Compact Aircraft Lidar for Aerosol Atmospheric Profiling

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1. Introduction
A compact aircraft lidar was built in the Science Directorate at NASA Langley Research Center for the purpose of aerosol and cloud atmospheric profiling. Aerosols are stable suspensions of solid or liquid particles in air ranging in size from 1 nanometer to 10 microns. It is important to study the size, origin, and height of aerosols in the atmosphere because they can affect weather, climate, and the health of humans that breathe in the small particles. To this end, ground based, airborne, and spaceborne lidar systems have been developed to study the effects of aerosols. For aircraft deployment, it is important to reduce the mass and size of the lidar system as much as possible. With this in mind, a compact, efficient aircraft lidar system was developed which uses a Nd:YAG pulsed laser, a fiber coupled telescope, and a three-channel receiver. The goal is to use this aircraft lidar system to make aerosol profile measurements in the Norfolk-Virginia Beach area and in the California Central Valley. The lidar system has also been used to make ground based measurements from NASA Langley Research Center. What follows is a description of the aircraft lidar system along with examples of atmospheric profiles recorded using the lidar system.

2. Lidar System Description
The lidar system is mounted on an aluminum frame of dimensions 108 length x 53 width x 64 cm height as shown in Figure 1. The frame sits on seat-track mounts designed to adapt the system into a Lear Jet aircraft. An aluminum breadboard sits atop four vibration isolation mounts, which are mounted on top of the frame. The breadboard allows the lidar to be pointed in the zenith direction for ground based measurements or in the nadir direction for aircraft based measurements. The laser is a frequency doubled Nd:YAG, 20 Hz, (Big Sky CFR-200) with 1.5 mrad divergence output. The 532-nm and residual 1064-nm pulses are transmitted into the atmosphere using a steerable 45° turning mirror. The laser electronics/heat exchanger package is mounted in the lower bay of the system frame, and the data acquisition computer is mounted just above it. The mass of the system is 114 kg. LCD monitors allow the lidar aerosol profile to be observed in flight as a function of altitude and distance. The power requirements, along with other lidar characteristics, are given in Table 1.

<table>
<thead>
<tr>
<th>Power Requirements</th>
<th>Mass</th>
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<tbody>
<tr>
<td>Computer, 396 W</td>
<td>Telescope, 9.5 kg</td>
</tr>
<tr>
<td>Receiver Supply, 20 W</td>
<td>Laser, 26.2 kg</td>
</tr>
<tr>
<td>Laser Supply, 350 W</td>
<td>Frame, 45.4 kg</td>
</tr>
<tr>
<td>Total = 766 W</td>
<td>Computer, 26.8 kg</td>
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<tr>
<td><strong>Total = 114.3 kg</strong></td>
<td><strong>Volume: 108 x 64 x 53 cm³ = 0.37 m³</strong></td>
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Table 1. Aerosol Lidar Characteristics
The aerosol lidar receiver uses a 30.5-cm diameter (f/2) parabolic telescope with a 1.6 mrad field of view. A 1-mm diameter optical fiber is mounted at the focal point of the telescope. The output from the fiber optic passes into the receiver box, shown schematically in Figure 2 [1]. The received light is collimated and split into 532-nm and 1064-nm channels, with a further split of the 532-nm channel into photon counting (10%) and analog (90%) signal channels. The 1064-nm signal passes through a 1-nm FWHM filter and then is focused by an aspheric lens onto a Perkin-Elmer avalanche photodiode detector (C30955E). The output from the 1064-nm channel is amplified using a Femto DHPVA-100 amplifier before passing into the data acquisition computer. The 532-nm signal passes through a 0.5-nm FWHM filter before being split into separate analog and photon counting channels. Both 532-nm channels are focused using aspheric lenses onto microchannel plate PMTs. The analog channel uses the Perkin-Elmer MH-943 module, while the photon counting channel uses the Perkin-Elmer MP-943 module. The power supplies for the 1064-nm and 532-nm channels, along with the power supply for the amplifier, are also located inside the receiver box.

Signals from the 1064-nm and 532-nm analog channels are filtered by a 1.5 MHz filter and then digitized with a 14-bit, 5-MHz waveform digitizer (Gage Applied Inc. CS1450). The waveforms are usually averaged for 2 s before being stored on the computer hard drive. This results in a 30-m vertical aerosol profile resolution, and at the typical aircraft speed of 200 m/s, a horizontal resolution of 400-m. The 532-nm photon counting channel is sent to a multichannel scaler (Advanced Measurement Technology Inc. #MCS-pci) where typically a 20-s integration (100 ns dwell) time is used prior to storing the file on the computer hard drive.

3. Results
The lidar has been operated in both ground and aircraft configurations [2]. Figure 3 shows some typical atmospheric results from the ground based measurements.

![Figure 3. Lidar returns for 532-nm analog, 532-nm photon counting, and 1064-nm versus molecular density for a clear day at NASA Langley Research Center, Hampton, VA](image)

4. Conclusion
A compact aircraft lidar has been built and used to make aerosol and cloud atmospheric profiles. The lidar system is easily deployable and relatively lightweight. A single operator is needed to run the system, or it could be made for autonomous operation. The lidar system can be configured for ground or aircraft based measurements.

References