Developing a lidar system for the stealth bomber required adjustments in the design, manufacturing, and test environments.

The B-2 Stealth Bomber features state-of-the-art photonics technology in the form of the Pilot Alert System (PAS), a laser radar (lidar) designed to detect aircraft condensation trails (contrails). Although lidar technology provides a number of performance advantages, ensuring that performance in a military environment posed several challenges to designers. For example, to reduce the likelihood of third-party detection of the aircraft platform, the system had to capture range-resolved measurements of contrail aerosol loading without using a pulsed laser, which would provide too much contrast with the background. The system achieves range-resolved aerosol backscatter return using a continuous-wave (CW) source through a unique, pseudo-random amplitude modulation sequence. The laser modulation bit rate is 7.5 MHz, and the analog-to-digital (A/D) conversion rate is 15 MHz. A/D over-sampling improves noise performance and range resolution.

Ophir was not the first to use this technique; other researchers pioneered random-modulated CW meteorological lidar in the early 1980s. We improved on these earlier efforts by increasing the bit modulation rate (achieving a smaller range bin size) and by engineering a rugged package design suitable for military use.

System demands

The PAS is an incoherent, range-resolved Mie lidar incorporating a gallium-aluminum-arsenide diode laser emitter and an avalanche photodiode (APD) detector. The laser radar consists of two line-replaceable units (LRUs). The 12 in. × 12 in. × 16 in., 52-lb primary LRU is the optical subsystem. This optical head uses a bi-static lidar geometry and contains the laser, transmission telescope, turning mirrors, collection telescope, APD, preamplifier, and five additional circuit cards (motherboard, backplane, laser control, modulation, and electro-magnetic interference suppression and filtering). The second LRU is a dedicated processor that includes control and communications cards, plus a digital signal processing card for lidar data processing; dual 40-MHz processors were required to provide results in real time.

The challenges that faced the design team can be divided into three broad categories: environmental, performance, and user-interface. The environmental protocol included performance testing of 17.5 G’s for 12 hours (4 hours/axis), shock, salt, fog, and dust, temperature/altitude, explosive atmosphere, humidity, and so on. The severe vibration requirement dictated that all optical components be cemented into place and that all optical subassemblies be hard mounted to a common optical bench. Aluminum heat ladders bonded to all major printed wiring boards provided sufficient structural integrity. These ladders also operated as conductive heat layers for high-altitude operation, during which convective cooling is dramatically reduced.

By far the most demanding electrical requirements were the MIL-STD-461/462 electro-magnetic interference compatibility (EMIC) tests. To successfully pass these tests, our engineers procured PI-filtered, MIL-C-38999 (round circular) interface connectors, which were specially designed for this application. All access covers and the long seams were sealed using EMIC gaskets constructed of conductive elastomers.

System-performance requirements included better than 99% detection probability and a false-alarm rate of less than one in each 10 operational hours. Meeting these requirements was assured early in the program by performing detailed system-performance modeling for the lidar detection process. In addition, we verified system performance requirements through rigorous, formal hardware and software testing.

Ophir designed seven test systems for this project. In total, 30 PASs were developed for the customer. Five systems were devoted entirely to system performance and environmental testing.

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References