IS LUNAR RANGING A VIABLE COMPONENT IN A NEXT-GENERATION EARTH ROTATION SERVICE?

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ABSTRACT

Several new "space" techniques have been used for episodic determination of Earth rotation parameters, usually the variation in apparent longitude (UT0) and apparent latitude of an observing station. Earth rotation services require more than episodic determinations; they need near-daily determinations. Since 1975, planning has been underway for a demonstration of the viability of lunar laser ranging for such a usage. The observing campaign named Earth Rotation from Lunar Distances (EROLD) was organized with the proposed activity to cover the years 1977-78. Progress has not been so rapid as hoped, but it remains true that lunar ranging has produced more Earth rotation information than other new techniques.

Silverberg (1979) has dealt with the generalities of the application of lunar laser ranging (LLR) to the problem of the experimental determination of Earth rotation. The theoretical bases have been so thoroughly presented in previous symposia and Commission meetings (e.g. Mulholland, 1977) that it seems unnecessary to repeat them here. It is rather my purpose to discuss the present actuality. In doing so, I will begin by stating my prejudice: Earth rotation is a phenomenon that requires continual monitoring, and any system that proposes determination of Earth rotation must address itself to the hard questions of service bureau operations before it can be taken seriously.

It was in this spirit that, in 1974, a proposal was presented to COSPAR for an observing campaign to be called "Earth Rotation from Lunar Distances" (EROLD). The goal was not just to make episodic determinations of the Earth rotation parameters, but to try to meet a regular and frequent schedule, such as those now followed by the BIH and the IPMS networks. The idea met with approval, and the organization moved forward, with the goal of a coordinated observing campaign to begin on 1 January 1977. The Bureau International de l'Heure accepted the responsibility for the combined data reduction, in collaboration with the Centre

D. D. McCarthy and J. D. Pilkington (eds.), Time and the Earth's Rotation, 257–260.

d'Etudes et de Recherches Géodynamiques et Astronomiques; the EROLD Steering Committee was composed with representatives of the two international services and each of the national observing groups. The date for beginning the campaign was chosen because it seemed likely that at that time there would be at least three stations that would be fully operational at that time; this is a practical (though not a theoretical) minimum for such an operation. As noted by Silverberg, however, this is a technique in which the relative ease of data reduction and analysis is heavily paid for in the difficulty of the operational aspect. The result is that, in May 1978, there is still only one station producing regular data of adequately high quality. The BIH/CERGA data processing system has been ready for experimental use since the beginning of 1977; in the absence of multiple stations, it has been used only to determine UT0 for the McDonald Observatory (Calame, 1979). Perhaps it is worthwhile here to give a brief summary of the observing situation.

AUSTRALIA -- The station at Orroral recorded its first statistically-significant event in July 1977. Since then, several system problems have been discovered and solved. It is believed that high-quality observations could begin any day.

FRANCE -- The new 1.5 m telescope was installed at Calern in June 1977. After the replacement of faulty parts, tracking tests were resumed in this past month (April 1978). The refurbished laser, which had been operated successfully in the Pic-du-Midi station, is installed, as is most of the other equipment. Operations could begin later this year.

GERMANY (Federal Republic) -- The artificial satellite laser station at Wettzell is being upgraded to lunar capability, but the first attempts at the Moon cannot be anticipated before Spring 1979.

JAPAN -- The Dodaira station has experienced much hardware difficulty. Recent modifications permit one to hope for rapid progress.

USA -- The McDonald station, in continuous operation since July 1969, continues to show that the technique is feasible. Although operations were reduced to 18 days per lunation for several months due to budget restrictions, they are back to 21-day operation now. For several years, McDonald has averaged about 25-30 observation normal points per lunation. Accuracies of 5-cm are now common, although not yet the rule. The Haleakala station continues to have a detector problem that prevents their lunar echos from being timed with an accuracy better than about 5 ns (75 cm). Regular high-quality data should be acquired regularly as soon as this problem is identified and fixed.

USSR -- Ranging operations at the Crimean station are still conducted only 20-25 days per year, which is inadequate for Earth rotation use. A dedicated transportable station is expected to be ready in 1980.

Thus, a summary of the present situation of EROLD is:
-- The data analysis and distribution is ready;

https://doi.org/10.1017/S0074180900036329 Published online by Cambridge University Press

-- One station demonstrates that near-daily operations can be maintained;
-- Three-station operation may become a reality at any moment;
-- Full network (5-6 station) operations cannot be expected before late 1978 or early 1979.

Unfortunately, excepting dates, this summary has not changed in more than a year. With only one station, it has not been possible to measure UT1 or the coordinates of the pole. On the other hand, it is not true that LLR has produced negligible Earth rotation information. In addition to Calame's work already cited, the following UT0 determinations have been made:
-- Stolz et al (1976) presented values obtained on 194 separate days over the interval 1970-75, applying a very strict hour-angle criterion to select the days to be studied;
-- Shelus et al (1977) selected a specific lunation, using all of the data to obtain both daily and 2-day means nearly continuously over a 21-day time interval;
-- King et al (1978) have analyzed essentially all of the data from 1969-76, but with averaging times of up to ten days, giving on the order of 150-200 determined values;
-- Williams (1978) reports having obtained UT0 values for about 500 individual days over the interval 1970-77.

The density is not high enough, but it is much better than is generally realized. In fact, there have been more determinations of UT0 by lunar ranging than by all of the other "space" techniques combined, and it is worse than an error to overlook this fact. The method has the unique advantage of providing a direct tie to the celestial coordinate system with only one station per observation; there are other advantages, and even disadvantages, but these have been detailed elsewhere (e.g. Mulholland and Calame, 1977).

I do not wish to leave you with the feeling that I know or believe that LLR is the solution for an Earth rotation system of the future. In fact, I believe that the future system (like the present one) will combine several techniques, in an attempt to capitalize on the strong points of each. The purpose of EROLD is to test a specific technique in a real-world mode, so that the strong and weak points might be evaluated realistically. It is a procedure that I recommend for each of the new techniques. When that has been realized, then rational choices can and (I hope) will be made.

ACKNOWLEDGEMENTS

I am grateful to E. C. Silverberg and O. Calame for helpful discussions and criticism of the manuscript. Preparation of this paper was supported by the U. S. National Aeronautics and Space Administration, under grant NGR 44-012-165.

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DISCUSSION

P. Paquet: In suggesting that lunar ranging should be a component of a future Earth rotation monitoring service, do you feel that it should contribute on a daily basis or as a system to recalibrate the reference system used to define the orbit of Lageos?

J. D. Mulholland: Whether lunar observations are required on 5, 10 or 20 days per month is, I think, still to be determined from experience. In any case, LLR will be required for Lageos calibration, because of the problem of rectification already mentioned by Melbourne. An orbit rectification is an artificial discontinuity in the mathematical description of the orbit, and it is needed because the models of the acceleration are inadequate. The Moon is free from this problem; when we speak of data analysis over an interval of eight years we mean a continuous, dynamically consistent orbit over the entire interval. This is important for geophysical reasons. For example, if the Chandler motion is driven by seismic activity then large seismic events will introduce real discontinuities into the rate of polar motion and rotation. It is important that such phenomena be discussed with techniques from from artificial discontinuities that could mask or mimic the real effects. Thus, it seems to me that significant LLR activity will be needed, but that the density of observations required is not yet known. This should be a primary goal of experimental observing campaigns such as EROLD.

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