RESULTS OF THE ADVANCED SPACE STRUCTURES TECHNOLOGY RESEARCH EXPERIMENTS (ASTREX) HARDWARE AND CONTROL DEVELOPMENT

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INTRODUCTION

Future DOD, NASA, and SDI space systems will be larger than any spacecraft flown before. The economics of placing these Precision Space Systems (PSS) into orbit dictates that they be as low in mass as possible. This stringent weight reduction creates structural flexibility causing severe technical problems when combined with the precise shape and pointing requirements associated with many future PSS missions. Development of new Control Structure Interaction (CSI) technologies which can solve these problems and enable future space missions is being conducted at the Phillips Laboratory, On-Location Site, CA.

RESULTS OF ASTREX HARDWARE AND CONTROL DEVELOPMENT

The Phillips Laboratory, On-Location Site, Edwards AFB, CA, has developed the Advanced Space Structures Technology Research Facility (ASTREX) to serve as a test bed, shown in Figure 1, for demonstrating and integrating technological solutions to the challenges of spacecraft structural control. Unique features of the facility include a large-angle slew capability, a realistic, 11,000 lb dynamically scaled structural model of a 3-mirror Space-Based Laser (SBL) beam expander (see Figure 2), and a powerful, adaptable computer for real-time control and system identification. Currently there are a total of eleven on-going and scheduled projects which will demonstrate various technologies and techniques for CSI. The planned efforts involve representatives from industry, academia, NASA, and DOD.

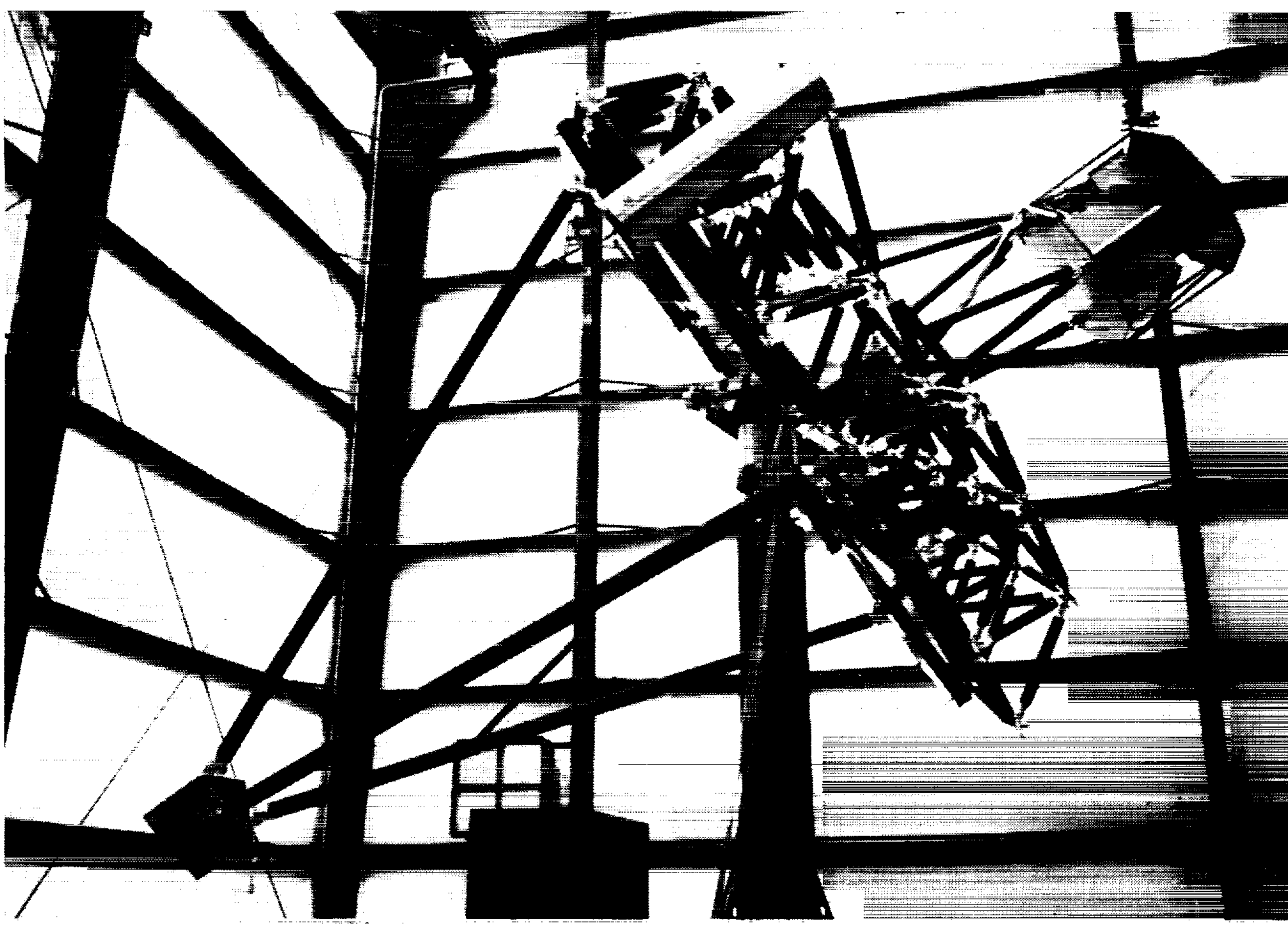

Figure 1. ASTREX Facility.

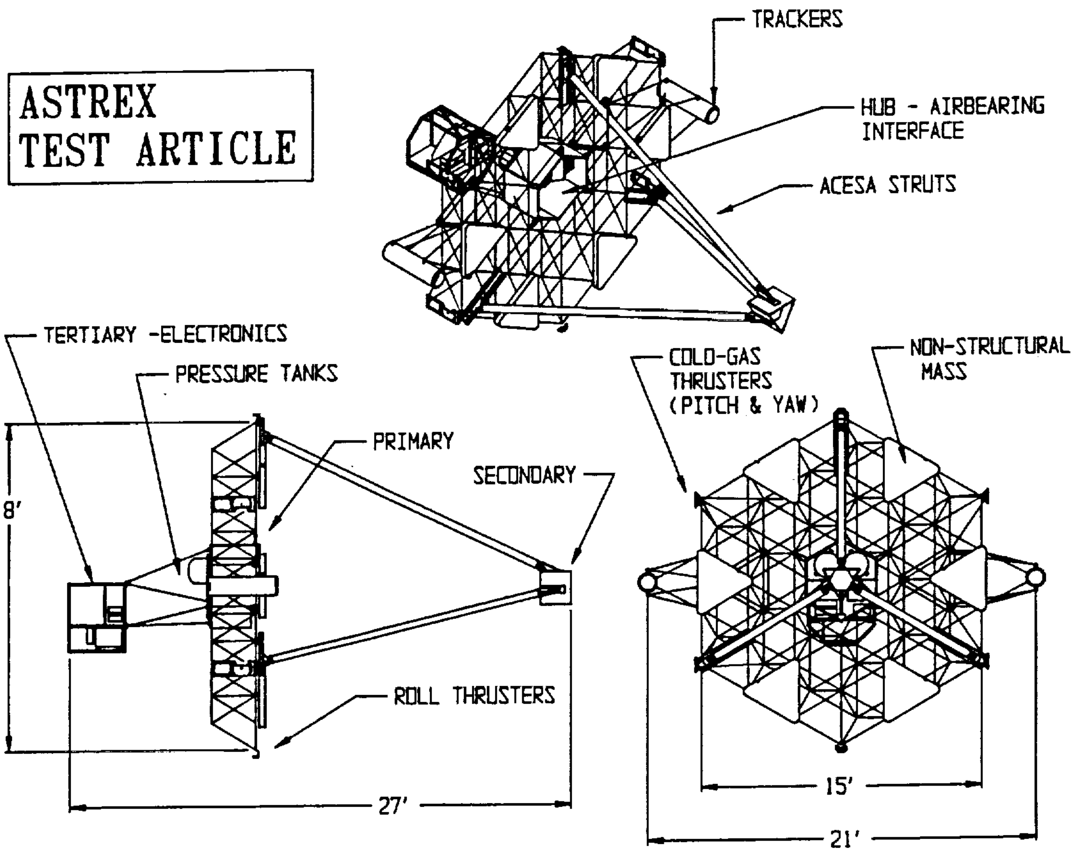

Figure 2. ASTREX Test Article.

In June 1991, engineers from Boeing Aerospace & Electronics installed and tested the 8 lb vernier thrusters on the ASTREX test article. Initial testing was limited to the compressor capability of only 200 psi. With the installation of a compressor with 500 psi ability and the eight 200 lbf thrusters in Dec 91, the reaction control system was finally assembled on the test article. Verification of thruster operation was completed in the second week of Feb 92 after hydrostatic testing of the flexible hoses and additional safety precautions were performed. The thrusters are available for use in research conducted by guest investigators. Currently, plans are being formalized to utilize the thrusters for in-house experiments in the Spring of 92. Additional testing of the thrusters was delayed to accommodate the installation of the Advanced Composite Embedded Sensors and Actuator (ACESA) struts developed by TRW.

The ACESA effort developed and produced three 17 ft struts which replaced the three non-active struts supporting the secondary mirror. These struts will be used to suppress vibrations caused by the tower modes, where most of the modal energy exists, of the Test Article. Installation of the struts was completed on 3 Feb 92. The electronics supporting the ACESA struts are being installed at the writing of this paper. Dr Allen Bronowicki of TRW managed the effort through the five phases of the program. An innovative manufacturing technique proved to be successful in embedding the sensors and actuators into a large graphite-epoxy tube. Dr Bronowicki is scheduled to test the struts for four months beginning in Mar 92. After the initial testing, the ACESA struts will be available for use by other guest investigators.

Additionally, a 2.5 ft-lbf reaction wheel built by Dr Thomas Pollock was installed on the secondary mirror to once again address the tower modes. The reaction wheel orientation is adjustable to accommodate one or two axes of authority. A second function of the reaction wheel allows it to operate as a disturbance source to be controlled by the actuators currently available and the actuators being developed. Dr Pollock is also building a larger reaction wheel with 12.5 ft-lbf torque ability. Plans to install the larger reaction wheel into the primary are being made.

Linear Precision Actuators (LPACT's) are being designed and built to be installed on the secondary mirror. The LPACT's are based on the proof mass actuator concept. However, they have been designed to avoid the non-linear effects associated with most proof mass actuators which use bearings.

The first active member to be delivered was the active strut developed and assembled by SatCon Inc. The strut was developed under the management of Dr Bruce Johnson using the magneto-restrictive material Terfonol-D. Testing has not been performed with this strut due to desires to test with other actuators first. In addition, an active strut using a cylinder piezoelectric stack is being developed by the Jet Propulsion Laboratory of Pasadena. Dr Moktar Salama manages the development and the strut is scheduled to be completed in April 92.

Currently, in-house efforts are addressing several issues involving a line-of-sight (LOS) sensor, modal surveys, model update, slewing control, and vibration suppression. Two line-of sight sensors are being developed. One uses a non-optical solution to determine LOS error by comparing angular rate sensor readings at the secondary mirror to sensor readings at the hub located in center of the primary mirror. This solution was chosen as the best candidate to measure LOS jitter of less than 1 micro-radian. The second solution uses a laser with a quad-cell detector. At this time the parts for this system are being acquired and measurement performance has not been determined.

The model update and modal survey effort is currently being worked by Dr Nandu Abhyankar. The possibility of bringing a third party to update the model is being heavily considered. All the work in this area is scheduled for completion by Jun 92. In-house goals also include the demonstration of slewing profiles and vibration suppression of the test article. This work accomplished by the in-house efforts will improve the work done by guest investigators at the facility.

Currently, three guest investigators, who will perform work at the ASTREX Facility, are participating in the NASA/DOD CSI Guest Investigator Program. Boeing Aerospace and Electronics is providing four control moment gyroscopes, CMG's, for one year. The CMG's will be installed on the primary mirror where slewing profiles with the CMG's will be demonstrated. The CMG's weigh 280 lbs and deliver from 200-800 ft-lbs of torque usable in slewing control. The project is being managed by Mr Dean Jacot. Texas A&M work will demonstrate control laws for near-minimum time slew maneuvers and vibration suppression. Using the thrusters and other available actuators, slewing profiles will be developed to minimize the disturbances caused during a slewing maneuver. Dr. Rao Vadali is managing this effort. MIT will be developing optimum passive damping using piezoelectric material. The basic idea is the dissipation of electrical energy created by the piezoelectric material through an RCL circuit. Dr. Andreas von Flotow is managing this effort. All of these efforts were started in Fall 91 and the efforts are scheduled for eighteen to twenty-four months.

The overall effort has been in the facility and hardware development stages for the past three years. With the scheduled research involving guest investigators and in-house personnel, the ASTREX Facility will demonstrate over eleven key technologies and ideas for spacecraft structural control. Future ideas for testing at the ASTREX Facility are only limited by the creativity of researchers involved in addressing the CSI issue.

Bibliography

1. Das, Alok; Berg, Joel L.; et al: *ASTREX- A Unique Test Bed for CSI Research,* 29th IEEE Conference on Decision and Control, Dec 5-7, 1990.