Laser Tracker III: Sandia National Laboratories' third generation laser tracking system

Duane L. Patrick

Sandia National Laboratories
Energetic and Environmental Test Department
Albuquerque, NM 87185

ABSTRACT

At Sandia Labs' Coyote Canyon Test Complex, it became necessary to develop a precision single station solution to provide time space position information (tspi) when tracking airborne test vehicles. Sandia's first laser tracker came on line in 1968, replacing the fixed camera technique for producing trajectory data. This system shortened data reduction time from weeks to minutes. Laser Tracker II began operations in 1982, replacing the original tracker. It incorporated improved optics and electronics, with the addition of a microprocessor-based real-time control (rtc) system within the main servo loop. The rtc added trajectory prediction with the loss of adequate tracking signal and automatic control of laser beam divergence according to target range. Laser Tracker III, an even more advanced version of the systems, came on line in 1990. Unlike LTII, which is mounted in a trailer and must by moved by a tractor, LTIII is mounted on its own four-wheel drive carrier. This allows the system to be used at even the most remote locations. It also incorporated improved optics and electronics with the addition of absolute ranging, acquisition on the fly, and automatic transition from manual joystick tracking to laser tracking for aircraft tests.

Keywords: laser tracking system, single station time space position information

INTRODUCTION

On other ranges, radar and video trackers, and combinations of both are used to produce tspi. These systems have one or more of the following limitations:

1.) Radar provides inaccurate range data with errors measured in the tens of meters.

2.) Radar is susceptible to ground clutter and other types of noise.

3.) Radar tracks the radar cross section. This reference changes with target orientation.

4.) Video trackers are limited by the data update rates of their cameras.

5.) Video trackers have problems with scene background changes like buildings, clouds, or mountains.

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6.) None of the variety of video tracking schemes can reference its position data to a consistent and specific point.

7.) Radar and video trackers have physically large, high inertia mounts. The sheer mass of these systems limit their ability to move quickly.

Laser tracker inertia has been minimized by mounting all system components on a three-dimensional optical pedestal and steering the line of sight by moving a light weight double-gimbaled beryllium mirror. Using these flexible software driven systems, Sandia can track test units with velocities from 100 to 10,000 feet per second. Position information accurate to plus or minus 6 inches is available within minutes of completion of a test. Close-in video and high speed film confirm test vehicle performance throughout the entire flight.

DESCRIPTION

Since Sandia's tracking needs vary from test to test, the systems are mobile. The self-propelled Laser Tracker III is placed as close to the experiment as safely possible. Once in place, the operator precision levels the system and surveys tracker location with respect to the local data coordinate system.

The operator's console consists of keyboard, joystick, and touch screen for input, with output to five computer screens and three video displays. At this console, all aspects of the rtc system used to run the laser tracker functions can be exercised. Here the operator compiles the test definition and data reduction parameters. The information from the test definition forms tell the control computers what is expected to happen and which mutually exclusive performance options to select. The reduction definition forms define the reduced data outputs and the system calibration information.

Acquisition of the target is accomplished in two ways. Acquisition on the fly occurs when the receiver optics see a laser return signal from the cooperative test unit during an electronic scan of a sector of space. Searching large sectors of space requires mechanical scanning with the tracking mirror with the laser beam out. Electronic acquisition of a return signal switches the system to automatic tracking. Slaved acquisition occurs when one tracker is slaved to another, receiving pointing information for the first part of the track until it sees sufficient return signal from its outgoing laser reflected from the approaching target. The downrange system then automatically tracks for the last part of the flight. The pointing information put out to the downrange tracker can also be provided to cinetheodolite or cinesextant optical mounts. After acquisition, all tracking functions occur automatically. Vehicle dynamics have never caused these systems to lose track. If loss of track occurs, the gimbal will continue to follow a constant velocity path for the operator specified amount of time. If the target is not reacquired, the gimbal will go either the last tracked position or a defined end of test location. Laser tracking is ideally suited for fully automatic tracking at all speeds. Tracking at night is not a problem. With the addition of an infrared (ir) video camera, the system can also be used to make dynamic ir measurements of a test unit in flight.

The optical pedestal (see figure 1) provides a rigid, level platform upon which the optical, laser, and gimbal components are mounted. The pedestal design incorporates short optical paths that minimize the size of diverging ray bundles and contains no unnecessary mirrors or beam

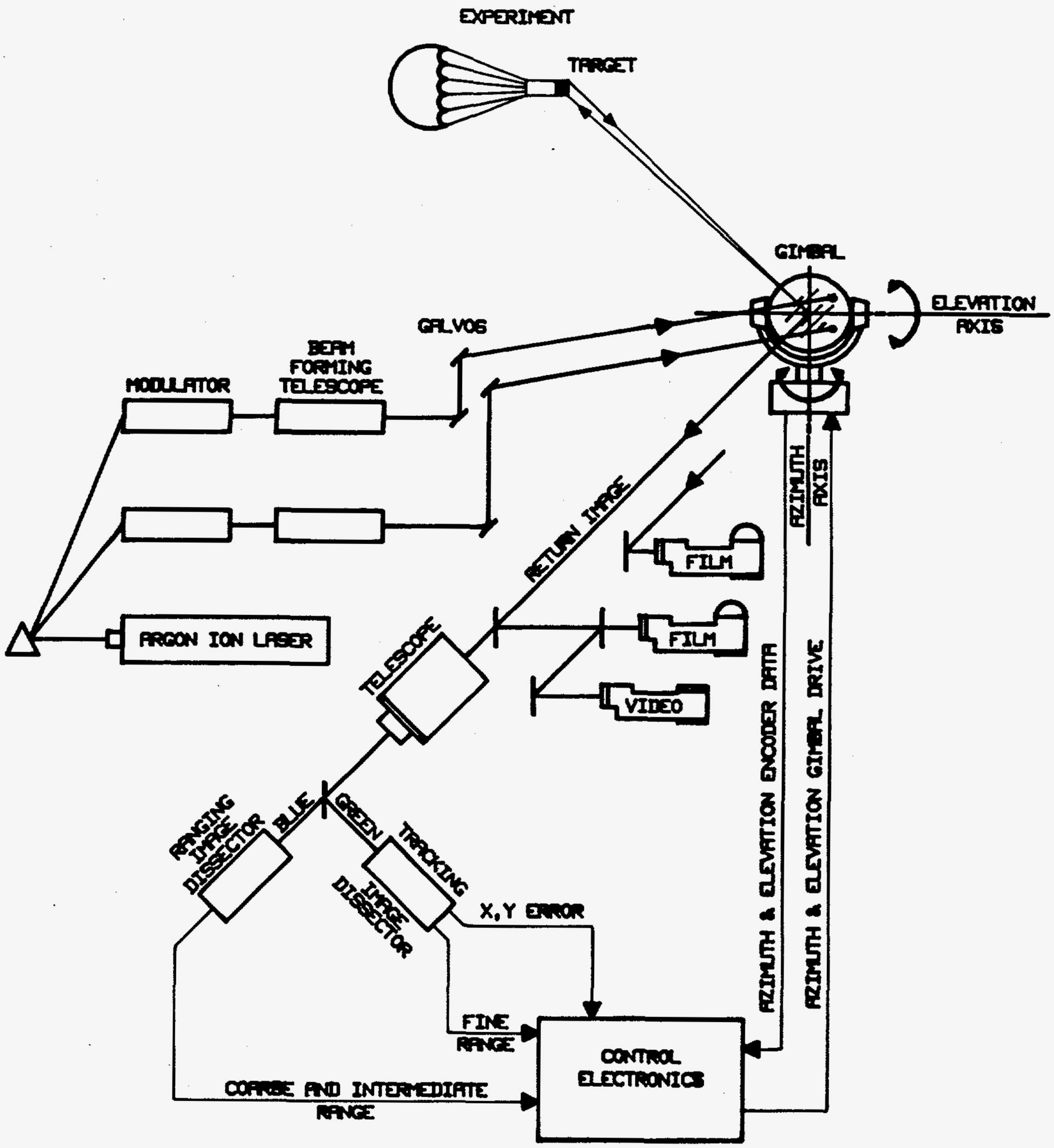

Figure 1- Optical Pedestal

splitters. The laser is a 6 watt ion argon continuous wave head, with the blue (at 488 nm) and the green (at 514 nm) lines selected for tracking and ranging functions respectively. At full power, .8 of a watt of visible light is aimed at the target. For adequate signal to noise ratio in the return image, the target is augmented with scotchlite reflective tape for short ranges (within 3 kilometers) and glass corner cube retroflectors for longer ranges (from 3 to 15 kilometers). Cooperative tracking allows the system to track a specific point on the test unit as well as following the proper target during experiment separation or fragmentation. The tracking and ranging functions are performed by a pair of image dissector tubes (the tracking image dissector TIDT and the ranging image dissector RIDT). An image dissector tube is a very sensitive random access television camera with a spiral scan. Prior to test, the TIDT is centered on the reflector area of the target vehicle via the tracking mirror. When the target moves, successive scans of the tube sense changes in position producing signals to operate the azimuth and elevation motors on the mirror gimbals. These signals compensate for changes seen in each successive sweep of the image, thereby keeping the tracking mirror on target. TIDT sees the green line and is used for tracking and coarse ranging information. RIDT sees the blue line and is used for intermediate and fine ranging information.
The rtc system consists of 7 single board computers residing on three interconnected VME chassis, the main chassis, and two subordinate subchassis. The main chassis has five processors performing the following tasks:

1.) Command interface with the operator and data processing and formatting.

2.) Communications with source and slave data and associated coordinate conversions.

3.) Trajectory prediction calculations when track is lost.

4.) Control of the tracking electro-optics.

5.) Control of the target ranging system.

Subchassis one controls all camera, camera derotation stage, lens, and laser beam forming telescope functions. Subchassis two performs gimbal control. Gimbal movement originates from operator joystick commands, test definition commands, or from tracking error signals generated by the TITD. Gimbal response and servo compensation are both determined digitally. During a test, all system parameters including gimbal pointing and ranging data are recorded by the system control minicomputer. The rate of this recording can be varied from 1 to 1,000 milliseconds. This data is translated from spherical to local to global coordinates. The data is reduced within 15 minutes after the test. Presentation of the data can be hard copy listings and graphs as well as an ASCII file on a diskette. Basic reduced data is x, y, and z position versus time and its derivatives. Copies of video and ir camera coverage are also available at this time. Other laser tracker specifications include:

1.) 18-bit absolute azimuth and elevation encoders with a resolution of 24 microradians.

2.) Total pointing accuracy of plus or minus 12 microradians.

3.) Maximum slew rate of 10 radians per seconds.

4.) Maximum acceleration of 150 radians per seconds.

SUMMARY

LT III provides a unique state of the art tracking capability for missile, rocket sled, aircraft, submunition, and parachute testing. Used in conjunction with LT II, the systems together can provide either simultaneous or extended range tracking. Mobility, accuracy, reliability, and cost effectiveness enable these systems to support a variety of testing at Department of Energy and Department of Defense ranges.