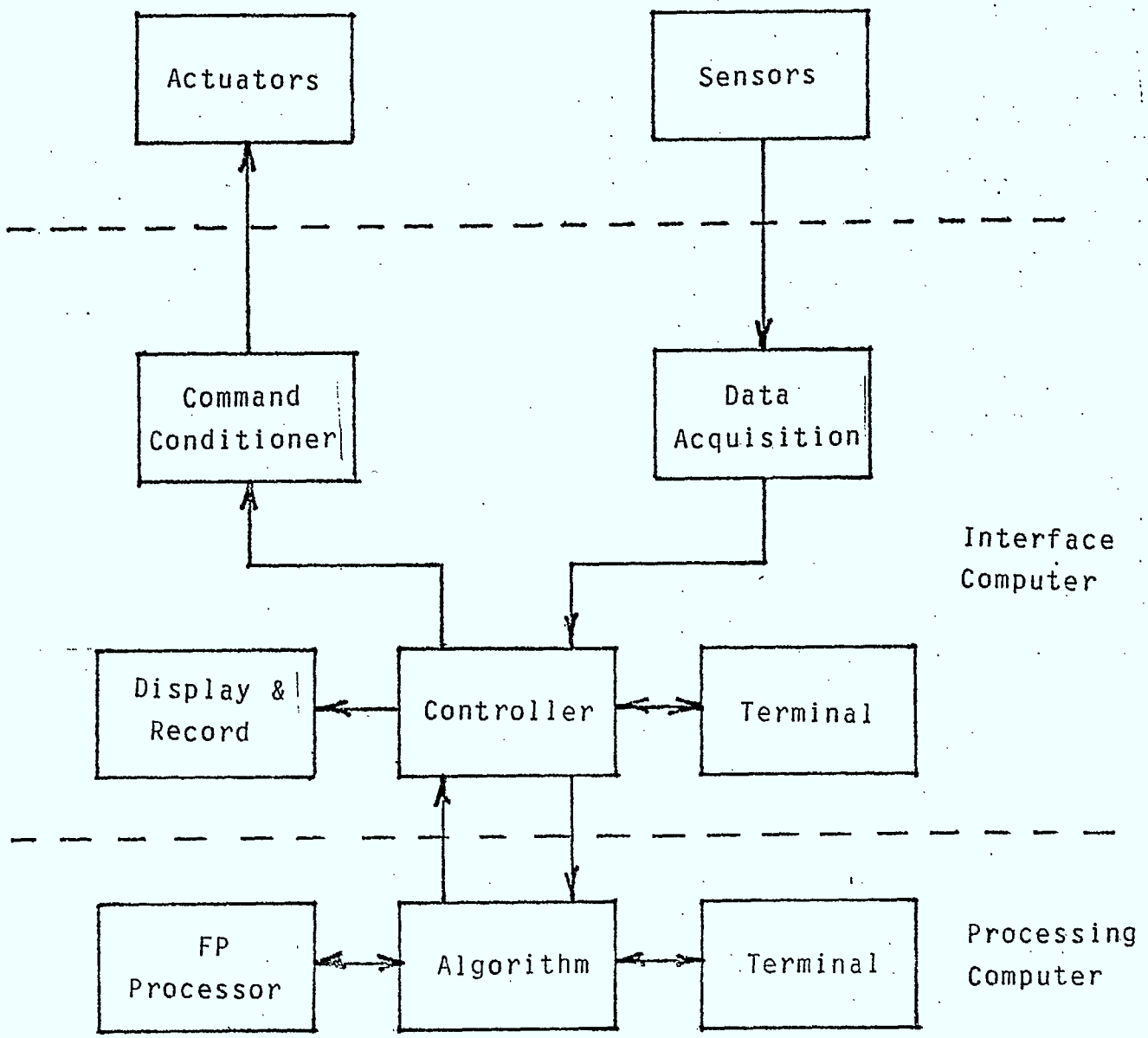


Figure 3-3 Block Diagram of Computer Facility

4.0 INTEGRATION AND TEST OF LAB DEMONSTRATION

The following paragraphs outline the integration and test sequence for the lab demonstration of controls systems using the demonstration structure.

4.1 Integration & Test with Hub Sensors/Actuators

The following tests will be performed as the hub sensors and actuators are integrated into the facility.

4.1.1 Inspection of Hub Sensors/Actuators

The inspection tests of paragraph 5.1 will be performed on the reaction wheels, angle encoders and angular rate sensors to confirm that these units are operational.

4.1.2 Integration of the Hub Sensors/Actuators

The hub set of sensors and actuators will be integrated one at a time with the interface computer in accordance to paragraph 5.2. These checks will ensure that the data flow in correct and the data interpretation is understood.

4.1.3 Stability Tests with Rigid Body

With the hub set mounted in the hub of the structure without the ribs attached, the control system will be tested for stability. The hub acts as a rigid body with inertia and the control loop will be closed with simple algorithms to check that all elements of the control system behave properly. The tests are provided in paragraph 5.3.

4.1.4 Response Tests with Hub Set

With the ribs added to complete the demo structure, response tests will be performed per paragraph 5.4 to check that the structural model is understood and that the data from the hub sensors correspond to the model.

4.1.5 Evaluation of Control Algorithms with Hub Set

Several control algorithms will be evaluated using the hub set of sensors/actuators in accordance to paragraph 5.5. These tests will determine if an algorithm can be successfully tuned to the structure and excitation using only the hub set of sensors and actuators.

4.2 Integration & Test with Rib Sensors/Actuators

The following tests will be performed as the rib sensors and actuators are integrated into the facility.

4.2.1 Inspection of Rib Sensors/Actuators

The inspection tests of paragraph 5.6 will be conducted on the accelerometers, displacement transducers, and linear actuators to ensure that these units are operable and ready for integration.

4.2.2 Integration of Rib Sensors/Actuators

The rib set of sensors and actuators will be integrated one at a time with the interface computer in accordance to paragraph 5.7. These checks will ensure that the data flow is correct and the data interpretation is understood.

4.2.3 Response Tests of Demo Structure with Complete Set

With the full complement of sensors and actuators integrated to the system, response tests will be performed per paragraph 5.8 to check that the structural model is understood and that the data from the complete set of sensors correspond to the model.

4.2.4 Evaluation of Control Algorithms with Complete Set

Several control algorithms will be evaluated using the complete set of sensors/actuators in accordance to paragraph 5.9. These tests will determine if an algorithm can be successfully tuned to the structure and excitation using the complete set of sensors and actuators.

5.0 TESTS

5.1 Inspection Tests of Hub Sensors/Actuators

The following tests will be performed on the components below in order to confirm normal operation.

5.1.1 Reaction Wheels

TBD

5.1.2 Angle Encoders

TBD

5.1.3 Angular Rate Sensors

TBD

5.2 Integration of Hub Sensors/Actuators

The following checks will be performed on each of the components as they are connected to the interface computer and equipment. These checks will ensure that communication and data flow paths are functional.

5.1.1 Reaction Wheels

TBD

5.1.2 Angle Encoders

TBD

5.1.3 Angular Rate Sensors

TBD

5.3 Stability Tests of Rigid Body with Hub

The following tests will be performed using the rigid body hub complete with its set of sensors and actuators. Disturbances will be introduced into the configuration using the following methods:

a. external deflection.
b. hub torque using a reaction wheel.
c. signal added to feedback path.

Several simple control algorithms will be incorporated into the test configuration and used to evaluate the stability of the system. See Figure 5-1 for a sketch of the test configuration.

Details are TBD.

5.4 Response Tests of Demo Structure with Hub Set

The following tests will be performed using the complete demo structure assembly including the hub set of sensors and actuators. Disturbances will be introduced into the configuration using the following methods:

a. external deflection.
b. hub torque using a reaction wheel.

The configuration will be operated in an open loop manner. The response data from the hub sensors will be used to confirm the dynamic model of the structure. See Figure 5-2 for a sketch of the test configuration.

Details are TBD.

5.5 Evaluation of Control Algorithms with Hub Set

The following tests will be performed to evaluate various control algorithms which will be incorporated into the test system. Disturbances will be introduced into the configuration using the following methods:

a. external deflection.
b. hub torque using a reaction wheel.
c. signal added to the feedback path.

The response data from the hub sensors will be used to evaluate the performance of each algorithm against criteria TBD. See Figure 5-3 for a sketch of the test configuration.

Details are TBD.

5.6 Inspection Tests of Rib Sensors/Actuators

The following tests will be performed on the components below in order to confirm normal operation.

5.6.1 Accelerometers

TBD

5.6.2 Displacement Transducers

TBD

5.6.3 Linear Actuators

TBD

5.7 Integration of Rib Sensors/Actuators

The following checks will be performed on each of the components as they are connected to the interface computer and equipment. These checks will ensure that communication and data flow paths are functional.

5.7.1 Accelerometers

TBD

5.7.2 Displacement Transducers

TBD

5.7.3 Linear Actuators

TBD

5.8 Response Tests of Demo Structure with Complete Set

The following tests will be performed using the complete demo structure assembly including both the hub set of sensors/actuators and the rib set. Disturbances will be introduced by the following methods:

a. deflection of one or more ribs by linear actuator(s).
b. hub torque using a reaction wheel.

The configuration will be operated in an open loop manner. The response data from the hub sensors will be used to confirm the dynamic model of the structure. See Figure 5-4 for a sketch of the test configuration.

Details are TBD.

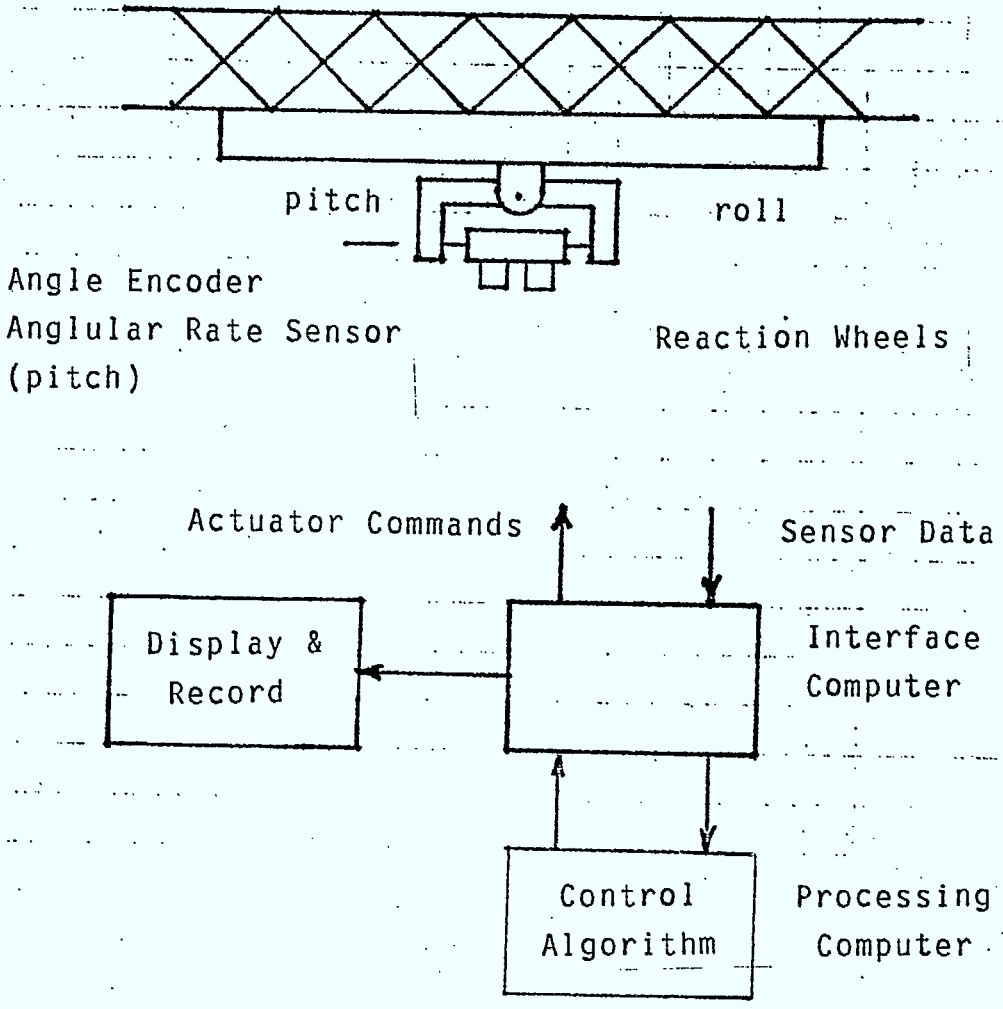
5.9 Evaluation of Control Algorithms with Hub Set

The following tests will be performed to evaluate various control algorithms which will be incorporated into the test system. Disturbances will be introduced as into the configuration using the following methods:

a. deflection of one or more ribs by linear actuator(s).
b. hub torque using a reaction wheel.
c. signal added to the feedback path.

The response data from the hub sensors will be used to evaluate the performance of each algorithm against criteria TBD. See Figure 5-5 for a sketch of the test configuration.

Details are TBD.

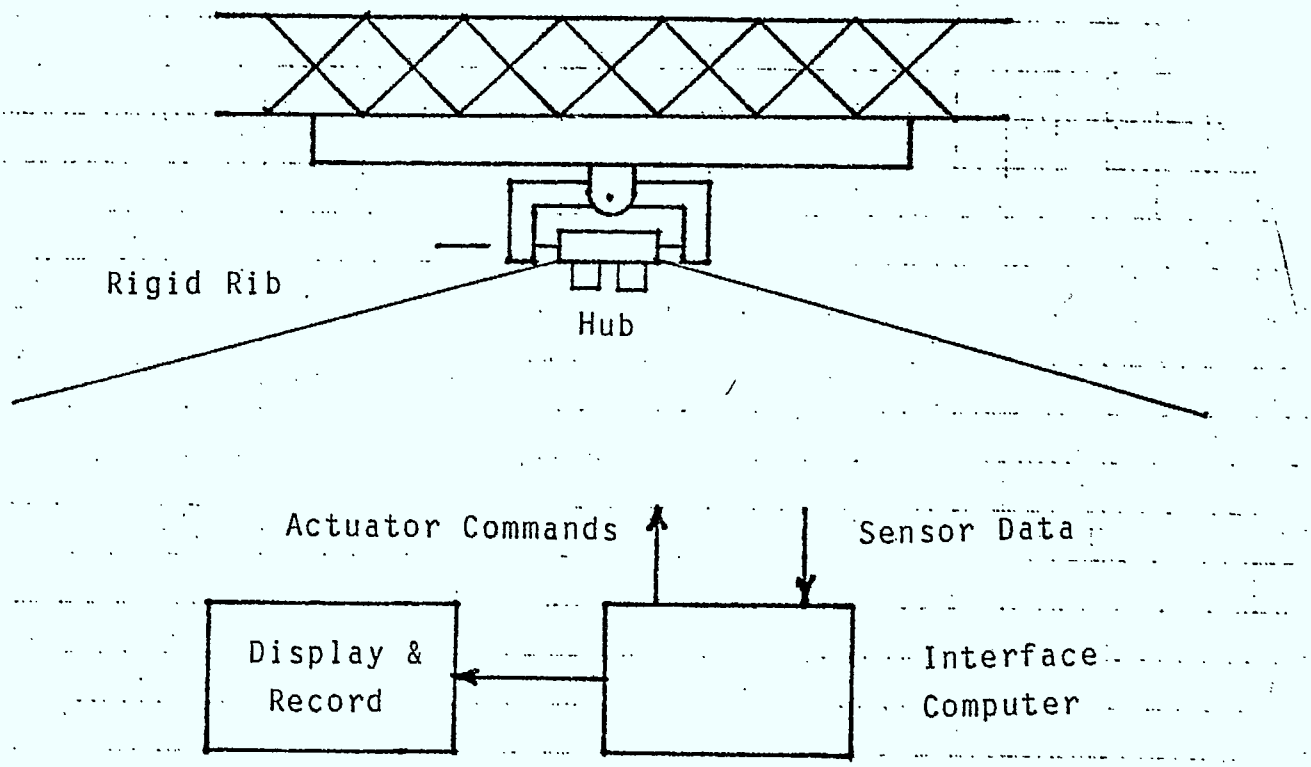


Configuration: Hub of Demo Structure
Sensors--Angle Encoders
Angular Rate Sensors
Actuators--Reaction Wheels

Excitation: External (manual) Deflection
Reaction Wheels
Signal Added to Feedback Path

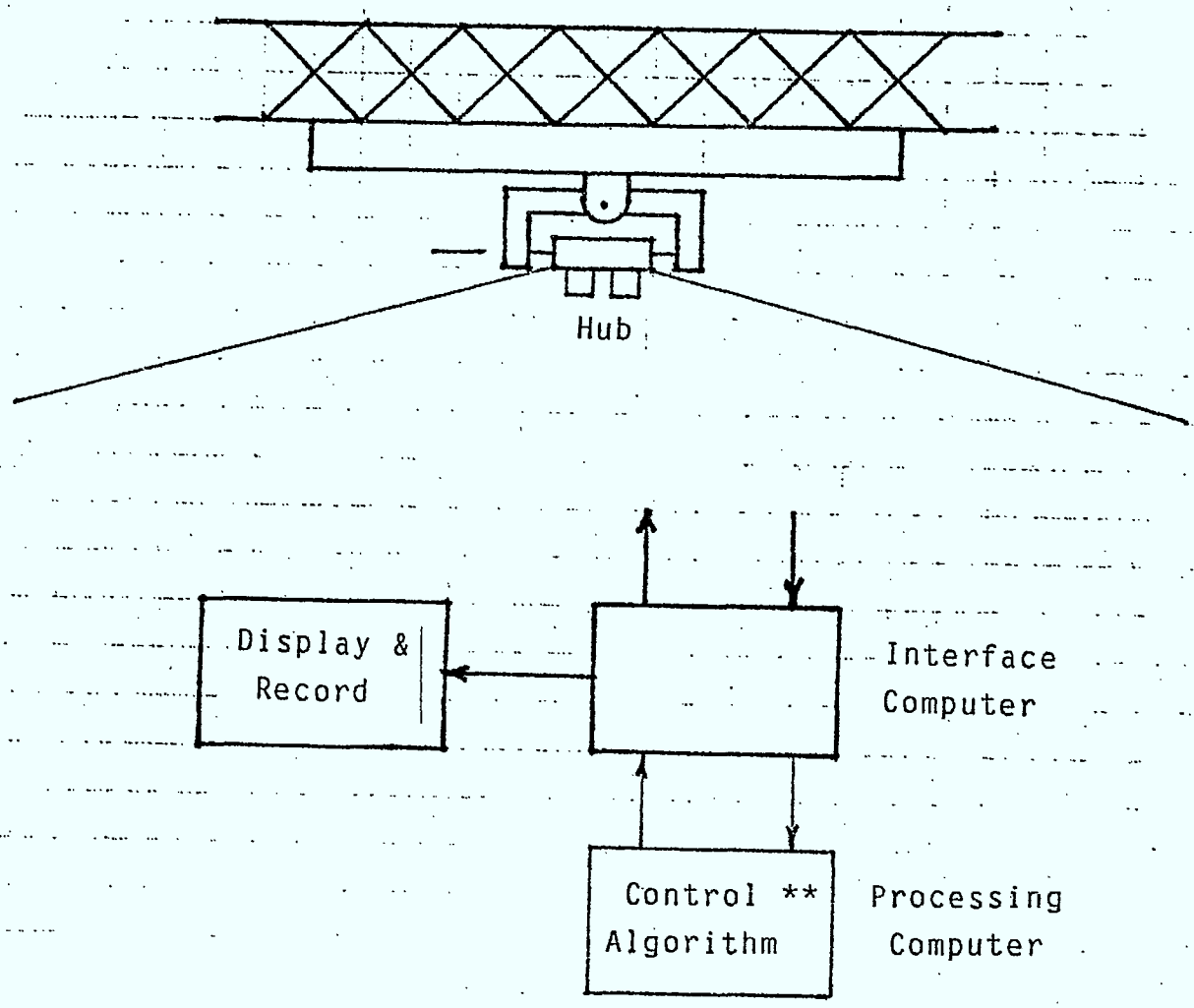
Purpose: Verify Stability

Figure 5-1 Configuration - Rigid Body with Hub



Configuration:	Complete Demo Structure Sensors--Angle Encoders Angular Rate Sensors Actuators--Reaction Wheels
Excitation:	External (manual) Deflection Reaction Wheels
Purpose:	Confirm Dynamic Model

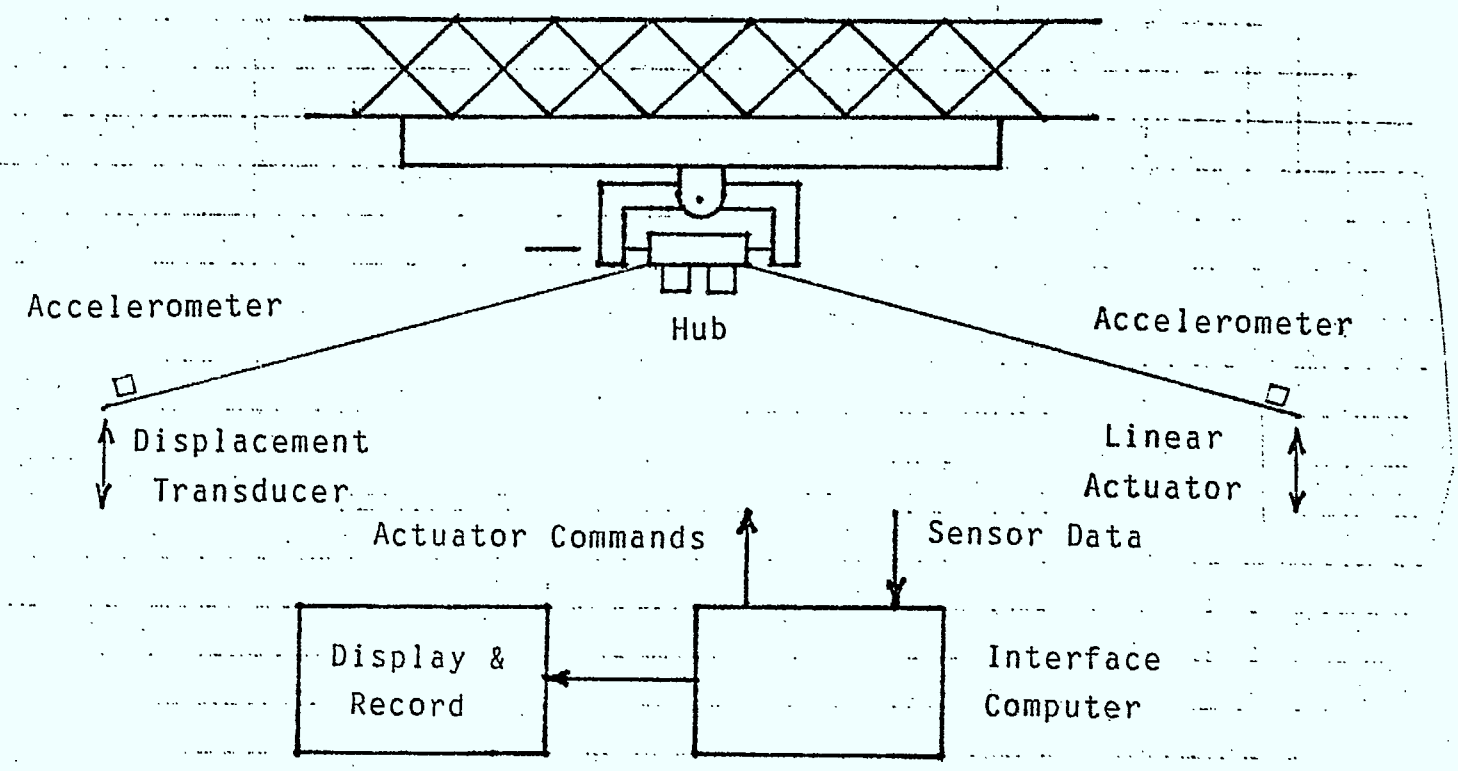
Figure 5-2 Configuration - Response Tests (Hub Set)



** Control Algorithm under test

Configuration:	Complete Demo Structure Sensors--Angle Encoders Angular Rate Sensors Actuators--Reaction Wheels
Excitation:	External (manual) Deflection Reaction Wheels Signal Added to Feedback Path
Purpose:	Evaluation of Control Algorithms

Figure 5-3 Configuration - Algorithm Evaluation (Hub Set)

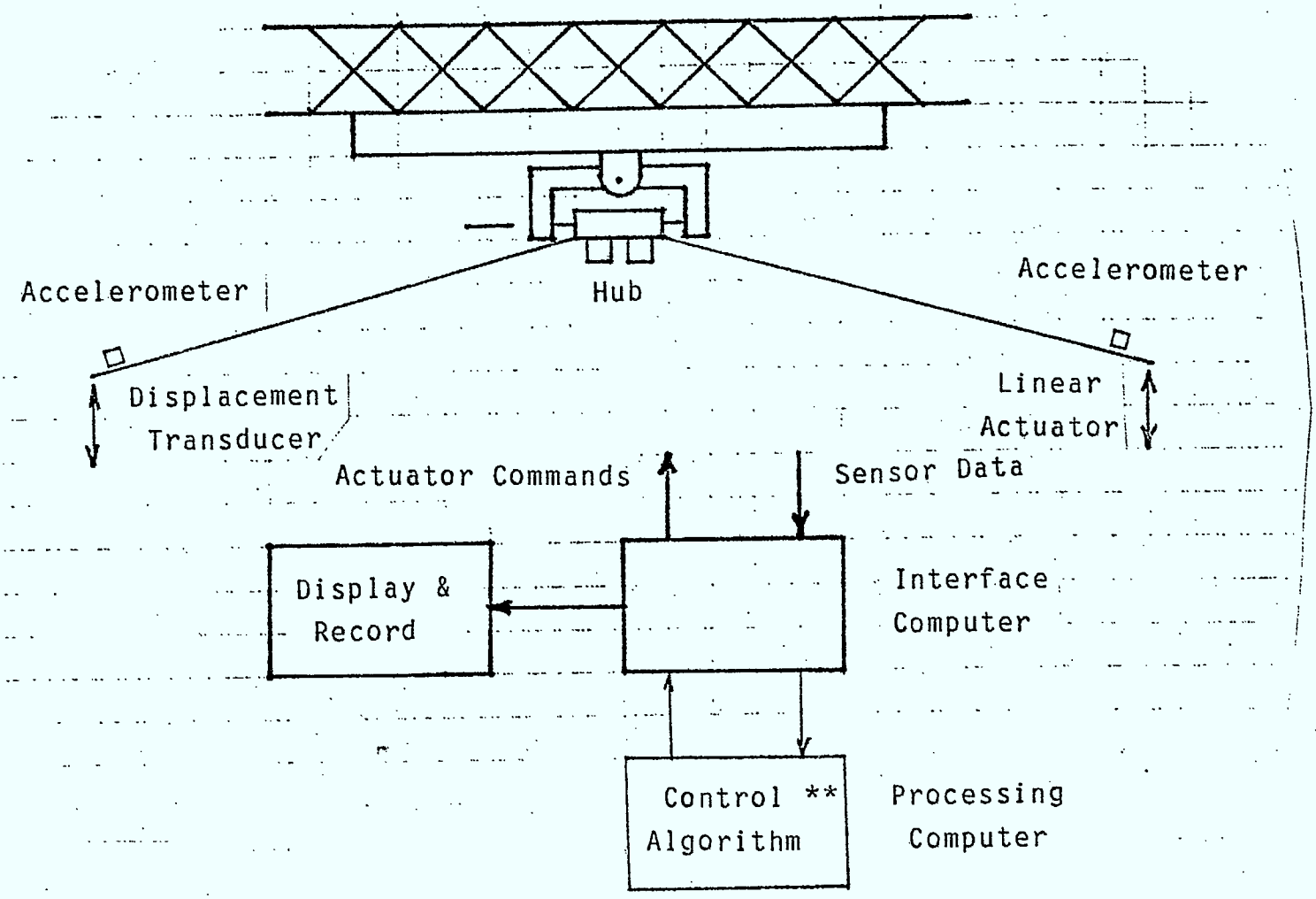


Configuration: Complete Demo Structure
Sensors--Angle Encoders
Angular Rate Sensors
Accelerometers
Displacement Transducers
Actuators--Reaction Wheels
Linear Actuators

Excitation: Reaction Wheels
Linear Actuators

Purpose: Confirm Dynamic Model

Figure 5-4 Configuration - Response Tests (Complete Set)



** Control Algorithm under test

Configuration:	Complete Demo Structure Sensors--Angle Encoders Angular Rate Sensors Accelerometers Displacement Transducers Actuators--Reaction Wheels Linear Actuators
Excitation:	Reaction Wheels Linear Actuators Signal Added to Feedback Path
Purpose:	Evaluation of Control Algorithms

Figure 5-5 Configuration - Algorithm Evaluation (Complete Set)

6.0 TEST SUPPORT REQUIREMENTS

6.1 Power Supplies

The requirements for the power supplies which supply the components and interface electronics are TBD.

6.2 Instrumentation

A wide range of general purpose lab instrumentation will be required to support the facility. This will include meters, oscilloscopes, analyzers, etc. A detailed listing is TBD.

6.3 Cables and Breakout Boxes

A number of cables will be required to interconnect the components and the interface computer, and possibly other equipment as well. The signals and functions of each of these cables will be defined in this section. Breakout boxes which will be required for integration and signal injection will also be specified. See Figure 6-1 for the interconnection diagram.

6.4 Test Software

The software required to support the test configuration will be specified in this section. The extent of this software will depend on the number of modes of operation that require separate configurations for the interface computer and the data acquisition equipment.

TBD

Figure 6-1 Interconnection Diagram

7.0 PRODUCT ASSURANCE PROVISIONS

Because of the developmental nature of this program, the product assurance provisions are limited to the following requirements.

7.1 Logbook

An engineering logbook shall be maintained by test personnel. The logbook shall be the written record of the history of the integration and test of the test facility and shall be used to document events and procedures clearly and concisely.

7.2 Data Records

All hardcopy data shall form part of the test record and shall be annoted indicating date, time (if required) and pertinent test plan paragraph. All data files created during testing shall be logged in the logbook indicating file name and test plan paragraph reference.

HERSOM, C.H.

Facility to study the control of flexible space structures: test plan (preliminary)