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Status of SLR upgrades at the U.S. Naval Research Laboratory's Optical Test Facility

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Abstract

The Naval Research Laboratory's satellite laser ranging facility was originally installed in 2001. Over the last decade many of the components of this system have become hard or impossible to find replacements. Two years ago NRL began seeking funding for repairs and upgrades to bring the system back to full functionality. L3 Brashear was contracted to evaluate the existing system and repair or replace all degraded or obsolete hardware and software.

Additionally, NRL has been working towards installing three new calibration piers and two additional laser ranging systems. A 1 kHz system transmitting at 1064nm and a 50 Hz system transmitting at 1560nm are currently being developed and installed.

Introduction

The U.S. Naval Research Laboratory (NRL) operates an optical test facility (OTF), which includes a satellite laser ranging site, in Stafford, Virginia. NRL began ranging operations at the OTF in the fall of 2002.

Over the last decade of operations several key pieces of hardware have failed or degraded to a level which requires replacement. Since the system was designed and built in the late 1990's some of this hardware is impossible to replace. In 2012 NRL decided that in order to maintain an acceptable level of operational readiness it was going to have to upgrade the SLR system. During fiscal year 2013 funding was secured and L3-Brashear was contracted to perform the upgrades.

The upgrade won't only replace failed and failing parts but also bring the telescope system up to the manufacturer's current baseline hardware and software configurations. This will include replacing the control computer, upgrading the focus drive assembly, upgrading the axis amplifiers, introducing sun avoidance software, introducing Ethernet based control interfaces and other necessary improvements to provide reliable operations and increased automation well into the future.

Along with the telescope upgrade there were three new calibration piers installed in 2013 and NRL is working toward installing two new lasers for use in the ranging system.

Existing System

The SLR system in use today is configured as follows:

- L3-Brashear 1-meter Telescope
  - Blind pointing accuracy better than 7 microradians while traveling at 25 deg/sec
  - Jitter: Better than 75 nanoradians RMS in Azimuth, 125 nanoradians RMS in Elevation
  - Precision better than 10 nanoradians
  - Wavefront quality: λ/64 primary, λ/12 at f/89 on optical bench
- Honeywell Event Timer
  - Enables sub-centimeter accurate range measurements
  - Provides 2 picosecond timing accuracy
  - Time tags over 6000 events per second
- 1064 nm high peak power laser for SLR
  - 200 ps pulse width at 10 Hz repetition rate
  - Typically transmit 100mJ/pulse
- SBIG CCD512 x 512 pixels, 25 micron pixel size, Integrating CCD
- Xybion Intensified CCD, 300 microradian field of view, EFL 12 meters, operation at 30 fps
- Honeywell Air-search radar with safety interlocks to laser system
- Honeywell interlock system
- Timing via GPS
- NRL developed software control system for tracking and ranging
- Single calibration retro mounted to metal radar tower

Baseline test results

L3-Brashear performed an onsite baseline test in September 2013. The baseline test included performing the original onsite acceptance test procedure to measure the telescope system performance. After the baseline test the results were compared to the original acceptance test results and indicate the telescope performs as well or better than when delivered in 2002.

Upgrades to be performed

L3-Brahshear will perform all telescope system upgrades with the primary goal being meet or exceed all original performance specifications. They will also clean the primary and secondary mirrors and replace degraded components with the latest technology. The primary focus of the hardware upgrades will be the control system computer, focus drive assembly, reflective memory interface, and axis amplifiers. Software upgrades will include the latest version of L3-Brashear's control system and user interface.

During the baseline testing it was revealed that the control system computer was operating with very little processing margin. The slightest increase in processing load on the computer resulted in the real time system missing deadlines and the telescope performance significantly degrading or being unable to operate at all. The computer will be upgraded to a quad-core CPU which will run the latest version of the QNX real time operating system. This will allow greater processing margin which will in turn allow for future functionality without threatening the stability of the system.

NRL interfaces with the telescope control system via a reflective memory interface (RMI). The RMI cards in the system have degraded over time which has reduced NRL's ability to control the system and retrieve status information. The existing cards are no longer manufactured and NRL has exhausted all known avenues for replacement. The upgrade will replace the existing cards with new ones from GE which will be supported for the foreseeable future. This issue was a primary driver for the upgrade.

The focus controller will be completely replaced with the latest version produced by L3-Brashear. The existing controller utilizes a stepper motor with limit switches to keep track of its position. This requires an initialization process which occasionally does not complete successfully. The new design uses a zero backlash drive screw and a position encoder. This design does not require an initialization which will simplify telescope operation, increase reliability and allow for increased automation.

L3-Brashear utilized a proprietary design for the axis amplifiers in the original system. The manufacturer no longer produces this card and there are no direct replacements available. The new axis amplifier cards use COTS hardware and will be easily serviceable. This removes a significant risk from the system.

Along with the updated control system hardware and software L3-Brashear will deliver a new telescope control system graphical user interface (TCS-GUI). The existing interface was written in Visual Basic and relied on a remote procedure call interface that does not exist in the newer versions of the telescope control system. The new TCS-GUI will be implemented in a more modern software language and will make use of the newer TCP/IP interface to the control system. The new TCS-GUI will also handle the star and lens calibration procedures which were previously handled directly in the telescope control system using a telnet interface. The new calibration procedure will be more user friendly and remove it from the real time system.

Potential risks

While L3-Brashear has upgraded similar systems in the past there are always risks when modifying precision instruments. The primary risk identified in the NRL-OTF upgrade was the replacement of the focus controller. In order to perform the replacement the entire controller must be removed then a new one installed. This directly affects the optical axis of the telescope since the secondary mirror is attached directly to the focus controller. A thorough plan was presented to NRL during the upgrade design review which minimizes the risks and provides for realignment of the system.

Another risk identified is the replacement of the RMI card. This replacement will require NRL to update its control software to incorporate the new card. The potential to affect the performance of the system is low but any delay in NRL's software update would directly affect downtime.

New calibration piers

Three new calibration piers were installed at the OTF in 2013. The new piers are concrete shielded with PVC. The piers accept both a GNSS antenna and retro reflector. Once surveyed these new calibration targets will allow NRL to validate the original GGAO/OTF baseline established in 2002 during the original installation of the SLR site. NRL is also looking forward to having several calibration options along with investigating seasonal height differentials.

Ongoing laser system upgrades

NRL has two new laser systems ready for install at the OTF. A 1kHz 1064nm ranging system is currently on the optical bench and has been aligned. This system operates from 200Hz to 1kHz with a 100 picosecond pulse width. At 200Hz the system transmits 2.3mJ per pulse and at 1kHz it transmits at 1.4mJ per pulse. The divergence of this laser is adjustable but will most likely be approximately 100 microradians.

The second system is a 50Hz 1560nm system. It is 1064nm shifted to 1560nm using a raman cell with phase conjugate mirror. This system has a 3nsec pulsewidth and is expected to transmit approximately 200mJ per pulse. This system is also on the optical bench but has not been aligned into the ranging system.

Conclusions and future efforts

NRL is in the beginning stages of a significant effort to modernize the satellite laser ranging site at the OTF. The telescope upgrade is scheduled to be complete by spring 2014 while the laser system upgrades are an ongoing internal effort. Once the laser systems are installed NRL will then update its software to provide support for ranging greater than the current 10Hz capability. NRL will also be updating its software in the near future to support the new calibration piers.