AN IMPROVED POLAR MOTION AND EARTH ROTATION MONITORING SERVICE USING RADIO INTERFEROMETRY

William E. Carter, Douglas S. Robertson, Michael D. Abell
National Geodetic Survey, National Ocean Survey
National Oceanic and Atmospheric Administration
Rockville, Maryland 20852, U.S.A.

ABSTRACT

The National Geodetic Survey (NGS) of the National Ocean Survey (NOS), a component of the National Oceanic and Atmospheric Administration has begun a project to establish and operate a 3-station network of permanent observatories to monitor polar-motion and Earth rotation (UT1) by radio interferometric observations of quasars. The project designation is POLARIS (POLar-motion Analysis by Radio Interferometric Surveying).

The POLARIS observatories will be equipped with a new generation of instrumentation and software, the Mark III data acquisition and processing system currently under development by a multi-organizational team.

1. INTRODUCTION

According to plate tectonics concepts, the outer skin or crust of the Earth, called the lithosphere, consists of a dozen or so large, relatively rigid plates that float on the partially molten aesthenosphere. New lithospheric material wells to the surface from deep within the Earth along the ocean ridges. The plates tend to migrate away from these spreading centers. When they collide, large stresses and strains develop causing volcanism, earthquakes, mountain building, faulting, and the subduction of the edges of some plates.

The combined effects of the plate motions and distortions result in changes in the relative locations of some topographical features by as much as several centimeters per year. Measurements of these motions, both on local and global scales, are expected to be very useful in quantifying plate tectonics concepts. They may prove to be very useful indicators for predicting impending cataclysmic events, such as earthquakes.

D. D. McCarthy and J. D. Pilkington (eds.), Time and the Earth's Rotation, 191–197.

Present operational geodetic methods of measurement do not have either the spatial or temporal resolution required for large scale geodynamic investigations. All of the presently known developmental techniques which are considered capable of achieving the required resolutions are astronomical or space techniques. These measurements are made in some exterior, or non-Earth-fixed, frame of reference. The transformations of the measurements to an Earth-fixed frame of reference requires knowledge of the orientation of the Earth, with respect to the non-Earth-fixed frame of reference, at the time of the measurements. Information presently available on polar motion and Earth rotation, which is largely derived from optical stellar observations, does not have sufficient spatial or temporal resolutions for use with these ultra-high accuracy methods.

The National Geodetic Survey, NOS, has reviewed the candidate methods for making geodetic measurements of sufficient accuracy for geodynamic applications. Our conclusion is that independent station radio interferometry, commonly referred to as Very Long Baseline Interferometry (VLBI), is the best method now available. This opinion is supported by the results of the series of experiments reported on by Robertson, et al. (1978), the successful completion of the initial field tests of the third generation (Mark III) VLBI data acquisition and processing systems during September 1977, and the impressive performance predicted by computer simulations for very modest VLBI networks.

We are planning to implement a comprehensive program in geodynamics which will make extensive use of radio interferometric surveying. The vanguard project in this program is known as POLARIS. Under this project, NGS will establish and operate a 3-station network of permanent observatories to determine polar motion regularly to ±10 cm and UT1 to ±0.1 milliseconds in averaging periods of less than 24 hours. This paper presents the status and plans for POLARIS.

2. THE POLARIS NETWORK

NOAA is working closely with the National Aeronautical and Space Administration (NASA) to establish the POLARIS network. Two existing, lightly used, radio telescope facilities have been identified for probable use in project POLARIS: the 18-meter diameter Westford telescope at the Northeast Radio Observatory Corporation site near Boston, Massachusetts, and the 26-meter diameter telescope at the Harvard Radio Astronomy Station (HRAS) near Fort Davis, Texas.

The Westford facility is particularly attractive because it is located less than 1.25 kilometers from the Haystack Observatory, which originated much of the design and developmental work on the Mark III

VLBI system. NGS will be able to rely on the expertise of the Haystack staff and time-share the Haystack multi-base line Mark III correlator. Other advantages include the joint use or comparison of local oscillators via the actively stabilized land line which connects the two facilities, joint observing programs to ensure the proper functioning and calibration of both systems, joint system improvement developmental programs, and cooperative data analysis.

The HRAS site also has some unique attributes. It is located less than 8 kilometers from the University of Texas McDonald Observatory, which has been used regularly since 1969 for lunar-laser ranging experiments (LURE). NASA, the University of Texas, and NOAA already have a cooperative program to monitor the stability of a region extending more than 100 kilometers from the McDonald and HRAS sites. A broad mixture of techniques are being used. These include electromagnetic distance measurements, spirit levelling, gravimetry, seismometry, and tilt measurements (Carter and Vincenty, 1978; Dorman and Latham, 1976).

Other existing facilities currently under consideration are the National Environmental Satellite Service Observatory near Fairbanks, Alaska, and a facility at the NASA Goldstone complex near Barstow, California.

Serious consideration is also being given to the construction of a new radio observatory on the grounds of the U. S. Naval Observatory's (USNO) Time Service substation, near Richmond, Florida. A network including the Westford and Richmond sites, which are both very near the Atlantic Coast, would be excellent for cooperative programs, including both geodynamic and time transfer, with European observatories. Shared operations between NGS and USNO would be economically desirable for both agencies.

The selection of the POLARIS sites will be completed during 1978, and instrumenting of the first two observatories will begin immediately thereafter. Cooperative observing sessions with other observatories which are being instrumented with Mark III VLBI systems may begin as early as July 1979. The goal is to have the total POLARIS system fully operational by the end of 1981.

3. INSTRUMENTATION

The POLARIS network will use the Mark III VLBI data acquisition and processing system. A simplified block diagram of this system is shown in Figure 1. Briefly, the more important characteristics include:

- Very wide band receiver front end (400 MHz) for high delay resolution.

https://doi.org/10.1017/S0074180900036238 Published online by Cambridge University Press

- Dual frequency (X and S band) receiving systems for extraction of the ionosphere delay.
- Continuous system calibration.
- Very stable hydrogen maser clock system.
- Water vapor radiometer and meteorological sensors for the determination of the tropospheric delay.
- A wide bandwidth (56 MHz) data recording system for good signal-to-noise ratio, even with small (10-meter diameter) antennas.
- Automated control and monitoring with a mini-computer in order to facilitate easy field operations.

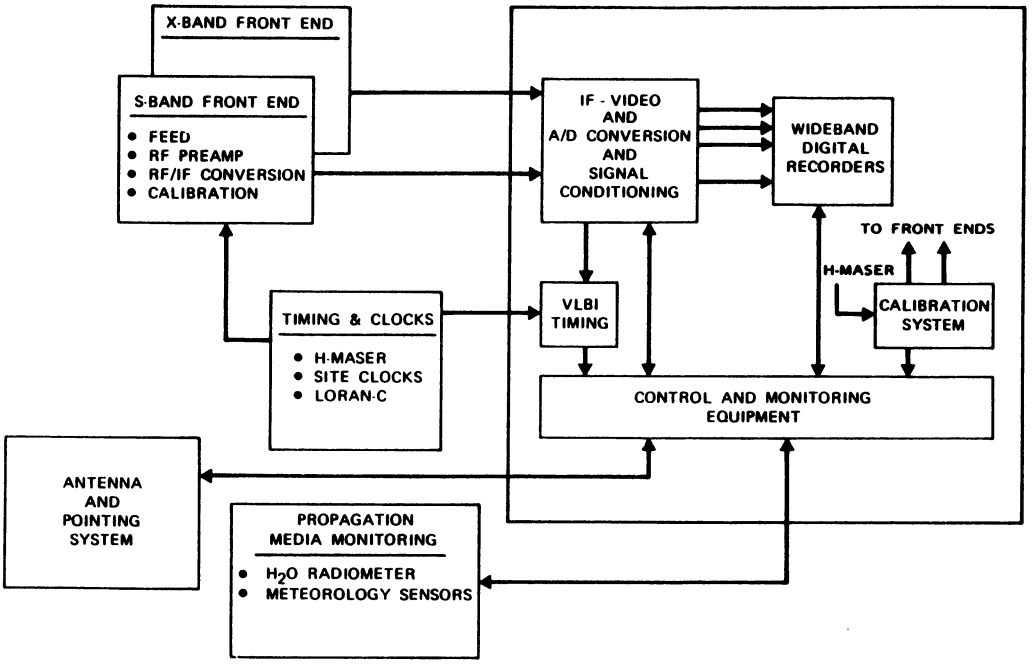

Figure 1. Block Diagram of Mark III VLBI Data Acquisition System.

https://doi.org/10.1017/S0074180900036238 Published online by Cambridge University Press

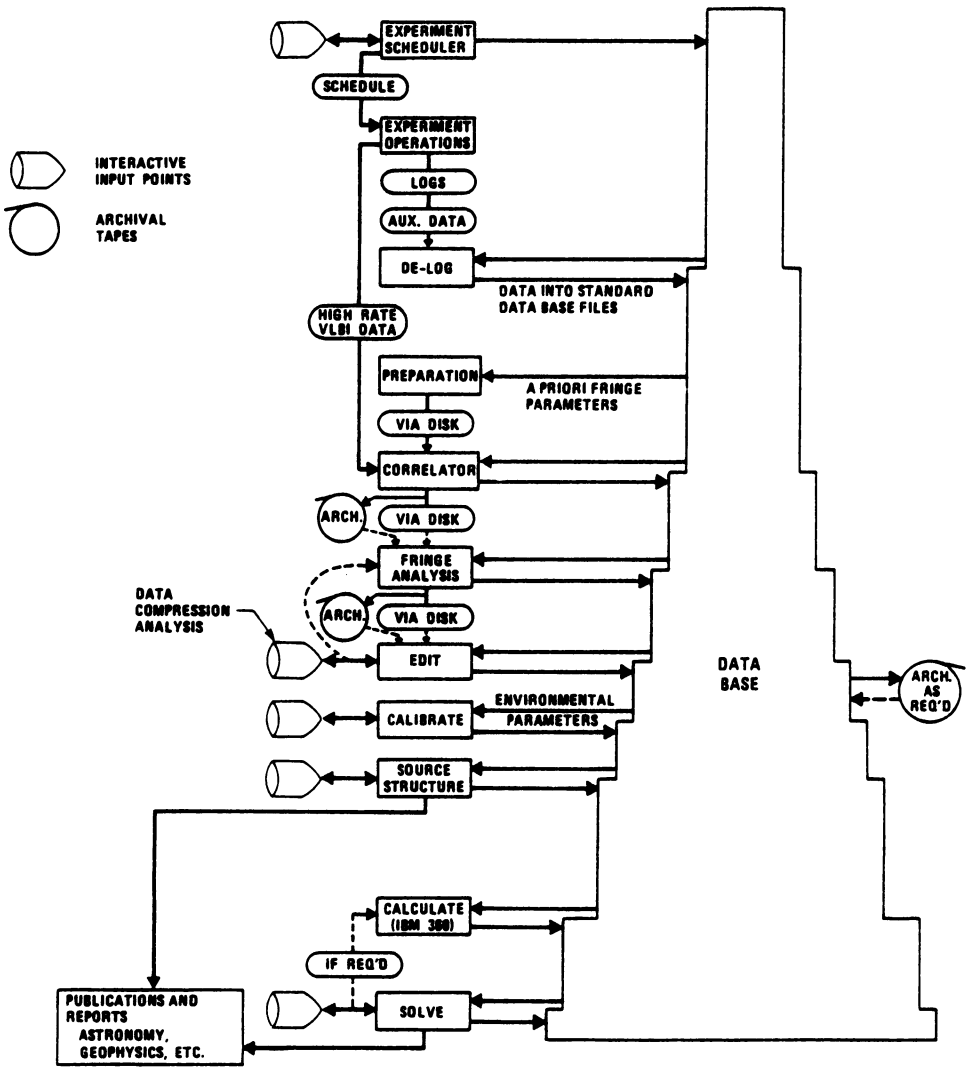

Figure 2. Schematic of the Mark III VLBI Data Processing System.

A completely new set of well-documented software has been developed as an integral part of the Mark III VLBI system. Figure 2 is a schematic representation of the system. The most salient characteristic is the structuring of the various programs around a central data base. A variety of programs, which accomplish such diverse functions

https://doi.org/10.1017/S0074180900036238 Published online by Cambridge University Press

as generating observing schedules, processing data, and preparing publications, all interact with this single data base.

The primary programs, i.e., those used to do the actual reduction of VLBI data to extract the geodetic information, are operational. In fact, the data reduction and analyses for the paper by Robertson, et al. (1978) were performed with the Mark III software but using Mark I data, on a mini-computer system at NASA Goddard Space Flight Center.

4. CONCLUDING REMARKS

The expected spatial and temporal resolutions of the POLARIS data constitute at least an order-of-magnitude improvement over presently available data. Until data of this quality have actually been collected and analyzed, we will not know the most desirable operating mode. The timely analysis of data and the adjustment of procedures and schedules for responding to the newly acquired knowledge from the analyses will be particularly important during the first few years of POLARIS operations.

The National Geodetic Survey intends to seek actively the advice and cooperation of the international scientific community. The POLARIS data will be disseminated as quickly as possible in the most convenient form that can be devised within budgetary constraints.

It is hoped that other nations will give serious consideration to establishing one or more observatories suitably instrumented and staffed for operational use of radio interferometry. We look forward to the development of an international network of observatories working cooperatively to advance both the theoretical and practical aspects of the earth sciences.

REFERENCES

Carter, W. E. and Vincenty, T.: 1978, "Survey of the McDonald Observatory Radial Line Scheme by Relative Lateration Techniques" NOAA Technical Report NOS 74 NGS 9.

Dorman, J. H. and Latham, G. V.: 1976, "Preliminary Geophysical and Geological Site Survey of the Region of the McDonald Observatory, West Texas" Final Technical Report, NASA Contract NGS 7159.

Robertson, D. S., Carter, W. E., Corey, B. E., Counselman, C. C., Shapiro, I. I., Wittels, J. J., Hinteregger, H. F., Knight, C. A., Rogers, A. E. E., Whitney, A. R., Ryan, J. W., Clark, T. A., Coates, R. J., Ma, C. and Moran, J. M.: 1979, this volume.

DISCUSSION

I. I. Mueller: Will the stations be available for 24 hours per day?
W. E. Carter: Fort Davis belongs to Harvard College, but we hope to get 50% of each day; Westford is available almost full time and if we build another station in Florida that probably will be, too.
K. Johnston: Is Fort Davis a reliable VLBI site, and does the Fort Davis - Haystack baseline really give optimum geometry?
W. E. Carter: We intend to update the Fort Davis antenna; Fort Davis is a good location within the USA and is close to other sites where relevant work is done.

https://doi.org/10.1017/S0074180900036238 Published online by Cambridge University Press