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13. ABSTRACT (Maximum 200 Words) This award was to procure a high-bandwidth adaptive-optic system. A system capable of operating at 20 kHz was contracted to be constructed by Boeing SVS, Albuquerque NM using hardware primarily furnished by Xinetics. The components and operational concept for the adaptive-optic system is described in this report.				
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# **HIGH-BANDWIDTH ADAPTIVE-OPTIC SYSTEM**

## **FINAL PERFORMANCE REPORT**

**Award Number F49620-01-0323**

5 June 2002

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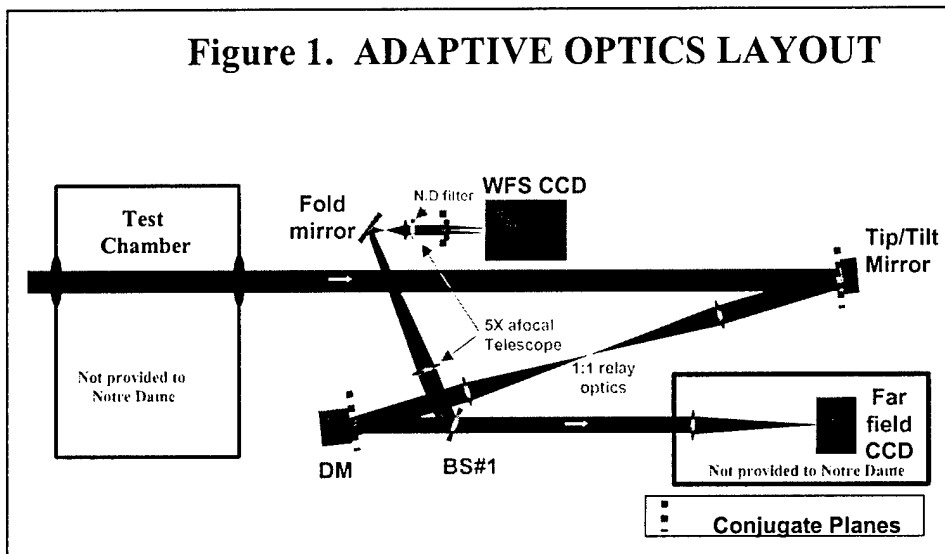
## Introduction

The purpose of this award was to procure a fully-operational, unique adaptive-optics system based on a new and innovative design. By constructing an adaptive-optics system according to this design, the system will operate at up to 20 kHz. To our knowledge, this system will be the fastest adaptive-optics system in the world, operating at approximately an order of magnitude higher bandwidth than any other system. The procurement of this system for \$200,000 was only possible because its construction, which includes the development of the enabling control-system software, is being done at special costs by the two major companies involved in its development, Boeing and Xinetics.

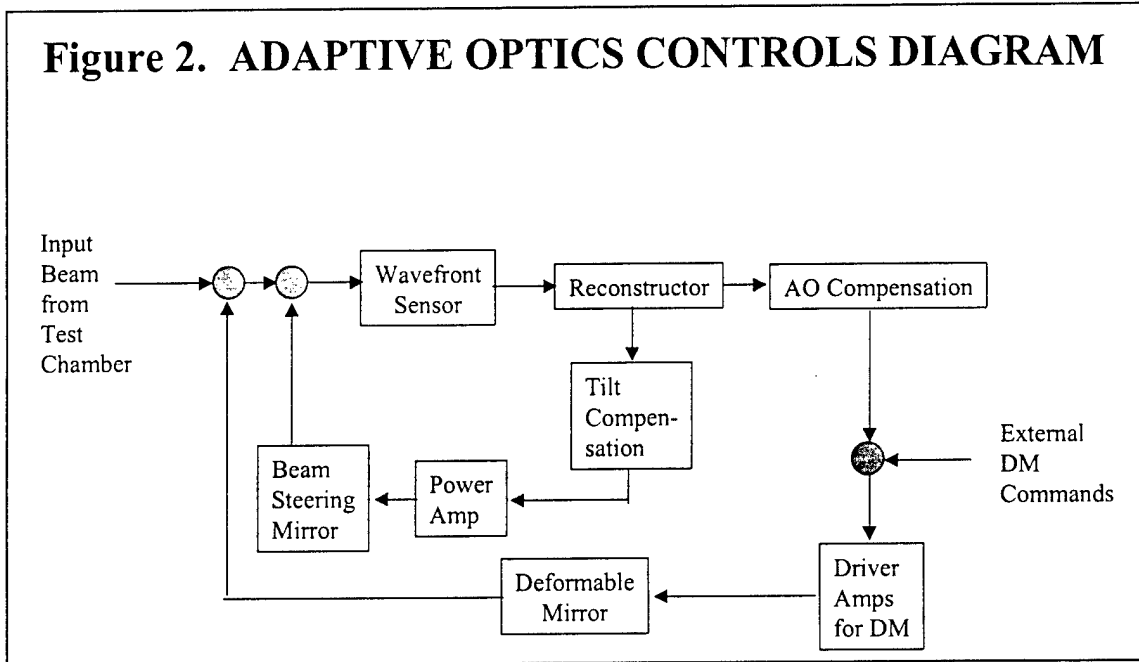
The existence of adaptive-optics systems with this high of a bandwidth will make possible wavefront corrections for optical viewing and laser projection through free shear layers associated with aircraft in transonic-Mach-number flight. Without the ability to correct for these aberrations, an airborne high-energy laser system's lethality has been shown in the associated research program to be reduced by more than 99%.

## Procured System

The High-Bandwidth Adaptive-Optics System, including hardware and software, were purchased from SVS Boeing, of Albuquerque, New Mexico. The majority of the hardware was furnished to Boeing by Xinetics. The System consists of many optical and computer subsystems, which are best described by referencing Figure 1. Figure 1 not only shows the subsystems, but also shows how these components are linked together to make up the System.



Referring to Figure 1, the system consists of an optical bench on which is mounted various optical components that include beam splitting mirrors (BS), folding mirrors, telescopes, neutral density filters, fast steering mirrors, a wavefront sensor, a 37 subaperture deformable mirror (DM) and associated electronics, a far-field camera, a laser and a dedicated computer for running the control software. The control software performs the control functions indicated in Figure 2.



**Major Subsystems to the High-Bandwidth Adaptive-Optics System:**

1. Deformable mirror. The deformable mirror for the system incorporates 37 actuator arranged in a circular pattern. The diameter of each actuator is 4 mm, 7 mm between centers, and each actuator is capable of more than 3 microns (peak-to-peak) of motion.
2. Wavefront sensor. There are two wavefront sensors used in the system; however, the fastest of these was developed at Notre Dame. The procured software/control system incorporates the Notre Dame sensor into the System. The slower, closed loop wavefront sensor has a 64 x 64 lenslet array, mounted on a CCD array camera. The output frame rate of the camera is greater than 950 Hz.
3. Reconstructor. The wavefront reconstructor for the slower closed-loop portion of the System is a simple least-squares reconstructor and supports 60 Hz bandwidth for the slower subsystem (or outer loop). The reconstructor projects out the modes needed to insure system stability. This reconstructor is also coupled through tilt output signals, x and y, to the beam steering mirror amplifier.

4. Drive electronics for deformable mirror. The drive electronics output analog commands to the input channel of the deformable mirror external from the control loop. The maximum rate of these external signals, which must be processed by the drive electronics, is 20 kHz. The drive electronics is powered by 110 volt, 20 amp supply.
5. Beam Steering mirror. A 2 axis beam steering mirror is included in the system and uses the tilt commands generated in the reconstructor. The bandwidth of the beam steering mirror is 500 Hz, open loop.
6. Beacon source. A sensing laser shall be included in the system. This laser is a HeNe laser, 6328 nanometer wavelength, and 10 mw.
7. Integration and Test of Electro Optical System. Boeing-SVS, Inc will integrate the complete electro-optical system either prior to shipping it to Notre Dame or at Notre Dame. This test shall include performance tests of the optical system, the deformable mirror, the wavefront sensor, the tilt mirror and the controlling software. The control loop diagram is shown in Figure 2. This system testing shall be documented in an Acceptance Test Plan
8. Experiment Integration and Support at Notre Dame. At delivery of the hardware to Notre Dame, Boeing-SVS, Inc will supply engineering support to demonstrate the system operation.

## **Progress**

As of this writing, the system has been procured. The instrument of procurement was signed out of Notre Dame on 2 December 2001. Delivery of the system to Notre Dame is expected in December 2002. Further progress on this system will be reported in the progress and final reports for the associated research project, Fluid-Optic Interactions III (see below)

## **Associated Research Project**

This DURIP procurement is in support of AFOSR research project *Fluid-Optic Interactions III*, F4920-00-1-0025. This research project is specifically directed toward the investigation of the fundamental physics of the various subproblems associated with the projection of high-energy lasers through the flow fields around near-transonic aircraft. An integral part of this research is directed toward the eventual demonstration of removing wavefront aberrations from a large-aperture laser beam incurred while propagating through a free shear layer simulating those that are encountered in flight for an airborne laser platform. This aberration removal and related experiments directed toward this end will use the procured High-Bandwidth Adaptive-Optics System.