

SLR2000 PERFORMANCE SIMULATIONS

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The SLR2000 Simulator is a software package designed to allow testing of new tracking and ranging algorithms prior to the actual hardware development of NASA's next generation of Satellite Laser Ranging Systems, called SLR2000. The simulator is written in FORTRAN, currently runs in the HPUX environment, and models relevant errors in the receiver system, tracking mount, weather sensors, station location, system timing, predictions, and others. Recent work includes adding a new signal to noise algorithm, improving the tracking mount model, and developing an acquisition search algorithm. As a consequence of this work, we feel that the simulation results now provide a more realistic example of SLR2000 performance. Simulations of SLR2000 tracking and ranging performance will be presented.

Introduction

SLR2000 is a low cost, totally autonomous, eyesafe satellite laser ranging system currently being developed at NASA's Goddard Space Flight Center. The eye safety constraint implies a low transmit energy (200 microjoules), narrow laser divergence (± 4 arcseconds), and a rapid fire rate (2kHz). Algorithms to distinguish signal from noise must be developed since the system will be operating in a very low signal to noise environment. The operator functions must also be replaced by algorithms to perform such tasks as scheduling passes, acquiring and tracking satellites, and determining if the weather permits ranging. Lastly, the predictions must be made more accurate in order to improve pointing (for the narrower laser divergence) and to reduce the slope of the range errors in the ranging window (for the signal to noise algorithm to succeed).

The performance of SLR2000 depends heavily on the design and development of these improved models and algorithms. The simulator allows us to test the design of the algorithms, see how these algorithms affect performance prior to development of the hardware, and work in a controlled environment where absolute truth is known and can be used to judge performance.

For a more detailed description of the SLR2000 system see the paper¹ by John Degnan in this Proceedings. For a theoretical analysis of the potential tracking performance of SLR2000 see Paul Titterton's paper² also in this Proceedings.

Simulator Description

The simulator models the ground instrumentation, the satellite orbit, the environment and the field software to produce a virtual SLR2000 system. The field software interacts with the hardware as in a real station to read in data and control the instrumentation. The System Truth, which includes where the satellite actually is, what the sky clarity is like, what time of day it is, and how the atmosphere is affecting the signal strength, is maintained to allow determination of actual system performance. The hardware readings are essentially System Truth perturbed by various measurement random errors and biases. The field software has no access to System Truth to ensure integrity of the testing process. Figure 1 illustrates this design. Recent enhancements include the addition of an angular search during acquisition, a model for a quadrant detector, moving clouds, and an improved tracking mount model. Listed below are some of the functions modeled in the simulator.

SLR2000 SIMULATOR HARDWARE FUNCTIONS / ERRORS MODELED

- POINTING SYSTEM
 - Bias of mount system (error in mount model and mount wobble)
 - Random jitter
 - Mount drive at 2kHz with limits on acceleration. & velocity
 - Actual mount pointing kept separate from encoder readings

- RECEIVER TIMING
 - Detector modeled (PMT or photon-counting APD)
 - TIU error modeled as random Gaussian noise
 - Computation of background noise above threshold
 - System delay bias applied

- RECEIVER ENERGY
 - Fixed transmitter energy
 - Gaussian pulse (spatial and temporal)
 - Computation of transmitter gain as function of laser divergence
 - Attenuation of energy with system and atmospheric transmission
 - Satellite treated as single cube with given cross-section
 - Moving cloud cover

- STATION READINGS
 - Station location biases
 - Weather sensor offsets
 - System timing bias

- QUADRANT DETECTOR
 - Simple model determines proportion of signal in each quadrant as function of pointing error
 - Noise rate is divided equally between the 4 quadrants

SLR2000 SIMULATOR ORBIT & FIELD SOFTWARE FUNCTIONS MODELED

- SYSTEM TRUTH
 - Orbital update using GEM10 and Texas Integrator
 - Sun position calculated and used in optical background determination
 - Environment truth maintained
- SOFTWARE POINTING COMPUTATIONS
 - Polynomial used to update satellite position (NASA SLR Network method)
 - Output to mount drive at 100Hz
 - Quadrant Detector output used as angular correction
- ALGORITHM COMPUTATIONS
 - EOO algorithm used to detect Signal from Noise
 - Time and Range Bias computed from Signal
 - Angular Search used to find target (spiral scan)

The simulator is written in FORTRAN and currently runs under HPUX on an HP735. There are approximately 4,000 lines of code. There are few HPUX unique system calls, so the simulator should be easily portable to other environments, and our plans are to convert it to run under Windows95. The simulator is currently lacking in user friendly menus and graphical interfaces; there are more than 70 different variables that can be modified, and each must currently be changed by editing the appropriate input file. A few of the possible parameters that can be changed, along with the values used in the Simulator Results section, are listed in Table 1. Future Windows95 versions will contain a graphical menu front end for helping the user configure the simulator and run it. There are also many possible outputs to select from, including mount errors, range O-C plots, and autotracking decisions. All of these are currently output as ASCII files which must be graphed post-run via an independent plotting package. This deficiency will also be corrected in the upcoming Windows95 version, where results will be plotted from the simulator's graphical user interface.

Table 1: Important Simulator Parameters

Parameter	Value used in Simulations
Quantum Efficiency	0.40
Energy /pulse at aperture(μ J)	200
One way path transmission	0.75 @ 90° elev. and 0.12 @ 20° elev.
Optical Cross-section (m^2)	0.65(10^6) for STARLETTE 7 (10^6) for LAGEOS 20 (10^6) for GPS35
Receiver Optics Transmission	0.12
Receiver Area (m^2)	0.196 for 50 cm diam.
Transmitter half-angle beamwidth (arcsec)	4
Optical Bandpass filter (A)	1.2
Solid angle FOV (sterad)	$1.81 (10^{-9})$
Background spectral radiance (watts/meter ² -ste-A)	$1.46 (10^{-3})$ day and $1.46 (10^{-8})$ night
Dark current density (amps/cm ²)	10^{-15}
Mount jitter (arcsec)	0.5
Mount wobble / model error (arcsec)	4

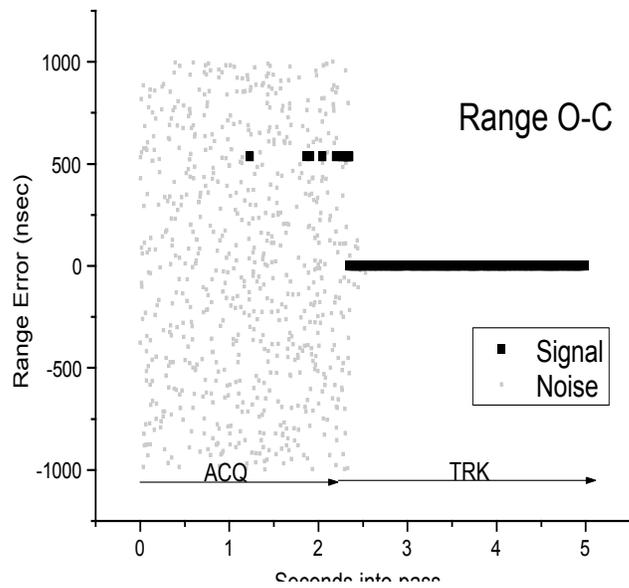
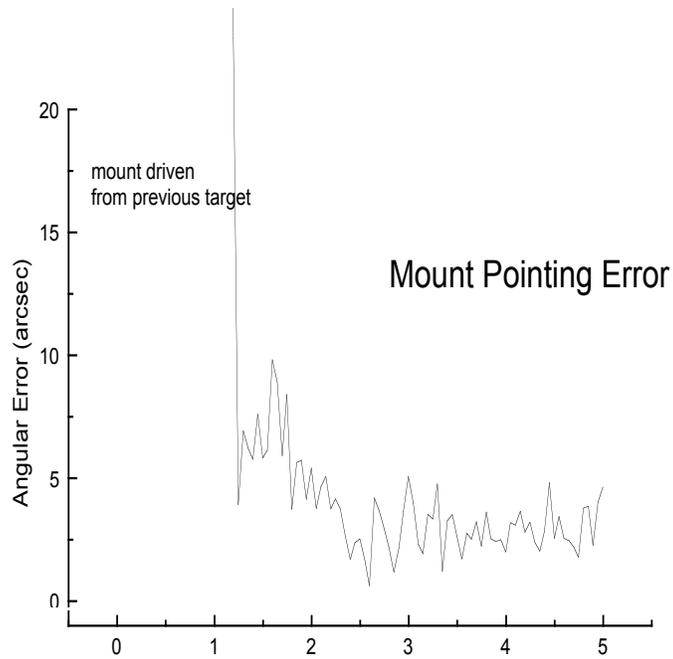
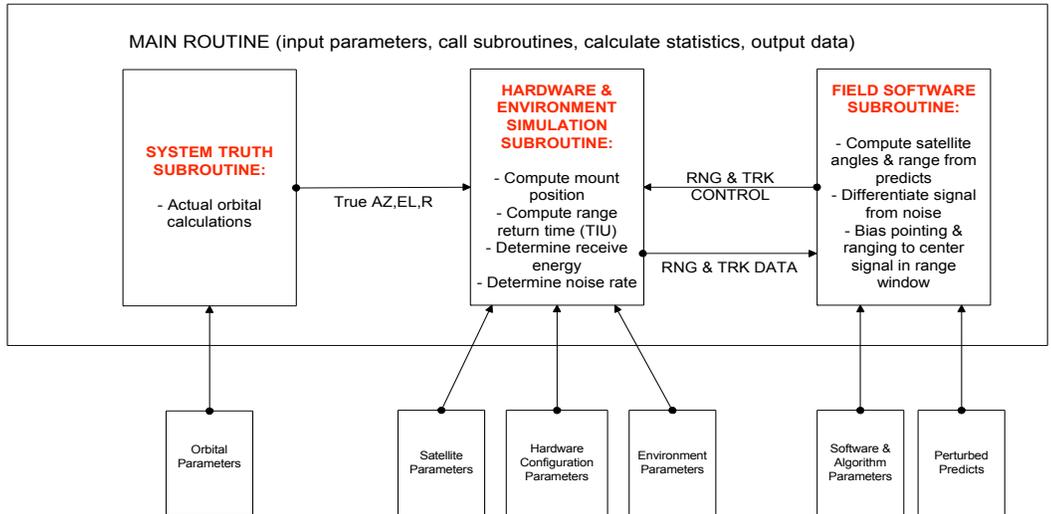
Simulator Results

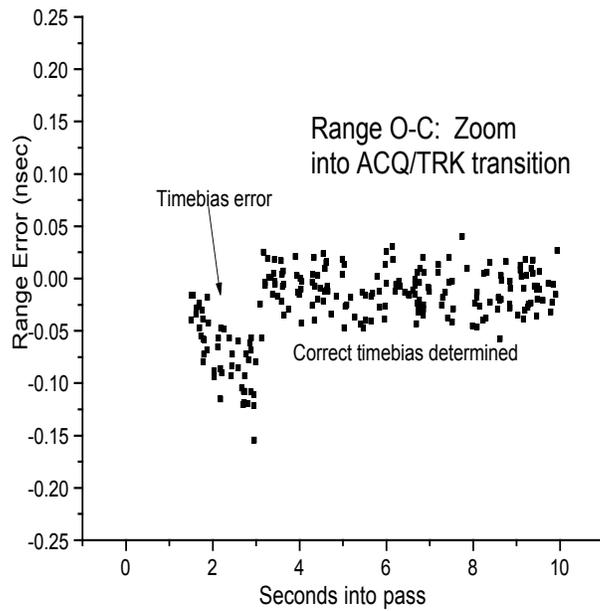
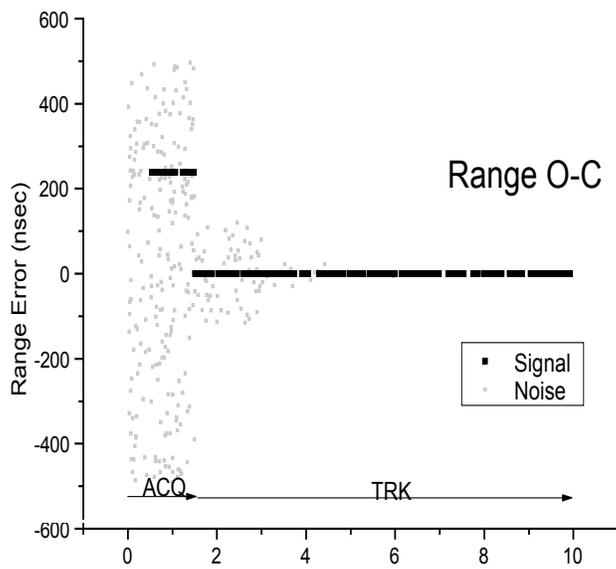
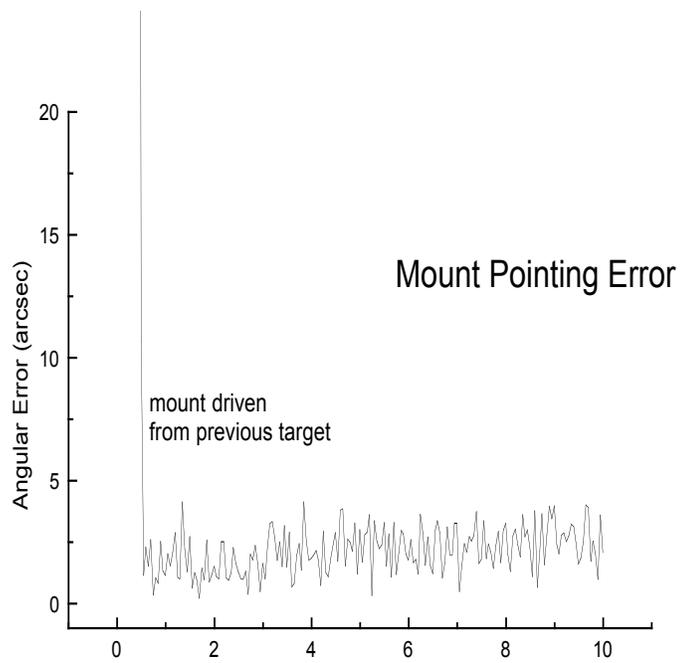
Figures 2 - 4 show simulations of the SLR2000 system acquiring STARLETTE, LAGEOS and GPS. The plots show Observed minus Calculated ranging data (O-C) in the range window along with the corresponding mount errors. The errors are graphed versus seconds into the pass. The darker range returns are the signal and the light gray returns represent noise. In all cases the simulator correctly finds the signal, corrects the pointing, range and time biases to center the satellite returns in the quadrant detector and center the signal in the range window. As the signal is acquired, the field software also closes down the range window. The mount errors shown include the time to close on the start of the pass from another mount position, the errors in the commands due to errors in the prediction polynomials, and the mount jitter and wobble. The polynomials used are those from the current NASA SLR Network and while accurate enough for the MOBILAS systems which have ± 10 arcsecond beam divergences and 100 millijoule laser energies, they are not accurate enough for SLR2000 requirements and will not be used in the actual system.

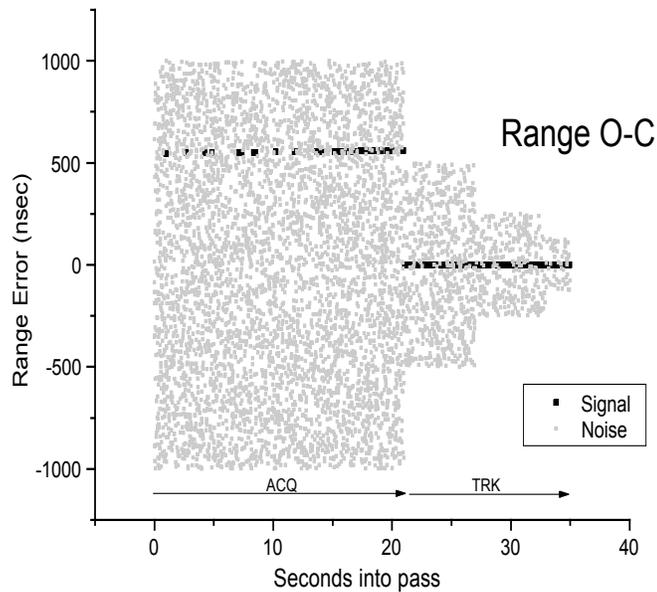
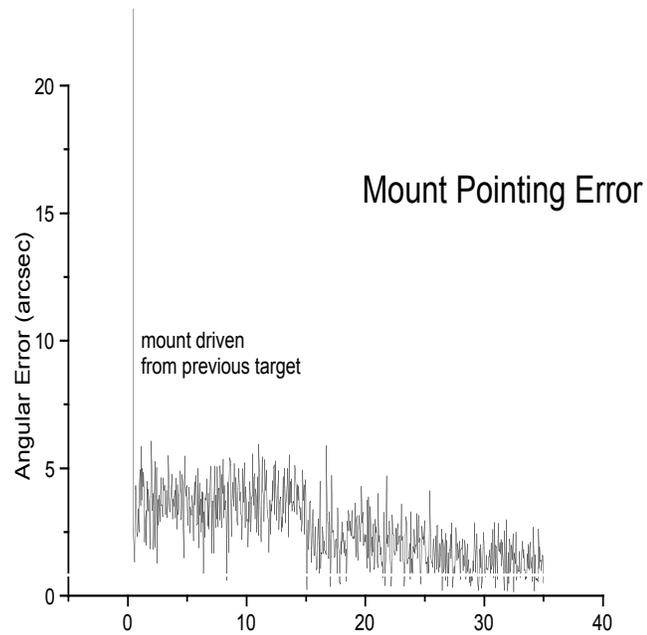
Figure 2 shows a STARLETTE acquisition at 20 degrees elevation with a slant range of around 2,000km. Figure 3 is a LAGEOS pass being acquired at 20 degrees with a slant range of around 8,500km. This figure also zooms into the range window to show the timebias correction being applied (the slope of the range error being zeroed). Figure 4 shows GPS being acquired at 30 degrees elevation with a slant range of around 23,500km. All results are for a 50 centimeter telescope with parameters shown in Table 1 above. It should be emphasized that in these simulations the algorithm does not mistake noise for signal, even in the GPS case with a 1 microsecond range window. Previous simulations, using a 30cm telescope, showed false acquisitions for daylight GPS. This agrees with theory which gives the probability of false acquisition for this telescope aperture to be nearly 100%. For the 50 centimeter telescope the probability of false acquisition is less than 20%.

Conclusions

Simulations of SLR2000 performance agree with the analytical conclusion that a low energy, 50cm telescope system with a quadrant detector, will be able to acquire and track, during daylight, all of the satellites currently tracked by the NASA Network from STARLETTE out to GPS.







References

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2. Titterton, Paul, and Harold Sweeney, "Correlation Processing Approach for Eyesafe SLR 2000," in this Proceedings.
3. McGarry, Jan.F, John J. Degnan, Paul Titterton, Harold Sweeney, Brion P.Conklin, Peter J. Dunn, "Automated tracking for advanced satellite laser ranging systems", in the proceedings from Acquisition, Tracking, and Pointing X, SPIE Aerosense, Orlando, April 1996.
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