

# EUROPEAN PTTI REPORT

Franco Cordara

Istituto Elettrotecnico Nazionale G. Ferraris  
Corso Massimo d'Azeglio, 42, Torino 10125, Italy

Andrea De Marchi

Politecnico di Torino, Torino, Italy

Michele Serafino

Politecnico di Torino (guest researcher)

Sigfrido Leschiutta

Politecnico di Torino and Istituto Elettrotecnico Nazionale

## Abstract

*Time and Frequency Metrology in Europe presents some peculiar features in all its four main components: research on clocks and time scales, comparisons and dissemination methods, and dissemination services. Apart from the usual and traditional tasks of the national metrological laboratories, an increasing number of cooperation activities between the European Countries are promoted inside some European organizations, such as the EC, EAL, and EUROMET, that will be dealt with in what follows. The present situation is evolving in four directions: national authorities strive to reduce nationally provided funds and suggest that their national laboratories compete in Brussels for community-provided funds, some trends toward a "privatization" of metrological and standardization activities, the upsurge of new labs and organizations, and the availability in some European countries of well-trained researchers coming from Eastern Europe. There are two additional problems, similar, as far we can presume on both sides of the Atlantic: the shrinking of defense-driven markets and the economical crisis of space agencies.*

## 1 INTRODUCTION

Time and frequency activities are alive and well in Europe, in all its four components: research on clocks and time scales, comparisons and dissemination methods, and dissemination services. European laboratories are more and more confronted with the ubiquitous GPS and are forced to explore new avenues. The scope of this paper is to present a report on these activities, pointing out practices or solutions that are peculiar to a developed continent such as Europe, that has to cope with a host of issues, political, economic, and also technical, such as GPS. Also, some technical or organizational aspects that are different from the practices followed in the United States will be pointed out. Some of the new developments and problems are presented and commented in the second section.

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

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

Section 5, dealing with research on dissemination systems, describes two major items: a relevant series of *one-way* and *two-way* experiments and research on the so-called marginal effects on GPS time comparisons, such as the instrumentation or the ionospheric and tropospheric effects.

Dissemination activities and their consequence, traceability, are presented in Section 6; two items are of interest, one in the realm of well known distribution services – frequency standard and time signal emissions, time codes, and so on – and the other in the certification of “external” or industrial laboratories.

Finally, 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 on 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 or Meetings, quoted in what follows. This paper is an update of a similar effort presented during the 23rd PTTI Meeting; consequently information still valid is not repeated here.

## 2 NEW DEVELOPMENTS AND PROBLEMS

### 2.1 Situation

In 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 have changed dramatically or are in the process of being 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 to a far lesser extent. This fact is obviously reflected in this report. Data presented here were mostly deduced by personal acquaintances, visits, or, as will be seen, inspection of the literature. Omissions, errors, or faulty guesses, of which the authors only will be responsible, will be undoubtedly detected.

The acronyms used are spelled out in the Annex to this paper, but some, more important, will be now introduced:

EC	European Commission, an organization with economical and political scopes; most of the Western European countries are members of EEC. It is planned that the political implications of EEC will increase with time, a major step, with profound resonance, being the adoption of a common currency in a few years time.
EUROMET	European Collaboration in Measurement Standards, secures a common metrological basis for all the activities on a regional basis. <sup>1</sup>
EAL	European cooperation for the Accreditation of Laboratories.

<sup>1</sup>There is an upsurge of metrological organizations with regional basis: NORAMET (Canada, Mexico, United States), APMP (Asia-Pacific Metrology Program), SIM (Sistema Iberoamericano de Metrologia), and COOMET (Cooperation among national Metrology institutes of Central and Eastern European states); similar organizations are active in Central-South Africa and in North Africa.

This somewhat complicated structure is needed in order to assure the uniformity of calibration criteria and standards. The running of these machineries is a formidable task; in history-laden Europe, there are twelve principal languages and six others have a recognized status, even if EC has only four official working languages.

There is a growing pressure from the 24 new states originating from the breakup of the communist area to join European organizations, with the risk of introducing big changes in the existing structures. This explains the struggle among EC members to find new criteria to stabilize the process.

## 2.2 Privatize or Not

Profound changes in the organization of metrology are under way, such as the "privatization" of the metrological activities, completed in the Netherlands and in progress in the United Kingdom. Another trend along with the privatization is the stress on these institutions to devote their activities to a research nearer to industrial needs or the demands coming from the world market.

Since these new approaches in some extent disrupt a century-long tradition, it seems interesting to provide some details as regards the privatization of NPL—the National Physical Laboratory—the standards Laboratory for the UK.

In 1992 the UK Government launched a study of possible changes in NPL's status. This included, but rapidly rejected, its sale or the creation of a "non-profit distributing" company. This was because these structures could fail financially and this was not acceptable to the Government. The solution they adopted, therefore, was that of a "Government-Owned Contractor-Operated" (GOCO) body modelled on similar American management arrangements for some of its own national laboratories, such as Los Alamos. Under GOCO, the Government owns NPL's equipment, buildings, and land, but the staff have formed a company "NPL Management Ltd.," which is a subsidiary of its management contractors (Serco plc) for the current 5-year contract. Key features of the new organization are:

- The Government has guaranteed a very high proportion of NPL's income throughout the contract. This stability (not available within the civil service structure) gives the Laboratory a sound base on which to plan its future development;
- costs have been reduced and the UK Government has reinvested these savings in new activities at NPL. As a result of this and other new contracts, NPL has taken on over 100 new staff in the last year; and
- as NPL remains constrained from taking unfair advantage of its "monopoly" position, it does not compete with accredited laboratories. In addition, it does not market its services outside the UK if these are available from the country's own national laboratory. This maintains NPL's previous operational policies.

## 2.3 The Impact of the European Community

The European Community (EC), now the European Union, is supporting a number of research programs, on competitive basis. In particular, the Standards, Measurements, and Testing (SMT) research program (1994-1998) is now underway, under the so-called IV Framework Programme for Research, Technological Development, and Demonstrations.

The objectives of the program are:

- to improve the position in all sectors of European industry,
- to promote research in support of the European standardization bodies,
- to support the further development of the European measurement infrastructure, and
- to promote the dissemination and application of good measurement practice.

Priorities are on:

- measurement in support of the research,
- measurement and testing in the industrial development phase,
- measurement and testing for the control of production
- technical support to total quality in measurement, and
- written standards for industry.

The indicative Community founding available in total for the 5-year period is 173 MECU (million ECU). ECU is the name adopted for the accounting unit, to become, hopefully, a currency. The quoted founding is equivalent to about 220 million dollars.

The development of common primary standards (devices) is included in these programs.

## **2.4 Regional Metrological Organizations – EUROMET**

The need for establishing a consistency of measurements worldwide, as required by increased industrial competitiveness, has been producing some changes in the traditional roles of the international bodies, namely the BIPM and the Consultative Committees of the CIPM, responsible for the uniformity of measurements, and is pushing toward the foundation of regional organizations for metrology.

If the main role of BIPM is the keeping and dissemination of the units of the International System, and the Consultative Committees are now concerned with the definition of key comparisons in the different fields among the national metrology institutes (NMI) to establish the equivalence of units, the regional groupings are going to take the responsibility for the consistency of measurements in a more limited (continental) area. This task is done by means of interlaboratory comparisons extending the traceability to the SI units at a larger number of laboratories.

The first of such organizations, EUROMET, was established in 1989 on a voluntary basis and its structure has been reproduced in other areas (APMP, NORAMET, SIM) and is going to be developed also in Africa. The membership of the NMI of Western Europe in EUROMET has been a way to coordinate researches and intercomparisons on measurement standards, to transfer metrological expertise among the members and to provide information about the resources and services available. Other important tasks of EUROMET are also the cooperation with the European calibration services and that of legal metrology. The framework for these activities has been provided by specific projects (cooperation, comparison, traceability, and consultation) activated in the 10 basic subject fields, each one coordinated by a Rapporteur. For any subject field, every NMI can appoint a Contact Person who takes part to the meeting organized by the Rapporteur, usually once per year.

In 1996, the EUROMET Committee accepted the first "associated members," namely the national metrology institutes of the Czech Republic, Slovak Republic, Poland, and Hungary, and there is a growing interest in joining the organization from other Eastern European countries. A new feature of the comparisons performed in this context between the national laboratories is publication in *Metrologia* of the final results to document the equivalence in measurements.

The projects agreed and running to date in the time and frequency field deal with: a) satellite time and frequency intercomparisons using PRN codes, b) research on new cesium primary standards, and c) stability characteristics of measurement systems. A new project on the uncertainty evaluation in time and frequency calibration has been proposed recently.

Updated information on proposed, agreed upon, and completed EUROMET projects in the different fields is available on World Wide Web at the following address: <http://www.dfm.dtu.dk>. A good occasion to exchange information on the activities performed at the NMI is given by the yearly Contact Persons meeting organized by the Rapporteur; for example, the last meeting held in March 1996 at NPL gave the chance to get detailed information on the structure and planned activity of the new Swedish time and frequency laboratory at the Swedish National Testing and Research Institute.

### **3 EUROPEAN TIME AND FREQUENCY LABORATORIES**

In the quoted report presented in 1993, a survey of the existing laboratories was given. The laboratories and institutes listed in that report are still active<sup>2</sup>, some with names or affiliations changed, but a large number of new institutions were formed in the last three years for three reasons :

- to reflect the political changes,
- to satisfy new needs of testing and calibrations in countries in which previously no sizable T/F activities were present, and
- to take profit from the emergence of traceability needs.

A special case in Europe is that of the BIPM, the Bureau International des Poids et Mesures, with seat in Paris; because this bureau belongs to an international organization based on the international treaty signed in 1875 during the "Conference Diplomatique du Mètre," its researchers and activities are not dealt with much in what follows. The relevant and continuous level of activity of BIPM in our field can be estimated anyway from the high number of contributions in the PTTI Meetings.

An attempt has been made to deduce, at least approximately, the "workforce" engaged in time and frequency activities in Europe, with the additional exception of the researchers working in military institutions, in industry, and in Russia and eastern countries.

The total number is about 170 people. About 50 are active in France (LPTF, LHA, LPMO, OCA, CNET, CNES, and universities); about 35 are estimated to operate in Germany (PTB, FTZ, Max-Planck Institute, DARA [the German space agency], and a host of universities). About 30 are in Italy (IEN, IMGC, ISPT, Cagliari Observatory, Matera laser ranging station,

<sup>2</sup>F. Cordara, S. Grimaldi, and S. Leshiutta 1994, "European PTTI Report," Proceedings of the the 25th Annual Precise Time and Time Interval (PTTI) Meeting, 29 November-2 December 1993, Marina del Rey, California, USA (NASA CP-3267), pp. 39-54.

and some universities) and about the same figure can be credited to the UK. The remaining people are working in Austria, Belgium, the Netherlands, the Nordic countries, Portugal, Spain, and Switzerland. A far larger number of experts in PTTI technologies are engaged in the calibration centers, at the moment 193 labs are active in Western Europe only, as will be shown in Table II.

To investigate "productivity" and types of interest, a bibliographical research was performed by examining all the papers that appeared in the last 10 years, from 1987 to 1995 and, whenever possible, 1996. Papers considered are those presented in oral or poster form at :

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

or that appeared in:

- **Metrologia** and
- **IEEE Transactions on Instrumentation and Measurement.**

For these two latter sources, the analysis was limited to the available printed material. For all the five sources, a referee committee is active.

The total number of papers prepared in European labs in the 10 years considered, in the domain of time and frequency and following the above-mentioned selection criteria, is some 700. Trends about the number of papers and the conference of presentation are presented in Fig. 1.

## 4 RESEARCH OF FREQUENCY STANDARDS AND CLOCKS

Using the database of the previous section, an inquiry was made about the subject of the research and the kind of laboratory involved, national metrological institute, national research laboratory dedicated to one specific topic – astronomical observatories included –, universities, and industries.

The results are gathered in Fig. 2. In the last 10 years, European labs have produced about 280 papers, 110 of which devoted to cesium devices (traditional, optically pumped, fountains, etc.). This figure reflects the strong and traditional European involvement in the standard that embodies the SI definition of the second. Nearly 35 papers deal with hydrogen masers. Since 1993 remarkable interest in the frequency stabilization of lasers, not so much as frequency standards, but as length standards or references, can be observed.

In more detail regarding the national laboratories, in the UK the cesium fountain is being studied. In France, in addition to the fountain research, an evaluation of an optically pumped cesium-beam was recently performed, and a factory started the production of an optically pumped cesium-beam standard. Future activities are planned toward atomic clocks to be operated in microgravity conditions. Germany has built two vertical cesium 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 an unconventional cesium-beam frequency standard.

Of some interest is an effort of support and coordination launched by the European Community in the field of cesium 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 researcher mobility. Labs in England, France, Germany, Italy, and Switzerland joined in this effort.

## 5 RESEARCH ON SYNCHRONIZATION SYSTEMS AND DISSEMINATION METHODS

Using the same database introduced in Section 3, a survey was performed about the papers on comparison, dissemination, and similar topics. The results are given in Fig. 3. The papers are over 430; the interest is evenly divided between comparison, dissemination, and applications of time and frequency technology. Differences between synchronization, comparison, and dissemination are indeed faint ones, since the same basic methods or technologies can be used for all three operations. Research and experiments on these topics are widespread and devoted to four major lines: satellite time transfer (two-way and one-way), GPS, broadcasting from special dedicated transmitters, and the use of modems on telephone lines.

### 5.1 Satellite Time and Frequency Transfer

#### *Two-way*

In this field, most of the activities performed by European laboratories have been related to the two-way intercomparisons on INTELSAT satellite 5-13 at 307°E using the PRN codes generated by MITREX modems. Six European laboratories (TUG, NPL, PTB, FTZ, OCA, and VSL) regularly performed three measurement sessions per week during 1994 and 1995 and were joined by two U.S. laboratories (NIST and USNO).

The huge amount of data collected has been analyzed by the participants and the results have been compared with those obtained from the GPS common-view technique, showing that further studies and characterization of the equipment used are necessary to reach the accuracy of  $10^{-15}$  over one day, obtained in common clock experiments, that makes the method so interesting for the comparison of the new primary standards.

Of particular importance is the measurement of the station delays by means of a satellite simulator, possibly at each synchronization session, and the knowledge of the long-term stability of the delays of the instrumentation used for time scale generation and distribution, in addition to that of the time interval counter used. In 1997 one more station (IEN) will be able to join the existing network that is expected to resume the normal comparisons schedule in January 1997.

Again using a two-way method, experiments of time and frequency dissemination by means of spread-spectrum coded signals, used for satellites tracking and transmitted with normal programs by ASTRA Direct TV broadcasting satellites, have been performed by Time Tech (Germany) with the aim to establish a very accurate dissemination system, usable by disciplined secondary standards at a level approaching that of hydrogen masers for integration times of about one day.

The modification of the SATRE modem, used in this experiment, to make it compatible with the MITREX codes, has also been nearly completed by the same source. Among the interesting features of this device we can quote the  $\pm 15$  MHz frequency agility, very helpful using V-SAT ground stations, the availability of codes with higher chip rates, fast acquisition times even at low signal levels, and the capability of remote control. The availability of such a device on the market is instrumental for the development of the two-way network.

As regards to the two-way time transfers using laser techniques, a new experiment called T2L2 (Time Transfer by Laser Link) has just been proposed by OCA, CNES, and the European and Russian Space Agencies. The payload will be put on the Russian space station Mir (380-410 km altitude,  $51.6^\circ$  inclination) in 1999 and is the first experiment scheduled after LASSO; the expected accuracy is 50 ps, ideal for comparing the cesium fountains clocks that should be in operation by the end of the century in a number of laboratories. Timing centers need to be connected with a laser station where the start time of the lasers pulses carrying the clock information and the time of arrival of the reflected photons are measured in the reference clock time scale. Special timers have been designed and the stability of the payload ranges from 1 ps over 300 s to 10 ps over 10 days.

#### *One-way*

Coming to one-way systems based on geostationary satellites, further activities have been performed in France and Italy using different techniques. The TV signals of the Direct Broadcasting Satellite (DBS) TDF2 has been used by four labs in France to synchronize clocks, correcting the results for the satellite movement by means of different techniques, e.g. averaging over one sidereal day and correcting for the longitude drift by one calibrated link, etc. The possibility of determining the satellite position from the synchronization data has also been tested comparing the results with the data supplied by the satellite control center, but the short baselines limited the precision. Frequency comparisons with Allan deviations of a few parts in  $10^{14}$  have been obtained over a period of 10 days.

The test performed by IEN in the frame of the INTELSAT 5-13 experiment was based on the reception of the MITREX codes transmitted by the other European labs by means of a DBS receiving station that had been frequency-stabilized to cope with the locking range requirement of the modem. The measurement results, after the correction for the satellite movement obtained from the pseudorange data of the two-way stations, showed that frequency transfer capabilities at the  $3 \cdot 10^{-14}$  for observation times greater than 2 days are achievable.

## 5.2 GPS SYSTEM

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 standpoint, the most important classes are the way to collect and treat the data, position of the antenna, equipment delays and their variations with time and temperature, and propagation effects.

#### *GPS for Comparisons*

Apart from the research performed at the BIPM on both GPS and GLONASS receivers behavior and on the obtainable accuracy of carrier-phase and P-code measurements, experiments have been performed to characterize the long-term stability of the GPS receivers delays and the noise of common-view time transfers (IREE-Czech Rep.) and on the use of modified geodetic receivers for time transfer (Astronomical Institute, Berne University, Switzerland). In this

last case, the results obtained from carrier-phase measurements and P-code observations, also compared with the common-view results, have shown a factor of 10 improvement of the precision with the carrier-phase comparisons over the code measurements, but also that relevant phase changes due to temperature effects on the receivers are present. Frequency comparisons at  $10^{-14}$  over 3 hours seem possible.

To get the utmost accuracy from the GPS comparisons, the need to use a more sophisticated model to compute the corrections for the tropospheric and the ionospheric delays, taking into account the local meteorological parameters, the position of the satellite observed, and the time of the day, has also been demonstrated.

#### *GPS for Dissemination*

The dissemination service scene in Europe has registered a high increase in the use of GPS signals both as time references at the microsecond level and to discipline quartz and rubidium standards, thanks to the availability of unexpensive multichannel receiving cards. No competition for the time being has come from European countries, but programs for the implementation of a global navigation system for the civilian market (GNSS - Global Navigation Satellite System) are entering the implementation (GNSS1) or the study phase (GNSS2).

The development of a system called EGNOS (European Global Navigation Overlay System) is promoted by the Commission of the European Union (CE), the European Space Agency (ESA), and EUROCONTROL and will include geostationary satellites to complement the existing satellite navigation systems (GPS and GLONASS) to meet the integrity requirements of civil aviation for all phases of flight and those of maritime, inland navigation, and rail transportation in the European Region. To these users one has to add the potential market (20 million) of the Intelligent Vehicle Highway Systems, that should offer in-car navigation facilities. What matters more for the time and frequency community is that EGNOS geostationary satellites, if the program is eventually approved, will also disseminate accurate time, synchronized to UTC, to the users, as will be done by the other augmentation systems under study in the United States (WAAS) and Japan (MTSAT).

Much reliance on this research comes 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 recent years. The development of this research was well covered in past PTI 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 in the propagation phenomena, both in the ionosphere and troposphere, and in the study of the equipment delays. A better knowledge of ionospheric delay variations was promoted by the possible use of the GPS system for the "precise" navigation of scientific satellites. Since the common-view method, on which at the moment the formation of TAI time scale is based, is a one-way method, studies and experiments are under way in Europe on the effects of the ionospheric delay.

## **6 DISSEMINATION AND TRACEABILITY**

### **6.1 LF Dissemination Systems**

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.

Coming back to these traditional dissemination systems, the situation of the broadcasting stations in the LF and MF band is nearly unchanged from the last report (1993). Nevertheless, an

increased use can be observed of such transmissions for the automatic synchronization of cheap electronic devices like wrist watches and wall clocks that address the wider consumer market. To give an example, the production of integrated circuits to decode DCF 77 emissions operated by PTB (Germany) has reached to date a total of 25 million units.

## 6.2 Time Dissemination via Modems and Telephone Lines

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 the UK.

The European telephone time code dissemination services, designed for the synchronization of computer clocks and following a common format, have been activated in a relevant number of countries as shown in the Table I, where also some international telephone numbers can be found.

Table I - European Time Code Services

Country	Laboratory	Telephone No.	Link Delay Measurement
Austria	TUG	+43 316 472 366	yes
Belgium	ROB	+32 237 303 20	no
Germany	PTB	+49 531 512 038	yes
Italy	IEN	(*)	no
Netherlands	VSL	+31 152 617 181	yes
Portugal	IPQ	+35 112 940 425	yes
Switzerland	OFMET	+41 313 233 225	yes
Sweden	SP	(*)	yes
United Kingdom	NPL	(*)	yes

(\*) service not available from abroad

Most services that use a time code generator, developed at the Technical University of Graz (Austria) have the capability to measure the round-trip delay and to correct the 1 pps markers for the one-way delay, allowing one to trace a local clock to the national time scale with an uncertainty of a few milliseconds. In the near future, the service will be operative also in Spain, Poland, and Turkey.

## 6.3 Traceability

The heavily increased demand of measurement and test equipment traceability to the national measurement standards, stimulated by the application of ISO 9000 Quality Standards and by the need of removing the technical barriers to the international trade agreements, has been faced in Western Europe by establishing in each country accreditation services for both calibration and test laboratories.

Since 1994 these activities, mostly related to interlaboratory comparisons, proficiency testing of accredited centers, and the development of guidance documents, have been coordinated by EAL (European cooperation for the Accreditation of Laboratories) that reached at the end of 1995 an overall membership of 20 countries. The calibration and testing bodies of 12 of these countries are signatories of the Multilateral Agreement of mutual equivalence and acceptance of calibration certificates and test reports involving 5,000 labs. There are of course strong connections between EAL and the national metrological institutes, as they guarantee

the vertical traceability to the SI units in each country, the European Commission, and the international organizations charged with scientific and legal metrology.

In 1995 the first accreditation bodies from Eastern Europe, namely from the Czech Republic, the Slovak Republic, and Hungary, joined EAL. As regards to the time and frequency field, the Table II reports the number of calibration centers accredited for each member country, updated to early 1996:

**Table II - European Calibration Centers Accredited for Time and Frequency**

Country	Calibration Service	Number of Accredited Centers	
		Frequency	Time Interval
Denmark	DANAK	8	5
Finland	FINAS	6	2
France	COFRAC	32	4
Germany	DKD	16	8
Ireland	ILAB	3	3
Italy	SIT	16	1
Netherlands	NKO	19	12
Portugal	IPQ	5	-
Spain	ENAC	2	2
Sweden	SWEDAC	8	7
Switzerland	SAS	13	3
United Kingdom	UKAS	64	15

The total number of accredited centers for frequency is 193, with an increase of about 40% versus the 1993 data, and the uncertainty levels are within  $10^{-6}$  and  $10^{-13}$ .

## **7 FINAL REMARKS**

A general remark is the fact that the research developed in the European countries finds no adequate industrial counterpart. A great deal of the research performed in the universities remains at academic level. The manpower and the allocated funds 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 words, 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 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 whom there is no need of research on something already existing on the market.

One could wonder why there are so many metrological laboratories in Europe, having a population of the same order of that of the United States. The answer it is not an easy one,

but the situation can be justified by the strong specialization of the individual labs, the different needs and levels of industries, the different priorities given by each country, and also – why not – psychological factors such as national pride.

What can be done, and has been done, is a painstaking effort of coordination. In the realm of standards (not the devices, the calibration and testing procedures), much has been achieved. But two major 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 the future, at least in some nations. The second one, a major task indeed, awaits the European laboratories in establishing cooperation plans with the 20-odd metrological laboratories or institutions of East Europe. Western European labs were and are, to some extent, technologically minded, whereas in Eastern labs the ingenuity was sometimes limited only by the available technology. A lot can be learned from both sides in this cooperation and amalgamation process.

In a previous PTTI meeting, another point was raised concerning an additional effort of organization to be attempted toward a possible coordination between the three annual symposia: EFTF, FCS, and PTTI. All three are very vital enterprises, 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. An encouraging step was recently announced with a decision from IEEE-Frequency Control Symposium and the EFTF (European Frequency and Time Forum) to check the advantages of holding alternatively two events on both sides of the Atlantic.

## ANNEX

### Acronyms Used in the Text

CNES	Centre National Études Spatiales, Toulouse, France
CNET	Centre National Études Télécommunication, Bagneux, France
COFRAC	National calibration service of France
DANAK	National calibration service of Denmark
DKD	National calibration service of Germany
ENAC	National calibration service of Spain
FINAS	National calibration service of Finland
FTZ	Forschung und Technologiezentrum, Darmstadt, Germany
IEN	Istituto Elettrotecnico Nazionale, Torino, Italy
ILAB	National calibration service of Ireland
IMGC	Istituto di Metrologia G. Colonnetti, Torino, Italy
IPQ	Institut Português de Qualidade, Monte de Caparica, Portugal
IREE	Ustav Radiotechniky a Elektroniky CSAV, Praha, Czech Republic
ISPT	Istituto Superiore Poste e Telecomunicazioni, Roma, Italy
LHA	Laboratoire de l'Horloge Atomique, Orsay, France
LPMO	Laboratoire Physique Misure Oscillateurs, Besançon, France
LPTF	Laboratoire Primaire Temps et Fréquences, Paris, France
NIST	National Institute of Standards and Technology, Boulder, Colorado, USA
NKO	National calibration service of the Netherlands
NPL	National Physical Laboratory, Teddington, UK
OCA	Observatoire Côte d'Azur, Grasse, France
OFMET	Swiss Federal Office of Metrology, Wabern, Switzerland
ORB	Observatoire Royal de Belgique, Brussels, Belgium
PTB	Physikalisch-Technische Bundesanstalt, Braunschweig, Germany
SAS	National calibration service of Switzerland
SIT	National calibration service of Italy
SP	Sveriges Provnings - och Forskning Institut, Borås, Sweden
SWEDAC	National calibration service of Sweden
TUG	Technische Universität, Graz, Austria
UKAS	National calibration service of the United Kingdom
USNO	U.S. Naval Observatory, Washington, D.C., USA
VSL	Van Swinden Laboratorium, Delft, the Netherlands