EUROPEAN PTTI REPORT

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Abstract

Time and Frequency Metrology in Europe presents some peculiar features in its three main components: research on clocks, comparisons and dissemination methods, and dissemination services. Apart from the usual activities of the national metrological laboratories, and increasing number of cooperation between the European Countries are promoted inside some European Organizations, such as the ECC, EFTA, EUROMET, WECC, that will be dealt witH in what follows. The present, evolving situation will be further influenced by the recent political changes in Eastern Europe.

1 Introduction

Despite a continental wide period of depression, Time and Frequency activities are well and alive in Europe, in all its three components: research on clocks, comparisons and dissemination methods , and dissemination services. In other terms the European laboratories accepted the struggle with the ubiquitous GPS and are trying to explore new avenues. The scope of this paper is to present a report on these activities, pointing out the practices or solutions that are peculiar to a developed continent that must cope with changing political and economical realities. Also technical or organizational aspects that are not alike to the practices followed in the States will be pointed out.

In the second section, with charts and graphs the distribution of all these activities over Europe is considered, along the selection criteria adopted.

Research on atomic clocks and related devices is presented in the third section, following two guide lines, the type of institution involved and the kind of research performed.

Section 4 – dealing with research on dissemination systems – sees three major items: a relevant series of ONE–WAY and TWO–WAY experiments, the research on the so–called marginal effects on GPS time comparisons, such as ionospheric and tropospheric effects and a continuing effort of the laser or optically based experiments for time dissemination.

Dissemination activities are presented in section 5. Two are the items of interest, one is in the realm of the well known distribution services – frequency standard and time signal emissions, time codes, and so on – , the other consists in the certification of "external" or industrial Laboratories.

Section 6 brings some news about the activities on time scale formation.

Information too has to be disseminated in a number of ways, as it will be seen in section 7.

In the last section, an exercise in summarizing the situation and in forecasting the future will be attempted, also taking into account the political changes occurring in the Continent.

Since this paper is a general survey, relevant bibliography will not be appended . The reader interested in the various technical topics, is referred to some Transactions or Proceedings of a number of devoted Symposia[1,2,3] and reviews[4,5].

2 ORGANIZATIONAL ASPECTS

Presenting a report on the PTTI activities in Europe, the concept of Europe itself has to be defined. For the recent political and economical changes, also the organization aspects has changed dramatically or are in progress to be modified.

While for the Western Countries general information is available or can be guessed, for Eastern Europe the past and the present situation is known with a far lesser extent. This fact is obviously reflected in this report . Data presented here were mostly deduced by personal acquaintances, visits, or, as it will be seen, by inspection of the literature. Omissions, errors or faulting guesses, of which the authors only will be responsible, will be undoubtedly traced.

The acronyms used are spelled out in the Annex, but some, more important will be now introduced in Table I.

TABLE I

EEC	European Economical Commission, an organization with economical and political scopes; most of the Western Europe Countries are members of EEC. It is planned that the political implications of EEC will increase with the time.
EFTA	European Free Trade Association, an organization with economical scopes only.
EUROMET	European Metrological Organization assuring collaboration in measurements standards, secures a common metro- logical basis for all the activities of:
WECC	Western European Calibration Cooperation, is an structure assuring the mutual recognition of calibration certificates between both EEC and EFTA Members.

This somehow complicated structure is needed in order to assure the uniformity of calibration criteria and standards for the obvious economical consequences.

The running of all the EEC and EFTA machineries is not an easy task; to give an example: in the history–laden Europe, there are twelve principal languages and six others have a recognized status, also EEC has only four official working languages.

Time and Frequency research is performed in:

- National Metrological Laboratories,
- National Research Laboratories, devoted to one specific topic (this is specially the case of France),
- Universities,
- Laboratories inside industries.

As regards to the National Metrological Laboratories, Europe is well equipped, as depicted in Table II, in which the Countries active now in the PTTI realm are listed in three groups depending on the period of the institution of their Metrological Laboratories.

For National Metrological Laboratory it is meant a State–supported institution performing on regular basis at least some of the four following activities:

- research on frequency standards,
- construction of a time scale
- research or activity on comparison and dissemination methods and systems,
- dissemination or calibration services.

TABLE II

around or before 1935	1950 -1980	around or after 1990
FRANCE OP – LPTF	CZEKOSLOVAKIA URE	DENMARK
GERMANY PTR – PTB	NETHERLANDS VSL	FINLAND
ITALY IEN	SWEDEN FOA	IRELAND
U.K. NPL	SWITZERLAND ON	PORTUGAL
	USSR VNIIFTRI	SPAIN

Some Countries, in particular France, has set an array of State–supported Laboratories via the national research Councils, usually linked to an University and devoted to a specific topic. For instance, are the well known L.H.A. (Laboratoire de l'Horloge Atomique), linked to the University of Paris–Sud and the L.P.M.O. (Laboratoire Physique et Metrologie des Oscillateurs).

Similarly, a few astronomical Observatories are engaged in research on frequency standards or in timing experiments, such as ON, the Observatoire Cantonal de Neuchatel, in Switzerland or OCA, Observatoire Côte d'Azur in France.

A great deal of activity is performed inside Universities, mostly on frequency standards and in a few cases – Austria (TUG), Germany (Stuttgart), Italy (Politecnico Torino), U.K.(Bangor and Leeds) – also in dissemination and comparison methods.

Finally, the PTTI research in Industry, even if some remarkable examples are available, is less of what is observed in the United States. Nevertheless in Russia at least two industrial concerns are manufacturing in series Hydrogen Masers and Cæsium beam standards, but the specific research activities and the number of researchers involved can be speculated only.

A special case in Europe is that of BIPM, the Bureau International des Poids et Mesures with seat in Paris; belonging this Bureau to and international 0rganization based the international Treaty signed in 1875 during the "Conference Diplomatique du Metre", its researchers and activities, in what follows, are not considered or if taken into account, a mention is given. By the way, BIPM is very active, as can be derived also from the program of this 25th PTTI Meeting, in which it is involved in at least five papers in Time Scale formation and on comparison methods.

With this limitation regarding BIPM, an attempt was made in order to deduce, at least approximately, the "work-force" engaged in PTTI activities in Europe, with the additional exception of the researchers working in military institutions, in Industry and in the Russian Labs.

The total amount is of about 130 people. About 50 are active in France (LPTF, LHA, LPMO, OCA, CNET, CNES and Universities); about 30 are estimated to operate in Germany (PTB, FTZ, MAX-Plank Institute, and an host of Universities). About 20 in Italy (IEN, IMGC, ISPT, and some Universities) and about the same figure can be credited to U.K., taking into account NPL, RGO, NAMAS and some Universities.

To investigate about the "productivity" and types of interest a bibliographical research was performed, by examining all the papers that in the last seven years, from 1987 to 1993 inclusive, were presented at :

- EFTF – the European Forum on Time and Frequency,
- FCS – the Frequency Control Symposium -, and at
- PTTI – the Precision Time and Time Interval Meeting,

or that appeared on:

- Metrologia and the
- Transactions of the IEEE Society on Instrumentation and Measurement.

For the two reviews obviously the analysis was limited to the available printed material.

At attempt was made to search also on Istmeritelnaia Technica and Radiotecnika i Electronika but the information gathered was not homogenuous, as time span, with the other sources; consequently data concerning the former USSR is not included.

The temporal window starts with 1987, when the first EFTF was held in Besancon in 1997.

This approach sounds very "academic", but it was felt adequate to gain a global idea of the amount and of the type of activities; of course all the five sources have a scientific committee operating a selection of the papers presented.

The total amount of papers prepared in European Labs in the seven years considered, in the domain of Time and Frequency and following the abovementioned selection criteria, is of some 520 titles, 15 of which coming from BIPM; the trends about the number of papers and the meetings of presentation, are presented in Fig.1 and Table III.

3 RESEARCH OF FREQUENCY STANDARDS AND CLOCKS

Using the data base of the previous section, an inquiry was made about the subject of the research and the kind of Laboratory involved, following the four types previously illustrated, i.e. National Standards Laboratory, national research laboratory dedicated to one specific topic – Astronomical Observatories included – , Universities and Industries.

The results are gathered in Table IV and Fig.2.

Over about 160 papers, near half are devoted to cæsium devices, traditional, optically pumped, fountains, etc.

This figure reflects the strong European involvement in the standard that embodies the SI definition of the second. Nearly 25 papers are dealing with the Hydrogen masers and the frequency stabilization of lasers, not so much as frequency standards, but as length standards or references.

More in detail, in the national Laboratories, in England the cæsium fountain is studied, in France to the fountain research an evaluation of an optically pumped cæsium beam was recently performed. Future activities are planned toward atomic clocks to be operated on microgravity conditions. Germany has built two vertical cæsium beams and some ion traps. Finally, in Italy, the final evaluation of the Magnesium beam standard was recently presented and a research activity was initiated on non–conventional cæsium beam frequency standard.

Of some interest is an effort of support and coordination launched by the European Community in the field of the cæsium devices. The responsibility of this activity was given to Politecnico di Torino. The aim of this effort is a coordination of the European laboratories, also via a support of researches mobility. England, France, Germany, Italy and Switzerland Labs joined in this effort.

As regards the kind of Laboratory, out of 165 papers, about 55 were prepared at National Metrological Institutes, about 65 at National research laboratories or Observatories, 30 in Universities and the last 10 ones in the industrial laboratories.

4 RESEARCH ON COMPARISON AND DISSEMINATION METHODS

Using always the data base introduced at point 3 a survey was performed about the papers on comparison, dissemination and other topics. The results are given in Fig. 3. Over 350 papers, the interest is evenly divided between comparison, dissemination precise quartz standards and applications of time and frequency technology.

The differences between synchronization, comparison and dissemination are faint ones since the same basic methods or technology can be used for all the three operations.

For these latter operations, four are the main lines of activity.

For comparisons, the so-called "two–way method" via a communication satellite and laser time transfer via satellites, for time transfer, the GPS ultimate accuracy capabilities and the time distribution systems via telephone lines.

4.1 Satellite Time Transfer — "two–way method"

The two–way method is one of the basic tools of time and frequency metrology. This time proven method was rejuvenated about ten years ago, at the University of Stuttgart by Prof. F. Hartl with the use of pseudo–random noise codes. The equipment is called MITREX (Microwave Timing and Ranging EXperiment) and is commercially available.

Two kind of activities are performed.

From one side the accuracy capability of the method and of the equipment was investigated, in comparison with other methods such as GPS and, in one instance, with LASSO.

LASSO stands for LAser Synchronization from Stationary Orbit; this method will be dealt with during this Meeting.

In the case of a comparisons with GPS, an experiment performed for about one year gave evidence that the time transfer results differ for about 3 ns, but a seasonal variation of about 8 ns was discovered.

This variation is possibly due to temperature–dependent delays in the GPS receiving equipment used.

The second activity about the two–way method lies in a program of mutual time comparisons between European Metrological Laboratories in Austria, France, Germany, Italy, the Netherlands, and United Kingdom. In one experiment, performed in August 1993, for the first time up to six stations took measurements at the same time; insofar the method was been used in bilateral or trilateral time comparisons.

For the researchers interested in this topic, NPL (National Physical Laboratory, Teddington, U.K.), has organized a periodic Newsletter[1]

Another satellite–related activity was a series of experiments on the one–way time comparison method, using the direct TV emissions from satellites. This method seems not used in the States.

The first experiment, on ECS satellites, started in 1988 and was coordinated by the IEN–Italy in the frame of a EUROMET project with the participation of eight European laboratories.

It was followed in 1991 by another one led by the NPL–U.K., joined by three other British

[1]Two-Way Satellite Time Transfer Newsletter, c.o. Dr. J. Davis, NPL, Teddington, Middlesex, U.K. TW11 0LW, fax +44 81 943 6452.

Laboratories and using two DBS (Direct Broadcasting Satellite), ASTRA and BRITSAT.

The last experiment to date has taken place in France between four Labs – Observatoire de Besançon, Observatoire de Paris, CNES/Toulouse, CERGA/Grasse – using TDF2 satellite.

All these direct–TV experiments aimed to demonstrate the utmost capabilities of the method for time and frequency comparisons and distribution over short and long baselines; a major effort has been done in reducing the synchronization error related to the position variation of the geostationary satellites.

This has been achieved exploring different ways to collect the results of the effect of the longitudinal drift of the satellites. It has been demonstrated that a synchronization precision from 10 to 100 ns, correcting for the satellite positions, are achievable.

4.2 Time comparison with laser techniques via geostationary satellites

This method was proposed to be tested on board of the Italian satellite SIRIO2, but a launch failure prevented any measurement. Later the experiment was successfully tested with the ESA satellite METEOSAT–P2 both inside Europe, between Austria and France, and later across the Atlantic Ocean.

This specific topic will be covered extensively during this Meeting by Veillet and Others.

At any rate it is worth mentioning that the European Space Agency decided recently to start a feasibility study involving spaceborne timing via lasers.

4.3 Extracting the utmost accuracy from GPS

The error budget of a time comparison or time dissemination via GPS or GLONASS satellites has a large number of entries, that can be gathered in a number of classes. For a time–minded user's stand point, the most important classes are the way to collect and treat the data, the position of the antenna, the equipment delays and their variations with time and temperature, and the propagation effects.

Quite a trust in these researches come from the BIPM, the Bureau International Poids et Mesures, in Paris and a great deal of research and experiments was performed at the BIPM itself in the recent years; the developments of this research was well covered in the past PTTI Meetings, mostly about the treatment of data and the influences of poorly known antenna coordinates.

These problems having been solved or identified, the interest is now on the propagation phenomena, boot in ionosphere and in troposphere and on the study of the equipment delays.

First results on these new lines will be presented during this 25th PTTI Meeting.

A better knowledge of ionospheric delay variations, was promoted by the possible use of the GPS system for the "precise" navigation of scientific satellites.

While some spacecraft, such as Earth observation satellites, are well above the ionosphere, other missions, such as the ARISTOTELES satellite of ESA are planned to be inserted in

orbits well below the bulk of the ionization of the atmosphere.

4.4 time dissemination via modems and telephone lines

Also in Europe, telephone services provide time and date information. These services find widespread use, and their characteristics, the services provided and their use inside the national calibration schemes are described in the next point of this report.

5 DISSEMINATION AND TRACEABILITY

5.1 Dissemination

A major difference between Europe and the USA lies in the fact that in Europe a large share of the dissemination services is performed via dedicated or broadcasting stations operating in the LF and MF bands, between 50 kHz and about 1600 kHz.

Stations performing Time and Frequency dissemination services only are listed in Table V.

TABLE V

STATION	CALL SIGN	NATION	FREQUENCY kHz
PODEBRADY	OMA	CZECH Rep.	50
RUGBY	MSF	U.K.	60
PRANGINS	HBG	SWITZERLAND	75
MAINFLINGEN	DCF77	GERMANY	77,5

These stations emitstandard frequencies, time signals and time codes.

In the same LF band are operating seven LORAN-C stations that are used in some cases as frequency and time references. On the same line are to be mentioned the six stations of the CHAIKA system operating in the former Soviet Union.

A number of broadcasting stations disseminate standard frequency, time signals and time codes providing a widespread coverage.

For example the French station FRANCE INTER, located in Allouis, radiates on LF a standard frequency with the carrier and a time code via a suitable slow rate phase modulation on the carrier itself.

In Italy, since 1979, also the FM emissions on VHF band are used to disseminate timing information. At the moment, about 1500 FM transmitters broadcast a time code, giving a complete date information (year, month. day of the month, day of the week, hour, minute and second, plus additional information about the legal time) 25 times per day. This particular service is used by a large amount of users, for a wide range of applications, from automatic clock setting to the electrical power plants dispatching. This time code is also used in automatic

devices to discipline remote oscillators. Using standard FM emissions, it was demonstrated that a frequency traceability within a few units in 10^{-10} can be achieved.

On the other end, the time proved dissemination services operating on HF bands were in practice discontinued in the last years, with the exception of the Russian transmitters operating at 10 and 15 MHz and one station in Italy, IAM, active on 5 MHz.

A peculiar service is provided via telephone lines, with time codes giving a complete time and date information, mostly for the PC synchronization. This service, born from a cooperation of four metrological Laboratories of Austria, Sweden, the Netherlands and Italy, has been an attempt towards a standardization of the format for Europe. These services can be used also from the USA, via telephone modems.

These telephone services were first implemented at the Technical University of Graz – Austria – in 1988 and subsequently in Sweden (1990), in Italy (1991) and are planned, using the same code, to be in operation in the near future in Germany, the Netherlands and in the United Kingdom.

5.2 Traceability

In many European countries, the national metrological laboratories operate calibration services consisting of high level calibration laboratories, independent or included in large companies or educational institutions.

These laboratories are accredited for the dissemination of the SI units while the national primary laboratories operate a surveillance program to verify their traceability. This assures the confidence level of the calibration system and allows to recognize a technical equivalence between the calibration certificates issued by the primary laboratories and the accredited laboratories, apart from their different uncertainties levels.

As regards time and frequency, table VI lists the number of accredited centers in the different countries updated at 1993, while in table VII are reported the different links used for the traceability to the primary laboratories.

TABLE VI

NATION	CALIBRATION SERVICE	NUMBER OF ACCREDITED CENTERS FREQUENCY	TIME INTERVAL
DENMARK	DANAK	5	5
FINLAND	FINAS	7	2
FRANCE	FRETAC	32	4
GERMANY	DKD	13	6
IRELAND	ILAB	3	3
ITALY	SIT	12	-
NETHERLANDS	NKO	16	10
PORTUGAL	IPQ	4	-
SPAIN	SCI	4	2
SWEDEN	SWEDAC	5	5
SWITZERLAND	SCS	8	1
U.K.	NAMAS	32	7

Out of the 17 Accreditation Services of the European Economic Area, 12 are consequently operating Time and Frequency Calibration Centers; 141 Centers are accredited for Frequency measurements, with uncertainties ranging from 1×10^{-9} to 1×10^{-12}, and 45 for time interval measurements.

TABLE VII
SOME OF THE METROLOGICAL LINKS USED FOR TRACEABILITY IN SOME CALIBRATION SERVICES

SERVICE	TV METHOD	GPS	HBG	DCF	MSF	BROADCAST
DANAK				X		
DKD				X		
FINAS	X					X
FRETAC	X	X	X	X		X
NAMAS					X	
NKO	X	X		X		
SCS			X	X		
SIT	X	X				X

Information given in Tables VI and VII is believed to reflect the situation at the end of 1993.

To ensure that the criteria followed in one Country are accepted in another, the Commission of the European Communities has supported the mutual recognition of accreditation schemes between Community States Members and EFTA Members, an activity that is performed by the organization of the National Calibration Services in Western Europe, called "Western European Calibration Cooperation" (WECC). EUROMET, that is a European collaboration in measurements standards, secures a common metrological basis for the WECC activities.

At present, 17 Countries cooperate to build up and maintain mutual confidence between their calibrations services to reach a state of the mutual agreement on the equivalence of the Services and of the Certificates issued by the accredited laboratories.

In other words, a Calibration Certificate emitted by an accredited Laboratory in any Country is accepted in each Member State.

6 TIME SCALES

A meeting devoted to the algorithms to be used on Time Scale formation was held in Turin, Italy, in 1988; the relevant proceedings were printed by the NIST.

Research on this rather elusive topic gave, in the period considered, 22 papers, most of wich prepared at BIPM, since the formation of TAI is entrusted with this Bureau and at IEN. A book by Graveaud on this topic will be quoted in the next section.

7 INFORMATION DISSEMINATION

As regard the dissemination of information, France and Switzerland started seven years ago the organization of an European Frequency and Time Forum; about this succesfull annual conference a detailed report will be presented later during this 25th PTTI Meeting.

Italy is organizing periodically summer schools on Fundamental Constants and Metrology. The last one was held in 1989, with the participation of some fifty students, coming mostly from metrological laboratories. The courses are given in English and the teachers are leading experts in the various fields.

The relevant text are issued by North–Holland.

Four books, one of which prepared partially in Europe, appeared in the last years.

The first is the well known "The Quantum Physics of Atomic Frequency Standards" by J. Vanier and C. Audoin. The second – "La mesure de la Frequence des Oscillateurs" – by KRONOS; under this pen–name are some French colleagues (Audoin, Bernard, Besson, Gagnepain, Groslambert, Granveaud, Neau, Olivier and Rutman). Also in the French language is "Echelles de temps atomique" by M.Granveaud, on the algorithms and criteria of time scale formation. The last one, written in Italian by A. De Marchi and L. Lo Presti, – "Incertezze di misura"' – deals with the representation of noises both in frequency and in time domain and with the uncertainty in measurements; this topic is seen from the point of view of the theorist and from that of laboratory–minded researcher.

Finally are worth of mention two efforts of my University – Politecnico di Torino – in organizing, since twenty years a course on Time and Frequency Metrology and in establishing postgraduate courses in Metrology in general and on Time and Frequency in particular. These courses lead to a Ph.D. degree in Metrology, in a 3 to 4 years period. These courses are given in Italian, but also foreign students are admitted. At the moment completing their curricula, are one Chinese and two Mexicans.

The information above is limited to Italy because the authors are familiar with their national situation; possibly some other courses are held elsewhere in Europe.

8 FINAL REMARKS

A general remark is the fact that the European developed research finds no adequate industrial counterpart. Quite a deal of the research performed in the Universities remains at academic level.

The man–power and the allocated founds appear adequate to the size of the populations and industries to be served, but the necessity to respect national priorities involves sometimes a duplication of efforts.

One must be aware of the fact that in the past the "technical standards" were a "polite" form of protection for the factories of a Country. In other terms the "acceptable technical standards" played the role of customs.

Speaking of "duplication" a word of prudence is of order. While in calibration and applied Metrology services the amount of resources to be dedicated, at the end must be proportional to the market to be served, the situation is quite different as regards the fundamental Metrology. In this realm, where the accuracy of a device can be only estimated and not measured, "duplication" of efforts is needed for two reasons. The search of systematic unknown effects from one side and of new avenues to reach a specific goal from the other. These facts are not usually appreciated by the Administrators for wich a cæsium standard is always a cæsium standard.

The situation is dramatically improved in the last years with the adoption of common standards, procedures and with the mutual acknowledgment of the calibration certificates, as was considered in point 5.2.

In some circles the idea of an European Metrological Laboratory was ventilated, but it seemed a too bold step. The difficulties are psychological – the national pride –, technical – the different needs and levels of industries–, and economical – such as the different priorities given by one Country.

What can be done, and has been done, is a painstaking effort of coordination. In the realm of standards (not the devices, the calibration values and procedures) much was achieved.

In the sectors of comparisons and dissemination some results were obtained, as seen in point 5.

Also for the research on primary frequency standards, an initiative is under way, as mentioned in point 3.

But two mayor problems, one economical, the second political stand in front of the research on Time and Frequency in Europe, the first is in the limited amount of money that will be allocated in future, at least in some nations.

The second one, a major task indeed, awaits the European Laboratories in establishing

cooperation plans with the metrological Laboratories of east Europe. Western European Labs were and are, to some extent, technology minded where in Eastern Labs, sometimes, the ingenuity was limited only by the available technology. A lot can be learned from both sides, in this cooperation and amalgamation process.

Another effort of organization to be attempted is a possible cohordination between the three annual Symposia : EFTF, FCS and PTTI. All three are very vital entreprises, but in a period of general shortage of resources, some considerations should be made about this topic, leading toward a sort of sharing in frequency or in time domain.

REFERENCES

[1] EFTF	Forum Europeen Frequence et Temps - European Frequency and Time Forum
[2] FCS	Frequency Control Symposium
[3] PTTI	Precise Time and Time Interval Applications and Planning Meeting
[4] METROLOGIA	Springer International, published under the Auspices of the International Committee of Weights and Measures
[5] IEEE	Transactions on Instrumentation and Measurement, a publication of the IEEE Instrumentation and Measurement Society

ANNEX I
ACRONYMS USED IN THE TEXT

BEV	Bundesamt fur Eich–und Vermessungwesen, Wien, Austria
CNES	Centre National Etudes Spatiales, Toulouse, France
CNET	Centre National Etudes Télécommunication, Bagneux, France
DANAK	National Calibration service of Denmark
DKD	National Calibration service of Germany
FINAS	National Calibration service of Finland
FRETAC	National Calibration service of France
FTZ	Fernmeldetechnisches Zentralamt, Darmstadt, Germany
IEN	Istituto Elettrotecnico Nazionale, Torino, Italy
ILAB	National Calibration service of Ireland
IMGC	Istituto di Metrologia G. Colonnetti, Torino, Italy
INS	Istitute of Navigation, Stuttgart, Germany
IPQ	National Calibration service of Portugal
ISPT	Istituto Superiore Poste e Telecomunicazioni, Roma, Italy
LHA	Laboratoire de l'Horloge Atomique, Orsay, France
LPMO	Laboratoire Physique M‹sure Oscillateurs, Besancon, France
LPTF	Laboratoire Primaire Temps et Fr‹quence, Paris, France
NAMAS	National Calibration service of United Kingdom
NKO	National Calibration service of Netherlands
NPL	National Physical Laboratory, Teddington, U.K.
OCA	Observatoire Cote d'Azur, Grasse, France
ON	Osservatorie de Neuchatel, Neuchatel, Switzerland
OP	Observatoire de Paris, Paris, France
ORB	Observatoire Royal de Belgique, Brussels, Belgium
PKNM	Polski Komitet Normalizacji Miar i Jakosci, Warszawa, Poland
POLIMI	Politecnico di Milano, Milano, Italy
POLITO	Politecnico di Torino, Torino, Italy
PTB	Physikalisch-Technische Bundesanstalt, Braunschweig, Germany
RGO	Royal Greenwich Observatory, Herstmonceux, United Kingdom
ROA	Real Instituto y Observatorio de la Armada, San Fernando, Espana
SCI	National Calibration service of Spain
SCS	National Calibration service of Switzerland
SIT	National Calibration service of Italy
SNT	Swedish National time and Frequency Laboratory, Stockholm, Sweden
SWEDAC	National Calibration service of Sweden
TUG	Technische Universitat, Graz, Oesterreich
URE	Ustav Radiotechniky a Elektroniky CSAV, Praha, Ceskoslovensko
VNIIFTRI	National Metrological Laboratory, Mendelejevo, CIS
VSL	Van Swinden Laboratorium, Delft, Nederland

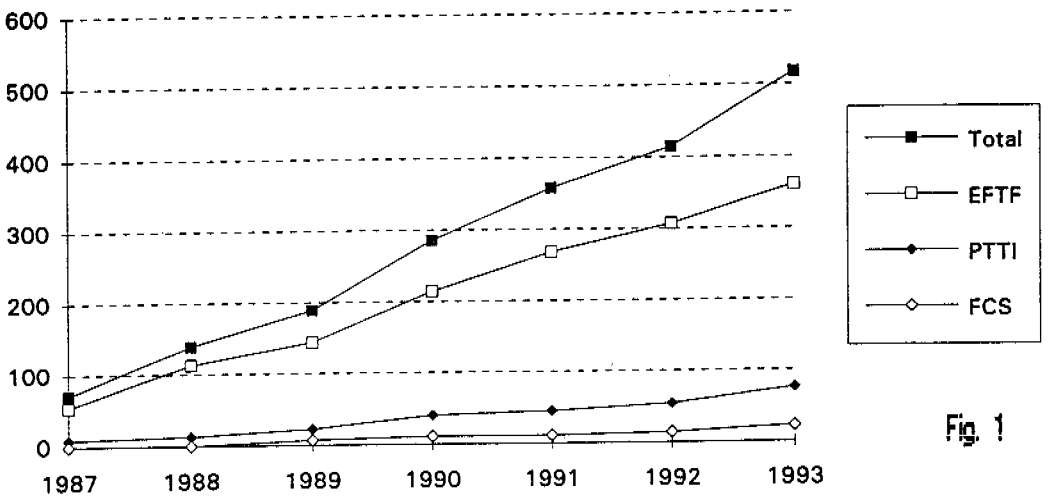

Fig. 1

PAPERS

TABLE III

Year	Total	EFTF	PTTI
1987	70	54	9
1988	138	113	13
1989	187	144	22
1990	284	214	40
1991	353	268	45
1992	409	307	54
1993	510	361	76

PAPERS ON ATOMIC FREQUENCY STANDARDS

TABLE IV

Year	Total	Caesium	Hydrogen	Rubidium	Ion trap	Laser	Magnesium
1987	17	8	4	0	1	2	1
1988	41	20	5	2	4	6	2
1989	52	27	5	2	4	9	2
1990	84	38	10	3	8	12	2
1991	117	52	18	6	8	20	4
1992	131	58	22	7	9	22	4
1993	165	74	28	8	10	28	6

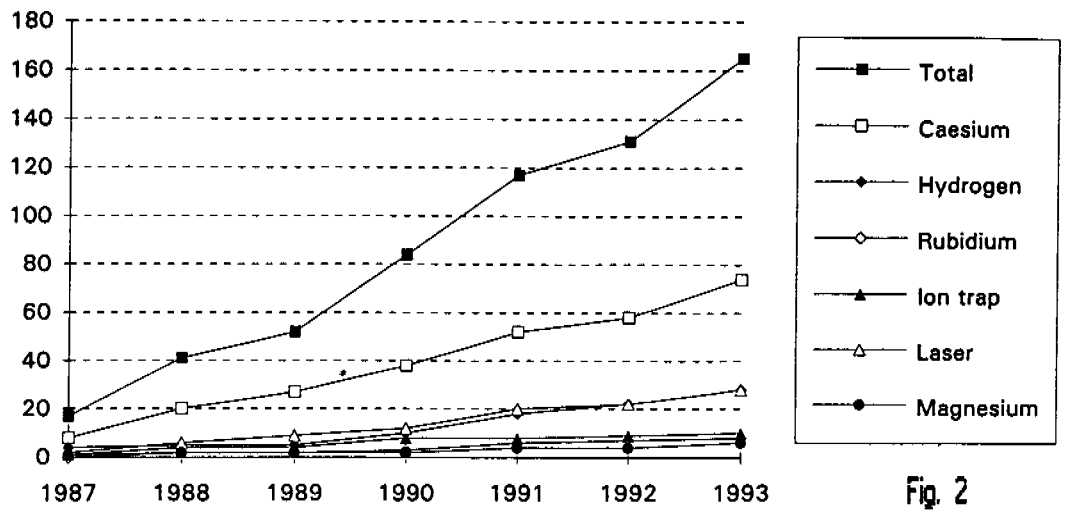

Fig. 2

PAPERS ON COMPARISONS AND DISSEMINATION						
Year	Total	applications	spectral purity	time scales	comparisons	dissemination
1987	36	6	2	4	6	3
1988	40	7	3	0	7	5
1989	41	6	7	1	3	12
1990	70	17	5	5	7	21
1991	41	0	3	1	12	12
1992	45	6	2	3	5	13
1993	73	4	1	5	24	15

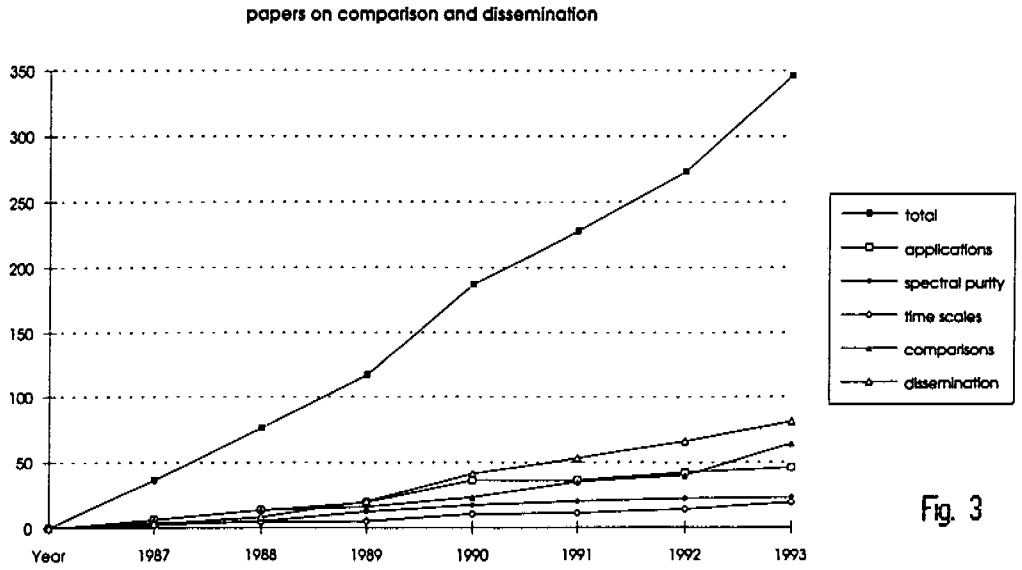

Fig. 3

QUESTIONS AND ANSWERS

Claudine Thomas, BIPM: I thank you, Professor Leschiutta, for mentioning the BIPM. But I think it is my duty to say again and to stress again here that the BIPM is an entirely environmental body and that we remain, as we have always been of course, at the service of all states that are members of the *Metre Convention*, or *Conservatoire de Metre* in French; and we have no particular relationship with Europe except with friendship because of the proximity, for instance, of the Paris Observatory. But that is all.

The other point is that you didn't mention a publication of the accuracy research of primary frequency standards which is operating at the Paris Observatory, the LPTF, the optical pumped primary frequency cesium standards which has been evaluated for one–second accuracy; and this accuracy has been published. It is not so good right now because it is only one part in ten to the 13 I think. But it has already been published in the BIPM security and maybe Metrology, I don't know. Thank you.

Professor Leschiutta: I thank you very much. But since I was rushing, I forgot to make some statement regarding this. All the papers prepared at the BIPM were not included in my calculations. As you will see in the text, I took account of the publication prepared at BIPM mostly on time–scale information and also recently on other topics. And you will find a precise order concerning that recognition. Obviously we are to some extent in Europe, stimulated heavily on the BIPM at home. But BIPM is an international laboratory in this situation.