TN-3

Testing the Gemini 8M Telescopes Using PCB® Accelerometers

Testing the Gemini 8m Telescopes using PCB Accelerometers

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University of Massachusetts Lowell

Overview

The design and analysis of large telescope structures pose many serious challenges. In general, the structures are often "assumed" to be rigid when considering the system control design. As these structures become larger and larger, it becomes a serious challenge to provide substantial stiffness for the supporting structures. Consequently, the structure is not rigid and control issues often do not address this fact. In addition, the wind, which is the main excitation source for the system, is difficult to accurately identify.

Clearly, the structure is an important consideration in the overall performance of a telescope. As larger and larger structures are considered, the effects of the wind on the structure and the inclusion of the structure flexibility may become much more important in the design specification of these large structures. With tighter performance specifications being specified for future designs and uncertainty in the environmental load characterization, the problem facing the designers is simple "Can we build a large structure that is insensitive to the environmental wind loadings to meet the design performance specifications?"

Photo courtesy of the Gemini Observatory webpage at www.gemini.edu

Problem

There are many environmental parameters which affect performance with wind being the dominant effect. Unfortunately, the dynamic effect of the wind is difficult to model accurately because of both limited knowledge of the actual wind power spectrum and the complex interaction of the wind with the structure. The effects of the wind on the pointing and surface error need to be more accurately defined and identified. The nature of the wind in terms of its correlation across the structure must also be determined. In addition, the specific wind loading profile, the frequency content of the wind and whether the modes of the structure are significantly activated are of concern. In order to further understand these effects, system performance must be evaluated using experimental approaches.

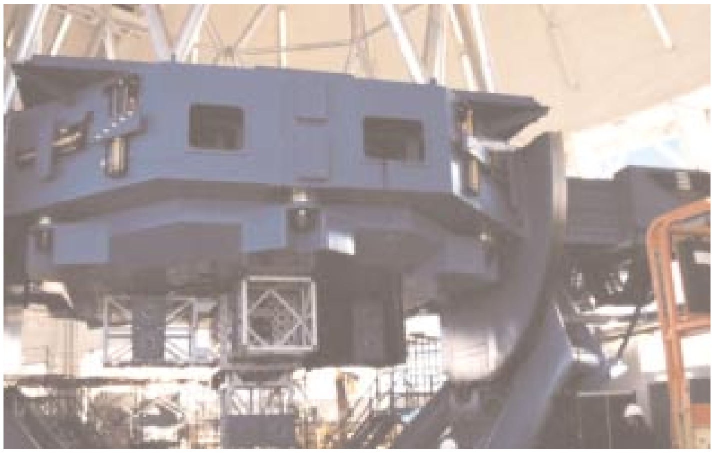
Structure Test Configuration

The Test

In order to better understand some of these effects, several tests were conducted on the Gemini North and South Optical Telescopes located in Mauna Kea, Hawaii and Cerro Pachon, Chile. This particular telescope is ideal for the study of the effects of wind loading. This large structure is housed in an enclosure which allows wind loading conditions that vary from nearly fully protected to nearly fully exposed to the environment. In addition, Cerro Pachon is at a stage in construction where the telescope could be operated under full control but no expensive mirror has been installed as yet.

The telescope at Mauna Kea was used for investigative purposes to determine if response levels were adequate to conduct a large scale test. The University of Massachusetts Lowell's Modal Analysis and Controls Laboratory (MACL) performed several exploratory tests on this large structure.

Since this telescope was operational, access to structural regions above the mirror surface was strictly prohibited.



Main Weldment

Therefore, measurements were only possible in the main weldment supporting the main mirror assembly.

Very highly sensitive PCB ICP® accelerometers (1 V/g and 10 V/g) were placed at critical response points on the interior of the weldment. These response locations were chosen adjacent to the mirror actuator support locations. A typical accelerometer mounting location is shown in the photo below. A small portable 8 channel data acquisition system was utilized for all the data acquisition. Data was acquired during operation to take into account normal environmental conditions as well as some of the operational maneuvers typically experienced during telescope operations.

In addition to running ambient wind loading measurements, several exploratory impact tests were made on the secondary

PCB Series 393 Accelerometer
Typical Mounting Location Inside Main Weldment

structure of the telescope. These tests were performed to determine whether it was feasible to utilized impact testing with the PCB small sledge hammer and still obtain reasonably good frequency response measurements. Rather than using a tremendously large impact device at the massive base of the structure, it is more desirable to utilize a reasonably size impact device at the extremity of the structure where it takes very little force to activate the modes of this large structure. (see photo)

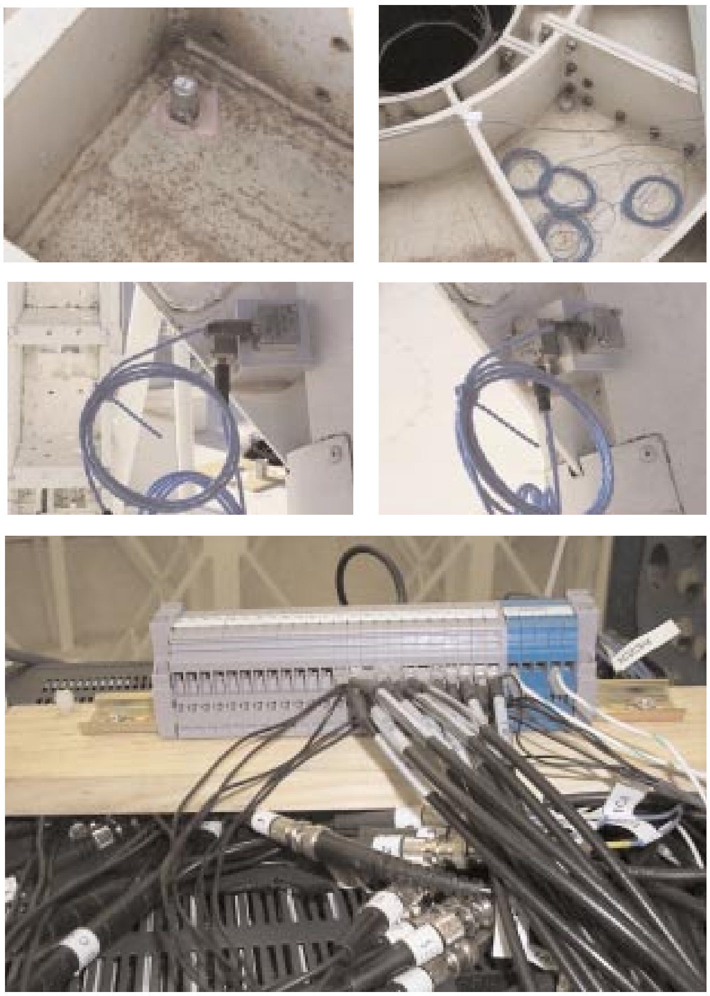
Letting out his frustration using a PCB Series 086 Sledge Hammer

Based on the preliminary measurements made at Mauna Kea, it seemed feasible to attempt a large scale test of the companion telescope under construction in Cerro Pachon.

Following these preliminary investigative tests, vibration test data was collected at the Gemini South 8m Optical Telescope in Cerro Pachon, Chile. The University of Massachusetts Lowell's Modal Analysis and Controls Laboratory (MACL) along with Michigan Technological University's Keweenaw Research Center (KRC) undertook the task of measuring the response of this large structure.

Of course, testing a structure of this size is no simple task and instrumentation to measure extremely low levels (<50 micro-g)

Structure Test Configuration



Typical Instrumentation Configuration

was necessary. This 8m telescope was instrumented with 75 channels of highly sensitive PCB ICP® accelerometers (1 V/g and 10 V/g) in order to record structural response. In addition, 24 pressure probes were mounted in the surface of a “dummy” mirror that was put in place for this series of tests. This allowed for the simultaneous measurement of both structural response and wind loading effects in one complete data set. The “dummy” mirror is shown in the photo to the left.

The instrumentation and related signal conditioning (along with close to a mile of cable) was strung out on the structure. PCB Piezotronics and The Modal Shop provided instrumentation to assist in the measurements on the structure. In addition to instrumentation, the 90 channel measuring system from KRC was supplemented with additional channels of Scalar Roadrunner data acquisition from LMS to support the simultaneous collection of all the required data. All data was collected using the LMS data acquisition software to acquire data and directly write to the computer hard drive; all spectrum processing was to be performed following the data collection phase.

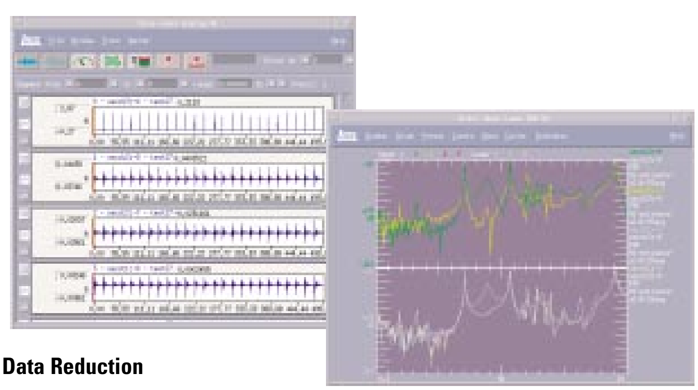
Over 50 individual operating tests were performed with the telescope in a variety of different configurations with respect to the wind to represent the multitude of geometric configurations possible. Structural responses and pressure responses in the mirror assembly were recorded along with wind-speed and direction. In addition to operating data, 4 separate impact tests were conducted to acquire calibrated frequency response measurements for use in the modal description of the telescope. In all tests, time data was captured and stored to the computer hard drive for further processing after the completion of all testing performed.

Data Processing and Post Test

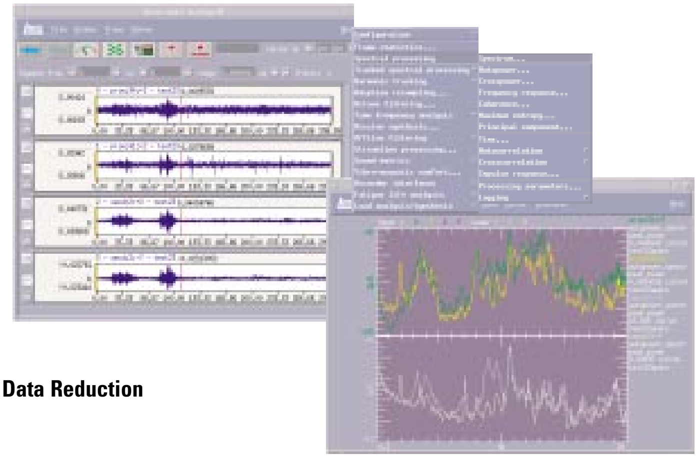
The data collection phase has been completed. Now the task of evaluating all the data collected has begun. Preliminary assessment of the impact data and operating data clearly show similarities in the deformation and mode shapes of the system.

The impact data sets have been evaluated in a preliminary sense to determine the characteristic shapes of the telescope. More detailed evaluations will be performed on this data but the preliminary findings are sufficient to clearly show some of the characteristic shapes of the telescope. Some typical data processing is shown below.

There are numerous telescope conditions under which the telescope operating data was collected. There is a significant amount of work yet to be performed on this very large data set but some preliminary assessments clearly show the operating



Data Reduction



Data Reduction

deformations of the system. Some typical data processing is shown above.

Both modal data and operating data will be further evaluated to determine the characteristics of the telescope configuration. In addition, work will be done to determine the acceptability of the finite element model currently used for the assessment of the structure. Also, spectral processing will be performed using the operating data and the frequency response functions from the modal test to determine the wind spectral forcing function based on the responses measured at the site. This work will continue for some time to come since an enormous volume of data was collected during the operating tests.

Post Test

Following completion of the test and preliminary data evaluation, the data has already revealed similarities in the modal and operating data acquired. Additional evaluations will continued to further scrutinize the data.

Further studies of this data will provide needed insight into the environmental effects on the performance of these very large structures.

Clearly, the data collected contains a wealth of information that is beneficial to the Gemini telescopes. However, the data will also be important in the design of next generation large aperture telescopes.

Acknowledgements

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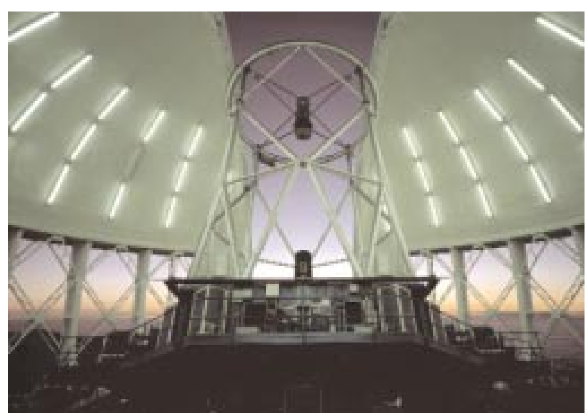

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