Safe Laser Beam Propagation for Interplanetary Links

Keith E. Wilson
JPL/CalTech

High power lasers for interplanetary communications

Ground-to-space laser uplinks to Earth–orbiting satellites and deep space probes serve both as a beacon and an uplink command channel for deep space probes and Earth-orbiting satellites.[1] An acquisition and tracking point design to support a high bandwidth downlink from a 20-cm optical terminal on an orbiting Mars spacecraft typically calls for 2.5 kW of 1030-nm uplink optical power in 40 micro-radians divergent beams.[2] The NOHD (nominal ocular hazard distance) of the 1030nm uplink is in excess of 2E5 km, approximately half the distance to the moon. Recognizing the possible threat of high power laser uplinks to the flying public and to sensitive Earth-orbiting satellites, JPL developed a three-tiered system at its Optical Communications Telescope Laboratory (OCTL) to ensure safe laser beam propagation through navigational and near-Earth space.

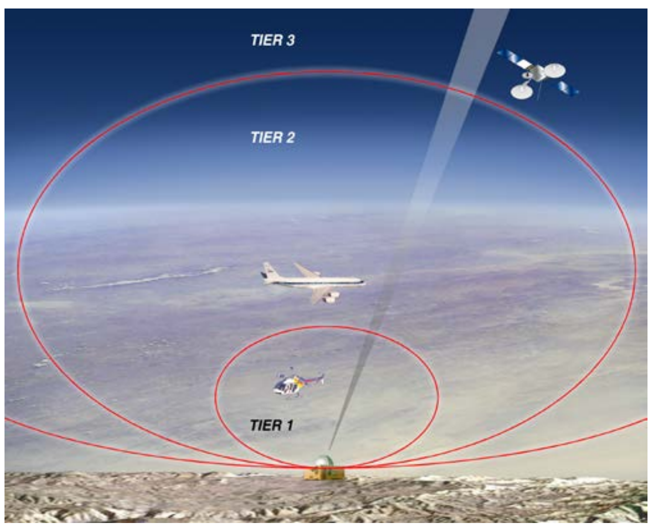

Figure 1. JPL three-Tiered laser safety system centered at the OCTL.

The Laser Safety System at the OCTL (LASSO)

The philosophy behind the development of the three-tiered LASSO shown in Figure 2 was to have a self-contained system at the OCTL. The system is shown in Figure 3 and was installed at the OCTL in 2004.[3,4] Sensors in the first two tiers detect objects in navigable air space. Tier-1 sensors consist of a wide field and a narrow field LWIR camera bore sighted with the telescope. [5] The cameras use a Raytheon Control IR 2000B BST (barium strontium titanate) focal plane array. Each array has a Noise Equivalent Temperature Difference (NETD) of 130 mKelvin, and is comprised of 320x240 active pixels. The narrow-field camera uses an F/1.0 75 mm germanium lens to generate a 12x9 degree field of view with heightened sensitivity to see small aircraft at the full 3.4-km design range. The wide field camera uses an F/1.0 18 mm germanium lens for a 46 x 35 degree field, for identifying rapid, low-flying aircraft at high angles before they encounter the beam. Both cameras are aimed at the same point in the far field, and the system is mounted to the telescope structure and bore-sighted to the center of the telescope's field-of-view. The Tier-2 sensor seen in Figure 2 is a phased array X-band radar capable of detecting a small single engine aircraft at a range of 26-km and a large jumbo-jet 82-km away.

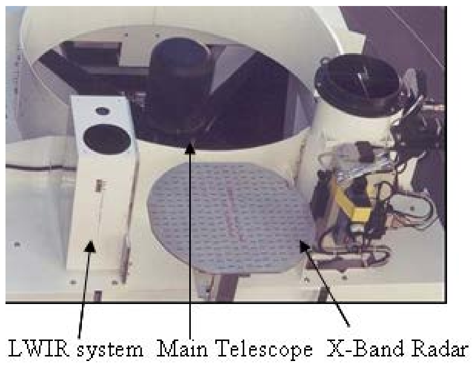

Figure 2. Aircraft detection sensors integrated and co-aligned with the OCTL telescope.

Figure 3. JPL OCTL facility located in Wrightwood CA.

The Tier-3 region lies within the purview of the US space command and provides for safe laser beam transmission through the near-Earth space environment. JPL registers the OCTL lasers that are used for ranging and/or optical communications with the US Space command. We provide the agency with permission to illuminate targeted satellite and notify the agency of planned laser transmissions to satellites or to a star for alignment calibration. The agency provides the OCTL a listing of predictive avoidance times when laser transmission is disallowed for any of the OCTL lasers. Figure 4 shows the percentage of time when laser transmission to the star Sirius was precluded for the three-month period. Yet not all lasers are subjected to predictive avoidance control Depending on the laser power, wavelength, beam divergence and operating conditions some laser links are waived from Space Command predictive avoidance procedures. The Tier-3 system control is not invoked for these laser transmissions.

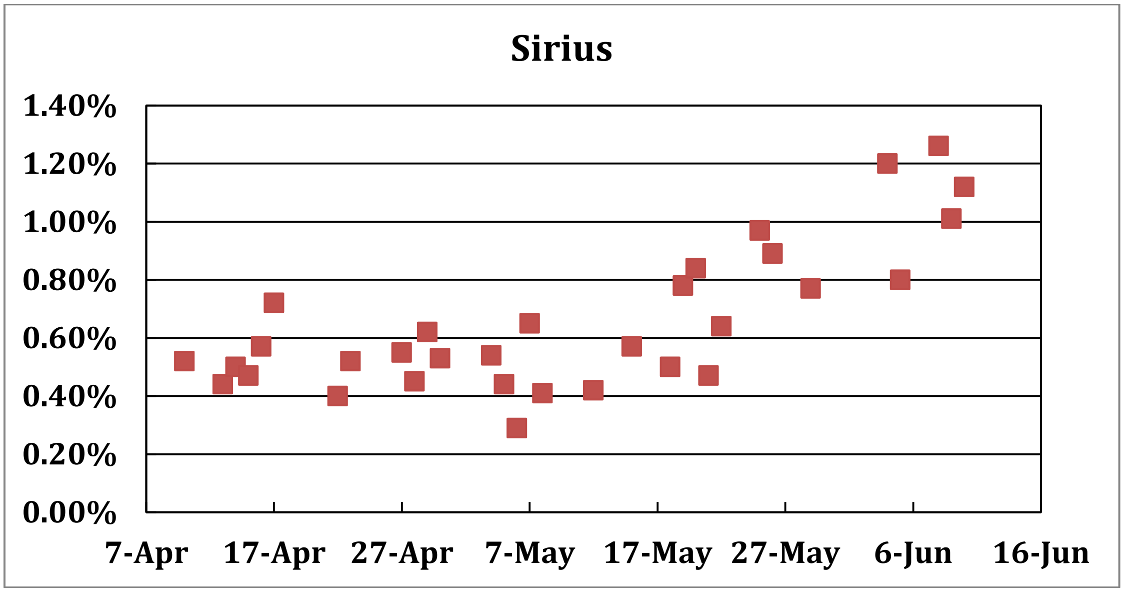

Figure 4: Tier-3 predictive avoidance outages over the three-month period when using the star Sirius for laser pointing calibration.

The LASSO sensors from the three tiers are coupled to the laser safety control computer (LSCC) through the laser safety electronics box (LSEB) shown in Figure 5. The radar output is also displayed on a monitor. The LSCC monitors and records the inputs from the tiers 1, 2 and 3 sensors and from the optical detector. It determines if all tiers are clear for transmission and releases the beam interrupt shutter- the default position is a closed shutter. The optical detector looks at the laser output partially reflected from a mirror surface to confirm the state of laser laser transmission.

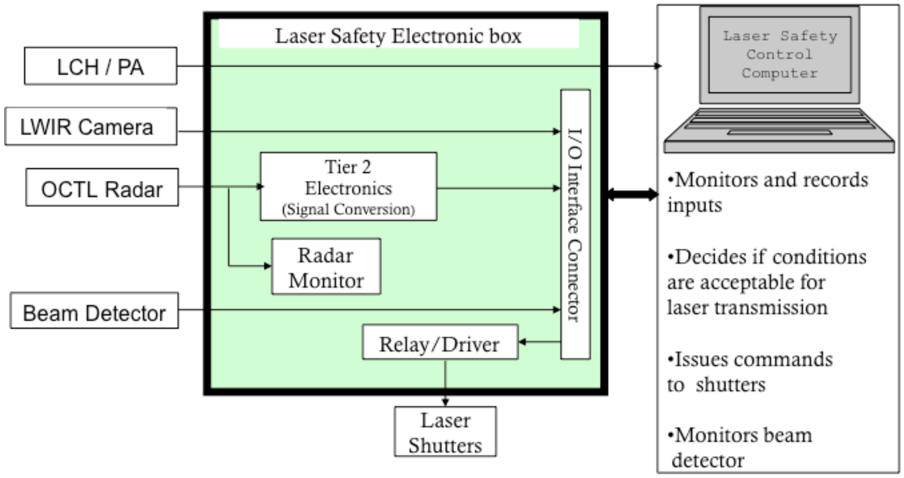

Figure 5. Schematic of laser safety control system. The laser safety electronics box I/O (input/output) board conditions the sensor outputs for input to the control computer.

The monitor and control computer displays a running graphical representation of the current LASSO status to a five-minute history to the operator. The LSCC data are stored as a record and for future statistical analysis. Since its inauguration in 2003, the LSCC has supported laser beam transmission into space without incident [6,7].

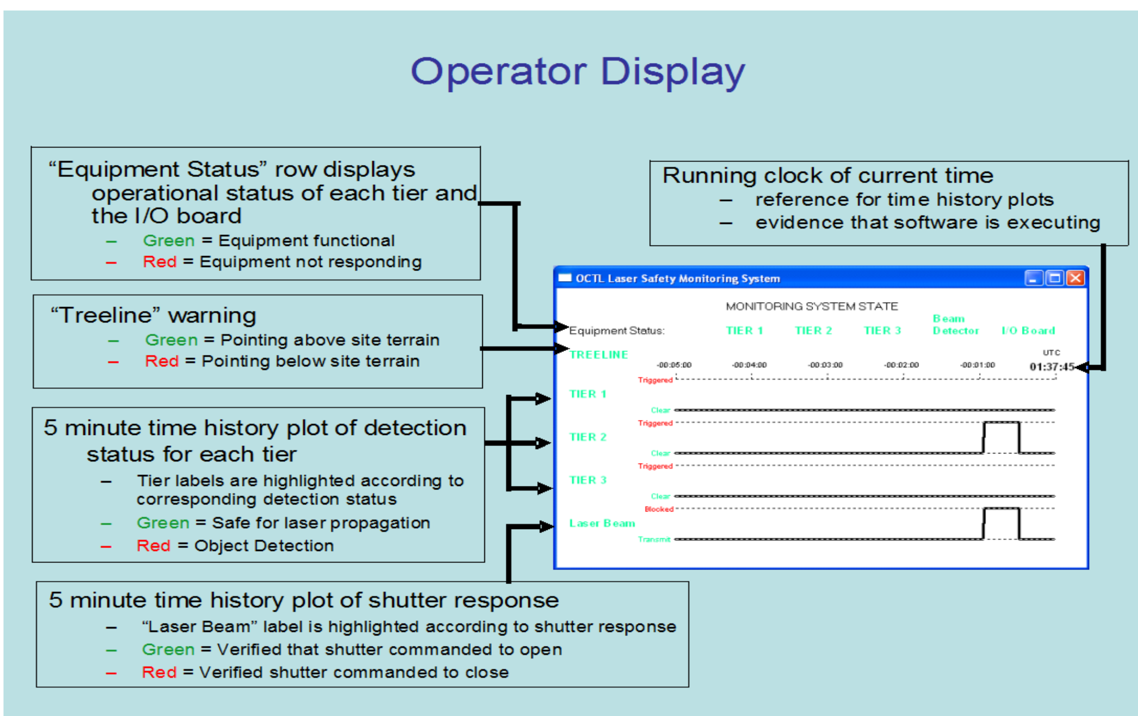

Figure 6. LSCC computer status displayed during operation.

Acknowledgements

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References

1. A. Biswas, M. W. Wright, J. Kovalik, S. Piazzolla, "Uplink beacon laser for Mars Laser Communication Demonstration (MLCD)," Proceedings SPIE, Free-Space Laser Communication Technologies XVII, Vol. 5712, 93 -100, 2005.
2. W. Thomas Roberts and Malcolm W. Wright “Deep Space Optical Transceiver (DOT) Ground Laser Transmitter (GLT) Trades and Conceptual Point Design” Interplanetary Network Progress Report, Vol. 42-183, Nov 15 2010.
3. Keith E. Wilson, Joseph Kovalik, A. Biswas, William T. Roberts, “Development Of Laser Beam Transmission Strategies For Future Ground-to-Space Optical Communications”, SPIE Symposium on Defense and Security, Vol. 6551, April 2007, Orlando FL.
4. Keith Wilson, Joseph Kovalik, Abhijit Biswas, William T. Roberts, “Recent Experiments at the JPL OCTL”, IPN Progress Report June 2008.
5. Brian Smithgall, Keith Wilson, “ Automatic Aircraft Detection to Support Aircraft Spotters During Outdoor Laser Propagation”, ILSC, March 2007, San Francisco CA.
6. K.E. Wilson, F.W. Battle, Brian Smithgall, “Laser Operations at JPL/NASA OCTL Facility” ILSC, March 2007, San Francisco CA.
7. Keith E. Wilson, Joseph M. Kovalik, Abhijit Biswas, Malcolm W. Wright, W. Thomas Roberts, Yoshihisa Takayama, Shiro Yamakawa, *Invited Paper* “Preliminary results of the OCTL to OICETS optical link experiment (OTOOLE)”, SPIE Free-Space Laser Communication Technologies Proceedings, Vol. 7587 January 2010, San Francisco, CA.

Keith Wilson holds a Ph.D. in Physics from the University of Southern California. He is a Principal Member of the Technical Staff in the Optical Communications Group at JPL, and is the Manager for JPL's Optical Communications Telescope Laboratory at Table Mountain, Wrightwood CA.