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APPLICATIONS OF SLR

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INTRODUCTION

Satellite Laser Ranging (SLR) has a rich history of development which began in the 1960s with 10 meter-level first generation systems. These systems evolved with order of magnitude improvements to the systems that now produce several millimeter single shot range precisions. What began, in part, as an interesting application of the new laser technology has become an essential component of modern, precision space geodesy, which in turn enables contributions to a variety of science areas.

Modern space geodesy is the beneficiary of technological developments which have enabled precision geodetic measurements. Aside fro SLR and its closely related technique, Lunar Laser Ranging (LLR), Very Long Baseline Interferometry (VLBI) has made prominent science contributions also. In recent years, the Global Positioning System (GPS) has demonstrated a rapidly growing popularity as the result of demonstrated low cost with high precision instrumentation. Other modern techniques such as DORIS have demonstrated the ability to make significant science contributions; furthermore, PRARE can be expected to contribute in its own right.

An appropriate question is "why should several techniques be financially supported"? While there are several answers, I offer the opinion that, in consideration of the broad science areas that are the benefactors of space geodesy, no single technique can meet all the requirements and/or expectations of the science areas in which space geodesy contributes or has the potential for contributing. The more well-known science areas include plate tectonics, earthquake processes, Earth rotation/orientation, gravity (static and temporal), ocean circulation, land and ice topography, to name a few applications.

It is unfortunate that the modern space geodesy techniques are often viewed as competitive, but this view is usually encouraged by funding competition, especially in an era of growing needs but diminishing budgets. The techniques are, for the most part, complementary and the ability to reduce the data to geodetic parameters from several techniques promotes confidence in the geophysical interpretations.

In the following sections, the current SLR applications are reviewed in the context of the other techniques. The strengths and limitations of SLR are reviewed and speculation about the future prospects are offered.

SLR Summary

Satellite Laser Ranging measures the round-trip time-of-flight for a laser pulse to travel from a transmitter to a target and back. Current and near-term satellite targets include Starlette (1000 km altitude), Ajisai (1500 km), ERS-1 (800 km), Lageos (59000 km) and Etalon-1 and -2 (25000 km). Future satellites include TOPEX/POSEIDON (August 1992 launch) and Lageos-2 (October 1992 launch). The geodetic satellites (Starlette, Ajisai, Lageos and Etalon) have a long orbital lifetime measured in thousands of years to millions of years for the high altitude satellites, thereby offering a distinct advantage that the satellite will be available at no cost for a very long period of time. Only the ground segment requires operation and maintenance support. By contrast, all other satellite techniques (GPS, DORIS, PRARE) rely on an active space segment with a lifetime determined by the on-board power system, usually several years. VLBI, on the other hand, uses extragalactic radio sources which will, presumably, be available for a very long time.

Precision Orbit Determination/Gravity

The traditional strength of SLR has been in the ability to determine the orbits of target satellite with high accuracy. In the case of TOPEX/POSEIDON, SLR is the primary means of precisely determining the orbit to the required 13 cm in the radial component in support of radar altimeter analyses. SLR tracking of NASA altimeter satellites has been an important element in the accomplishment of the respective mission goals. SLR, however, has a distinct disadvantage created by dependency on atmospheric transparency. Radiometric systems, such as GPS and DORIS, are potentially able to provide essentially continuous tracking. Since TOPEX/POSEIDON includes SLR, GPS and DORIS, it will provide a unique opportunity to evaluate the performance of all systems. The focus of tracking systems on future satellites may be GPS with SLR as a backup. Nevertheless, it is important to note that the passive nature of SLR provides an extremely reliable space segment--it simply will not fail except under catastrophic circumstances. A cautionary note for the future is in order. The risk of regarding SLR as a backup system encourages the reduction in operating systems for budgetary reasons, but as systems close, it becomes more difficult to reactivate them in the event that the backup mode must be initiated.

Improvements in the gravity field, including the gravitational parameter GM, are other areas where SLR has made very significant contributions. The development of new models in preparation for TOPEX/POSEIDON have benefitted from the SLR data base that has been accumulated over the years, some of which has been used in previous fields and some has not. Gravity fields used for GPS applications, such as the Department of Defense WGS-84, have used SLR data from Lageos and Starlette which have particularly contributed to determination of low degree and order gravity coefficients. Current GPS applications use GEM-T3 or other, more recent fields, which have relied on SLR data. Furthermore, the Etalon satellites can be used to study gravitational effects that will be somewhat similar to those influencing the GPS satellites, except for the particular GPS effect of deep gravitational resonance.

SLR has made unique contributions to the study of temporal variations in the gravity field, both tidal and non-tidal variations. These studies have, in part, been made possible by the nature of low area-to-mass ratio satellites (Lageos and Starlette), which diminish the nongravitational forces. This diminishment enhances the opportunity to identify the spectral content of gravitational effects. Furthermore, the study of temporal changes in gravity has been enhanced by the ability to investigate the orbit evolution over long periods of time, spanning in some cases more than 15 years.

Earth Orientation/Reference Frame

All satellite techniques are, conceptually, able to define a reference frame coincident with the center of mass. VLBI, by using extragalactic radio sources, is insensitive to the center of mass; however, if VLBI is used to track artificial satellites, VLBI would have the sensitivity of the other satellite techniques. The SLR precision and long term continuity (Lageos was launched in 1976) has been a consideration in adopting the SLR origin to be the origin of the International Earth Rotation Service Terrestrial Reference Frame.

All space geodetic techniques have demonstrated sensitivity to polar motion. Current comparisons between polar motion series obtained from SLR and those obtained from VLBI show agreement at the 0.5 milliarcsecond level. GPS developments are underway, including the proof of concept International GPS Geodynamics Service (IGS) slated to begin in June 1992.

VLBI provides long term UT1 that cannot be matched by the satellite techniques at the present time. Lageos has been demonstrated to provide independent determinations of UT1 over a 50 day interval. The higher altitude of the Etalon satellites suggests that a much longer period of UT1 determination is possible, but the sparse SLR tracking of the Etalon satellites has allowed only limited demonstrations of the UT1 capability. It is worth emphasizing that the low area to mass ratio of Lageos and Etalon result in much smaller nongravitational forces than the GPS satellites. The nongravitational forces are a significant factor in the GPS satellites that limit the use of these satellites to very short term UT1 (sub-daily to a few days).

Comparisons have been made between SLR and VLBI reference frames using collocated instruments, either permanent or mobile. These comparisons have shown agreement at the 2 cm level.

FUTURE

With the launch of Lageos-2, there will be two Lageos and two Etalon satellites. Within a few years, a second Starlette satellite will be launched. Starlette and Lageos have provided much of our knowledge about variations in the gravity field as well as contributing to the development of gravity models for science applications and for precision orbit determination. Two Lageos satellites, for example, will enable improved Earth rotation determination and more rapid determination of site positions. New developments in on-site software have enhanced the ability of SLR to provide high precision quick-look data that can be used for science applications and to assure tracking of the diverse constellation of satellites now available for SLR tracking. Nevertheless, only one satellite can be ranged at a time and the involvement of the science community in the process of establishing priorities is essential.

No single space geodetic technique can meet all of the application requirements of the science community. Each technique provides some unique contribution, though most of the techniques overlap in some areas. In an era of diminishing budgets, the determination of the appropriate balance of techniques and the prospects of losing or eliminating some science applications must be considered as emphasis is redistributed.

The international collaboration in the SLR community has been outstanding. The promotion of further collaboration will enhance the prospects for long term availability of a global SLR network, thereby assuring the continued collection of data for the purpose of gaining better scientific understanding of our planet.

Timely Issues