LRO-LR Ground System Requirements

- **Deliver between 1 and 10 femtoJoules per sq.cm of signal to the receiver aperture. For SLR2000 (55 microrad laser divergence) ➔ 30mJ per pulse.**

- **Wavelength must be 532.x . Wavelength will be determined in spring 2007. Filter assembly will be sent to all interested stations (2007) to determine if station laser meets wavelength requirements. Filter width is 0.3 nm (FWHM).**

- **Laser pulsewidth =< 8ns (onboard receiver impulse response is ~6ns).**

- **Maintain the transmitted pulse time stamp accuracy to within 100 ns of UTC.**

- **Measure the relative laser time of fire to better than 200 ps (1 sigma) shot-to-shot over a 10 sec period. Laser fire time must be recorded to <100 psec resolution.**

- **Deliver laser pulses into the LOLA earth window at least once per second.**
  Laser fire rate cannot exceed 28 Hz!

- **Shot to shot measurement of the output laser energy is desired.**

- **Data should be delivered to CDDIS in ITDF format daily (or faster).**

Link Calculations for SLR2000 as Ground Station

SLR2000 system characteristics

$E := 0.030$ laser energy (out of laser) in Joules

$\tau_{sys} := 0.5$ system transmission

average power (watts) at laser

$f := 28$ laser fire rate (Hz) $P := E \cdot f$ $P = 0.84$

$\theta := \frac{55}{2} \cdot 10^{-6}$ laser divergence (radians) - half angle - to open loop point

$\tau_z := 0.7$ atmospheric transmission at zenith (standard clear)

$a_e := 6378. \cdot 10^3$ radius of earth (meters)

$R_z := 400000 \cdot 10^3 - a_e$ spacecraft altitude above earth (meters)

$\varepsilon_{deg} := 20$ elevation of mount (degrees)

$\varepsilon := \varepsilon_{deg} \cdot \frac{\pi}{180}$ $\theta_2 := \left(\frac{\pi}{2} - \varepsilon \right)$ $\theta_1 := \mathrm{asin}\left[\frac{a_e}{(a_e + R_z)} \cdot \sin(\theta_2) \right]$

$\tau_a := \tau_z^{\left(\frac{1}{\sin(\varepsilon)} \right)}$ $R_s := (a_e + R_z) \cdot \left(\frac{\sin(\theta_2 - \theta_1)}{\sin(\theta_2)} \right)$

Pointing Errors: Prediction & Mount Model

$p_{acc} := 4000$ prediction accuracy (m)

$\delta_p := \frac{p_{acc}}{R_s}$ prediction pointing error (3-sigma) $\delta_p \cdot 3600 \cdot \frac{180}{\pi} = 2.0742$

$\delta_c := 2 \cdot \frac{\pi}{180 \cdot 3600}$ pointing error due to mount model (with correction by pre-pass star)

$\delta := \sqrt{\delta_p^{\,2} + \delta_c^{\,2}}$ total pointing error (3-sigma) $\delta \cdot 3600 \cdot \frac{180}{\pi} = 2.8814$ asec

$\delta_2 := 2 \cdot \frac{\delta}{3}$ 2-sigma pointing error

Energy Density (femtoJoules per sq.cm.) at LRO

$$E_{LRO} := \frac{\left(E \cdot \tau_{sys} \cdot \tau_a \cdot \frac{2}{\pi \cdot \theta^2 \cdot R_s^{\,2}}\right) \cdot e^{-2\left(\frac{\delta_2}{\theta}\right)^2}}{100^2}$$

$E_{LRO} \cdot 10^{15} = 2.2362$

Energy density for SLR2000 at LRO in fJ per sq centimeter given 30 mJ per pulse laser. Second column is with ~ 2.9 arcsec pointing error, third is with no pointing error.

Mount EL	E(LRO) w/error	E(LRO) no error
20 deg	2.2	2.8
30 deg	3.1	4.0
40 deg	3.7	4.6
50 deg	4.0	5.1
60 deg	4.3	5.4

Examples of other SLR systems

MOBLAS-7

Energy density for MOBLAS-7 at LRO in fJ per sq centimeter given 100 mJ per pulse laser, a 30 arcsec laser divergence (FWHM), and a 5 arcsec mount pointing error after correction on a pre-pass star.

Mount EL	E(LRO) w/error	E(LRO) no error
20 deg	2.1	2.4
30 deg	3.0	3.3
40 deg	3.6	3.9
50 deg	3.9	4.3
60 deg	4.1	4.5

MLRS

Energy density for MLRS at LRO in fJ per sq centimeter given 60 mJ per pulse laser, an 8 arcsec laser divergence (FWHM), and a 5 arcsec mount pointing error after correction on a pre-pass star.

Mount EL	E(LRO) w/error	E(LRO) no error
20 deg	2.3	10.6
30 deg	3.2	14.9
40 deg	3.8	17.5
50 deg	4.1	19.2
60 deg	4.3	20.0

MOBLAS-7 satisfies the energy requirements, but MLRS may have to widen their divergence to ensure maximum energy density at the spacecraft is not exceeded.