European VLBI for Geodesy and Astrometry

Informal Meeting held at the Geodetic Institute
in Bonn 28-29 April 1980

I. Introduction and general Status, Projects

1. At the opening of the meeting Prof. H. Seeger, director of the Bonn Geodetic Institute, summarized the status of the project of a dedicated geodetic VLBI telescope, which is to be built at the satellite tracking station of Wettzell in Southern Germany. This project will be supported jointly by geodesists in Munich, Francfort and Bonn with a combined funding by the German Science Foundation (Deutsche Forschungsgemeinschaft) and the Federal Government. The 20-25 m telescope will be equipped with receivers for the commonly used VLBI frequencies including the NASA S- and X-bands. A Mk III recording terminal has been ordered and a H-maser frequency standard for Wettzell is under construction at Ebauches S.A. in Switzerland. The principal activities of the future VLBI station will be concentrated on the participation in global as well as regional geodynamics programs.

2. A brief overview concerning the situation of geodetic and astrometric VLBI in Europe was given by J. Campbell. Since the inception of VLBI about 10 years ago there have been some sporadic geodetic VLBI activities in Europe; in particular the close cooperation between the Onsala Space Observatory (Sweden) and the MIT-Haystack-Group using the Mk I bandwidth synthesis system: this resulted e.g. in the measurement of the baseline Haystack-Onsala with an accuracy of half a decimenter in length.

   A group at Chilbolton, England joined the Canadian VLBI group carrying out astronomical and geodetic experiments with the Canadian analog VLBI system.

   The NASA/JPL Deep Space Tracking station of Madrid has been involved in regular VLBI experiments for precise station locations, polar motion and radio source positioning. The necessary delay resolution was obtained with an 8-channel Mk II bandwidth synthesis spanning 40 MHz.

   In 1978 a series of astrometric VLBI experiments was started on the Effelsberg-Maryland Point baseline in a cooperation between the MPIfR and the Naval Research Laboratory, Washington D. C.

   Late in 1979 the Mk III system was introduced in Effelsberg and Onsala and a series of high precision VLBI experiments for geodetic and geophysical purposes (plate tectonics, continental drift) was initiated. The second experiment in this series is due end of July this year.

   In recent years a number of geodynamics projects have been elaborated, in which the use of VLBI is included as one of the most powerful geodetic observing methods:

   The goals and objectives of a global program of Earth dynamics research are described in a NASA document entitled "Application of Space Technology to Crustal Dynamics and Earthquake Research" (NASA Technical Paper 1464, August 1979). The Nasa Geodynamics Program has been established to promote and support national and international activities in this field, with the final aim to contribute to the National Earthquake Hazard Reduction Program. With a similar goal the European Space Agency has created an Earth-Oriented Research Working Group (ERG) supporting

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a joint European Effort in Earthquake Prediction Research. An ESA document about the Proceedings of a European Workshop on Space Oceanography, Navigation and Geodynamics (Elmau-Song-Conference, Jan. 1978, ESA SP-137) collects a variety of thoughts and ideas about possible activities in Europe. This conference was followed by meetings in the individual countries and has led to the creation of different groups concerned with the elaboration of geodynamics projects (with the permanent danger of too much diversity, of course).

For Europe the areas of special geophysical interest are located in Scandinavia (Fenno-Scandian uplift) and in the Mediterranean region, especially in the Eastern part with the Transanatolian fault system, as well as in Southern Spain and Portugal. A concept with a number of fixed reference stations in central Europe, some fixed stations on the Scandinavian Shield, and some south of the Alps and the Pyrenees could form the heart of a long term geophysical program. In connection to this, a number of mobile stations (one or two quasar referenced stations and a large number of satellite interferometric stations, i. e. GPS-stations) would operate in the Eastern Mediterranean fault zones.

In such a scheme the operation of a certain number of fixed stations for geodetic VLBI appears as a useful and sensible objective, especially if at the same time a participation in global projects such as the Mk III Continental Drift Experiments and the anticipated MERIT Polar Motion and Earth rotation Experiments is considered.

The stations of Madrid and Bologna, as well as the planned station in Sicily will be of a particular value due to their favourable location in the Mediterranean region.

On the global scale the extension to South Africa (Radio Astronomy Observatory of Hartebeesthoek) will add an interesting North-South connection in order to study the relative motions of the Eurasian and African plates.

The support by European stations of international programs such as project MERIT is most desirable because of the necessity to have reference points for Earth Rotation on all major plates. Earth Rotation in itself is a very complicated problem of Earth and planetary dynamics, which needs the cooperation of many well equipped stations.

Details about Project MERIT (Monitoring Earth Rotation and Intercomparison of the Techniques) are contained in the documents circulated earlier this year. The preliminary observation campaign covers the period of August - October 1980. The US National Geodetic Survey (NGS) and NASA jointly sponsor a program of concentrated Mk III-VLBI-observations with the Haystack - Owens Valley - Fort Davis stations covering the two periods of Sept. 26 - Oct. 2 and Oct. 15 - Oct. 22. During these periods there will be cooperation with the European stations of Onsala, Effelsberg and Chilbolton.

There is a strong interest for more European VLBI activity and the main purpose of the present meeting is to establish what are the technical and organizational means available, and to initiate some geodetic observation campaigns. The station reports that follow provide information about the present situation at most of the European observatories concerned with VLBI.

II. Station Reports

1) Instituto Nacional de Technica Aeorspacial (INTA/NASA), Orense 11, Madrid-20, Spain (A. Rius) and Instituto Geografico Nacional, General Ibanez de Ibero 3, Madrid-3, Spain (E. Calero).

The NASA Deep Space Tracking Facility at Robledo near Madrid comprises one 64 m

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antenna and one 34 m antenna equipped with a Mk II VLBI terminal. A third antenna is located at Cebreros, a separate site at a distance of about 10 km west from the two others. On the background of the considerable earthquake hazard in Southern Spain a project for the application of VLBI techniques to geodetic activities has been initiated in close cooperation between INTA/NASA and the Instituto Geografico Nacional (IGNIS-Project, see annex). E. Calero, member of the IGN, has taken on the responsibility for data reduction and the comparison with geodetic survey results. A. Rius has been assigned by INTA/NASA to give the necessary assistance within the agreement of host country activity granted by NASA.

The amount of available observing time is, of course, highly dependent on the station's tracking activities, but it appears that some 5 % of the total time could be at the free disposition for European VLBI experiments (Astronomy and Geodesy). There is a strong interest of the Spanish group to participate in European VLBI programs, both in Astronomy and Geodesy.

2) Institut Géographique National, 2, avenue Pasteur, 94160 Saint Mandé (C. Boucher).

In France a working group consisting of members of the Institut Géographique National (IGN), the Centre National d'Etudes Spatiales (CNES) and the Centre d'Etudes et de Recherches Géodynamiques et Astonomiques (CERGA) is considering four different types of VLBI activity:

a) the development and implementation of a geodetic VLBI data reduction programme (C. Boucher, M. Sadi, IGN, Paris).
b) a programme of differential VLBI to track the Russian VENERA 83 balloon probe in the atmosphere of Venus in assistance with NASA/JPL (R. Preston, Pasadena; M. Lefèbvre, Toulouse).
c) study the possibility to build or obtain a mobile VLBI station of the ARIES type (P. Cormier, Grasse).
d) develop mobile stations capable of performing interferometric positioning with coded signals from artificial satellites. The study is conducted to disembogue into an ESA proposal for the construction of suitable satellites of the GPS type (F. Nouel, Toulouse).

3) Nuffield Radio Astronomy Laboratories, University of Manchester, Jodrell Bank Observatory, Macclesfield, Cheshire, SK11 9DL, UK (R. Booth).

The activities at Jodrell Bank are centered on the operation of the Multi Telescope Radio Linked Interferometer (MTRLI), which has been completed very recently. There is however also some VLBI activity going on in parallel: chiefly 6 and 18 cm observations for astronomy within the European network. It is hoped to complete the H-maser, which is being constructed at the observatory, by 1981. The procurement of a Mk III terminal (a transportable unit) for a shared use at Jodrell and Chilbolton has been considered but financial competition by the optical telescope projects at the Canary Islands (La Palma) threatens this project.

There have been no concrete steps towards a participation in the MERIT project. In this respect there will be a British contribution by the Cambridge 5 km local interferometer (B. Elsmore).

A committee comprising leading geodesists and astronomers in the U. K. has been looking at the future possibilities of geodetic VLBI but no commitment for financial support has been made yet.

4) Rutherford and Appleton Laboratories, Ditton Park, Slough SL3 9JX, Berkshire, UK, Chilbolton Observatory (P. Richards).

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The Chilbolton station has been participating in astronomic and geodetic VLBI experiments with the Canadian group (Algonquin Radio Observatory, Herzberg Institute of Astrophysics, NRC of Canada, University of Toronto and York University, Toronto) using the analog system with standard commercial video recorders (bandwidth ~5 MHz). Recently these recorders have been replaced by the much more economic cassette recorders (~3.5 MHz). The geodetic data analysis has been carried out by the Toronto group (W. Cannon et al.) and by scientists of the Nottingham University (D. McLintock). The results appeared in JGR 1979, p. 229.

This year several 2-channel bandwidth synthesis experiments are scheduled with 20 - 30 MHz separation between the bands. First test experiments on the Algonquin-Chilbolton baseline are due in May-June this year. If these are successful, a campaign during the Project MERIT period is planned. The principal observing frequency is 10 GHz (2.8 cm).

At Chilbolton a 6 cm paramp will soon be completed. A Mk II terminal with IVC and cassette recorders is available. The H-Maser, which is on loan from the Canadian group, has failed and is being repaired.

The VLBI activities at Chilbolton are being reconsidered by the supporting agencies (mainly NRC) in view of the competing astronomical projects (La Palma telescopes). At the moment the financial support is assured only for one more year. In this critical situation it may be vital to emphasize the importance of the Chilbolton station in a European VLBI network. (The other uses of the Chilbolton station are centered on the study of the upper atmosphere).

5) Radio Laboratory of the Helsinki University of Technology, Helsinki, Finland, Metsähovi Observatory (S. Tallquist).

The main purpose of the 14 m antenna at the Metsähovi site West of Helsinki (about 100 m away from the Satellite Laser Station of the Helsinki Geodetic Institute) is high frequency radio astronomy. There is however enough time left for intensive geodetic observing programs. Cooperation with the Helsinki Geodetic Institute has begun (J. Kakkuri and T. Parm) but the financial support still presents a severe problem, because of the priority of the Laser ranging project. It is hoped that after the completion of the Laser, some funds can be made available for VLBI experiments. Up to now only a few experiments were performed with equipment on loan from Onsala.

6) S. Tallquist and G. Lundquist provided some information about the EISCAT-Project (European Incoherent SCATter experiments for aurora study): Three standard communications antennae (Ø = 34 m) at the sites of Tromsö, Norway (high power transmitter for 940 MHz), Kiruna, Sweden and Sodankilä, Finland (receiver only) are to be used in an atmospherical program, which is considered to last only a few years. After that the antennae could be available for VLBI. The antenna surface, after adjustment of the panels, would be good for frequencies up to at least 10 GHz. At present, however, there does not appear to be any inexpensive way to make use of these antennae for VLBI.

7) Onsala Space Observatory, Chalmers Technical University, Onsala, Sweden (G. Lundquist)

Since about ten years the Onsala Space Observatory has been involved in a geophysical research program conducted by the Massachusetts Institute of Technology to determine plate motions (continental drift) and Earth rotation in addition to the baseline and source position parameters. Until November last year the Mk I bandwidth synthesis system has been used successfully to yield an rms accuracy of 5-8 cm on the baseline length between Haystack and Onsala (synthesized bandwidth ~100 MHz). This program

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will continue with the Mk III equipment, which has been acquired in November 1979 (financed to the larger part by NASA).

The OSO 25.6 m antenna will be used primarily for geodesy in the future. It will be resurfaced with solid panels (at present the efficiency at 8 GHz is only 15 %).

A short baseline experiment between OSO 20 and OSO 25.6 is planned (end of June) using the same clock and Mk III terminal, and a comparison with the terrestrial survey results will be made.

A scandinavian working group is considering a joint project of a mobile VLBI station. A proposal will be presented in autumn this year.

The Mk II terminal will be equipped with an RCA cassette recorder of the type recommended by W. Zinz MPIfR, Bonn (VDT 501).

The main interest at the Onsala Space Observatory is centered on the observation of galactic line sources, such as OH-Maser sources. This is why a number of very low noise narrow band receivers are available (cooled masers with $\sim 20^{o}$K).

8) Radiosterrenwacht Dwingeloo/Westerbork, Stichting Radiostrating van Zon en Melkweg (SRZM), Oude Hoogeveensedÿk 4, Dwingeloo, Holland (R. T. Schilizzi).

The Westerbork Array can be used as a single instrument representing an equivalent diameter of 93 m. The old 25 m telescope at Dwingeloo is limited at 5 GHz (6 cm), whereas the Westerbork Array can observe at up to 10 GHz (2.8 cm). The Westerbork array operates as a local interferometer with a fixed 10 MHz bandwidth (double sideband system). A Mk III terminal has been ordered (delivery early in 1981) and the acquisition of a hydrogen maser frequency standard is planned. A 3.8 and 13 cm receiver will probably be procured for one of the Westerbork antennae.

The SRZM is supporting the ESA Satellite linked VLBI project. A two-way phase link via OTS is in the experimental stage. A broad band signal link is planned using the L-SAT telecommunications satellite, which is to be launched by the end of 1984. The ESA Astronomy Working Group has approved the L-SAT project. Six telescopes with a transmitting band of 30 MHz could have access to L-SAT simultaneously. The satellite would be available one week in three for VLBI. One of the steerable spot beam antennae on bord the satellite could be aimed at Haystack Observatory.

The central processing facility will be located at Bonn or Westerbork, but decisions on the support of the facility are still open. Using part of the existing processing facilities at Westerbork, the necessary funding would amount to about 1.5 mill. DM. A staff of 8 people at the processing centre would be necessary to run the satellite system on a continuous basis.

The stations that would take part in the satellite linked system are Jodrell Bank (or Chilbolton), Westerbork/Dwingeloo, Effelsberg (MPIfR), Onsala, Bologna and probably Haystack (U.S.A.).

9) Max-Planck-Institut für Radioastronomie (MPIfR), Auf dem Hügel 69, Bonn, Germany (E. Preuß).

A transportable Mk III recording terminal has been in operation in Effelsberg since November 79; it will be replaced by a permanent one this year. A three

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station Mk III processor has been ordered at Haystack Observatory, it is expected to be operational in 1982.

The MPIfR does not posses an S-X-band receiver at present; there is one on loan from Haystack, which will have to go back in October this year.

The procurement of a water vapor radiometer is being considered.

In addition to the 100 m telescope at Effelsberg, the old 25 m telescope on the Stockert (10 km NW of Effelsberg) and the 34 m Haystack-type telescope at Werthoven should be mentioned. Furthermore, the MPIfR in cooperation with France is building a 30 m telescope for Millimeter wavelengths on the Calar Alto near Granada, Spain (IRAM project). A submillimeter telescope of 15 m diameter is planned on the Canary Islands.

10) Dr. Campbell gave a short report about the situation in South Africa (Radio Astronomy Observatory Hartebeesthoek, NITR Johannesburg, P.O. Box3718, Director G. D. Nicolson). There is a 26 m antenna which is now fully available for radio astronomy former NASA DSS 51. The station is equipped with an IVC-Mk II-terminal and a HP 5065 A Rubidium clock. A cooperation for geodetic VLBI has been started with an 18 cm experiment in February this year. The main objective of this experiment is to monitor the ionospheric phase fluctuations on a long North-South baseline. It is hoped for the future that a growing geodetic and geophysical interest in South Africa will allow for increased investments such as a H-maser frequency standard and other equipment needed for maximum geodetic accuracy. The extraordinary location at the Southern tip of the African plate makes this station a most attractive partner for all kinds of geophysical experiments.

11) Dr. Schilizzi, who had visited Bologna very recently, gave a summary on the status of the Italian VLBI-project to build two dedicated VLBI antennae. One of these, near Bologna, is scheduled to have its first tests in September 1981. The other one is thought to be built near Catania or Syracuse on Sicily. Both telescopes are built by TIW(a subsidiary of Toronto Iron Works, in Sunnyvale, California); they are the same 32 m dishes as the EISCAT antennae. The first receivers to be used will be 2.8 cm and 6 cm. 1.3 cm and 18 cm will follow later. A Mk III recording system is considered for both antennae. The Italian Project is considered to be a most valuable augmentation of the European VLBI network, for astronomy as well as for geophysics.

III. Geodetic VLBI experiments in Europe with Mk II: a proposed use of the NASA/JPL bandwidth synthesis method (J. Campbell).

1. The use of the Mk II recording system for geodetic accuracy is limited in several ways: the single channel 2 MHz delay resolution is

$$\sigma_\tau \approx \frac{1}{W_{SNR}} \cdot \Delta\tau_h$$

where $\Delta\tau_h = 1/B$ is the halfwidth of the main peak of the delay resolution function. In the case of strong sources and good interferometer sensitivity (SNR $\geq$ 10) the delay estimation factor $1/W_{SNR}$ is about 1/100, in exceptional cases (3C273) 1/500.

Thus the maximum estimated delay precision is ± 5 ns (± 1 ns in case of 3C273) with the available large antennae and standard receiver equipment (70 $^\circ$K). Here the integration time is set at 1 min, which represents a typical value for a single geodetic observation.

The use of the fringe rate observable, which is not as strongly dependent on the

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effective bandwidth as the delay does not allow to determine the z-component of the baseline (incomplete baseline fix). Therefore it does not attract the same interest for geodetic VLBI as the delay observable. The use of the fringe phase gives rise to the problem of 2π - ambiguities, which have to be eliminated, if the full baseline determination is to be obtained. To study this matter experimentally, an 18 cm geodetic test experiment was carried out in February 1980.

The available sensitivity of geodetic Mk II observations (with 1 min integration time) sets a limit to the brightness of the sources to be used. This in turn may introduce difficulties, because practically all of the stronger compact sources show structure at the milliarcsecond level. This will limit the attainable geodetic accuracy especially on the "longer" baselines (b measured in wavelengths). In this respect the introduction of the Mk III system will bring about a twofold improvement: first, the high sensitivity (gained by the much wider available bandwidth) will allow to observe weaker (and more compact) sources and second, it will also permit the use of smaller and less sensitive antennae.

2. While waiting for the proliferation of the Mk III system it appears to be profitable to make the best possible use of Mk II, taking advantage of the positive experience of the NASA/JPL DSN and ARIES groups with the sequential bandwidth synthesis scheme. A full description of this system in its initial form is given by J. B. THOMAS in JPL Technical Report 32-1526, Vol XVI, p. 47-64, 1973. In accordance with the width of the receiver passband at the DSS antennae a bandwidth of about 40 MHz was synthesized with eight channels on the DSN intercontinental baselines (10 000 km) and with two channels on the much shorter ARIES baselines (100 - 200 km). On the European scale the two channel approach, which minimizes the loss in sensivity, is considered to be the best choice, because it is relatively easy to implement at most of the European stations.

3. The 40 MHz two channel approach leaves an ambiguity of 25 ns in the delay determination. This means that a good a priori knowledge of the baseline-source geometry is required: J. B. THOMAS set the tolerable error of the computed delay at 1/5th of the ambiguity, which results in 5 ns or 1.5 m in the baseline and $0\overset{''}{.}02$ in the sources as well as in the Earth orientation parameters on baselines of $\sim$ 1000 km length. A $\sim$ 2 m baseline accuracy can be achieved with simultaneous Doppler satellite tracking at the telescope sites. On the other hand new iterative methods of data analysis (e. g. A. Rogers in JGR 1978, p. 325) allow ambiguity elimination with much greater tolerances in the a priori parameters (In our case 20 ns and 10 meters or $0\overset{''}{.}1$ respectively).

4. Examples of the <u>technical realization</u> of the 2 channel synthesis scheme are given in the appendix and can easily be adapted to the particular conditions at the observatories. It is important to note that precautions should be taken to ensure that the phase of each of the synthesized IF's must be unaffected by the switching between the channels. The switching rate will be conveniently set at 1 Hz on the UTC time scale so that a simultaneous operation of all participating observatories does not present any problems. Before the experiments all participants will be notified (among other things) about which of the 2 channels will be assigned to the odd and even seconds of UTC.

The amount of work to implement the switching scheme will not surpass three man-months, in most cases it is much less.

With cassette recorders, it may be interesting to use two Mk II terminals at the same time. This would open the possibility to use S- and X-band synthesis simultaneously. In the X-band alone it would eliminate the switching and increase the SNR by a factor of $\sqrt{2}$.

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5. The data processing of multi-channel Mk II observations can to a certain level be done at Bonn (there is an option for swichted data), but for precise delay analysis the data will have to be correlated at the JPL-Caltech processor (A member of the Bonn VLBI group could be sent to Caltech to assist at the job). The post-processing will be carried out with the JPL "Phasor" and "Fitdelay" programs which have been implemented at the IGN, Madrid by E. Calero. The delay accuracy, which should be achieved by the 2-channel approach, will vary between 0.3 - 0.1 ns depending on the station equipment (clocks etc.). With this observational accuracy it is possible to derive baseline parameters with a precision

$$\sigma(b_x) = \sigma(b_y) \approx \pm 5 \text{ cm}$$

$$\sigma(b_z) \approx \pm 5 \text{ cm}$$

$$\sigma(\text{baseline length}) \approx \pm 3 \text{ cm}$$

from a 12 hour experiment (the baseline components at a given epoch of time are subject to Earth orientation errors, which do not propagate into the length).

6. After a discussion of the technical and organizational requirements for possible future experiments the participants agreed that two groups of geodetic activities in Europe should be realized in the near future:

a) Mk II bandwidth synthesis experiments at 8.4 GHz with Madrid. Although the availability of the NASA X-band at other European observatories is limited to the station of Onsala (at Effelsberg there is an S-X-band receiver on loan from Haystack), there is a strong interest to promote the use of the NASA-S- and X-band frequencies in Europe. Most of the geodetic projects will rely on a close cooperation with the US and it is understood that the American VLBI groups will predominantly use the NASA frequencies in the forseeable future. In the cooperation with Madrid two experiments appear to be feasible this year:

- a first test experiment of a few hours duration, which coincides with the July Mk III continental drift experiment (July 26-28). The advantage of this is that the S-X-receivers are mounted both at Onsala and Effelsberg during that time.
- a second experiment coinciding with the planned Mk III-MERIT observations late in September.

Principal observers in these experiments will be:

A. Rius, E. Calero, Madrid
B. Rönnäng, G. Lundquist, Onsala
J. Campbell, W. Beyer, Bonn

b) Mk II bandwidth synthesis experiments at 5.0 GHz (6 cm). R. T. Schilizzi pointed out that there would be a strong interest among Astronomers to improve the baseline calibration in Europe to a level of a few cm. This would justify the use of observing time within the allocation of the recently established European VLBI Network. A proposal to be presented to the European Network Program Committee was worked out by J. Campbell and F. Brouwer (Delft) (see annex).

This proposal provides a basis for repeated geodetic VLBI experiments (2 x 24 hours a year) between most of the European observatories. The next 6 cm Network experiment is scheduled for the beginning of October.

7. Outside the Sept. 26 - Oct. 2 and October 16 - 22 Mk III observations ~~planned~~ organized by the US National Geodetic Survey in cooperation with NASA, participa-

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tion in the preliminary MERIT campaign in Europe will be confined to the test experiments described above unter a) and b).

The stations taking part in the MERIT Mk III observations will be Onsala (for most of the time during the two periods), Effelsberg and Chilbolton (only for a few days out of each period). Effelsberg and Chilbolton will share the transportable Mk III terminal.

IV. All participants agreed that the informal geodetic VLBI meetings are useful and that they should be continued. J. Campbell proposed to have the next meeting coincide with the IAU/IAG-conference on the first results of the MERIT campaign, this conference is scheduled for spring '81 in Grasse (France).

V. Participants

E. Calero	Instituto Geografico Nacional	Spain
A. Rius	INTA/NASA Madrid	Spain
E. Preuss	Max-Planck-Institut für Radioastronomie Bonn	Germany
R. Booth	Nuffield Radio astronomy Labs., Jodrell Bank	UK
G. Lundquist	Onsala Space Observatory	Sweden
M. Geffert	Sternwarte Hoher List, Daun/Eifel	Germany
P. Richards	Science Research Council, Rutherford and Appleton Labs.	UK
F. Brouwer	Dept. of Geodesy, DELFT, University of Techn.	The Netherlands
C. Boucher	Institut Géographique National, Paris,	France
S. Tallquist	Helsinki Techn. Univers. Radio Lab.	Finland
R. Schilizzi	Westerbork Radio Obs. Dwingeloo/Westerbork	The Netherlands
F. Lohmar	Geodetic Institute Bonn	Germany
H. Seeger	" " "	"
J. Campbell	" " "	"