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The instrumentation purchased under this DURIP was in support of an ongoing effort to understand the dynamics of inflated satellite components and then to provide both shape and vibration control based on the discovered dynamics. Inflatable space-based devices have become popular over the past decade due to their minimal launch-mass and launch-volume. Once inflated, these space structures are subject to vibrations induced mechanically by guidance systems and space debris, as well as thermally-induced vibrations from variable amounts of direct sunlight during orbit around the Earth. Understanding the dynamics of inflated components and controlling the shape and vibrations of spaced-based structures is critical to ensuring optimal performance.

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Dynamics and Control of Inflated Satellite Components

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Abstract

The instrumentation purchased under this DURIP was in support of an ongoing effort to understand the dynamics of inflated satellite components and then to provide both shape and vibration control based on the discovered dynamics. Inflatable space-based devices have become popular over the past decade due to their minimal launch-mass and launch-volume. Once inflated, these space structures are subject to vibrations induced mechanically by guidance systems and space debris, as well as thermally-induced vibrations from variable amounts of direct sunlight during orbit around the Earth. Understanding the dynamics of inflated components and controlling the shape and vibrations of spaced-based structures is critical to ensuring optimal performance.

2. Summary of Contributions

Our objective for this DURIP award and the host grant (F49620-99-1-0231) addresses the mechanics models needed, and the suppression techniques offered by smart materials as applied to optical systems mounted on satellites. The objectives of this research effort are to provide instrumentation to address the dynamics and control of flexible optical systems for both vibration suppression and vibration using smart materials as the actuation component and sensing component. The specific objective was to test a generic torus system, using multiple sensing and control elements. These objectives were met, as summarized here.

The results of this DURIP grant can be summarized as follows:

- Performed MIMO Ground Testing of an Inflated Torus
- Comparison of Inflated Torus Models and Tests
- Performed MIMO Control Tests

All of the results developed here center around a thin membrane material (Kapton) formed into an inflated torus. A torus forms one of the basic elements of the perceived inflated satellite reflector system. The research results have focused on generic results applied to the specific case of an inflated torus. The inflated torus was chosen because it is a basic element being considered by AFRL.

Instrumentation was requested to perform multi-input-multi-output (MIMO) measurement and control of inflated components using smart materials. The system purchased consists primarily of an Agilent VXI 16-channel digital signal analysis system and a 28- channel dSpace controller unit, plus the computers required to run these combined systems. This gave us the capability to perform dynamics and control experiments using smart materials as sensing and actuation components, to combine our results in a digital environment and manipulate them in the computer code environment used to develop our analytical predictions.

Results:

The new equipment (data acquisition and control) was used to verify the analysis results obtained in the first two years of the host grant. Most of these details can be found in the Masters Degree Thesis of Mr. Eric Ruggiero, which is available electronically at:

http://scholar.lib.vt.edu/theses/available/etd-05072002-180854/

In addition, the experimental verifications allowed by the DURIP award are contained in the publications listed in the following section. The main results are that the ultra flexibility of large inflated satellites requires multiple inputs and multiple outputs (MIMO) in order to measure the broad range of frequencies excited in a simple torus. In addition, it is well known in control theory that MIMO systems give better overall performance than do single-input systems. For the ultra-flexible systems of interest here, this result is even more significant, and the dSpace controller hardware purchased under this DURIP allowed us to investigate the magnitude of the increase in performance.

This equipment was also used in our DARPA-sponsored program, "Distributed Modeling and Control of Adaptive Wings," (AFOSR Award F49620-99-1-0294), where MIMO control was again key in understanding the concepts of morphing wings and providing the ability to perform wind tunnel testing on prototype wing designs.

List of Equipment Purchased:

dSpace 28-channel controller	$28,260.00
Dell Computers (2)	$5,563.36
Agilent VXI 16-channel analyzer	$28057.50
Dell Computer Pentium 4, 1.7 giga	$1,037.39
m+p international software	$4,125.00
PCB Piezotronics	$1,693.00
National Instruments	$4,522.50
DELL 8200 Computer	$2,290.46
Stat-Ease software	$196.79
Total Spent	$75,746.00

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Park, G., Sausse, M., Inman, D.J., Main, J.A., 2001. "Vibration Testing and Finite Element Analysis of an Inflatable Structure," *AIAA Journal*, to appear

Park, G., Ruggiero, E. and Inman, D. J., "Dynamic Testing of an Inflated Structure using Smart Materials," *Smart Materials and Structures*, 2002, Vol. 11, pp 147-155.

Ruggiero. E., Park, G, Inman, D. J. and Wright, J., "Multi-Input, Multi-Output Modal Testing Techniques for a Gossamer Structure," ASME IMECE Adaptive Structures Symposium, November, 2002.

Inman, D. J., "Historical Perspective for Gossamer Structures: Lessons Learned from the Large Flexible Space Structure Era," AFRL/DARPA Workshop on Ultra-Large Space Antenna Structures, May 21-22, 2002, Santa Fe, New Mexico.

Inman, D. J., "Applications of Smart Materials in Structures," Tutorial, National Space and Missiles Materials Symposium, June 24-28, 2002, Colorado Springs, CO.