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## B. SLR 2000

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SLR 2000 is a concept for a totally automated subcentimeter SLR system presently being studied at GSFC. If funding permits, a prototype would be installed and tested at the Goddard Geophysical and Astronomical Observatory (GGAO) in FY98 and a small number of automated stations would be fielded by the year 2000.

Unlike present systems, the "SLR 2000" system is being designed to: 1) operate autonomously without the need for onsite operators; 2) present no hazards (i.e. optical, electrical, and/or chemical) to personnel in the vicinity or to overflying aircraft; and 3) have a mean time between failures (MTBF) of at least three months. It is assumed that the systems are located at "friendly" sites where some level of security is provided and where certain low level service functions (e.g. commercial power, communications, heat pump service, cleaning, etc.) are available or can be contracted for locally on an as-needed basis.

The main system, which is illustrated in Figures 1a and 1b, consists of two parts - an optical head and electronics rack. The optical head contains the laser transmitter and power supply, transmit/receive switch, optical telescope, tracking angle sensor (intensified CCD camera), detector and power supply, two angular encoders, azimuth and elevation motors, and a protective dome. The optical head mounts directly to the top of a concrete pier which contains the geodetic monument and forms part of the environmental housing for the hardware and servicing personnel. It is equipped with electronic levels for leveling the mount and monitoring its stability.

The electronics rack, depicted in Figure 2, is located inside the pier and contains the computer and hard disk with UPS (Uninterruptible Power Supply), a GPS-disciplined rubidium oscillator, gating and timing electronics, encoder electronics, azimuth and elevation servo electronics, auxiliary power supplies, security/environmental sensor interfaces, and power and communications interfaces. Temperature and humidity inside the pier is controlled by an external heat pump and an internal emergency backup heater. Two-way data communications is established via NASA Science Internet (NSI). A phone for use by maintenance personnel is provided in the central pier.

An external meteorological station continuously monitors ambient pressure, temperature, humidity, and wind speed and transmits the data to the system computer. A collocated GPS geodetic receiver also transmits its data over the NSI dataway.

# SLR 2000 STATION FRONT VIEW

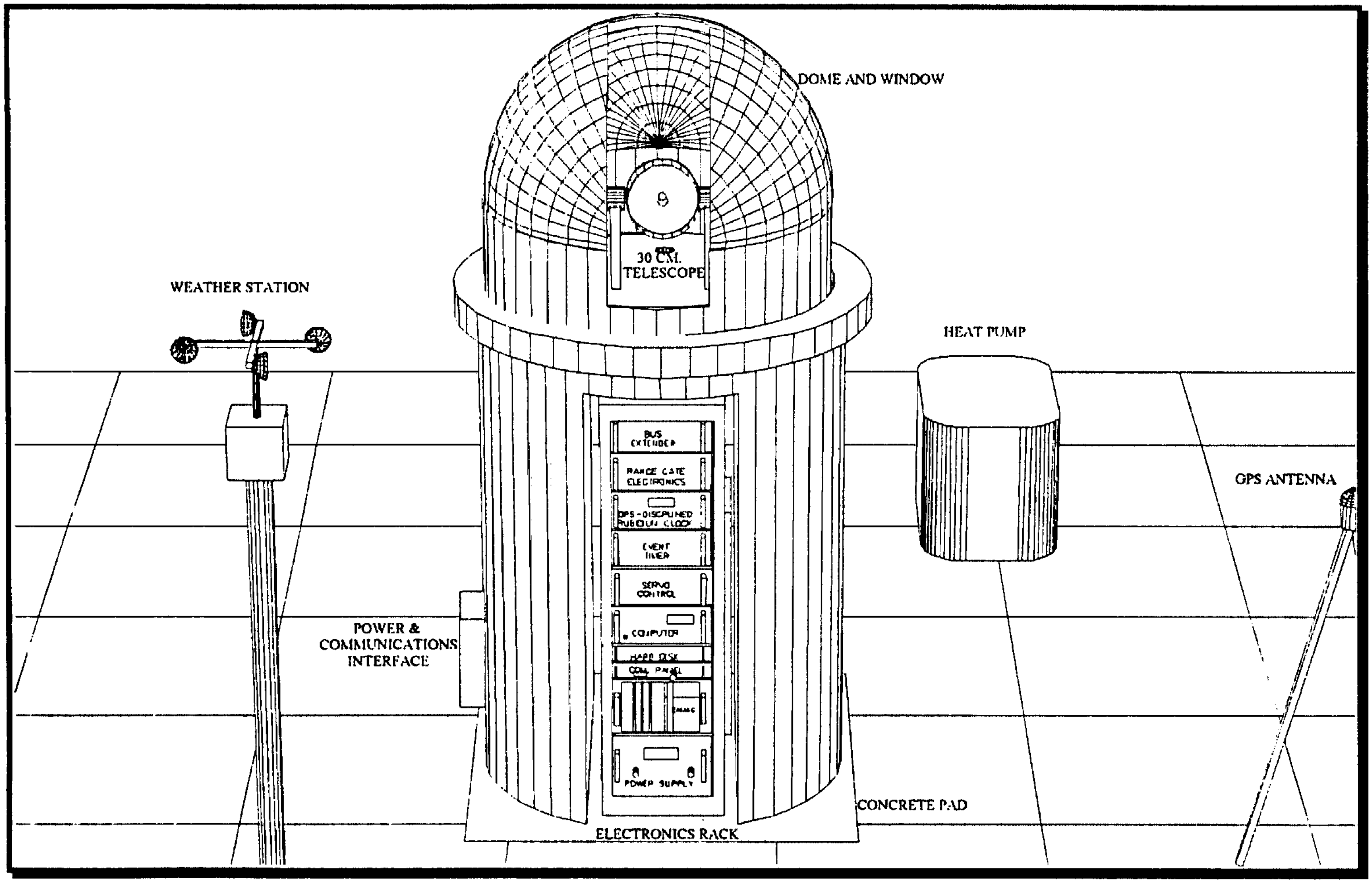


Figure 1a.

# SLR 2000 CUT VIEW

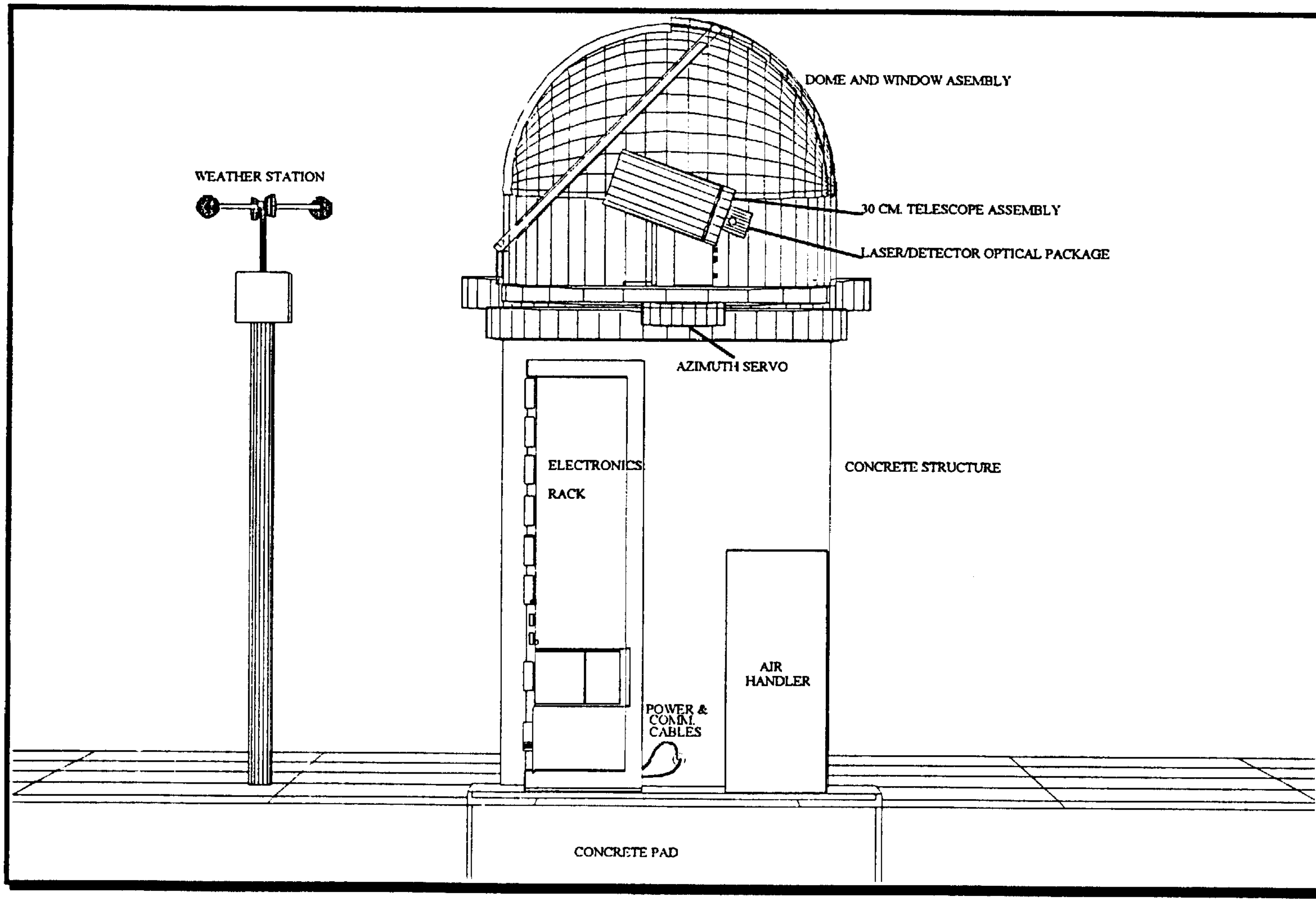


Figure 1b.

# SLR 2000 ELECTRONIC RACK LAYOUT

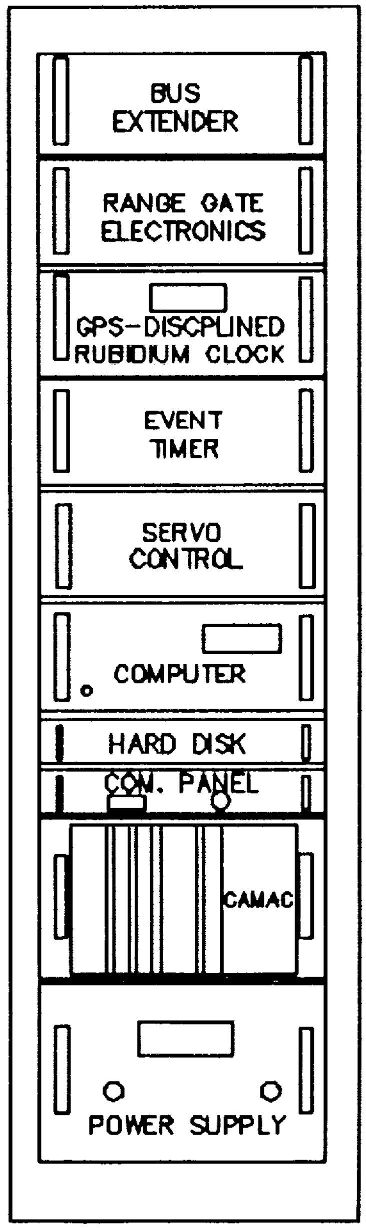


Figure 2.

To keep capital costs low, the telescope is assumed to be comparable in size to present TLRS systems, i.e. on the order of 30 cm diameter. It is further assumed that, to meet eye safety requirements at close range, the transmitter and receiver share the full aperture of the telescope. Since the single pulse eyesafe limit is 0.5 [mu]J/cm2 at a doubled Nd:YAG wavelength of 532 nm, the maximum allowable transmitted single pulse energy from a 30 cm aperture is 353 [mu]J or almost three orders of magnitude smaller than the present TLRS-3,4 energy of 100 mJ. To overcome this sizable loss in pulse energy and still maintain a comparable number of single shot ranges and precision per normal point, one must substantially increase the pulse repetition rate over the current 5 Hz and/or reduce the transmitter divergence angle from its present nominal value of 30 arcseconds full width. However, because of the integrating effects of the eye, a green laser operating at 1 KHz must be reduced to about 88 [mu]J per pulse to meet ANSI eye safety standards.

Recently developed Q-switched "microlaser" technology has demonstrated the capability to deliver over 30 [mu]J per pulse at 4 to 5 KHz rates. These diode-pumped devices are extremely small, rugged, and simple and can be mounted directly to the telescope. The demonstrated pulsewidths of 270 picoseconds are already adequate to support subcentimeter ranging and can most likely be driven below 100 picoseconds. Energy can be easily scaled upward through the use of small, passive, diode-pumped amplifiers.

Figure 3 shows the number of single shot ranges expected in one two minute normal point interval from Lageos as a function of the mean signal strength in photoelectrons (pe) and the detection threshold (1, 2, and 3 pe). If the single shot range precision is 1 cm, then 100 range returns per two minute interval would result in a 1 mm precision Lageos normal point. From Figure 3, this can be achieved with a mean signal strength of only 0.001 pe for a 1 pe threshold, 0.045 pe for a 2 pe threshold, and 0.18 pe for a 3 pe threshold.

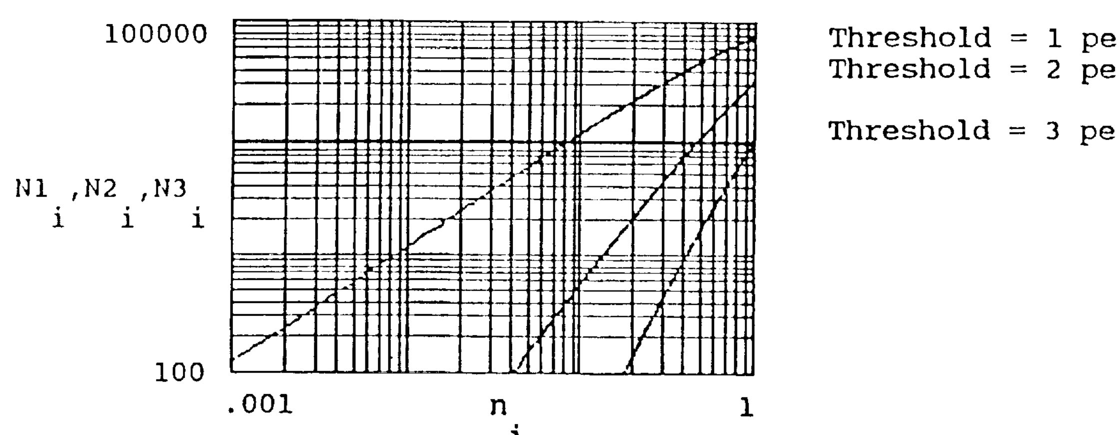


Figure 3.

Calculations show that it will be necessary to set a 2 pe threshold for daylight operation of the system although it can be lowered to 1 pe at night to increase data yield. For a "clear" atmosphere (defined as 15 Km visibility) at a minimum elevation angle of 20$^{o}$, the transmitter beam divergence (and corresponding receiver field of view) must be about 8 arcseconds full width to achieve the desired data rate of 100 Lageos ranges per normal point with a 2 pe threshold, fully eyesafe beam, and 30 cm receive aperture. At night, however, this would increase to 5000 ranges per normal point by resetting the threshold to 1 pe. For higher elevation angles and better atmospheres, these numbers would increase whereas, for worse atmospheres (e.g., in the presence of light haze or cirrus clouds), they would decrease. Satellites lower than Lageos would, of course, experience much higher rates of return.

Although the eight arcsecond beamwidth has implications for acquisition and tracking, the required level of tracking precision is within the state of the art - especially with angular feedback from the intensified CCD camera. Some relaxation of detection threshold (and hence beamwidth and spatial field of view requirement) may be permitted by more effective spectral and temporal filtering. Recently developed commercial filters (Accuwave Inc.) claim spectral bandpasses as small as 0.0125 nm (with optical throughputs of 15%) compared to the conservative value of 0.3 nm used in the present calculations. Adaptive range gate widths would further reduce the false alarm rate in daylight operations. Another possibility to be considered seriously is the use of longer wavelengths, specifically the fundamental infrared Nd:YAG wavelength, which would permit the transmission of ten times more energy per pulse (~1 mJ) and provide much better atmospheric transmission. Laser transmitters at eyesafe wavelengths of 1.5 microns or higher also exist and would permit still greater energies per pulse and low repetition rates, but feasibility rests heavily on the successful development of new high speed infrared detectors (e.g. GaAs) with projected quantum efficiencies in the 5 to 10% range and efficient, compact short pulse transmitters.

In summary, the present SLR 2000 concept seems feasible but further tradeoff studies need to be completed in order to identify the optimum wavelength of operation. Additional research and development is required in areas such as the laser, event timer, spectral and temporal filtering, and detector.