MEMORANDUM OF UNDERSTANDING

AMONG THE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION,

THE

UNITED STATES NAVAL OBSERVATORY,

AND THE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FOR THE

DEVELOPMENT AND OPERATION

OF THE

MARK IV VLBI SYSTEMS

10/25/93
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1. Purpose of Agreement

The purpose of this agreement is to delineate the respective roles and responsibilities of the National Oceanic and Atmospheric Administration (NOAA), the United States Naval Observatory (USNO) and the National Aeronautics and Space Administration (NASA) in the joint design, development and operation of a Mark IV Very Long Baseline Interferometry (VLBI) Data Acquisition System and a Mark IV Correlator to be used by the agencies in their interrelated VLBI programs.

2. Background

NASA

One goal of the NASA DOSE (Dynamics Of the Solid Earth) VLBI program is to increase system precision to the millimeter level. To attain this level, the Mark III system will be improved in an evolutionary manner, to a level which can be considered a Mark IV system. This upgrade will double the sensitivity of the data acquisition and correlator systems. The key elements that will cause this to occur include:

1) Upgrading the Mark IIIA correlator to support new modes and to increase the capability of the data-recording system, and

2) More than quadrupling the existing maximum data rate of the Mark IIIA data acquisition system from 224 Mbits/second to 1024 Mbits/second.

USNO

Earth orientation data and predictions are required by the Department of Defense for navigation, tracking, and guidance. Accurate predictions require accurate, timely, and reliable observations. VLBI has been chosen as the Navy technique because it is the most accurate and is all-weather.

New technology leading to major improvements in the VLBI technique (Mark IV), will permit the use of smaller antennas, weaker sources, and reduction of observing time required for each source. The ability to observe sources better distributed over the sky and the ability to move antennas quickly around the sky will reduce systematic errors, the dominant source of error in current observations.

Reduced observational errors will lead to improved prediction accuracy. The reduced processing time made possible by real-time VLBI will also make an important contribution to improved prediction accuracy.

NOAA

NOAA has statutory authority to monitor variations in latitude and longitude. Under this authority NOAA is involved in the construction and maintenance of a global terrestrial geodetic reference frame suitable for scientific and engineering purposes with objectives as various as precise navigation, surveying, and monitoring sea-level variations as part of its Climate and Global Change program. NOAA is involved in a continuing effort to identify and employ the most modern, accurate, and cost-effective technologies to achieve these goals.

Very Long Baseline Interferometry has been the cornerstone of the NOAA effort for more than a decade. Detailed studies have demonstrated that VLBI has significant advantages over the other observing technique presently available, advantages in accuracy, reliability, and long-term stability and cost. Only for relatively short baselines (~100 km) do other techniques such as the Global Positioning System (GPS) satellite observations have a comparable performance at lower cost.

The continuing progress of VLBI technology is of critical importance to NOAA. The proposed improvement to millimeter accuracy would substantially improve NOAA's ability to monitor errors in sea-level measurements, and would greatly enhance its overall program for developing a global terrestrial reference frame.

3. Scope of Activities

The participating agencies agree to design, develop, deploy, and operate new generation Mark IV VLBI data acquisition systems and associated Mark IV correlator. All plans, designs, development, testing and the associated staffing, schedules and funding will be agreed on jointly by the three participating agencies. Responsibilities for specific subdivisions of the work will be assigned on the basis of negotiations, subject to organizational and resource constraints. Tasks required to design and develop the new systems that have been identified and assigned thus far are listed in Appendix A. Additional tasks and assignments, including detailed development, replication, deployment and operations plans will be formulated and added to the MOU as Appendix B, prior to the completion of the design task.

4. Duration of the Program

The primary observational programs in which the new systems will become a part, such as the NOAA/USNO NEOS program and the NASA DOSE Science program are intrinsically long-term activities, all lasting through the 1990's. Therefore, it is expected that they will have a useful life of at least ten to fifteen years, and with upgrades incorporating new technological improvements, may continue in operation for several decades.

5. Usage of the Newly Developed Systems

The primary purposes for the development of the new systems are to improve the accuracy of VLBI measurements with particular emphasis on the vertical. Each of the agencies has need of the new systems for their programs and have agreed to share in their development including the development of the first pilot units It is anticipated that NASA will establish industrial source(s) for production units, sustaining engineering and maintenance support for the newly-developed systems so that the agencies can each procure them to meet their own program requirements. Funding for production units designated for specific VLBI facilities may be on a joint basis if the facility is vital to each agency's program.

6. Withdrawal from Program

A participating agency may withdraw from this MOU and cancel its participation in the development of the new systems by giving written notice to the other agencies. Such notice should be given at least six months prior to the effective date of the cancellation.

7. Availability of Funds

All obligations expressed or implied by this MOU are contingent upon the participating agencies receiving the projected funding, and are subject to delay, modification, or cancellation in response to final funding levels.

Appendix A

A1 Management of Activities

All activities associated with the design, development and production of the Mark IV systems and Mark IV correlator will be directed by an Interagency Mark IV VLBI System Management Board (M4B). NOAA, USNO and NASA will each have a representative on the M4B. The NASA representative will serve as Chairman of the M4B, subject only to a unanimous vote of the M4B to rotate the chairmanship to another agency.
Three affirmative votes will constitute approval of routine actions by the M4B. However, any dissenting vote may be cast as a veto. Matters which cannot be resolved by the M4B will be submitted to higher management in the participating agencies. Actions by the M4B involving the commitment of funds or personnel will constitute recommendations, subject to approval by higher management in the participating agencies.

A2 Design and Development Phases

The NASA DOSE VLBI Program group will provide technical management for the design and development of the various system elements:

- Mark IV correlator
- Mark IV data system including recorders & elements of the new receiver
- New S- & X-band feed design

The NASA DOSE VLBI group will supervise and coordinate the day to day design activities and arrange for regular meetings of the M4B to review the design, assess progress, and reach decisions on major technical and management issues. Table 1 is a preliminary list of the major tasks of the design and development phases and their dates of accomplishment .

The first prototypes of the various Mark IV Data Acquisition System elements will be assembled at the Goddard Optical Geophysical and Astronomical Observatory (GGAO) for integration, testing and evaluation, using the Mobile VLBI System 3 (MV-3) as a testbed.

A special contract for the development of the Mark IV correlator has been negotiated by NASA.

NASA will serve as the lead agency in the purchase of production units of all Mark IV systems. Based on initial agency and DOSE requirements with accompanying funding assurances, the quantities for the first production will be set and appropriate contractual agreements will be made.

A3 Funding for the Design & Development Phases

Table 2 is a preliminary estimate of the costs for the design and development of the various elements of the Mark IV system. Distribution of cost will be decided by the M4B.

A4 Schedules and Funding for the Production Phase

Tables 3 and 4, which will be provided near the end of the design and development phase, are respectively, a preliminary cost estimate on a unit cost basis and, a schedule for the various system elements of the Mark IV systems. It is assumed that individual agencies will provide funding to NASA for the systems they need to meet their individual program requirements.

TABLE 1

MARK IV VLBI DESIGN & DEVELOPMENT TASKS

DATE	MILESTONE
	Task I Mark IV 1-gigabit/sec Recording System
1/90	Demonstrate 1-gigabit/sec record capability
10/90	Mark IV program start (agency concurrence at CDP Working Group)
2/91	New formatter demonstrated (single channel only)
6/91	18 Mbits/sec/track recording demonstrated
4/93	First new Mark IV formatter prototype completed & tested
4/93	Second formatter completed & tested
4/93	First full test of Mark IV Data Acquisition System
	Task II Mark IV Correlator System
3/92	Mark IV Correlator contract signed
9/92	Correlator VLSI Chip design study completed
12/92	Contract for VLSI development and production signed
2/94	System integration begins
3/95	Design and study for Station Units completed
3/95	Design of Correlator Units completed
3/95	Prototype Correlator Units built and tested
3/95	Replication of Correlator and Station Units begins
2/96	Prototype Station Unit completed and tested
3/97	Correlator delivered to USNO

TABLE 1 (CONTINUED)

MARK IV VLBI DESIGN & DEVELOPMENT TASKS

DATE	MILESTONE
	Task III Mark IV Field System Software
1/92	Present Mark III software ported to PC-class computer and operating at MV-3
3/92	VLBA software extensions completed
6/92	Mark IV software/controlled Mark IV recorder at MV-3
9/92	Mark IV software/first tested with Mark IV formatter
11/92	PC field system for new Kokee antenna on line

TABLE 2

COST ESTIMATE FOR DESIGN AND DEVELOPMENT PHASES

OF THE MARK IV VLBI SYSTEMS

(in $1,000s)

SYSTEM NAME	FY92	FY93	FY94	FY95	TOTAL
1. Mark IV correlator					
- VLSI Chip development		394			394
- Correlator develop. (2 x 3 baseline)	1,000	1,403	2,400		4,803
- 9 Station Correlator electronics			520		520
- Computer system		165			165
2. Field System Unification	167				167
3. Mark IV DAT (initial development)					
- Formatter	140	118			258
- Recorder	30	80	78		188
- Video converter		22			22
- System tests		92			92
	1,337	2,274	2,998	0	6,609