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Sincerely,

Edwin W. Eloranta

Enclosure 4

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REPORT DOCUMENTATION PAGE	*Form Approved* *OMB NO. 0704-0188*

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE 29 August 2001	3. REPORT TYPE AND DATES COVERED Final Report - 31 Mar 2000 - 30 Mar 2001

4. TITLE AND SUBTITLE

A Proposal to Upgrade the University Volume Imaging Lidar for Studies of the Atmosphere

5. FUNDING NUMBERS

DAAD19-00-1-0090

6. AUTHOR(S)

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7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(ES)

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8. PERFORMING ORGANIZATION REPORT NUMBER

1A

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

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12 b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This grant purchased components to upgrade the University of Wisconsin Volume Imaging Lidar (VIL). The VIL provides a unique ability to image 4-dimensional atmospheric structure. However, application of the instrument has been constrained by the time interval required to complete a volume scan. Many applications require temporal coherence between structure observed in successive scans. In conditions of high turbulence or when the sizes of the observed aerosol structures are small, turbulent decay often destroyed coherence during the 2-3 minutes required to complete a volume scan. Application of the system has also been constrained by safety considerations. Energy densities in the transmitted beam are sufficient to cause eye injury by exposure to the direct beam. The laser beam could never be allowed to impact the ground surface and a safety observer with a system shut off switch was required to prevent illumination of low flying aircraft. As a result, the system could not be deployed in locations with complex topography or low altitude aircraft operations. This grant has purchased equipment to help overcome these limitations.

14. SUBJECT TERMS

eyesafe lidar, volume imaging lidar

15. NUMBER IF PAGES

6

16. PRICE CODE

17. SECURITY CLASSIFICATION OR REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500

Enclosure 1

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102

Upgrading the University of Wisconsin Volume Imaging Lidar for Studies of the Atmosphere

Final Report

E. W. Eloranta
Principal Investigator

28-August-2001

U.S. Army Research Office
DAAD19-00-1-0090
UW 144-JJ64

University of Wisconsin
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1 Abstract

This grant purchased components to upgrade the University of Wisconsin Volume Imaging Lidar (VIL). The VIL provides a unique ability to image 4-dimensional atmospheric structure. However, application of the instrument has been constrained by the time interval required to complete a volume scan. Many applications require temporal coherence between structure observed in successive scans. In conditions of high turbulence or when the sizes of the observed aerosol structures are small, turbulent decay often destroyed coherence during the 2-3 minutes required to complete a volume scan. Application of the system has also been constrained by safety considerations. Energy densities in the transmitted beam are sufficient to cause eye injury by exposure to the direct beam. The laser beam could never be allowed to impact the ground surface and a safety observer with a system shut off switch was required to prevent illumination of low flying aircraft. As a result, the system could not be deployed in locations with complex topography or low altitude aircraft operations. This grant has purchased equipment to help overcome these limitations.

2 Work completed

2.1 System Design Study

A system design study was undertaken to optimize the proposed lidar configuration. The goal of this study was to allow eye-safe operation while maintaining the sensitivity and improving the scan rate of the current University of Wisconsin Volume Imaging Lidar. Limitations in both laser sources and detectors currently prevent using an eye-safe wavelength to achieve this goal. Thus, we have elected to use the current 1064 nm wavelength in the upgraded system. In order to reduce the energy density in the transmitted laser beam the upgraded lidar will employ the receiving telescope as a beam expander to spread the transmitted beam over a much larger area. As a first task, the optical performance of several lidar configurations were modeled using Zemax optical design software.

This study concluded that adequate performance could be achieved with a high repetition rate laser and 1 m diameter telescope. To achieve eye-safe operation, both the per pulse energy density and the average power density must remain within ANSI safety limits. For a given average power, increasing the laser repetition rate decreases the per pulse energy density. However, the maximum repetition rate is limited by the round trip time required for photons to reach the target and return. At high repetition rates, the safe average power density becomes the limiting factor. When the pulse rate limit is reached, ($\sim$ 4 kHz) the only option is to increase the diameter of the transmitted beam. For observers far from the lidar, this could be accomplished by increasing the beam divergence of the transmitted beam. However, this would still not be eye-safe near the lidar and the larger receiver acceptance angles would introduce excessive scattered sunlight. This would degrade daylight operation. Furthermore, the 14 in by 28 in beam steering mirrors currently employed in the Volume Imaging Lidar are not sufficiently flat to accommodate the small angular acceptance angles needed to block background light in the upgraded system. Given a choice between purchasing expensive new steering mirrors with out improving the light gather power of the telescope and increasing sensitivity with a larger telescope, we have chosen to increase the beam diameter to 1 m and steer the entire telescope rather employ a fixed telescope with large steering mirrors.

Rapidly steering a large mirror could require unacceptable large telescope mountings or induce mechanical distortions of the the primary mirror. A finite element mechanical model was employed to model bending of the telescope mirrors while scanning and to predict design a method of mounting the primary mirror without inducing unacceptable distortions. Torques required to steer the telescope were also modeled. These models showed that light weight mirror blanks substantially decreased the mechanical difficulties of scanning. These design studies led to the selection of the following lidar components.

3 Equipment Purchases

3.1 Laser Transmitter

To enable operation at a higher repetition rate than is possible with the current 100 Hz laser transmitter, we have purchased a Cutting Edge Optronics, Inc. model SS-020-QMIP-0020 Nd:YAG laser. The specifications of this laser operating at 4 kHz are:

Item	Value
Wavelength	1064 nm
Ave. Output Power @4kHz	14 W
Beam Quality-M^2	6.8
Pulse width @4kHz	75 ns

The new laser was delivered to our laboratory in August of 2001.

3.2 Data Acquisition Computer

To accommodate the higher repetition rate of the new laser we purchased a new data acquisition computer. To increase the utilization of the computer it was specified with sufficient memory to execute Large Eddy Simulations (LES) in addition to it's primary data acquisition task. We selected a Dell Server model 4400 with dual, 1 GHz processors , 4 GB of memory, 150 GB of disk storage and a DLT tape to archive results. This computer has already been employed extensively in data reduction and LES modeling for a University of Wisconsin PhD thesis submitted by Shane Mayor (August 2001).

3.3 A/D Converter Purchase

The VME-bus based A/D converter currently used in the Volume Imaging Lidar will not be able to accommodate the data transfer rate required for the new system. A dual-channel

12-bit A/D converter (Computer Boards model PCI-DAS4020/12) was purchased. This will be installed in PCI bus of the above data acquisition computer.

3.4 Telescope Mirror

In order to decrease the transmitted energy density while maintaining the lidar sensitivity we elected to transmit the laser through the receiving telescope and to increase the telescope diameter from 0.5 m to 1 m. A Dall-Kirkham Cassegrain telescope with a 1 m diameter, F2 primary and a 36 cm diameter secondary was specified. This produces a compact telescope with a total length of 1.6 m. Because the entire telescope will be steered, the weight of the telescope mirrors must be minimized. Thus, the mirror substrates are of a honeycomb design. The telescope mirrors are long lead time items–they are scheduled for delivery in December of 2001.

Dr. Edwin W. Eloranta, the Principal Investigator, is the only person who was supported on this grant.

Item	Application	Cost
1 m diameter, light weight telescope optics	Transceiver Telescope Mirrors	$96,510
4 kHz repetition rate 25 watt Nd-YAG laser	Laser Transmitter	$36,510
1 GHz, Dual Processor, computer	Data Acquisition Computer	$17,344
20 MHz A/D Converter	Data conversion	$1,186