A Survey of Experiments and Experimental Facilities for Active Control of Flexible Structures

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MOTIVATION

We wish to identify large space structures (LSS) ground test experiments and facilities, both past and current, for comparison with the planned Langley Research Center's (LaRC) Control/Structures (CSI) Program's experiments and facility. This will give a better perspective of the ground testing work to be performed at LaRC.

TO IDENTIFY LSS GROUND TEST EXPERIMENTS AND FACILITIES, BOTH PAST AND PRESENT, TO PUT THE CSI TEST PLANS INTO PERSPECTIVE

INTRODUCTORY COMMENTS

NASA's future space missions will involve advanced space systems, such as the Hubble Space Telescope and the Mission to Earth platform. These systems will be comprised of large, flexible structures of complex, multi-body designs. They will also have increased on-orbit performance capabilities, such as large angle (non-linear) slewing, in order to accomplish their missions.

It is envisioned that new interdisciplinary (CSI) design methods will be required to tackle the challenges stated above. These new design and analysis methods will inevitably result in new concepts that must be validated via thorough ground testing. Ground experimentation will be required for (1) concept development - the testing of new configurations and concepts for space structures, optimized in terms of both controls and structures and (2) analysis verification - verifying new control algorithms or structural identification techniques in the laboratory. Both of these must be checked out in the most realistic scenarios as feasible. This will include advanced suspension systems and in testing in special controlled environments.

- **NASA FUTURE SPACE MISSIONS WILL INVOLVE:**

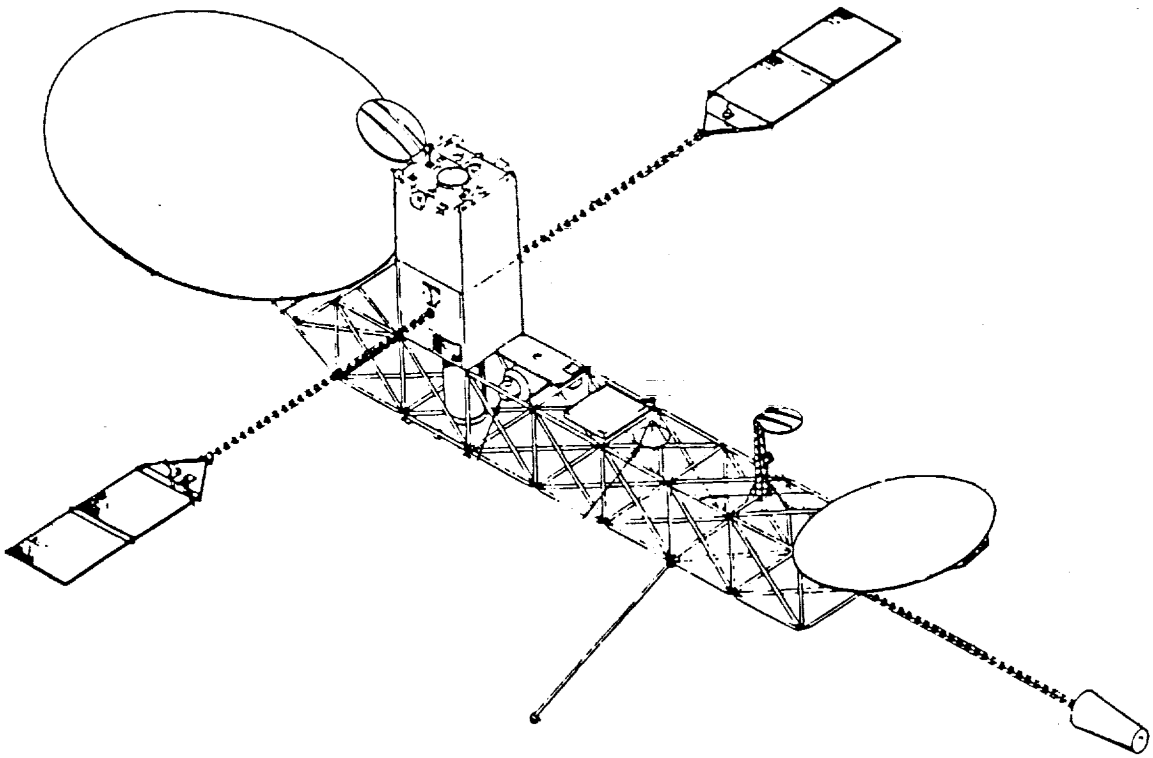
  LARGE, FLEXIBLE STRUCTURES
  COMPLEX, MULTI-BODY DESIGNS
  LARGE ANGLE (NON-LINEAR) MANEUVERS

- **NEW INTERDISCIPLINARY DESIGN METHODS WILL BE REQUIRED TO MEET THESE CHALLENGES**

- **GROUND TESTING WILL BE REQUIRED FOR :**

  CONCEPT DEVELOPMENT
  ANALYSIS VERIFICATION
  REALISTIC SIMULATION

MISSION TO EARTH PLATFORM



OUTLINE

This survey will cover large space structure ground testing in the following order: (1) the pre 1982 experiments, the last survey was conducted in 1982 and this paper will take up from that point, (2) post 1982 experiments and facilities, those recently concluded or are still ongoing, and (3) the planned future experimental facilities, concentrating on Langley's CSI ground test program. In the descriptions of each experimental set-up, pertinent components of the test article and/or test procedures that address flexible spacecraft issuses (e.g., vibration suppression, slewing and pointing control) will be emphasized.

The paper only reports on U.S. experimental programs (with the sole exception of one test bed from Canada). Also, even with the increased work in flexible robots, the topic of robotics is not included in this survey. It is felt that it should be treated as a separate issue.

- **PRE 1982 EXPERIMENTS**
- **POST 1982 EXPERIMENTS & FACILITIES**
- **FUTURE EXPERIMENTAL FACILITIES**
- **SUMMARY**

PRE 1982 EXPERIMENTS

The following chart, taken directly from an Air Force Rocket Propulsion Laboratory (AFAL) report [1], shows the ground experiments pertaining to large space structures studies undertaken up to 1982. They were relatively simple test articles, being beams or plates, as compared to present structures. None were specifically tailored to control-structure interaction studies.

One interesting note: the general types of actuators (torquers, proof masses, piezoelectrics, ...) and sensors (rate gyros, lasers, accelerometers, ...) used then were pretty much the same as today's. There is certainly an opportunity to develop and test new types of these devices in the CSI program.

Company	Type	Description	Sensor	Actuator	Demonstration
Draper	Beam	Fixed-free 1/4" X 1" X 60" Aluminum	Piezoelectric Accelerometers	Electrodynamic Shaker	Observation/control spillover modern modal control
Lockheed	Beam	Fixed-free 40" Magnesium	Optical rate sensor	Proof-mass	Low authority control
	I-Beam	Fixed-free 25' X 18" (400lbs) Aluminum	Optical rate sensor	Single gimbal CMG	Low authority control
	Vertical Beam	Fixed-free 6' Aluminum lead tip masses	Accelerometers, quad-detector photodiodes	Pivoted proof-mass	Low authority control System identification
	Circular plate	Suspended, 2 meter diameter, Aluminum	Multi-channel micro-phase optics	Pivoted proof-mass	Low authority control Low/High authority control System identification
	POC *	Suspended, 4.5 meter boom, 3 meter reflector, Aluminum	Accelerometers, rate gyros, laser	CMG, proof mass	Classical & modern control of vibration & slew
	Toysat	Suspended rigid body 1.6 m cantilever beams Aluminum	Accelerometers, LVDT velocity pickoffs	Electrosesis actuators	Open loop torque profile high authority control
Convair	Plate	Fixed-free 68" X 103" Aluminum 4" X 5/16" welded beams	Rate gyros	Torque wheels	Modern error sensitivity suppression
JPL	Beam	Pinned-free 150" X 6" X 1/32" stainless steel	Eddy current position sensor	Brushless d.c. torque motor	Modern modal control
LaRC	Beam	Suspended 12' X 6" X 3/16" Aluminum	Noncontacting deflection sensor, load sensor	Electrodynamic shaker	
TRW	Plate	Clamped 1.73 m X 1.22 m X 1.66 mm Aluminum	Rate sensors, accelerometers	Bending moment actuator	Vibration suppression and damping augmentation

*Lockheed's Proof of Concept (POC) experiment, for ACOSS support, is the most sophisticated test article on this chart. It was tested from 1981 to 1983.

POST 1982 EXPERIMENTS

The following charts show the flexible structures experiments of the present day. The catagories are broken into four parts: (1) experiment name, the responsible organization and a contact name, (2) the general description, (3) actuator and sensor types used, and (4) the main goal(s) of the experiment. This list is certainly not all inclusive but does provide a good sample of experiments recently concluded or ongoing. This list was compiled through direct contacts with researchers in the large space structures community and by literature search [2-17].

There are several experiments in this chart that are of particular interest, in terms of CSI. The Harris Plate Experiment is especially interesting since one of its test objectives is the study of actuator and sensor placement. This important issue is one of the basic concerns in the CSI Program (not only the placement of hardware, but possibly the development of new types).

The Spacecraft Control Laboratory Experiment (SCOLE) is a good test article for rigid-body slewing and vibration suppression testing. The fault detection tests performed on SCOLE are very important, since real spacecraft hardware failures are inevitable. This issue will be studied carefully in the CSI Program.

POST 1982 EXPERIMENTS

EXPERIMENT	DESCRIPTION	ACTUATORS/SENSORS	TEST OBJECTIVE
Advanced Beam Experiment (ABE) - AFWAL [Robert W. Gordon]	71 in. aluminum beam, vertically hung, cantilevered at top	Proof mass actuators, accelerometers	active vibration suppression
12 m Truss Control AFWAL [Robert W. Gordon]	Aluminum truss, vertically oriented, cantileverd at base	Proof mass actuators, accelerometers, photodiode	active & passive damping
TRW Truss Experiment [Maribeth Roesler]	115 X 55 in. truss box	optical sensor	active & passive damping
Compound Pendulum Harris Corp. [John Shipley]	2 beams, connected at middle and bottom end	Harris Linear DC motor, accelerometers	testing of Harris LDCM on lightly damped structure
Plate Experiment Harris Corp. [John Shipley]	4 sq. ft., 1/8 in. thick plate, suspended vertically	microshakers, accelerometers	surface roughness control, sensor/ actuator placement studies
Multi-Hex Prototype Experiment (MHPE) Harris Corp. [John Shipley]	10 ft diameter, 7 graphite epoxy panel segmented test bed	Harris Linear Precision Actuators (LPACTS), piezoelectrics, optical sensor	generic testing of large segmented reflectors, surface shape control
Air Force Planar Truss Experiment USAFA-AFOSR [William L. Hallauer]	23.3 ft, 20 bay truss, horizontal on bearing	thrusters, proof mass actuators, accelerometer	actuator-structure interaction studies
Beam Cable - VPI [William L. Hallauer] 2-D Pendulous Plane Grid VPI [William L. Hallauer]	80 in. vertical steel beam, with aluminum cross beam, hung by cables Aluminum grid with steel top beam	force actuators, velocity sensors	active damping, theoretical/ experimental comparisons
Slewing Grid - VPI [William L. Hallauer]	Aluminum plane grid, pivots about steel shaft	reaction wheels, servo accelerometers	active rigid body slewing and vibration suppression

POST 1982 EXPERIMENTS (CON'T)

EXPERIMENT	DESCRIPTION	ACTUATORS/SENSORS	TEST OBJECTIVE
Hoop-column antenna Langley [Thomas Campbell]	15 m mesh antenna, supported by outer graphite hoop, a 13 m column in center	accelerometers, proximity probes	deployment, electromagnetic, structural tests
Three-body rapid maneuvering experiment Langley [Jer-Nan Juang]	two flexible, horizontal panels, one on each side of a rigid hub, hub rotates in horizontal plane	gearmotor, strain gauges, potentiometers	rapid slewing experiments
Multi-body maneuvering experiment - Langley [Jer-Nan Juang]	1 m flexible panel, projecting out from a cart, cart travels on a horizontal 3 m beam	gear box motor, direct drive motor, tachometer, potentiometer, strain gauges	rapid translational & rotational control of flexible panel, can be mini-test article for CSI
Daisy Test bed Dynacon Enterprises [P.C. Hughes]	central rigid hub, 10 equally spaced rods projecting out total diameter 19 ft.	thrusters, reaction wheels, accelerometers, digital angular motion encoders	generic test bed for flexible spacecraft studies
Ohio State University Control Research Lab [Ü. Özgüner]			
Free-Free Beam	1.8 m horizontally suspended aluminum beam	proof mass actuators, accelerometers, strain gauges	system ID, vibration suppression
Slewing Beam	40 in. horizontal aluminum beam, attached at end to hub, counter-weight attached at opposite side of hub	direct drive motor, motor encoders, accelerometers, tachometer	slewing control and vibration suppression
Smart Structures Lab VPI [Harry Robertshaw]			
Variable Geometry Truss	2 module variable configuration truss, with beam suspended vertically in center	electric motors, linear potentiometers, strain gauges	truss configuration, beam control
Planar Truss	1 bay truss, contrained on one side, horizontal on table	jack screws, strain gauges	vibration and slewing control
Free-Free Planar Truss	1 bay truss, free to move horizontally on table	jack screws, strain gauges, linear potentiometers	

POST 1982 EXPERIMENTS (CON'T)

EXPERIMENT	DESCRIPTION	ACTUATORS/SENSORS	TEST OBJECTIVE
Flexible Satellite Slew Test bed - AFAL/CSDL [P. Madden]	hub with 4 horizontal arms (9 ft total diameter), suspended on air table	cold gas jets, proof mass actuators, angle resolver, accelerometers	active vibration suppression, rigid body slewing control
MIT Space Systems Lab [Ed Crawley]	composite beam, horizontally hung by wire	embedded piezoceramic actuators, strain gauges	active vibration suppression
	25 ft. brass beam, horizontally suspended by wire	shaker, accelerometer	traveling wave experiments
	horizontal truss on soft springs	piezoceramic actuators, PCB structcel accelerometers	active structural member studies
Aluminum Beam Expander Structure (ABES) AFWL [David Founds]	SBL Beam Expander Model 9 m tripod, 6 m base	shakers, triaxial accelerometers	system identification
Spacecraft Control Laboratory Experiment (SCOLE) - Langley [Raymond Montgomery]	rigid platform, with 10 ft beam with a 40 in. diameter offset reflector frame, all suspended by steel cable	cold gas jets, reaction wheels, control moment gyros, rate gyros, optical sensors, accelerometers	slewing and pointing experiments, with vibration suppression, system identification tests, failure detection and reconfiguration tests
Advanced Structures/ Controls Integrated Experiment (ASCIE) Lockheed [Ken Lorell]	truss supporting a 2 m diameter, 7 hexagonal aluminum plate, segmented mirror	proportional electro-mechanical flexure levers, optical sensor	control test bed for segmented reflectors
Space Integrated Controls Experiment (SPICE) - AFWL [Capt. Robert Hunt]	SBL test model	active suspension (SAVI) and passive	
Passive and Active Control of Space Structures (PACOSS) AFWAL/MMDA	Dynamic Test Article (DTA) various components		Active and passive control
Joint Optics Structure Experiment (JOSE) AFAL-TRW-Litton-ITEK [Capt. Robert Hunt]	Primary/secondary reflector optical truss - Halo structure	proof mass actuators	

POST 1982 EXPERIMENTS (CONC)

EXPERIMENT	DESCRIPTION	ACTUATORS/SENSORS	TEST OBJECTIVE
SUNY - Buffalo [Daniel Inman]			
	vertically oriented aluminum beam, cantilevered, active hinge connecting beam with second flexible beam	torque motor, strain gauges, tachometer (active hinge)	slewing/vibration suppression control
	cantilevered composite beam	proof mass actuators	transverse vibration control, actuator/sensor interaction tests
	horizontally cantilevered beam	torque motor	eigenfunction based slewing control
	planar truss structure	proof mass actuator	periodic trusses modeling
	cantilevered beam and truss	electric motors	slewing/vibration control, actuator/sensor interaction tests
	horizontal beam, hinged at end, suspended at other end	active track/cart system	active suspension tests
Vibration Control of Space Structures (VCOSS) MSFC-AFWAL-LMSC-TRW [Henry B. Waites]	13 m Astromast with asymmetric cruciform at base, vertically oriented, cantilevered at top	linear momentum exchange devices, LVDT, accelerometers	pre-cursor to ACES
Active Control Technique Evaluation for Spacecraft (ACES) - MSFC [Henry B. Waites]	13 m Astromast with 3 m offset antenna, vertically oriented, cantilevered at top	linear momentum exchange devices, accelerometers, laser	general test article, vibration suppression, system ID
Mini-Mast - Langley [Richard Pappa]	vertically oriented, 20 m, 18 bay truss, cantilevered at base	reaction wheels, proof mass actuators, position sensors, accelerometers	vibration damping and system ID, general test structure

AIR FORCE PLANAR TRUSS EXPERIMENT

The following experiment was built to study the interactions between a structure's flexible modes and the dynamics of the structure's proof mass actuator used for vibration suppression. This important work will look into these interactions and how they may be taken advantage of when designing control systems. The test article is a 20 bay, 23.3 ft. long planar truss resting horizontally on ball bearings. A pair of air thrusters for low frequency vibration suppression and the proof mass actuator for high frequency vibrations serve as actuators. An accelerometer is used as a sensor.

Attachments will be added to this planar truss to build up an article that better mimics more elaborate space structures after the above study is completed. This interactions work will continue on the more complex dimensional test structure. Futhermore, various types of proof mass actuators, their locations and their mountings on the structure will be examined.

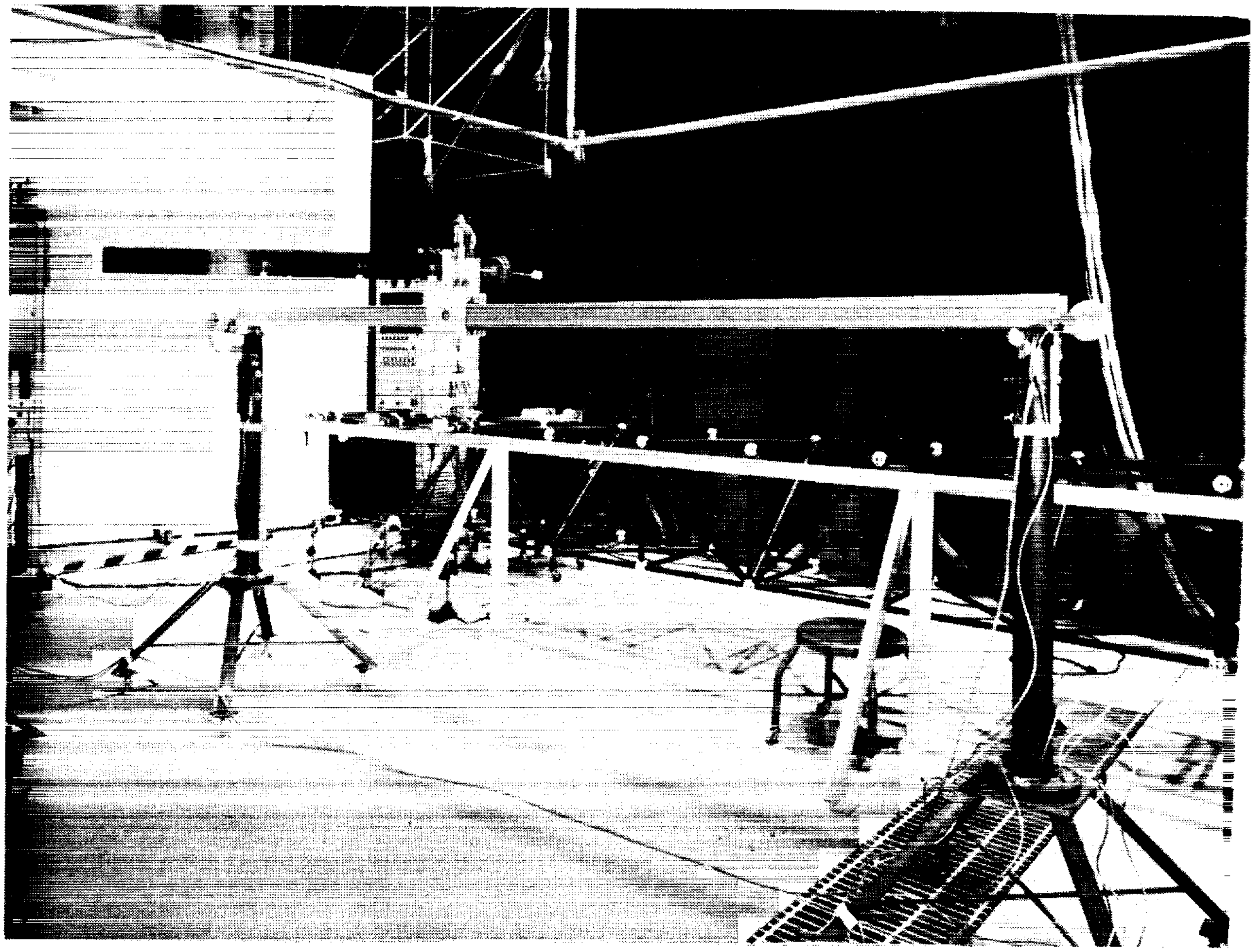
The work is currently sponsored by the Air Force and is being conducted at the Air Force Academy. The principal investigators are Steven Lamberson, William Hallauer, John Duke and David Wagie.

- **EXAMINES ACTUATOR & STRUCTURE INTERACTION**

- **INCLUDES INTERACTION EFFECTS IN CONTROL SYSTEM DESIGN**

- **PROVIDES BACKGROUND FOR MORE COMPLEX TEST ARTICLES**

PHOTOGRAPH OF LANGLEY'S MULTI-BODY MANEUVERING EXPERIMENT



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HARRIS MULTI-HEX PROTOTYPE EXPERIMENT

Harris Corporation has built the Multi-Hex Prototype Experiment (MHPE) to act as a test bed for control/structure interaction studies. The test article represents a generic large, deployable segmented antenna or mirror. It is made up of seven graphite epoxy panels, resulting in a total diameter of 10 feet. This test article will address several issues: vibration suppression, pointing control and the important surface shape control. Harris developed linear proof mass actuators, called Linear Precision Actuators (LPACTS), and piezoelectric actuators will be used, as well as an optical measurement system for sensing.

Currently, system identification work is being performed on the MHPE. It is planned to use an optical quality surface, wavefront sensors, additional piezoelectrics and a pointing system to complete the MHPE test article set-up. The test bed can also serve as a platform for the development and testing of new actuators and sensors.

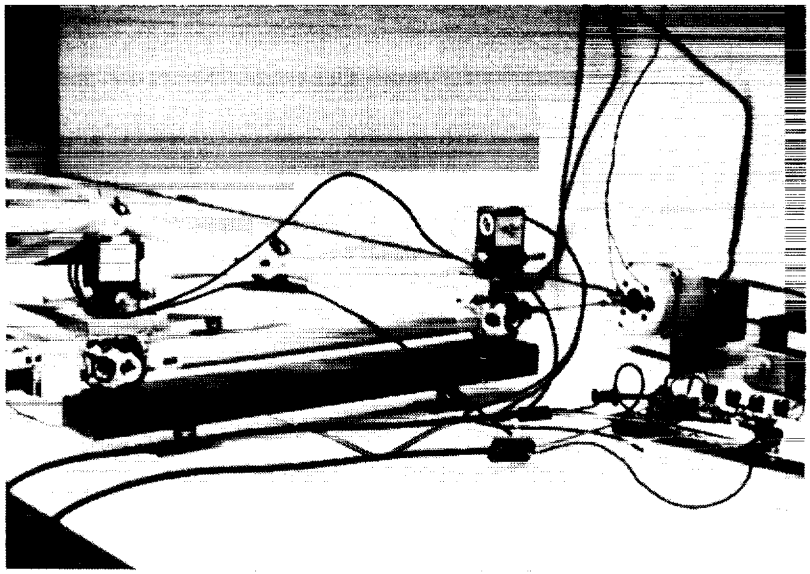
- **TEST BED FOR GENERIC LARGE SEGMENTED MIRROR OR ANTENNA STUDIES**

- **VARIOUS CONTROL FUNCTIONS WILL BE TESTED:**

  VIBRATION SUPPRESSION
  POINTING CONTROL
  SURFACE SHAPE CONTROL

- **CAN BE USED AS PLATFORM FOR NEW ACTUATOR AND/OR SENSOR DEVELOPMENT**

AIR FORCE PLANAR TRUSS EXPERIMENT



Truss Tip Instrumentation

Photograph of Planar Truss

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MULTI-BODY MANEUVERING EXPERIMENT

A test article for studying rapid translational and rotational motion control of a flexible panel has been built at NASA Langley. This structure consists of the following parts: 1 m flexible panel projecting out from a cart which can travel along a straight, horizontal 3 m beam. The flexible panel is also oriented horizontally, but is at a right angle with respect to the beam. A direct drive motor on one end of the beam moves the cart along the beam, while a gearmotor on the cart provides moments at the end of the flexible panel. Strain gauges attached to the flexible panel and a potentiometer on the cart give sensor measurements.

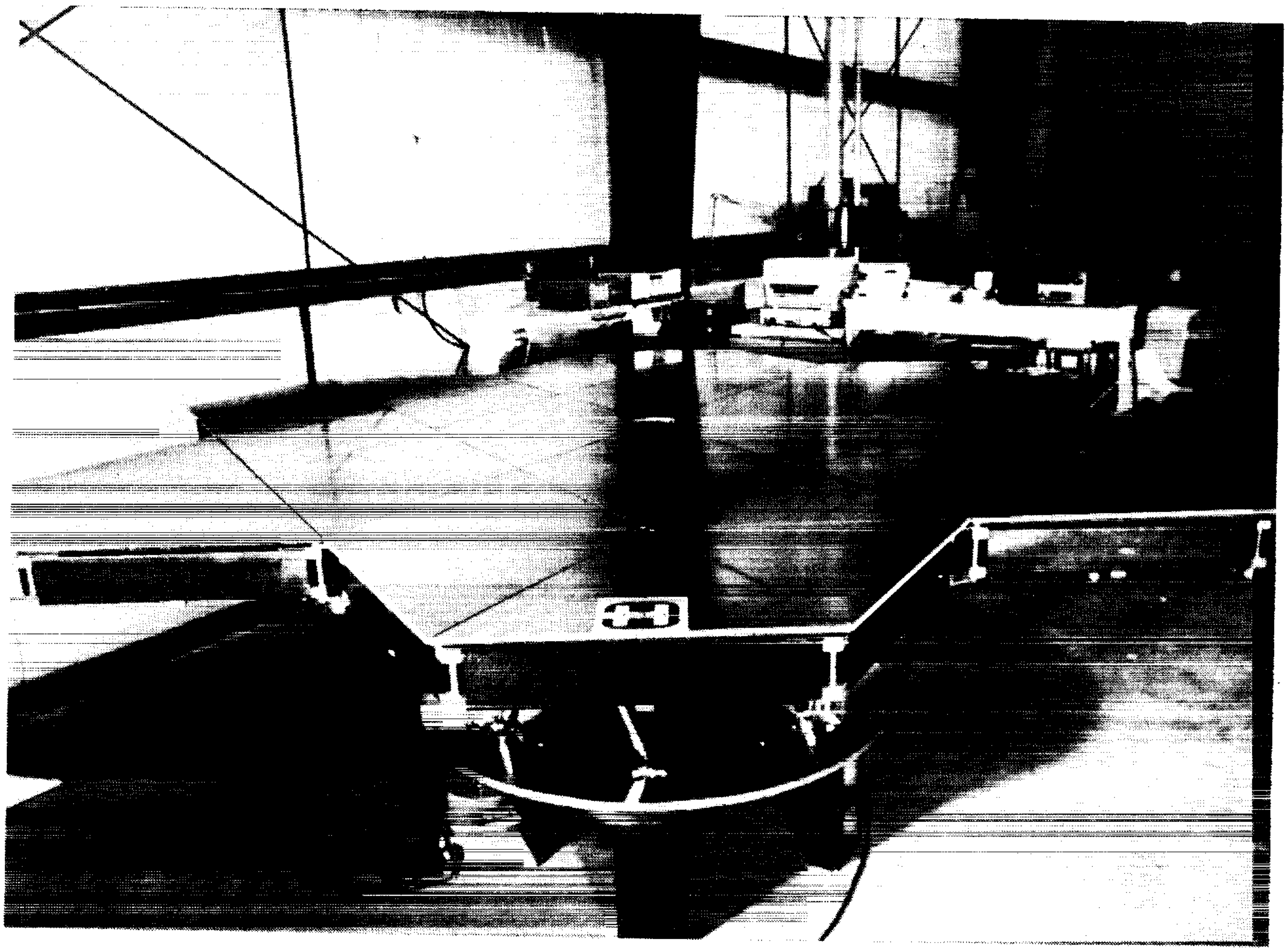
This is an on-going experiment that addresses rapid maneuvering of payloads. However, its small size precludes it from becoming a full test article for the CSI Program. It is hoped that this particular article can be used to perform initial control tests before placing the same control algorithms on the full size CSI test model.

- **RAPID TRANSLATIONAL & ROTATIONAL MOTION CONTROL OF A FLEXIBLE PANEL**

- **ADDRESSES RAPID PAYLOAD MANEUVERING PROBLEMS**

- **TOO SMALL FOR FULL SIZE CSI TEST ARTICLE, CAN BE USED FOR PRELIMINARY CONTROL ALGORITHM VERIFICATION**

PHOTOGRAPH OF THE HARRIS MULTI-HEX PROTOTYPE EXPERIMENT



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POST 1982 FACILITIES

The attached chart shows current large structure research facilities. The facility, in this survey, includes the test article on which the experiment is being performed, the computer systems and other necessary equipment to support the test work.

The catagories for the facilities chart are as follows: (1) the facility name, (2) general description, both of the experiment and the laboratory, (3) the computer and data acquisition systems used, (4) the actuator and sensor hardware on the test article(s), and (5) the test objective(s) of the facility.

The Large Space Structure - Ground Test Facility (LSS-GTF), the Advanced Space Structure Technology Research Experiment (ASTREX) facility, the JPL Testbed Facility and Langley's Large Component Test Laboratory (LCTL) are all dedicated to CSI experimentation. The AFAL ASTREX facility supports DoD CSI tests while the facilities at MSFC and JPL support NASA's CSI programs. The LCTL currently houses a Space Station truss article for structural dynamics testing. In a short time, a CSI dedicated test structure will also be placed in this laboratory.

POST 1982 FACILITIES

EXPERIMENT	DESCRIPTION	COMPUTER SYSTEM	ACTUATORS/SENSORS	TEST OBJECTIVE
Large Space Structure - Ground Test Facility (LSS-GTF) - MSFC [Henry B. Waites]	currently houses ACES - I, has Single Structure Control (SSC) Lab. future plans: Pinhole Occulter Facility (POF), Multi-Payload Pointing Mount (MPPM), Unobtrusive Sensor and Effector (USE) Lab, Robot Enchancement Lab and Vacuum/ Thermal Chambers. 5m x 5m x 36m	HP 9000 - 9200	advanced gimbal system (AGS), base excitation system (BET), linear momentum exchange devices (LMED), rate gyros, laser system, accelerometers	facility to test LSS articles
Large Space Systems Lab (LSS Lab) - AFAL [Alok Das]	currently houses 25 sq. ft. aluminum grid structure	ISI Max 100	accelerometers, load cells, proximity sensors	system identification
Advanced Space Structures Technology Research Exp. (ASTREX) Lab - AFAL [Alok Das]	40 ft x 40 ft x 40 ft lab space for Space Based Laser (SBL) model	VAX 8600, MicroVAX III	control moment gyros, gas jets, proof mass actuators, rate gyros, accelerometers	specific control-structures studies
Control Technology Verification Facility (CTVF) - JPL [Dan Eldred]	40 ft diameter, 26 ft tall space, houses 19 ft diameter rigid hub structure with 12 equally spaced ribs projecting out.	DEC VAX II/ STD bus based with 8088 microprocessor	force actuators, position sensors, optical sensor, RVDT angular sensor	facility for control studies, system ID

POST 1982 FACILITIES (CONC)

EXPERIMENT	DESCRIPTION	COMPUTER SYSTEM	ACTUATORS/SENSORS	TEST OBJECTIVE
MIT Apparatus for Structural Testing & Research on On-orbit Vibration & Control [Ed Crawley]	10 ft diameter vacuum chamber (10**-6 to 10**-8 torr.), 14 ft in height	IBM PC, Microvax, Lecroy and custom built A/D, D/A	strain gauges	free fall tests in a vacuum
JPL Testbed facility [Jim Fanson]	Lab is 1966 sq ft and 20 ft ceiling	PDP 11/73	shakers, piezoelectric actuators, accelerometers, laser	active structure control, system ID, CSI support
Modified Astromast	5 ft fiberglass model of Astromast, vertical, cantileverd at bottom			
Precision Truss	6 ft, 6 bay truss, vertical, cantilevered at base			
Free-Free Truss	13 bay truss, horizontal, cantilevered or suspended in center			
Large Component Test Lab - Langley [Jer-Nan Juang]	80 ft x 80 ft X 80 ft building, currently houses Space Station Truss model	CAMAC - Cyber 175		facility for CSI tests, Space Station modelling

JPL TEST BED FACILITY

The JPL Test bed facility was built primarily for testing active control structures, though system identification work can also be done. Currently, this facility supports the CSI program.

There are three test articles in this facility, they are:

Modified Astromast - This structure is a 5 foot, 3 longeron, fiberglass segment of the Astromast. Its base is designed such that the supporting system is statically determinate. The structural elements can be easily replaced, either by active structural members or sensors. Also, the top has a steel plate on which masses can be added or removed as desired.

Precision Truss - This test article is a 6 foot, 6 bay, 4 longeron truss with special joints which allow for the changing of structural elements and masses. Thus, the dynamic properties of the test truss can be varied for study. The lowest frequency is approximately 8 Hz and lowest damping ratio value is .04%.

Free - Free Truss - This test structure is like the precision truss in that the structural members and masses are changeable. The 13 ft. free - free truss consists of 13 bays and 3 longerons and can be either cantilevered or suspended (free-free) at the center of the truss.

There are various excitors (2 - 150 lbs) and accelerometers available, as well as a laser interferometer system and piezoelectric actuators (50 lb) as active structural components.

The most important aspect of these test articles is the fact that their structural members are changeable, lending themselves to control systems/structures effects studies.

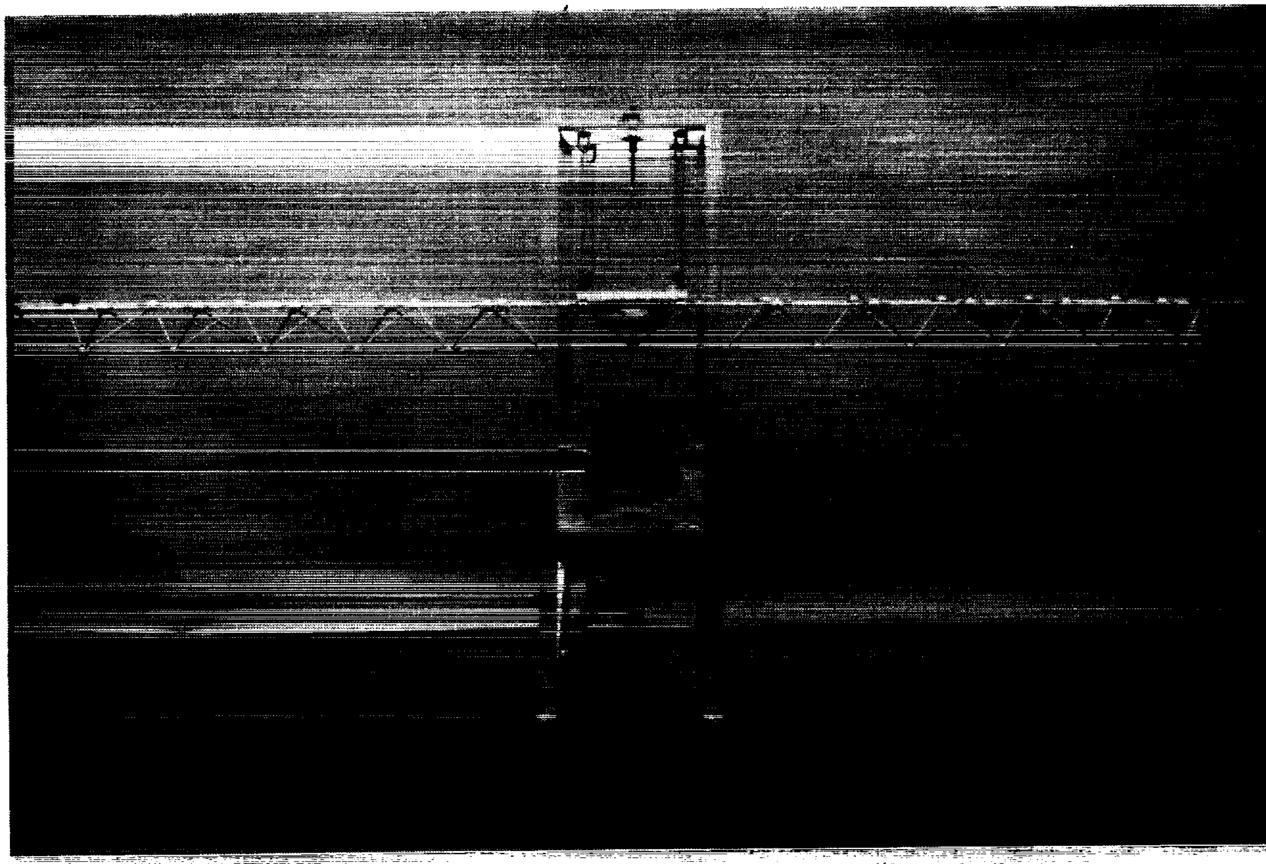
- **ACTIVE STRUCTURAL MEMBERS TESTING, IN SUPPORT OF CSI PROGRAM**

- **THREE TEST ARTICLES IN USE :**

  MODIFIED ASTROMAST
  PRECISION TRUSS
  FREE - FREE TRUSS

- **STRUCTURAL MEMBERS ARE CHANGEABLE ON THE THREE TEST ARTICLES**

PHOTOGRAPH OF JPL FREE-FREE TRUSS



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NEED FOR NEW FACILITIES

The pre 1982 experimemts were mostly simple structures, being either beams or plates. The testing performed on those were vibration suppression and/or small angle slewing. The post 1982 experiments, though using larger, more complex structures, still are chiefly vibration suppression and small angle slewing tests.

With newer, more advanced facilities, we can address the space structure design challenges brought out earlier in the paper. Larger facilities are required because the test articles will be larger (by using larger structures, up to full size, the problems with dynamic scaling can be reduced). Also, room must be available to perform large angle slewing motion tests, both for any pointing substructures and of the structure itself.

These facilities must have the state of the art in computer and data acquisition systems, and other support equipment to properly test the new control/structure optimized configurations and their advanced systems. More sophistication in control algorithms and system identification techniques will need better computing power to be fully exploited for CSI.

- **PRE-1982 EXPERIMENTS:**

  MAINLY SIMPLE TEST ARTICLES
  VIBRATION SUPPRESSION/SMALL ANGLE SLEWING

- **POST 1982 EXPERIMENTS:**

  MORE COMPLEX, LARGER STRUCTURES
  STILL CHIEFLY VIBRATION SUPPRESSION & SMALL ANGLE SLEW TESTING

- **MORE ADVANCED TESTING IN LARGER, BETTER EQUIPPED FACILITIES IS NEEDED**

FUTURE EXPERIMENTAL FACILITIES

Several facilities are being expanded to improve their capabilities for LSS ground testing. The MSFC's LSS-GTF, AFAL's ASTREX and JPL's Test bed facilities each have their respective plans for adding new equipment in support of CSI.

As NASA's lead in CSI, Langley will also expand their CSI LCTL facility. We are currently in the process of purchasing advanced computer and data acquisition systems, instrumentation and support hardware and expanding and modifying the LCTL area for the CSI evolutionary test model. We will continue to share this laboratory with the Space Station people.

Another LaRC facility, the Large Spacecraft Laboratory (LSL), has been proposed. If constructed, it will house full scale spacecraft models for testing in a controlled environment. The building will be 310 feet in diameter and 150 feet tall at its apex. However, unlike the LCTL, which will be fully operational in the very near future, the LSL is still in the proposal stage at this point.

SEVERAL FACILITIES HAVE EXPANSION PLANS FOR THEIR GROUND TEST PROGRAMS:

LSS - GTF

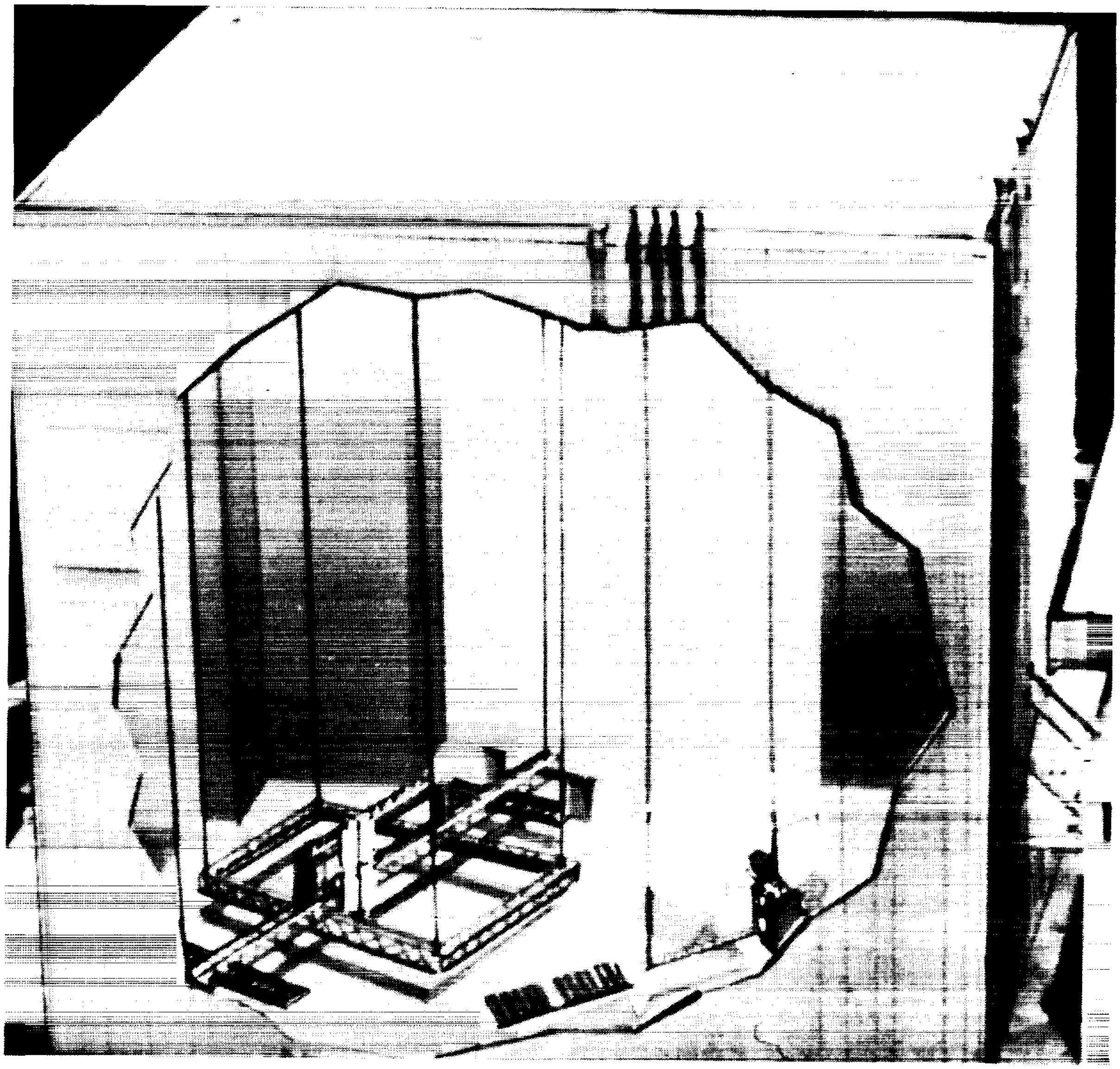
ASTREX

JPL

LaRC LARGE COMPONENT TEST LAB

LaRC LARGE SPACECRAFT LAB

ARTIST'S CONCEPTION OF LANGLEY'S LARGE COMPONENT TEST LABORATORY



INITIAL CSI GROUND TEST PLAN

The ground test team is responsible for all experimental test work to be conducted under Langley's CSI Program. The team's initial plans are as follows:

(1) Support of the Mini-Mast Guest Investigators Program. The Mini-Mast test article is situated in our laboratory area and we will be providing the computer and data acquisition systems, hardware and technical support to the visiting investigators to allow them to perform their respective experiments. In addition, the ground test team will also be conducting their own tests on the Mini-Mast.

(2) Work on the CSI Evolutionary Test Model. This model is called 'evolutionary' because it is being built specifically for CSI experimental testing. In its initial phase, it will be a simplified version of a Mission to Earth spacecraft. It will consist of a 55 ft truss and will be comprised of 10 inch bays, with a 12-16 ft offset antenna frame at one end. The test work on this structure will be performed in two steps:

   (a) Modal Testing - System identification, including static and dynamic testing of the structure and its subcomponents.

   (b) Control Testing - Initial plans call for vibration suppression, suspension system studies (a permanent suspension system has not been decided upon) and small angle slewing testing, in that order. We will then proceed to a more complex verison of this test article and perform antenna pointing and large angle slewing control studies.

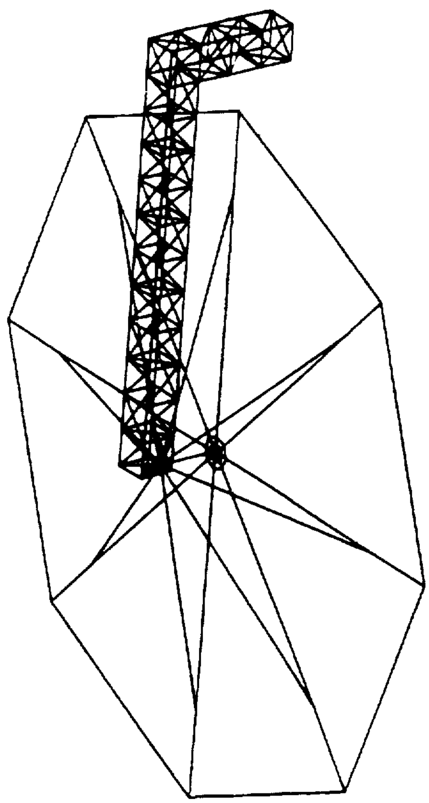
- SUPPORT MINI-MAST GI PROGRAM

- BEGIN WORK ON CSI TEST MODEL, TO BE PERFORMED IN TWO PARTS:

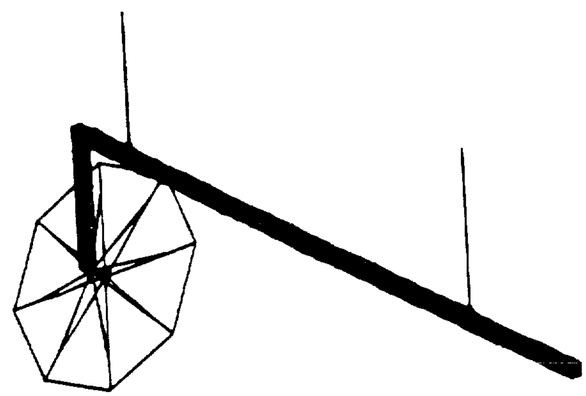
MODAL TESTING - SYSTEM ID

CONTROL TESTING - VIBRATION SUPPRESSION
SUSPENSION STUDIES
SMALL ANGLE SLEWING

GENERIC GEO SPACECRAFT
INITIAL TEST MODEL



TRUSS LENGTH 55 FT
ANTENNA DIAMETER 12-16 FT



SUMMARY

A brief survey of large space structure control related experiments and facilities has been presented. This survey covered experiments performed before and up to 1982, and those of the present period (1982 -...). Finally, the future planned experiments and facilities in support of the CSI Program were reported.

It has been stated that new, improved ground test facilities are needed to verify the new CSI design techniques that will allow future space structures to perform planned NASA missions.

PRE & POST 1982 EXPERIMENTS AND FACILITIES SURVEY INDICATES THAT:

TESTING MAINLY ON VIBRATION SUPPRESSION & SMALL ANGLE SLEWING

IMPROVED GROUND TEST EXPERIMENTS & FACILITIES NEEDED TO SUPPORT FUTURE NASA SPACE SYSTEMS

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