

**Evaluation of the
Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin**

December 16, 2002

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Summary

In 2002, the Physikalisch-Technische Bundesanstalt (PTB) was comprehensively evaluated with respect to its profile and the quality of the work by an international commission consisting of 11 auditors, headed by Prof. H. Weule (Karlsruhe University).

The assessment and the recommendations of the commission are summarised in the following:

Mission

- PTB has an important metrology-related mission with great benefits for the German economy and society. PTB should continue to orient its activities consistent with this mission.

Organisation

- With a view to its mission, PTB's integration in the BMWA is appropriate.
- For PTB to more efficiently perform its mission, restructuring of the competencies, authorities and responsibilities of PTB management, BMWA and Kuratorium is recommended. The core feature of this restructuring should be the formation of a Supervisory Board (Aufsichtsrat) and a Board of Management (Vorstand) as well-established in industry. The management of PTB should be as autonomous and self-governing as possible. This structure should be supported with a Technical Advisory Council (Fachbeirat).

Staff and budget

- The reduction of the number of staff positions by 1.5 % per year endangers PTB's ability to meet its mission. It is recommended these positions remain with PTB and be dedicated to activities in new fields.
- The introduction of a global budget is recommended to improve efficiency. It should include flexibility of the staff plans as an essential feature. The fixed job cone constricts the fulfillment of the mission.
- The overall budget of ca. 130 Mill. Euro is about adequate in order to fulfill the mission, as it is currently defined, but will not permit PTB to enter new fields with high strategic importance or broaden and deepen existing fields where needed. An increased budget will be necessary for this.
- It is recommended that the mean budget per employee that is available for technical investments be increased and stabilised in order to maintain the good scientific-technical capabilities.
- The fraction of the budget spent for research and development (60 %) is appropriate, since achieving PTB's mission requires a high scientific-technical competence.

- Given the long-term nature of the tasks, their fundamental significance and the demand for independence and sustainability it is necessary to maintain the high percentage of core funding in PTB's budget.
- The income resulting from patents and technology transfer should stay with PTB as an addition to the core funding. PTB should have more autonomy for the handling of R&D-cooperations and should be allowed to keep the related income.

Planning and review processes

- For PTB's strategic program planning, positioning and orientation, the following four processes should be established and combined in an appropriate way:
 1. systematic identification of customer needs
 2. analysis of the long-term developments in economy and society
 3. assessment of the technical work by the customers
 4. evaluation of the scientific work by international auditors on a regular basis.

Scientific/technical work

- In summary, the scientific-technical competence and work of PTB's staff are excellent.
- The equipment is generally very good. However, there are some obvious needs for investments in certain of the laboratories.
- The activities in the important area of metrology in chemistry should be extended – preceded by a detailed study including consideration of other institutions with relevant responsibilities. PTB should be charged as coordinator in this area.
- Such a study should also be undertaken for the area of metrological information technology. Depending on the outcome of the study, the activities of this area may also need to be extended.
- PTB should continue to support rigorously patents and technology transfer.

National and international integration

- In summary, the scientific reputation is very good. PTB is well integrated and respected in the national, European and international communities.
- The establishment of an international network of cooperating national metrology institutes should be further fostered.

1. Procedure

1.1 Assignment and commission

In November 2001, the Federal Ministry of Economics and Technology¹ (BMW_i) appointed an international commission with 11 auditors, headed by Prof. H. Weule (Karlsruhe University) to carry out a full-scale evaluation of the profile and the quality of the work of the Physikalisch-Technische Bundesanstalt (PTB). PTB desired to be the first large departmental-research institute to undergo an external evaluation.

The members of the commission were:

Bernard Athané, Bureau International de Métrologie Légale

Prof. Dr. Alexander Bradshaw, Max-Planck-Institut für Plasmaphysik, Garching

Dr. Karen H. Brown, National Institute of Standards and Technology, Gaithersburg

Dr. Ralf Christoph, Werth Messtechnik GmbH, Giessen

Prof. Dr. Karl Joachim Ebeling, Infineon Technologies AG, München

Prof. Dr. Detlev Ganten, Max-Delbrück-Centrum für Molekulare Medizin (MDC), Berlin

Dr. Robert Kaarls, NMI Van Swinden Laboratorium, Delft

Dr. Günther Maaz, Sartorius AG, Göttingen

Prof. Dr. Dr. Werner Martienssen, Universität Frankfurt

Dr. Terry Quinn, Bureau International des Poids et Mesures

Prof. Dr. Hartmut Weule, Universität Karlsruhe (Chair).

In a „Structure and Position Paper“, PTB described its structure and its profile of activities. The BMW_i formulated six “Terms of Reference (ToR)”, for which PTB prepared explanatory documents, the “Supplements to the ToR”.

The detailed mandate to the commission as contained in the ToR can be grouped under two main questions as regards effectiveness and efficiency:

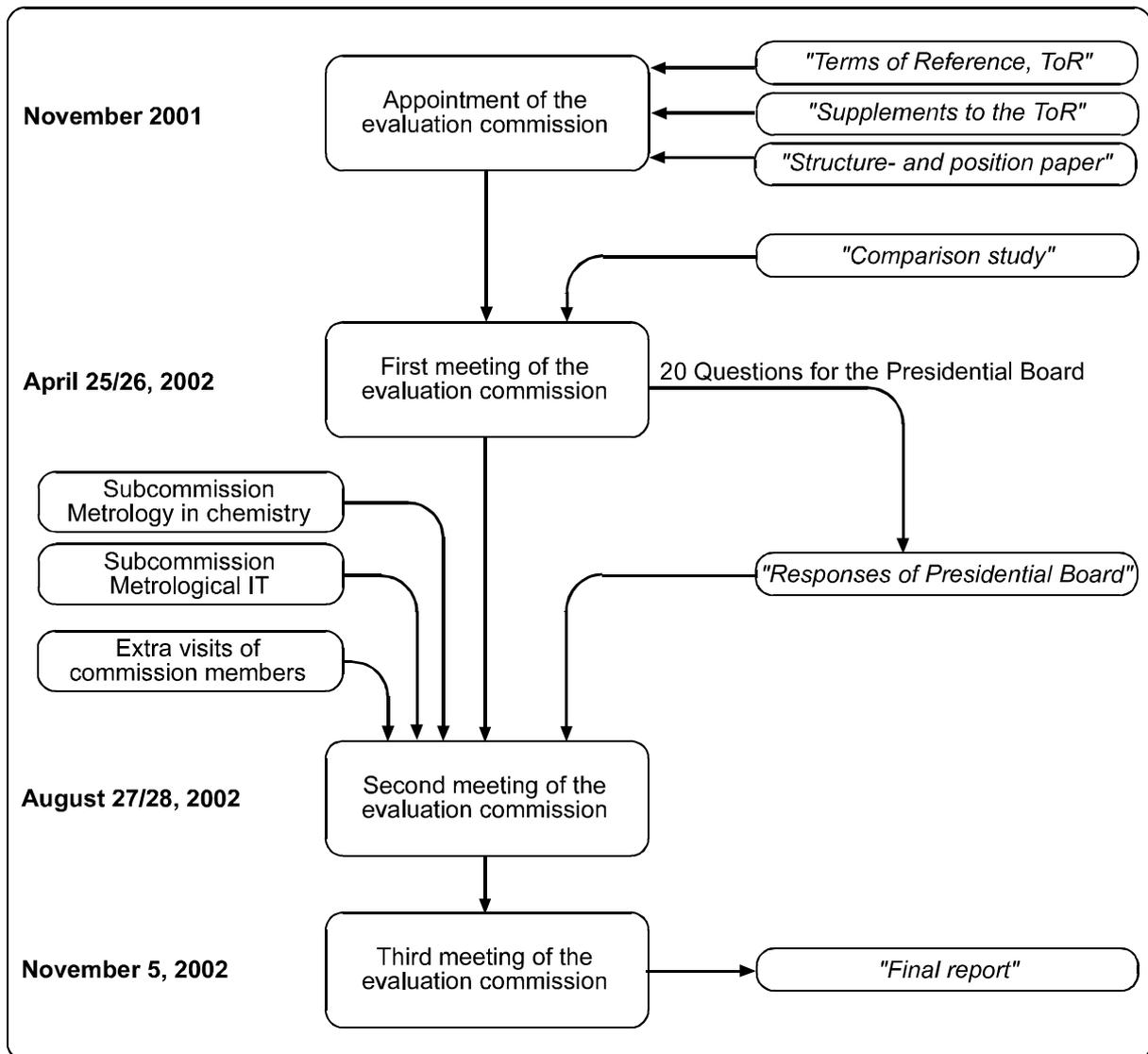
Effectiveness alludes to the question of whether “the right things are being done”, i.e. is there a surplus or are their shortcomings in the portfolio of tasks and are the mechanisms for the selection of the portfolio of tasks adequate.

Efficiency alludes to the question of whether “the right things are being done *the right way*”, i.e. is PTB able to do research, development and application in the area of physical-technical metrology on a level that matches the expectations on a governmental institution that was founded especially for this mission? Is PTB able to provide sufficient stimulation and flexibility for its researchers to create creativity, motivation, and own initiative? Is PTB able to be a leader of the progress of metrology in Germany and to sufficiently represent this internationally?

¹ from October 22, 2002 Federal Ministry of Economics and Labour (BMWA)

1.2 Course of the evaluation

The following description gives the chronological course of the evaluation.



At the time of the nomination and the appointment of the commission the assignment had been formulated. PTB's situation and plans had been described by the „Structure and Position Paper“. Between January and April 2002 PTB prepared an additional comparative study. This was at the request of the chairman of the commission to provide an improved basis for the evaluation work. This study compares the processes of strategic task definition as well as the resources and their allocation in the five largest metrological state institutes in the world, namely PTB, Bureau National de Métrologie (BNM, FR), National Metrology Institute of Japan (NMIJ, JP), National Physical Laboratory (NPL, GB) and National Institute of Standards and Technology (NIST, US).

During the initial meeting of the evaluation commission on April 25 and 26, 2002 in Braunschweig, there was a discussion on what kind of work the commission could render. The commission was in agreement that it could make an assessment and give recommendations on questions of effectiveness and efficiency, i.e. on the structure of PTB, on strategic planning processes, on organisational processes and on the processes of resource allocation. Furthermore, it could make statements on the spectrum of tasks as well as assess the quality of the work in selected areas and give a summary. It could not do a PTB-wide comprehensive assessment.

This would correspond to a “broad-based evaluation”. In addition, the commission decided to appoint subcommissions for the areas of “Metrology in Chemistry” and “Metrological Information Technology” to allow for a selective „in-depth evaluation“ and thus, for detailed technical expert assessment and recommendations.

It was decided to pursue an interactive evaluation process with an active integration of the Presidential Board. This would allow the results of the commission work to be used by PTB as quickly as possible. This approach was the determining factor on the course of the first evaluation meeting. As part of the meeting the Presidential Board of PTB was asked questions that originated from the impressions gained through visits of 11 laboratories that took place during the meeting and from the discussion of the comparative study. The Presidential Board prepared its response to these questions between May and August 2002. During that time, the audits of both subcommissions as well as a number of additional specific visits by 7 members of the commission took place.

During the second meeting of the evaluation commission on August 27 and 28, 2002 at PTB’s Berlin-Charlottenburg site, there were additional laboratory visits and discussions on the results of the subcommissions, on the responses of the Presidential Board, on the laboratory visits as well as on the structure of the final report.

The third meeting on November 5, 2002 served to prepare the final report.

2. Mission

2.1 General mission

PTB is the national metrology institute (NMI) for Germany. It is PTB's task to ensure progress and reliability in metrology for society, for industry and for science. The tasks are laid down in 27 laws, ordinances and directives. They include the realisation, maintenance and dissemination of legal units; the build-up and the development of a uniform internationally applicable system of units, the *Système International d'Unités* (SI), in international collaboration with all national metrological institutes; and assignments in the health sector, safety engineering, consumer protection, industrial safety, radiation protection and environmental protection. From the tasks as defined per legislation and from its mission, PTB derives four intertwined fields of activities: "Fundamentals of Metrology", "Metrology for economy", "Metrology for society" and "International Affairs".

PTB is responsible for the realisation of primary and transfer measurement standards as well as the development of measurement techniques. This provides a base that has effects on almost all industries that require measurement technology, down to the individual person who has to rely on the adequacy of measurements for his or her health and safety and for any business and official public activities.

Since its foundation in 1887 under the name of PTR, PTB's core mission has remained constant despite continuous scrutiny and modifications of the scientific-technical spectrum. This has allowed many activities to build on a long and well-nurtured tradition, and PTB has become well-established nationally and internationally. Combining all metrology tasks centrally in a national institute was the model for similar institutes in other countries.

One of the key topics of the comparative study of the five largest metrological institutes worldwide prepared by PTB was their mission. The purpose was to enable the commission to cross-check PTB's current mission. The result was a large-scale correspondence between the missions as well as in the definitions of the four fields of activities.

To fulfil its mission, PTB has an annual overall budget of ca. EUR 130 million. In comparison to the gross domestic product or the volume of foreign trade, the PTB budget is comparable with those of NPL or NIST. Despite the decreasing budget during the last few years – reduction of the budget for investments, reduction of the number of staff positions of 1,5 % per year resulting in the loss of 238 positions during the last nine years – PTB was able to strengthen or start activities through increased efficiency. These activities include metrology in chemistry, developments of optical atomic clocks, femtosecond metrology, scanning probe measuring techniques, thermal energy metrology, extreme ultraviolet metrology, nuclear magnetic resonance techniques, etc.

Assessment and recommendations

The commission considers PTB's metrology-related mission to be appropriate and important. The relevance and the benefits of this mission for the export-oriented national economy of Germany are high, as an industrial nation with medium and high technology that requires a high degree of metrology. There are equally important benefits for the safety of people and for the living conditions.

The commission recommends PTB's activities continue to be focused consistently on this mission. The commission considers the provision of the metrology base through a central governmental institution such as PTB to be indispensable. It needs to be a governmental institution to guarantee the necessary reliability, continuity, independence and neutrality. It needs to be a central institution for the flexibility to modify the spectrum of activities, to profit from synergy effects and to have international weight.

The overall budget is about adequate to fulfil the mission, as it is defined now. It will not permit PTB to enter new fields or to address in an appropriate way the most relevant metrological issues in the important and very broad fields of chemistry and of information technology as suggested by the Commission. Even the resources that could be released through improved efficiency, outsourcing of activities that are not directly related to metrology, or even metrological activities, would not be sufficient to allow PTB to strengthen activities and enter new fields to the extent needed. An increase in the budget will be necessary. The commission is concerned about the reduction of the number of staff positions which, if continued, endangers PTB's ability to fulfil its mission.

2.2 Management structure

External management structure

PTB is a Federal Higher Authority and a public-law institution under the auspices of the Federal Ministry of Economics and Labour (BMWA). The complete supervisory function of the BMWA is distributed to various departmental sections, the technical supervision e.g. is the duty of the BMWA section VI A2. It is carried out by concluding and tracking target agreements between BMWA and PTB, by allocating funds as well as by supervising the technical work. PTB's management discusses and negotiates a number of detailed questions with the BMWA with the participation of various competent sections. The BMWA examines e.g. the foundation and dissolution of permanent organisational units, transfers of functions, promotions above the A-15 level and the career qualifications of civil servants in each individual case. In particular, building projects, individual purchases from EUR 25,000 onwards and the expenditure on information technology are planned for within the framework of annual budget preparations. Changes of the staff plan have to be within budgetary planning and are subject to approval by the Federal German parliament, the Bundestag.

PTB and BMWA receive advice from an Advisory Board, the Kuratorium, that currently consists of 29 members from industry (14), science (13) and public authorities (2). This is laid down in the by-laws of PTB. The Board is chaired by that director general of the BMWA whose division is responsible for the technical supervision of PTB. With its recommendations, the Kuratorium influences decisions on major capital investment and work priorities. The discussions generally take place during the annual meeting of the Kuratorium at PTB. In addition to the Kuratorium, there are other bodies such as both the Advisory Board (Beirat) and the technical committees of the DKD (German Calibration Service), the General

Assembly for Verification and the Advisory Board for Medical Metrology that provide advice to PTB.

Apart from technical supervision and the advisory bodies no further external bodies are responsible for the systematic evaluation of the technical performance of PTB.

Assessment and recommendations

Given PTB's mission, the commission believes the integration of PTB in the BMWA to be appropriate. After an extensive discussion, however, the commission came to the conclusion that from the point of view of the mission, the existing structure of PTB management, BMWA and Kuratorium including the regulation of the supervisory function by BMWA is not an optimal or modern solution. Therefore, the commission recommends a restructuring of the competencies, authorities and responsibilities of PTB management, BMWA and Kuratorium. The core feature of this restructuring should consist in the formation of a Supervisory Board (Aufsichtsrat) and a Board of Management (Vorstand) as is well-established in industry. The management of PTB should be as autonomous and self-governing as possible. This structure should be supported through a Technical Advisory Council (Fachbeirat).

The Supervisory Board is recommended to consist of a maximum of 10 representatives from the Ministry, industry and science. The PTB Board of Management would correspond to the Presidential Board. The Supervisory Board and Board of Management should conclude target agreements that make mission compliance measurable. The Technical Advisory Council would correspond to the current Kuratorium and its tasks should focus on advice for the Board of Management on strategic issues. In order for the Technical Advisory Council to be able to work efficiently, a size of not more than 15 members and a clear definition of the tasks, possibly with reporting obligations, are recommended.

The commission recommends to conclude the complete restructuring, after verification of the legal framework and establishing rules of procedure, within one year.

Internal management structure

PTB consists of eight technical divisions, divided mainly along the lines of physical and technical subjects, one division for cross-sectional tasks and one division for PTB-internal central administration and service functions. PTB is headed by a Presidential Board with three members.

The Presidential Board concludes target agreements with the heads of the divisions on the basis of annual work plan discussions and an assessment of last years' results. Discussions on the work programme and appropriation of funds are included. Moreover, the establishment of facilities with large investments and a purchasing volume of above

EUR 250,000 is discussed throughout PTB in the framework of a scientific symposium, often lasting various days.

In the divisions, there is a three-level hierarchy with heads of divisions (Abteilungsleitung), heads of departments (Fachbereichsleitung) and heads of laboratories or heads of projects, respectively. It is planned, beginning 2003, to reduce the hierarchy to two levels of management by creating new departments with a size between that of the old departments and the laboratories, but without new laboratories as independent organisational units. All areas of work within a new department will generally be of a temporary nature.

Assessment and recommendations

The commission welcomes the internal restructuring of the organisation that will contribute to shortened lines of communication and allocating resources in a more flexible manner.

2.3 Budget

The total annual budget of PTB of ca. EUR 130 million has remained rather constant over the last few years. It includes personnel costs, costs of investments and consumables, and construction costs. The resources available for investments have been decreasing continuously due to inflation and compensation for increased salaries and wages as well as due to the five per cent efficiency yield of flexible titles transferred to the Federal Ministry of Finance. The EUR 7.9 million for investments available in real terms are clearly below the EUR 25 million of depreciation costs calculated from the inventory of equipment which serves as an indicator for the funds needed to keep equipment at the current technical level.

PTB has a staff of about 1,500, with a mean theoretical funds allocation of EUR 87,000 per employee (incl. personnel costs etc.). The ratio between personnel costs and the technical investment costs (incl. consumer goods and construction measures) is 1:0.8. In comparison to other large national metrology institutes, the funds per employee available to PTB are clearly lower. In the case of NPL, PTB's are lower by 30 % and in the case of NIST by 50 %. PTB has the legal obligation to reduce 1.5 % of its positions annually without changing the balance of salary scales (prescribed "job cone"). Thus, over the last nine years 238 positions were abolished.

Most of PTB's expenditure titles are flexible, i.e. within the main groups they are completely eligible for contribution and between the main groups, they are eligible for contribution up to 20 %, as regulated in the annual budgetary law. Rollover of money from flexible titles is allowed to the next fiscal year without causing the budget to decrease, if the formation of such remainders has been accepted by the Federal Ministry of Finance as being coherent. For this flexibility, PTB has to transfer an annual efficiency yield of 5 % to the Federal Ministry of Finance, e.g. in the 2002 plan this was EUR 4 million.

One part of PTB's budget plan is the staff plan which prescribes the quality and quantity of personnel in a binding manner. PTB cannot deviate from these orders, even if it has no effect

on the budget. Changes are only possible during budget negotiations with a one-year lead time and with the consent of the German parliament, the Bundestag. The only possibility for more flexibility provided by the budgetary law is not used by PTB, because it requires a second efficiency yield of another 5 % for the budget for the flexibilised positions.

About 93% of the PTB budget is core – independant of income from services. This number does not greatly differ from that of other institutes, with the exception of NPL which has a different legal form.

Assessment and recommendations

PTB does not have enough flexibility in budget matters in order to react adequately to changing tasks. PTB's autonomy should be strengthened for the efficient fulfilment of its mission. In particular the regimentation of staff positions is an obstacle to PTB's work.

Therefore, the commission recommends to introduce a global budget. This global budget of PTB should include the following core elements:

- Flexibility of staff plans with a maximum quota for total personnel spending, especially cancellation of the fixed job cone
- budget items eligible for contribution
- annual transferability
- a cost-performance calculation and a mission-related controlling.

One model that is based on these core elements is the budgeting model that was introduced in the research centres of the Hermann-von-Helmholtz Gemeinschaft (HGF). Although PTB is different from the research centres of HGF due to its legally and politically defined tasks, the commission holds the view that the budgeting model of HGF should be investigated for adaptability to PTB.

The mean budget for investments is too low to maintain performance over time. The commission recommends increasing the budget per employee available for technical investments to at least partly compensate for the reinvestment deficits. Additionally, the Board of Management should ensure by suitable measures, that the new ratio between the technical investments and personnel costs is maintained.

A continuation of the reduction of the number of staff positions of 1,5 % per year will not allow an adequate development of PTB's staff structure and will prevent PTB from entering new fields and strengthen metrological activities such as in the important fields of chemistry and information technology to the extent necessary. The commission recommends that the positions remain with PTB and be used for staffing activities in new fields or fields where activities have to be broadened. In parallel, activities in new fields have to be based on careful study and they should be consistent with PTB's metrological mission.

Because of the long-term nature of tasks, the fundamental significance for German industry and society and the demand for independence and

sustainability it is necessary to maintain the high percentage of core funding of PTB's budget.

Third-party funds

PTB obtains ca. 7 % of its budget from third-party funds. These funds mainly come from research networks and cooperations. Income from services (ca. EUR 10 million per year), licenses, and savings due to outsourcing of PTB-internal services, generally have to be transferred to the Ministry of Finance. PTB's policy is to work in a subsidiary manner in the service sector and not enter into a competition with private service providers.

Assessment and recommendations

The commission considers PTB's policy to provide only subsidiary service activities appropriate.

Third-party funds should not form a substantial part of financing of those PTB's long-term core tasks. These require independence and a sustainable building-up of metrological competence. However, a stronger supplement to the budget financed by basic funding through third-party funds – especially through more intense cooperation with industry and through participation in international, European and institutional research projects with universities and other research institutions – would create more flexibility to work on new tasks and to improve the personnel situation and to facilitate an even closer link to highest level research.

It is recommended that the income from licenses remain within PTB to create incentives. Such additional funds could be used for temporary employment of young scientists, to promote spin-offs and staff mobility, or it could be used to award performance bonuses.

2.4 Balance of the spectrum of tasks

The largest fraction (approximately 60 %) of the budget is used for research and development. The international comparative study shows that this percentage is comparable to that of other large national metrology institutes. PTB covers a very broad range of technical subjects. As regards metrology, only NIST covers a comparable range, those of NPL, NMIJ and BNM are smaller. As regards legal tasks, the fields of activity "Metrology for Society" and "International Affairs", PTB's range of activities is broader than those of the other national metrology institutes.

Assessment and recommendations

The mission including the legal and political tasks assigned to PTB requires a high level of scientific-technical competence. This can only be achieved and maintained through substantial fundamental research and development. Therefore, the commission deems the research and development percentage in the overall budget to be adequate. It is important to point out again that the role of PTB requires very specialised and highly qualified staff. This also brings concerns for a balanced age distribution across the staff.

The spectrum of tasks is well-balanced and adequately in line with the requirements from industry, science and society. In the medium term, the commission sees the potential to decrease resources in some classical fields through stronger distribution of tasks in Europe. This would enable a shift of those resources towards necessary new activities.

In both metrology in chemistry and metrological information technology, areas of the more detailed evaluation, the relevant subcommissions gave detailed recommendations. The commission recommends a continued development of internal mechanisms to optimise the work focus, along the lines of the processes described in Chapter 4. With the recommended new management structure of PTB it should be the task of the future Board of Management to review the balance and allocation of the spectrum of activities. This should be studied with the division heads and the help of the Technical Advisory Council at regular intervals.

3. Technical work and national and international integration

A number of PTB laboratories were visited by individual auditors during the commission meetings, with each auditor selecting specific laboratories, and also by individual visits between the first and the second meeting. These visits were supplemented by evaluations by the subcommissions for the fields of metrology in chemistry and metrological information technology. With the backgrounds of the auditors, the breadth and depth of PTB and the time allotted, it was not possible to yield a PTB-wide comprehensive assessment of all laboratories. However, the commission deduced a summary from all the specific laboratory visits.

Besides the qualitative assessment of the scientific work the commission focused to the strategic position of PTB among nationally and internationally comparable institutions. A further focus was PTB's integration in the national and international scientific communities.

Summary assessment of PTB's scientific-technical work

The laboratory visits made obvious that the quality of PTB's scientific-technical work and the competence of the staff are predominantly excellent. The commission got the impression that the resources are spent in a very focused manner and well in line with PTB's mission. PTB's research activities are well integrated in the national and international research landscapes and PTB's reputation is high, especially among metrological institutions.

The future tasks of PTB will arise not only from the present needs of the customers, especially from industry, but also from basic research in universities, research institutions and international research facilities, and from other areas in society, like the sectors of laboratory medicine, food, forensics, drugs and pharmaceuticals. All this will bring new technology and thus new needs for modern metrology. Therefore even better integration in the whole research system is important in order to identify and align future work more rapidly. The participation in national, European and international project funding in the frame of research programs in cooperation with other institutions and researchers is a related issue.

Specific impressions from laboratory visits:

Because commission members visited selected laboratories, the impressions from the visits are based on the impressions of single auditors. To improve comparability, each auditor assessed for each visit the selection of the tasks, the efforts in relation to the needs, the scientific-technical qualification of the staff and the equipment within a simple assessment scheme.

Division 1: Mechanics and Acoustics

Hydrodynamic test field

With the hydrodynamic test field, the department has established an elaborate measuring apparatus for volume and flow measurement of flowing liquids. This equipment is an extraordinary engineering achievement and it is unique in the world.

The main tasks of the hydrodynamic test field are type approvals, assurance of traceability, international comparisons, testing and calibration activities, and dissemination of the relevant units to verification authorities, test centres, laboratories of the DKD and national metrological institutes of other countries. The assurance of uniformity in the area of flow measurement, where the hydrodynamic test field will contribute as national primary standard, is economically very important. In Germany's test centres alone, more than 1000 test facilities for water meters are available, as well as some hundred test facilities for liquids other than water with very different parameter ranges.

After several years of development, the department is now in an excellent position to strengthen its scientific work.

The selection of the tasks and the efforts in relation to the needs appear adequate. The scientific-technical qualification of the staff appears very good and the equipment excellent.

Division 2: Electricity

The division's activities extend from the realisation of electric units and the determination of fundamental constants to research and development in the field of electrical precision measuring techniques in cooperation with industry and to the maintenance of verification and calibration services. The establishment of a new structure comprising six departments – direct current and low frequency, electromagnetic fields and high frequency, electric energy measuring technology, quantum electronics, solid-state physics and magnetism, electric units – is imminent.

In future, the metrological tasks will be focussed in particular on the further development of quantum standards based on the selective manipulation of individual flux quanta or charges. For this purpose, the division deals with investigations into quantum mechanical phenomena at a high scientific level. It is, for example, the division's aim to use the Josephson effect for the realisation of programmable voltage standards. These can be used to realise voltage curves which can optionally be varied with time. It is generally predicted that the development of electrical metrology will tend towards a combination of precision measuring technique and dynamic measurements. In this context, the term "dynamic" refers among other things to an extension of the frequency range, shorter integration times and digital signal scanning. In addition to the utilisation of quantum mechanical processes, this development will require a diminution of structures in the sub- μm range and a linkage of electric, electronic and mechanic functions.

Fundamental research in the field of physics plays an important role in this division – in particular in the quantum electronics department – and requires sophisticated equipment. Some of the infrastructure facilities such as the clean rooms will soon reach the age where they need to be renewed. Metrology for society and the economy are other activities of great importance. These provide in metrology for society for example type approval of meters and instrument transformers, testing of standard instruments for test centres and verification authorities. “Metrology for Economy” includes cooperation in the accreditation and assessment of DKD calibration laboratories, calibration of standards and standard equipment for industry, advisory services and evaluation of new methods of measurement.

In the next few years, considerable investment will be required to guarantee adequate funding of fundamental work. In the important areas of semi-conductors and nanoelectronics PTB is faced with major challenges to keep pace with the rapid advancement of technology. To support industry the equipment must remain up to date. Important equipment in the cleanroom centre such as the molecular beam epitaxy tool is not up to date anymore.

The selection of the tasks and the scientific-technical qualification of the staff appear excellent. The efforts in relation to the needs appears very good and the equipment adequate or good in most cases.

Division 3: Thermodynamics and Explosion Protection

Metrology in Chemistry

During the first evaluation meeting on April 25 and 26, it was decided to add to the “broad-based evaluation” an “in-depth evaluation”. Based on the discussions of the laboratory visits and from other documentation, the commission decided to appoint two subcommissions for the areas of „metrology in chemistry“ and „metrological information technology“. The complete reports of the subcommissions can be found in the annex. During its meeting on August 27 and 28, the commission discussed the report of the subcommission for metrology in chemistry in detail.

Assessment and recommendations of the commission

The commission supports the results of the subcommission. Because of PTB’s mission and the importance of chemistry in German industry, trade and society (including aspects like environment, health care, food, pharmaceuticals, drugs and forensics), a marked extension is called for. A solid study should precede this extension and the activities should be well focused to PTB’s mission. The processes as described in Chapter 4 are recommended for this study.

In the medium term, PTB should aim at a leading role in the area of metrology in chemistry nationally and should be established as one of the more important national institutes in Europe. Therefore, it is recommended to initiate a process of

transferring some of the metrological activities in chemistry now existing in other German institutes to PTB in long term. On the other hand, one should consider transferring non-metrological activities now at PTB to other German institutes. Therefore, the commission recommends a study of such activities and responsibilities, and a plan for better aligning these activities be prepared and implemented.

Given the enormous field of metrology in chemistry the commission welcomes the initiatives taken by PTB to establish a network with other key laboratories having capabilities and competence in these areas, institutes like the BAM, UBA and the DGKC. The commission recommends continued broadening of this network with other key laboratories in Germany having expertise and capabilities in additional fields of metrology in chemistry. These other institutes in the network may act on behalf of PTB as a national metrology institute for certain defined quantities/measurands and measurement ranges.

The commission recommends that PTB be charged with overall coordination of the programme and international representation (assisted by the other institutes involved) in order to establish a network meeting the needs of German trade, industry and society and to insure representation of German interests in metrology abroad.

The broad plan for the field of metrology in chemistry, including an estimate of the required resources, should be developed within one year.

The selection of tasks within the limited possibilities, the efforts in relation to the needs, and the equipment all appear very good. The scientific-technical qualifications of the staff are also very good especially when one considers that this chemistry unit is relatively new.

Explosion protection

The field of explosion protection is considered to have a bridging function between legislation, economy and science. The knowledge especially about the ignition processes of explosions is developed through fundamental research. The available technologies are constantly changing which leads to the requirement for on-going research activities and parametrisation of the conditions for safe operation. This thorough research is the basis for PTB both as discussion partner and adviser such as in legislation and standardisation and as partner in research and development cooperations. Testing activities are only a part of all activities in this field. Over the years PTB helped to develop a number of various organisations such as the TÜV towards qualified test centres.

The unit on explosion protection may be viewed as a spin-off activity of the expertise in measurement technology existing at PTB. Moreover, this activity by PTB is based on existing German legislation. However, in general this type of activity is not considered to belong to the core activities of a national metrology institute. It may well fit in related safety testing activities carried out by other institutes having comparable responsibilities in this

field. If resources have to be made available for new metrology areas, such as chemistry, bio-technology and information technology, consideration should be given as to whether resources can be, at least partly, made available by decreasing the activities of the unit on explosion protection, leaving these activities to other institutes.

In itself the selection of the tasks and the efforts in relation to needs and existing legislation appear, like the scientific-technical qualifications of the staff and the equipment, very good.

Division 4: Optics

Photometry, Radiometry

The photometry and radiometry program has many industrial and other applications. In addition to such basic tasks as those related to the units of candela, lux, lumen and the colour temperature for the important lighting industry, there are now many new aspects of photometry and radiometry related to medical safety, ergonomics of the workplace, traffic control and lighting systems using LEDs. The LED work is likely to be of increasing importance in the future. All of this seems to be well adapted to current needs and future requirements. A major investment is the novel robot-controlled goniophotometer. This is a good example of the sort of instrument that can only be set up by an institute such as the PTB. It will be a unique European facility. It was a good decision to embark upon this project.

The selection of the tasks, the efforts in relation to the needs, the scientific-technical qualification of the staff, and the equipment appear excellent.

Time

The realisation of the legal time is one of the most well known activities of PTB, and a large part of PTB's international reputation is related to this activity. The PTB remains the principal reference for the world's time scale UTC. PTB disseminates the national time via long-wave broadcast DCF77 which binds significant resources, via the telephone network and increasingly via internet. The economic benefits of this service are significant not only in jobs created in the field of radio-controlled clocks but also in the VAT tax accrued, outweighing by a factor of 12 the running costs of the PTB time laboratory. This is a field in which advances in basic science are taking place rapidly and it may be that major new investments will be necessary in the not too distant future in relation to primary clocks.

The selection of the tasks, the efforts in relation to the needs, the scientific-technical qualification of the staff appear excellent. The equipment of this well-recognised laboratory is excellent at many places, modern solid-state lasers, however, as they are standard in other institutions, are not yet used in all experiments of the laboratory.

Division 5: Precision engineering

Mask metrology

The mask metrology program is strongly industry-needs oriented. The very good results of PTB's work make sure that advanced ultra-precision standards are established and thus compatibility in the field of lithography (nano- and microelectronics) and surface techniques (storage devices) is guaranteed. Further improvements of the accuracies are required, however, in order to maintain competitiveness. This will necessarily require new investments. PTB's work, which is done with high competence, is related to nanotechnology. It serves a limited number of companies in the fields of semiconductors and ultraprecision engineering and is focussed to safeguard technology leadership. The work thus contributes to the enormous added value in this area of high technology.

The scientific-technical qualification of the staff and the motivation appear excellent. The technical work is well recognised by industry. Cooperation with industry and use of extremely expensive ultra-precision facilities of industry should be considered. If this is possible it could lead to a reduction of PTB's reinvestment needs. Such a cooperation model could also be helpful for accelerating technology transfer.

Coordinate metrology

PTB's activities in the field of coordinate metrology are exceptional with respect to their combination of orientation to industry and scientific level. The close cooperation with small and medium enterprises and large industry companies is exemplary. This becomes obvious especially in the joint development of measuring instrumentation and even in a transfer of devices which are developed in PTB to industry.

Outstanding technical results were achieved in the field of traceability of geometric measurements on coordinate measuring devices. Here PTB has become an international leader both for the development of calibration methods and the validation of related software components. In addition, new methods were developed for the measurement of micro-geometries which have already found wide-spread application in industry.

The selection of the tasks corresponds very well with the needs. Through their own initiative and cooperation with industry, the equipment is good. The scientific-technical qualification of the staff is excellent. The efforts support the international leadership position of German manufacturers of coordinate measuring devices in a useful and adequate manner.

Division 6: Ionising radiation

The work of the Division is a good example of PTB's tasks for "Metrology for Society". The varied spectrum of activities encompasses not only metrological developments for the economy but also important tasks for medicine, environment and basic research.

The selection of the tasks, the equipment, and the efforts in relation to the needs appear very good. The scientific-technical qualification of the staff appears excellent.

Radioactivity

The realisation and maintenance of the unit of activity, the Becquerel, as well as the development of techniques to determine very low activity are important objectives of the department, above all for the environment. The dissemination of the unit of activity is ensured by the availability of standards in the form of radioactive sources and by calibration of measuring instruments for industry and research. Radionuclide data form the basis of all activity measurements and therefore are determined and evaluated in this department. The delivery of about 300 standards for approx. 30 nuclides, as well as 140 calibrations and 110 air dust analyses per year are a proof of the efficiency of this department. The dissemination of the radon standard, the calibration of measuring instruments that are carried out in an accessible radon chamber where temperature, atmospheric pressure, humidity and aerosol content can be varied, play a particular role.

Dosimetry in medicine

The tasks of this department cover the realisation and dissemination of the unit of water absorbed dose, the type evaluation of dosimeters for radiodiagnostics, the dose measuring procedure for external radiation therapy and brachytherapy as well as the measuring technology for X-ray diagnostics. For these tasks reference radiation sources are developed and provided. The PTB was the first NMI to use water absorbed dose based dosimetry for external radiation therapy. In future, the calibration of measuring instruments for cardiovascular brachytherapy will still gain in importance; for this area a secondary standard for dose determination in the near field of beta emitters has recently been developed. Also in the area of X-ray diagnostics, the department has made numerous contributions to improving the measuring technique, which have made their way into ISO standards.

Dosimetry for radiation protection

This department deals with the units of the radiation protection measurands for photon and beta radiation. Dissemination is ensured by calibration of secondary standards the department in part develops itself to pass them on to industry for manufacture and sale. On behalf of legal metrology (especially on the basis of the verification, X-ray and radiation-protection ordinances), the division also carries out type evaluations for area and individual dosimeters. Both on the national and on the international level, the department enjoys a good reputation as a competence centre and is frequently consulted by federal ministries for technical assistance in solving important problems (e.g. exposure to radiation due to radar systems).

Neutron metrology

PTB has an extensive program in neutron metrology. The tasks include the realisation of several primary standards and the calibration of dosimeters. Radionuclide-neutron

sources are used for calibrations of area dosimeters and for test irradiations of personal dosimeters that are in official use. The department is well integrated in the international community. It is indispensable that Germany, i.e. PTB, maintains competence in this field, mainly due to the long operating times of nuclear power plants and due to the large interest for new neutron sources for research. Regarding the neutron metrology and dosimetry the commission finds a high-level research.

Division 7: Temperature and Synchrotron Radiation

Temperature

There is a long history associated with the temperature work at the Berlin site that has even led to Nobel prizes. There is a strong sense of history in the institute. The fact that the mission remains essentially the same, although much extended in scope and updated to follow advances in science, reflects current needs and provides a solid basis for decisions on future work.

Accurate temperature and heat measurement are an essential requirement in a wide range of mostly industrial activities. Increasingly, and for obvious reasons, heat metering is of industrial importance. This is properly reflected in the large effort and new installation for thermal energy measurement, which is another unique European facility. The result of this closeness to industrial needs is that there are many direct contacts between the PTB staff and industrial users in this field.

Future work and research in the thermometry area is decided on the basis of the close contacts that exist among the temperature groups of NMIs worldwide. There is not much in the way of basic physics development in this area but the industrial need is high and there must be continual striving to maintain capabilities. The research programme provides a good mix of practical problems together with longer-term more speculative related ones. In the low-temperature physics area there are good links to universities and research institutes where academic studies in low-temperature physics relate well with the PTB work.

The selection of the tasks, the efforts in relation to the needs, the scientific-technical qualification of the staff, and the equipment appear excellent.

Radiometry with synchrotron radiation

PTB operates a laboratory for ultraviolet, vacuum ultraviolet, and X-ray radiometry with synchrotron radiation at the electron storage ring BESSY II in Berlin-Adlershof. Making use of the calculable properties of synchrotron radiation the radiometric quantities and primary detector standards are realized for this spectral region, and transfer sources and detectors are developed. The operation of the facility is very expensive, but it is unique in Europe and – based on earlier work at BESSY I – it has brought PTB in a worldwide leading position. The early decommissioning of BESSY I has made the work in the

spectral region from infrared to vacuum ultraviolet significantly more difficult. Thus it is planned to build an own small storage ring for larger wavelengths on the BESSY site.

The applications of radiometry with synchrotron radiation are increasing in number and importance. PTB now provides the radiometry reference for the ESA missions SOHO and the X-ray Multi Mirror as well as for the NASA mission Chandra. PTB develops measurement capability in support of future semiconductor chips, which will be manufactured using extreme ultraviolet lithography. There is a close cooperation with industry in this field. Both the investigations of optical properties of surfaces of extreme ultraviolet optics and the quantitative X-ray fluorescence measurements of wafer surfaces are unique in Europe.

The facility for synchrotron radiometry at BESSY II is very impressive, and it is an excellent example of how a strategic decision taken some years ago to develop synchrotron radiometry at PTB has turned out to be of high industrial importance for reasons that were not necessarily clear at the time.

The selection of the tasks, the efforts in relation to the needs, the scientific-technical qualification of the staff, and the equipment appear excellent.

Division 8: Medical physics and metrological information technology

Medical measuring techniques and biosignals

Medical physics is a field of work of PTB which is rich in tradition, well developed, of high reputation and of high social relevance. Main fields of work of the departments "Medical measuring techniques" and "Biosignals" are biomagnetic measuring techniques, high field nuclear magnetic resonance measuring techniques and biomedical optics. In these fields, the departments have reached an internationally recognised - and in part leading - position. They operate unique measuring equipment such as the magnetically shielded room with a multi-channel vector magnetometer which is under construction, a magnetoencephalograph and a well-equipped high-field whole-body tomograph.

The conventional fields of medical measuring techniques, such as partial blood count, blood pressure, intra-ocular pressure, pulmonary volume etc., are handled with innovative methods. Metrological developments for molecular medicine, i.e. clarification of the molecular causes of diseases, however, are dealt with only in the initial stages and should be strengthened or initiated, respectively. Additionally, this field is well suited for cooperations with science and economy. Efficient data analysis and modelling is regarded as indispensable for medical physics. This supports the interdisciplinary mutual stimulation among groups with physics and with mathematical/information technological focuses.

By the development of innovative medical measuring methods and measuring apparatus, including data analysis, the departments make original research contributions on a high scientific level, which also serve standardisation.

The two departments are cooperating with a large number of clinics, universities, biomedical research centres and industry, in particular in the Berlin area, but also on a national and international level. These cooperations are altogether very successful and in many cases possible only with the aid of third-party funds.

Close cooperations with clinics guarantee an efficient orientation to the medical needs and ensures that PTB scientists get access to clinical data. At the same time, the departments share their measuring equipment, part of which is operated at clinics, their metrological infrastructure and their metrological know-how with its cooperation partners, for example at the newly established Berlin Neuroimaging Centre, where the departments participate with two metrological infrastructure projects.

What distinguishes these departments are their particularly good contacts to the science community, their participation in latest developments, and their strong regional, national and international cross-linking and presence. The commission welcomes these developments and thinks that they may serve as a model for other divisions.

The importance of medical physics will increase not only for PTB, but for all NMIs. This applies in particular to the research fields which are at present most dynamic, e.g. molecular medicine and biotechnology, in which rapid developments are to be expected in future. The stronger integration in national and international research activities is of high priority for these fields. PTB is well aware of the needs and intends to do this.

The selection of the tasks, the efforts in relation to the needs, the scientific-technical qualification of the staff, and the equipment appear excellent.

Metrological information technology

During the first evaluation meeting on April 25 and 26, it was decided to add to the “broad-based evaluation” an “in-depth evaluation”. Based on the discussions of the laboratory visits and from other documentation, the commission decided to appoint two subcommissions for the areas of „Metrology in Chemistry“ and „Metrological Information Technology“. The complete reports of the subcommissions can be found in the annex. During its meeting on August 27 and 28, the commission discussed the reports of the subcommissions for metrological information technology in detail.

Assessment and recommendations of the commission

The commission supports the results of the subcommission. The commission recommends a comprehensive review of the entire field of work to establish which activity is of internal relevance and which is of external relevance. With the latter the responsibilities of other federal institutes have to be clarified. It must be ensured that the tasks carried out by PTB are focused on the mission and the legally defined tasks particularly as regards data security.

It is recommended to define a methodology for the selection of tasks and the derivation of the benefits thereof. The processes described in Chapter 4 should be included for this review.

The review and plan of the whole field of metrological information technology, including an estimate of the required resources, should be completed within one year.

The commission agrees to the view held by the subcommission that the internal activities in metrological information technology are cross-sectional tasks which should be made evident and implemented accordingly. A balanced number of staff should be considered.

In relation to the limited resources, the commission considers the quality of the work as good.

Division Q: Scientific and Technical Cross-Sectional Tasks

The division Q is the only technical division that is not organised along physical and technical subjects, but holds various cross-sectional tasks. The departments are “Fundamentals of metrology”, “Certification and quality management” that includes legal metrology, “Infrastructural information technology” as well as “Technical cooperation”. A restructuring of the division is planned.

The commission supports the planned restructuring of the division towards a consistent integration of the cross-sectional tasks into the structural organisation of PTB, and it especially supports the consequent linking of the cross-sectional area of “Fundamentals of metrology” with the problems in the individual technical divisions.

Legal Metrology, Certification and Quality Management

Legal metrology is an area of metrology regulated by specific laws and ordinances. Due to Germany’s federal structure the 16 Länder maintain own verification authorities and about 90 local verification offices. Additionally, about 370 state-approved test centres exist with manufacturers and utilities for electricity, gas, water and heat. PTB’s responsibilities include all type approvals, advice to the Federal Government, to the verification authorities and test centres, and providing traceability for the standards of those authorities and centres. PTB will become Notified Body in the frame of the European Measuring Instruments Directive (MID).

The laboratories of PTB that carry out type approvals and testing are integrated into the technical divisions. Within the department “certification and QM” of division Q, a section is responsible for coordination of PTB’s activities related to legal metrology, and additionally there is a steering committee. A committee „Legal Metrology“, composed of representatives from the Federal Government and the Länder (Bund-Länderausschuss), has a coordinating function, especially for matters of legal metrology related to economical issues. The General Assembly for Verification decides technical details under the chair of PTB. The Bund-Länderausschuss is requested by the Conference of the Ministers of Economics to provide in January 2003 a paper outlining the future structure of the verification system.

The organisation of legal metrology in Germany and the organisation of the corresponding activities of PTB should generally remain as they are. In particular PTB's sole responsibility for the primary standards and the integration of the laboratories that are active in legal metrology in the individual technical divisions are of great use. These structures guarantee a mutual stimulation with the basic-research oriented laboratories and a high competence.

The commission, however, recommends the establishment of a "Legal Metrology Advisory Board" in which the higher responsibilities are bundled. These responsibilities include the coordination of tasks of the Federal Government and of the Länder, international contributions, coordination of legal metrology within PTB and the identification of future developments in this area. This Board should not be an additional committee, but it may emerge from PTB's section within division Q, PTB's steering committee for legal metrology, and the General Assembly for Verification. Better efficiency and visibility of the activities related to testing and verification through bundling appears important in view of the competitive situation with other national metrology institutes.

The commission recommends that the plan for such a "Legal Metrology Advisory Board" be completed within one year.

In the laboratories „weighing instruments“, „electricity meters“ and „heat meters“ that were visited by commission members, the selection of the tasks and the scientific-technical qualification of the staff appear excellent. The efforts in relation to the needs and the equipment appear very good.

Technical Cooperation

PTB's activities in the field of "International Affairs" are not only related to cooperation with other NMIs and to international responsibilities in the area of metrology, but they are also related to technical cooperation with developing countries, countries in transition and threshold countries. Most (18 of 26) of the positions are funded by the Federal Ministry for Economic Cooperation and Development (BMZ).

Placing such activities under the umbrella of PTB is of great mutual benefit to the work of PTB and that of the BMZ. While German industry, which PTB supports as one of its tasks, benefits from easier market access, the BMZ uses PTB's technical competence.

The selection of the tasks and the efforts in relation to the needs appear good. The scientific-technical qualification of the staff appears very good.

Division Z: Administration and Service Sections

Division Z is responsible for PTB-internal central administration and technical services. Over the last few years, more jobs were eliminated than necessary based on the legally prescribed job reductions. This meant that jobs were transferred to the technical departments in real terms. Nevertheless, some sections of division Z need substantial

resources, i.e. related to the operation of the electronic budgeting system (from the company SAP) and the cost-performance calculation.

The division seems to be very efficient. However, the commission recommends that the division relook at how they might gain additional efficiency in order to provide more resources to the technical tasks of PTB. Administration tasks should not just be transferred into the technical divisions. This could actually be detrimental to the main tasks. In addition PTB should study whether there are administrative tasks distributed in the technical divisions that might be concentrated in division Z.

Vocational Training

PTB trains more than 100 young people in 11 apprenticeships within the framework of a political mandate. The equipment provided for this is excellent. About 20 % of the trainees remain at PTB in permanent jobs. PTB clearly does more than just provide for its own needs in this area. It has been most interesting for the auditors that the training activities are de facto separated, and that – due to a virtual company – the trainees learn to cope with the marketability of their activities and economic aspects of their work. This puts the training close to the market and might be one additional reason for the excellent results the trainees have achieved and their success on the job market. Although the number of persons trained exceeds the number of jobs PTB can offer after completion of the training, PTB should consider whether this system should be extended and thus serve as a model for other institutions working in the area of public research.

The selection of the tasks, the efforts in relation to the needs, the scientific-technical qualification of the staff, and the equipment appear excellent.

4. Processes

4.1 Processes with international relevance

The PTB has participated extensively in the international arena since its foundation. Through cooperation in international organisations and committees, PTB aims to support the worldwide development of the SI-system of units, to remove non-tariff barriers to trade, achieve adequate protection of the citizen, to improve and strengthen the position and international recognition of the German national measurement standards and measurement and calibration capabilities of PTB (incl. the recognition acceptance of measurement and calibration certificates issued by PTB). The most important organisations with PTB participation are the Inter-Governmental Treaties of the Metre Convention and the OIML, the Regional Metrology Organisations EUROMET, COOMET, and WELMEC, many national and international scientific and technical organisations and several standardisation committees. The PTB is a signatory of the CIPM Mutual Recognition Arrangement (MRA) under the Metre Convention. Additionally, close cooperations exist with a number of other national metrology institutes. Further, largely funded by the Federal Ministry for Economic Cooperation and Development (BMZ), well received support is given to the development of the metrology infrastructures in developing countries, countries in transition and threshold countries.

PTB does extensive research to maintain the basis for its mission compliance. Science and research at the highest level are only possible in cooperation and in competition, and thus also require the integration in the international community. PTB favours in particular international cooperation within the European framework. However, it is noted that formalised international cooperation is often hindered by different objectives, priorities and policies of the respective countries and their NMIs, as well as by complex international administrative procedures.

Recent developments, triggered by the EU Directive on In-Vitro Diagnostics, in which the PTB, together with the DGKC, participates concern the creation of the Joint Committee on Traceability in Laboratory Medicine - JCTLM, bringing together all stakeholders like the Metre Convention, the International Federation of Clinical Chemistry and Laboratory Medicine - IFCC, the World Health Organisation - WHO, the International Laboratory Accreditation Cooperation – ILAC, industry associations, regulators, and standardisation bodies.

It is expected that also in other areas, like the food sector, this type of international cooperation will become established.

Assessment and recommendation

The commission regards strong national, European and international participation and cooperation by PTB essential for efficient mission fulfillment. The commission therefore recommends strengthening and continued development of this international participation and cooperation as far as possible.

The realisation of an institutionalised, international network of cooperating NMIs should be pursued and is considered almost inevitable in the field of metrology in chemistry. A division of work and sharing of capabilities, in particular in the

certification and characterisation of primary pure substances (primary certified reference materials) is strongly recommended.

Quality assurance

Another aspect of the international integration is feedback related to the quality of the technical work and the strategic plan at PTB. Presently, feedback is realised mainly on the working level via the various contacts of PTB staff.

Recommendations

The commission recommends carrying out scientific evaluations in the individual areas of work at regular intervals, for example every five years. These evaluations should be initiated by the Board of Management with participation by the future Technical Advisory Council. They could be organised as were the in-depth evaluations of the two subcommissions. Each evaluation should include both technical and management quality and the strategic direction. The results should be reported to the Board of Management and they should be part of the general strategic planning process and help promote an efficiency-oriented allocation of funds.

4.2 Processes with national relevance

With the diversification of „classical“ metrological tasks and the creation of new technologies it will be more and more important for PTB's management to have mechanisms and processes available that allow to recognise necessary changes in the spectrum of tasks at an early stage. These are processes with external, mostly national relevance, together with processes related to technology transfer, patents, outsourcing of activities, and spin-offs.

The mission-oriented definition of tasks requires the identification of short and medium-term needs of customers. This allows for tailor-made short-term and medium-term reactions. The processes for the identification of customer needs may also serve to get feedback on the quality of the technical work of PTB. The identification of long-term, for PTB's mission relevant developments, especially in new fields of technology where customers are not (yet) known, requires additional processes.

Identification of customer needs and assessments

In its comparative study of the five largest NMIs, and in its responses to the evaluation questions PTB describes how it identifies customer needs and assessments by way of contacts between the staff and external groups in industry, science and society.

On the basis of the suggestions of the commission, the Presidential Board plans to systematise and supplement identification of customer needs. This includes integrating the processes in the target agreements and carrying out global surveys and analyses.

Assessment and recommendations

Generally, the commission recommends identifying customers in each area of work and studying the needs of customers in order to derive conclusions for the definition of tasks. Additionally, the results should be assessed by the customers at regular intervals.

Because of the broad range of tasks of PTB, it is important to maintain and use the various ways of communication between PTB staff and customers. In all of the laboratories visited by the commission, customer contacts exist and are vital.

To determine valid customer requirements it is important that contacts between PTB staff and customers are at many levels, not only the working level but also at upper management levels.

Because of the many, differing tasks of the technical divisions different mechanisms may be needed for the identification of customer needs and assessments, such as surveys or the formation of advisory boards. PTB's Board of Management should make sure that the assessment criteria allow for comparability.

Identification of long-term developments of economy and society

At the moment, neither PTB nor the BMWA nor the Kuratorium provide a systematic analysis of long-term developments in industry and society relevant for PTB. Based on ideas discussed with the commission, PTB plans to start its own analyses and to evaluate external studies and surveys.

Assessment and recommendations

For a strategic cross-divisional approach of PTB it is necessary to identify tasks to be expected in the long term that are relevant to PTB. Such questions have to be dealt with at the Board of Management since decisions especially about new tasks that have not yet been handled by any division have to be guided by the overall mission of PTB.

The coordination and handling of these questions as planned by the Presidential Board is appropriate and should be pursued consistently. The focus should be on an analysis of the future developments and requirements of German industry and society. However, it is desirable to cooperate in this question also with European and international partners, mainly with the metrological institutes. A regular and substantial involvement of the Technical Advisory Council would be desirable.

Technology transfer and patents

PTB's activities related to technology transfer and patents were evaluated in 1997 (together with BAM and BGR) on behalf of the BMWi by the Fraunhofer Institute for Systems and Innovation Research with a positive result.

PTB emphatically supports technology transfer and increasingly supports patents. In 2001 6 service inventions were released and 16 were used by PTB and submitted as patents. Income from licenses must be transferred to the Federal Ministry of Finance, with the exception of the inventor's bonus up to EUR 25,000.

Mainly small and medium enterprises are involved in the technology transfer via R&D cooperations. If a partner wishes an exclusive right of use of the expected development or just a time advantage, a contract must be placed between PTB and the partner, and PTB must charge its service on the basis of a cost covering calculation. PTB must transfer 70 % of the according income to the Federal Ministry of Finance, only 30 % remain at PTB for hiring the additionally needed staff or for purchasing special equipment.

In general PTB does not follow this path. Rather, it makes use of the possibility to agree with the partner on a financial contribution for an R&D service ("contribution without service in return"). In this case the income can be completely spent for the purpose. Precondition is, however, that PTB has an interest on its own on the planned R&D project, and the partner does not get an exclusive right of use.

Assessment and recommendations

It is appropriate to support technology transfer and patent applications and this should be pursued consistently. With a view to the scientific and technological competence of PTB, the number of patents seems rather low. More systematic support would be easier if PTB were to keep the license income which would have a significant incentive effect on the staff.

PTB should get more autonomy for the realisation of research and development cooperations and the income from orders should remain with PTB. The management of PTB must ensure on its own responsibility that in the medium term the technology transfer benefits not just one but a large number of enterprises. PTB should analyse how new incentive schemes can be established to encourage the staff to participate in collaborations with industry. They should also examine what simplifications of administrative procedures related to technology transfer are possible. Models may be the technology transfer activities underway in organisations such as the Max-Planck-Society (Garching Innovation), the Fraunhofer-Society or the Helmholtz-Gemeinschaft (Ascension technology transfer agency). What is important is not only that patent matters are put on a professional basis but also that the whole spectrum of possibilities of technology transfer from patenting to licensing to new forms of commercial exploitation is dealt with as an integral whole by an own agency or jointly with an external agency that is already being operated efficiently.

The commission recommends to the Presidential Board to develop a conception regarding technology transfer and patents.

PTB should be allowed to keep the income from R&D cooperations without replacing core funding of primary tasks. PTB must ensure with appropriate measures that all projects are consistent with PTB's mission.

Optimisation of cooperation

PTB faces a significant challenge in that some of its infrastructure facilities require expensive modernisation while simultaneously needing to start or broaden and deepen metrological activities.

There is the possibility that outside users share some of PTB's infrastructure such as happens in the case of the clean room center and charging the users on a cost basis which would help to defray some of the costs. In addition PTB could investigate the use of external facilities such as happens in case of the synchrotron radiation source BESSY II. PTB also participates in investigations in the frame of the EUROMET project MERA which addresses how metrological activities in Europe may be better coordinated and metrological responsibilities may eventually be distributed.

Assessment and recommendations

The benefit of and the need for cooperation in the scientific context have been described earlier.

The commission recommends that it is investigated how PTB's infrastructure and know-how can be made available at cost for external users, in order to allow for a more cost-effective operation of the facilities. Especially where large investments are required to maintain the equipment at the state-of-the-art and where only a limited number of customers is served (such as in the field of semiconductors/mask metrology), the possibility of using external facilities should be investigated. The shared use of facilities should be considered not only within the national industry and science, but also in the international, but first of all, European context.

The benefits of this type of cooperation must be controllable by the Board of Management. It is essential that a sustainable capability of PTB to provide metrological services to fulfill its mission is ensured.

Outsourcing of activities and spin-offs

PTB pursues a mixed policy of proprietary services and third-party services (outsourcing) for administrative work or, more generally, for activities that do not fall under the core activities of PTB. However, any savings it generates from more cost-efficient external service providers must be transferred to the Federal Ministry of Finance.

The Presidential Board has a positive attitude towards spin-offs and suggests this to the staff, albeit with little success for the time being.

Assessment and recommendations

The policy pursued by PTB as regards outsourcing and spin-offs seems appropriate. However, income thus generated should remain with PTB as an incentive for more efficiency.

The commission recommends a consistent support for spin-offs which would go hand in hand with an increase in efficiency as well as a direct form of technology transfer. In providing funding, the PTB management would have to ensure that PTB's interests are safeguarded vis-à-vis the interests of individuals.

4.3 Processes with PTB-internal relevance

Strategic planning processes

Strategic planning for PTB's focussed work areas must include adequate mechanisms for identification of needs and mechanisms for the assessment of technical work.

Assessment and recommendations

The analysis of long-term developments in industry and society complements the identification of customer needs, which is a rather short-term process. Assessment of the technical work by customers on an on-going basis with short-term feedback complements the recommended evaluation of the scientific work by international auditors on a regular, i.e. 5 years, basis.

The commission recommends use of these four processes in an appropriate mixture to identify and react to short-term challenges, to be prepared for future challenges and to maintain and strengthen PTB's scientific-technical competence.

Control and administration processes

The Presidential Board concludes target agreements with the divisions within PTB as well as with the BMWA. The target agreements between the Presidential Board and the divisions are at the cross section of a bottom-up approach when formulating the individual projects in the divisions and the top-down component of strategic guidelines provided by the Presidential Board. Competence in specific scientific-technical details as well as specific customer wishes come from the staff of the departments and from their contacts to companies, institutes and associations, and thus, find their way into the target agreements. The Presidential Board, however, has to ensure that the strategic direction of the PTB as a whole is well-balanced and corresponds to the mission.

The Presidential Board has accomplished considerable shifts of tasks and resources in the past. In order to expand these possibilities, the Presidential Board will in future reserve about 10 percent of the funds available for materials and investments as a preliminary allowance. The funds will be used to tackle new subjects, to implement projects of great strategic importance and also to support very original and innovative project proposals (after external assessment, if appropriate). A similar approach will be used in staffing. It is planned to create a "job pool" encompassing about 40 temporary positions mainly for scientists. The decisions on these positions will be taken by the Presidential Board - where appropriate, with support from external experts – to promote certain projects or to meet strategic needs.

Since January 1, 2000, PTB has been developing a cost-performance calculation, and it is implementing a controlling system. At this point in time (middle of 2002) the main function of these instruments is to provide the management (division heads and the Presidential Board) with an overview on the resources employed, and it allows calculation of the costs for services.

Assessment and recommendations

The concept of target agreements is appropriate and should be maintained. It must be made sure that the agreements are concrete and measurable and that compliance is monitored. Suitable measures in case of deviations from agreements are medium-term and long-term adaptations of allocated funds and performance bonuses for the staff.

The commission deems both the job pool and the reservation of 10 percent of the funds available for materials and investments as a preliminary allowance to be appropriate and important in order to improve flexibility for strategic decisions.

Based on the efforts undertaken, it would be desirable if the cost-performance calculation were used for control processes to a greater extent. Cost-performance calculations should be part of the global budget. In order to manage a global budget, a further extension of the cost-performance calculation towards a mission-oriented controlling is required with precise reference to administrative data and to the processes as recommended in this report.

Personnel management

The regulations that apply to the staff plans are described in Chapter 2. PTB is subject to legally prescribed job reductions of 1.5 % every year. Mostly, this is handled by not filling positions that are open due to retirement. This leads to a continuously increasing mean age of the staff.

PTB has only very limited possibilities to employ younger staff, i.e. by acquiring third-party funds at DFG for Ph.D. candidates and postdoctoral fellows, by using unfilled permanent positions or by using positions for part-time retirement.

For 3 years, PTB has been using the possibility to award bonuses to the staff for special achievements as determined in the regulations for the public-service sector (maximum is one

monthly salary per member of staff, for a total maximum of 10 % of staff in a given year, total budget EUR 200,000 per year).

Supporting staff mobility is an important way to increase motivation and efficiency. At the moment, mobility within PTB through job rotation is used rarely, with the exception of temporary employees. The number of visits by PTB staff to other institutions as guest scientists is clearly lower than the number of external guest scientists coming to PTB (ca. 30 at any given date). The Presidential Board supports mobility and, based on suggestions from the commission, plans to establish an internal planning group to further intensify these activities.

Assessment and recommendations

The scope of action available to PTB in the personnel area is not sufficient. Here, a greater flexibility is needed. The commission recommends abolition of the rigid staff plans. The global budget as recommended by the commission should include that flexibility.

Performance bonuses are an effective instrument for increasing motivation and productivity of staff by providing pay for achievements. Bonuses should be used consistently and, if possible, to an even greater extent in the future.

The legally prescribed job reductions is very counterproductive to a competitive position of PTB because it prevents hiring of young staff. Highly qualified young staff must be hired in order to meet new requirements – of course while adhering to budget limitations.

These measures for staff mobility will only help to a limited extent among the older age distribution. Even so, they should be extended and pursued consistently.

The commission is convinced that it is important to have structured processes which are transparent in order to manage and control them, and that they have to be integrated into the quality management system.

5. Terms of Reference

The answer to the terms of reference is essentially found in the evaluation report as follows:

ToR 1

As the national metrology institute, the PTB is at the top of the hierarchy of the German metrology system for the German economy. It is its task to contribute to the metrological infrastructure of the country and to render advice with a view to providing one of the essential prerequisites for highly developed research and innovative industrial production. This is aimed to significantly further the competitiveness of our economy, especially of the small and medium-sized enterprises.

Does the contribution of the PTB to the metrological infrastructure meet the needs of the target groups and is optimum transfer to the customers ensured?

The commission deems PTB's tasks as described in ToR1 within its general mission to be adequate (compare Sec. 2.1). The assessment and recommendations of the commission regarding the fulfillment of customer needs and the transfer to the customers are described in detail in Chapter 4, and – related to specific laboratories – are included in Chapter 3.

ToR 2

The PTB is bound by a number of laws to ensure reliable measurements in the focal areas of environmental and consumer protection, safety and medical engineering as well as radiation protection, and thus to make an important contribution to maintaining and enhancing the quality of life. In this respect, due to the enterprises' increasing own responsibility, the activities of the PTB are shifting from technical testing and approval activities to the development of novel measuring and testing procedures, particularly to support the institutions responsible for market surveillance.

Does the PTB master this responsibility in all areas? Does it respond appropriately to changes in this process by shifting focuses of research, testing and transfer of knowledge?

The commission deems PTB's tasks as described in ToR2 within its general mission to be adequate (compare Sec. 2.1). The assessment and recommendations of the commission regarding this task are – related to specific laboratories – described in Chapter 3. The mechanisms for the identification of the needs of economy, society and science are described in detail in Chapter 4, recommendations for the mechanisms for the realisation can be found in Chapter 2 and Sec. 4.3.

ToR 3

In a Europe growing close, according to its European and global role, the PTB has the task to safeguard the economic interests and the international responsibility of Germany as a trade nation, particularly by collaboration in the international network of metrology institutes as well as by technical co-operation with developing countries.

Does the PTB master its responsibility as regards the realisation of the future European metrological infrastructure? How is the PTB to be assessed in comparison with the metrology institutes of other leading economic nations?

The commission recognises the need for international cooperation and for an international harmonisation of regulation and standards, mainly for the removal of non-tariff barriers to trade. This need lies in the nature of metrology itself. PTB fully matches these requirements by its manifold participations in committees and bodies. Due to the enormous complexity of the subject matter, however, the commission is not able to give detailed recommendations for the development of an international metrology infrastructure. The international comparison study – that was prepared by PTB at the request of the chairman of the commission – describes PTB's position among the five world-wide largest national metrology institutes, making PTB's leading position obvious.

ToR 4

With its basic research in metrology the PTB is meant to make an essential contribution to the continuous innovation process in economics and science. The focuses are the realisation, maintenance and dissemination of the SI units, particularly on the basis of fundamental constants and quantum phenomena as well as the utilisation of technological innovations for metrology. This area of tasks which is continuously updated worldwide is the focus of work of all competent metrology institutes.

Do these core activities of the PTB fulfil the requirements for a national metrology institute integrated into the worldwide metrological network, and in which direction should the focuses of this area be shifted?

The commission deems PTB's strategy to be adequate to build and maintain competencies in all fields of activity by allocation of about 60 % of the resources to research and development. Assessment of the technical work in selected, representative laboratories of all divisions is given in Chapter 3. Specific recommendations are given for the fields of metrology in chemistry and metrological information technology, based on the results of the two

subcommissions. Additionally, the commission, however, does not want to give more detailed recommendations regarding the termination or start of specific tasks. In contrast, models of a new management structure (Sec. 2.2 and 2.3) and processes (Chap. 4) are recommended, that aim to provide the PTB management with the required flexibility and mechanisms to adequately adapt PTB's spectrum of activities – oriented to the mission – according to changing needs.

ToR 5

In Germany, the responsibilities for metrological basic research, metrology for industry and metrology for the area under legal control - combined with international co-operation - are concentrated on one institution - the PTB - and are closely interwoven. This provides the prerequisite for setting up a competence base in each individual area of activities, which cannot be realised otherwise. Tasks which in the opinion of the PTB would be more expediently dealt with by other bodies are given up - except for the extent necessary to maintain competence - so that additional resources will be available for new tasks.

Can the synergies resulting from the linking of the areas of activities be better utilised? What entrepreneurial strategy and what criteria should the PTB adopt when in future entrusting activities to external parties?

The commission deems PTB's strategy adequate to provide competence for all fields of activity through extensive basic research. The commission recognises a synergy benefit from the intertwining of the fields of activity and the thus enabled communication about needs and assessments of customers from economy, society and science. The mechanisms that are recommended for the selection of tasks and for the realisation are described in detail in chapter 4. Additionally, recommendations for the outsourcing of activities can be found here.

ToR 6

The PTB controls its activities on the basis of efficiency and transparency considerations with a flexible project structure and using suitable management tools. With the Kuratorium, the BMWA and the PTB are assisted by a competent external advisory and steering body, particularly for the permanent evaluation of the current spectrum of activities and for its strategic orientation to future tasks.

The PTB endeavours to support the coming generation of scientists and technicians by specific measures. To cover the future demand for qualified staff, the PTB must gain attractiveness and recognition by the quality of the tasks and the equipment necessary for handling these.

Do the internal and external control elements of the PTB meet the increasing requirements? What conditions are to be modified to enhance, and ensure also in future, the efficiency of its work? Does the PTB sufficiently support its future generation of scientists? How can the attractiveness of the PTB and the awareness of the public be increased?

The recommendations by the commission regarding the organisational structure are described in detail in Sect. 2.2 and 2.3. The recommendations for related processes and management instrument, including staff management, are described in Chapter 4.

6. Follow-up process

In the evaluation of PTB, the commission introduced a novel concept. It was characterised by an accompanying, interactive integration of the management of PTB. This concept led to changes already during the evaluation process and the formulation of plans, in particular in the context of internal management issues, was initiated. The commission attaches great importance to the process thus initiated being consistently implemented along the lines of the recommendations. It suggests that the management of PTB and the Federal Ministry of Economy and Labour report to the commission about the implementation and on-going plans after one year and after three years. The commission offers its support in the process of sustainable development of PTB.

Braunschweig, December 16, 2002

Annex

A1 Results of the subcommission for metrology in chemistry

The subcommission was given the assignment,

- 1) to comment on the expected future development of the field,
- 2) to evaluate PTB's present activities from this point of view, and
- 3) to derive recommendations for PTB's future activities, respectively.

Future development of the field

Metrological concepts are increasingly being developed for chemical quantities. This view is supported by the activities of the Comité international de poids et mesures (CIPM) and of the Comité Consultatif pour la Quantité de Matière (CCQM) during the last 10 years. So far, various topics such as gas analytics, environmental analytics and clinical chemistry, were covered by CCQM in a selective manner. The global society and industry will increasingly generate needs for traceable measurements in analytical chemistry. Thus it will be necessary to cover the missing topics in order to create the basis for a global infrastructure, which guarantees traceability of measurements in the whole field of analytical chemistry.

Recently, a committee within Bureau international de poids et mesures (BIPM) has been founded (Joint Committee on Traceability in Laboratory Medicine, JCTLM), with the goal to globally develop metrologically oriented reference measuring systems in laboratory medicine. Consequently, hierarchical structures have to be established, which allow to link the clinical-chemical field laboratories via reference laboratories with a highest-level metrological institute – a national metrological institute – which provides the primary reference materials and primary reference measuring methods. Given the diversity of analytical chemistry it becomes more and more obvious that also in food analytics and in environmental analytics corresponding hierarchical structures must be established.

Additionally, related research and development will be necessary in new fields such as metrology in nanoanalytics and bioanalytics. Presently, however, it is not yet possible to precisely quantify the metrological needs in these rapidly developing fields.

Present activities

PTB's resources in this field are not sufficient, both to adequately meet the needs of the German industry, and related to the claim of PTB to be a worldwide leader in metrology – a claim that is justified by PTB's tradition, achievements and competence.

These statements are derived from

- the economical needs of Germany being a leading developed nation

- the needs of German society related to health (laboratory medicine), nutrition (surveillance of food chain), and environment (metrological surveillance)
- the world-wide reputation of PTB in many areas of metrology.

The benchmark study indicates that, compared to the National Institute of Standards and Technology (NIST, US) and also to the National Metrological Institute of Japan (NMIJ, JP) and the National Physical Laboratory (NPL GB), the resources allocated to metrology in chemistry are clearly smaller than those of the physical quantities. This is true even if one considers that in Germany beside PTB also the Bundesanstalt für Materialforschung und -prüfung BAM, the Umweltbundesamt UBA and the Deutsche Gesellschaft für klinische Chemie DGKC are entrusted by contracts with metrological tasks. Referring to a preliminary information about 30 to 40 persons are involved in the field outside PTB.

The impression of the poor resources were confirmed during the laboratory visits.

The results, both the quality of the scientific work and the international reputation, are surprisingly impressive related to the resources (both budget and positions). This impression is supported by the results in the frame of the key comparisons within CCQM. The unit (Fachbereich) covers a broad spectrum of tasks. The selection of the individual tasks is appropriate and the equipment and the infrastructure are efficiently made use of.

Related to the poor resources the unit is focussed on holding the status, and concepts for starting activities in new fields have not yet been developed.

The unit, however, has identified the importance of the new fields of nutrition and forensics. The unit tries to approach modern key technologies such as biotechnology and nanotechnology, and succeeds by raising third-party funds. The strategy of the unit for initiating activities in new fields is first to consolidate the core competencies and then start to acquire specific additional competencies. It may be expected that PTB will be able to significantly contribute to the metrology in these new fields.

Recommendations

We recommend that the resources be at least doubled. In our opinion it is important that the unit Chemistry broadens its scientific/technical basis in order to comprehensively provide traceability of chemical quantities and in order to limit the risks related to the present limitation to few selected competencies. The legally prescribed job reductions should be stopped, since the expansion of the activities in the new, broad and seminal field of „metrology in chemistry“ is probably not possible just by reallocation of resources from other parts of PTB.

We recommend, however, that the focus be traceability issues in the fields that appear suited for starting or expanding activities. In fields in which traceability is of minor importance we recommend the raising of third-party funds for the necessary minimum staff and budget.

Generally spoken, the unit Chemistry should first consolidate present activities, subsequently, however, broaden the scientific/technical basis. We recommend the consolidation or start of the following fields, listed in prioritised form:

Priority 1	Metrology in laboratory diagnostics
	Metrology in element analytics
	Metrology in electrochemistry
Priority 2	Metrology in environmental analytics
	Metrology in nutrition analytics
	Metrology in forensics in collaboration with BKA
Priority 3	Metrology in nanoanalytics
	Metrology in bioanalytics

Before starting new fields the vision and the conception should be carefully formulated. Cooperations with universities and industrial companies such as they exist e.g. within the competence centre nanotechnology should consequently be aimed at also in future.

We are aware of the fact that not all areas can be covered by the unit Chemistry, even if the resources are substantially increased. Therefore we explicitly support the concept of distributed competencies, and we suggest to extend the already established network. Furthermore we suggest to intensify national and international cooperations, especially in research. This requires a powerful conceptual and organisational structure.

When the network is extended it has to be made sure that one leading institute exists that efficiently represents the network. Whenever metrological matters such as traceability are concerned, PTB must be this leading institute, and in consequence PTB must demonstrate its related claims.

In order to be able to coordinate the network the field should be represented by one single unit within PTB which is responsible for all decisions.

Given the increasing importance of metrological concepts in analytical chemistry, in medium or long term the unit Metrology in Chemistry should be established as a separate division with an own management.

Taken the variety of different tasks, already now the senior scientists should be given working units (Fachbereiche) below the division management such as for element analytics, electrochemistry, and laboratory diagnostics. These scientists should have the responsibilities for the program of work and for international representation and they should have the possibility of own decisions. Specifically, they should have responsibility for the staff – both disciplinary and scientifically – as well as for the budget. A merging of hierarchical functions (Hierarchieebenen) does not appear useful.

Additional general recommendations

Given PTB's reputation, role, size and especially tradition of thinking, we would understand a more self-confident appearance of PTB's staff. PTB could be more active in the formulation of European directives and could contribute in a leading position to ISO-, CEN, and IUPAC

standards. This is probably not possible, however, without more resources (in some cases there is only 1 person per field of tasks).

A long-term vision could be the establishment of a European institution for the metrology in chemistry, which originates from PTB. Given the diversity of Europe such a institution must be a network. However, it would strengthen Europe's position world wide. Subsequently, such a well-working European network may get model character for a world-wide network.

We recommend that a cost-benefit study be worked out externally, in order motivate the resources and to demonstrate the importance of the metrology in chemistry in Germany. It can be expected that the benefit outweighs the costs.

We suggest to fix within the quality management system that 75 to 80 % of the working hours be dedicated to the main laboratory-related tasks. The fraction of administrative duties (e.g. writing working reports) should be limited.

The administrative efforts for small purchases should be limited to enable short-term deliveries of urgently needed chemicals and instrumentation.

An additional comment is related to accreditation. The PTB unit accreditation of calibration laboratories ensures a competent accreditation of laboratories in a few areas and traceability is guaranteed by PTB. An expansion towards other areas such as environmental analytics and nutrition analytics appears necessary. It should be guaranteed by the selection of suited auditors that all accreditations are done with technical competence rather than with focus on management issues only.

Braunschweig, August 22, 2002

The members of the subcommission:

Prof. Dr. Paul DeBièvre, Kasrterlee, Belgium

Prof. Dr. Klaus Peter Jäckel, BASF AG Ludwigshafen

Prof. Dr. Lothar Siekmann, DGKC Bonn, chair

A2 Results of the subcommission for metrological information technology

The subcommission was given the assignment,

- 1) to comment on the expected future development of the field,
- 2) to evaluate PTB's present activities from this point of view, and
- 3) to derive recommendations for PTB's future activities, respectively.

The three items are treated separately for the fields software quality and data security, and data analysis.

a) Software quality and data security

Future development of the field

In many areas software is part of devices under test, thus it itself is under test (e.g. within legal metrology). Furthermore software in metrology is an important test method and tool. In both applications it is of increasing importance. Software extends or replaces physical components of measurement instruments and thus creates new requirements for testing those instruments.

At the same time, new technologies such as open networks or the Internet cause novel threats, not only for data transmission but also for devices in which data is generated and stored.

Present activities

PTB does not pursue its own basic research in this field. Such research is, however, not considered as a primary task given PTB's core tasks and given the fact that software testing is a PTB-internal service. Making use of results from science and industry (e.g. via committees of DATech or cooperations with appropriate university institutes), however, could be improved.

We find the quality of PTB's software-technological and software-ergonomic activities very good. However, presently there is no obligation for making use of PTB's software testing laboratory. The aspects of safety and security are covered only selectively (e.g. with respect to the transmission of data). Contacts to external groups and bodies such as standardisation committees or VDE Fachgruppen exist.

The international visibility of the group (e.g. at the MID) is good. The group's leadership is internationally recognised. The external visibility appears better than the internal visibility.

Recommendations

In contrast to the problem-oriented, vertically organised divisions, metrological IT must be considered as a method-oriented, horizontal cross-sectional task. This fact, together with the increasing importance of the area, implies that better visibility in the organisational structure is appropriate.

The obligation of software testing should be strengthened with respect to PTB's self-declaration according to ISO 17025. At least within legal metrology, wherever software is under test or used as a tool, this obligation should be fulfilled and monitored. The software-testing laboratory should have the appropriate responsibilities for all software-related matters.

Given the needs of quality assurance, the aspects of safety and security should be more thoroughly covered. We recommend the extension of the present selective work to a more

comprehensive approach in the fields of safety and security – not only covering data transmission but also data generation, storage and access to data.

A certain increase of staff will be necessary for these tasks. However, the generation of PTB know-how may be cost-effectively supported by external consulting. Additionally, it is possible to profit from many results from industry and science, if PTB staff contributes on a regular basis to committees such as sector committees of DATech. A strengthened weight of research appears desirable, not however through PTB's own fundamental research, but mainly through a better implementation of external research results and through co-operations.

Finally, better internal PTB communication with respect to matters of software quality and data security appears desirable.

b) Data analysis and modelling

Future development of the field

The standardisation of units, measuring methods, and methods for data analysis including uncertainty evaluation has always been a core area of metrology. The importance of this task will grow since in more and more areas of economy and of public life quantitative measurements are required and measurement methods become more complex and indirect. Especially technologies such as life sciences, medical technologies and nanotechnology will generate challenges in data analysis. In a highly technical and global economy the importance of PTB will increase in particular in this core area.

Present activities

Given the importance of data analysis, the number of staff in this PTB department is not sufficient and the integration of the department in the scientific community is weak. Especially validation of data and measurement models is not sufficiently covered.

In relation to the limited resources, we consider the quality of the work as good.

Recommendations

Both data analysis and the development and validation of data and measurement models should be better covered. The number of staff should be increased beyond a critical mass in order to enable the raising of third-party funds and thus to help to strengthen this PTB department. The focus of the work, however, should stay with metrology.

The integration in the wider research landscape should be improved, e.g. through seminars with the participation of external guests or through participation in committees (structures like the UK Metrology Cubs may be considered, i.e. the Software Support for Metrology Club). The contacts to mathematical disciplines, e.g. statistics, stochastics, and numerical mathematics, should be strengthened. Also an improved PTB-internal communication appears desirable, e.g. through seminars on a regular basis that help to communicate the

usefulness of a mathematically sound data analysis or even to initiate co-operations. At the moment, in comparison with NPL, many more PTB laboratories could benefit from services in the field of data analysis and modelling.

The establishment of uniform guidelines for PTB-internal program libraries (mathematical software infrastructure) should be considered. Experiences at NPL, where such libraries have already been established, may be called upon.

c) General recommendations

Metrological IT, in this context comprising software quality, data security, and data analysis, with the exception of gambling machines and voting machines, is a *method-oriented* (horizontal) cross-sectional task, in a similar way to quality management, coordination of legal metrology, or parts of international cooperation. In contrast, the scientific/technical tasks such as realisation and dissemination of SI units are *problem-oriented* (vertical) tasks, which are grouped in the divisions within PTB's organisational structure. The organisational implementation of metrological information technology in the form of a department within the (vertical) division 8 does not appear logical and is not suited to guarantee the PTB-wide horizontal integration.

We recommend the combination of the present organisational structure with elements of a matrix organisation. In this case, however, it has to be ensured that *both* partners of a connection point have the responsibility of give *and* take. Therefore monitoring would be needed. Due to the importance of metrological IT, which is expected to grow, this horizontal task should be placed on the same footing as the vertical tasks, and this equality should be visible in the organisational structure.

We recommend that marketing (contacts, promotion) in universities and research institutions is intensified in order to help to improve PTB's visibility and to compensate for the problematic recruitment situation. We expect that this situation will become even worse within the coming years, and thus we suggest that consideration be given to a more comprehensive (PTB-wide) strategy for recruiting and keeping staff.

A larger number of staff and more flexibility of the budget, such as by means of a global budget, will be necessary to be able to meet the future needs in the field of metrological IT. For tasks in legal metrology permanent staff is required. For other tasks external know-how may be acquired through guest researcher programs and temporary staff. We support the raising of third party funding.

The fields of voting and gambling machines are defined by law. We consider the work as very good and the resources seem adequate. We suggest that consideration be given to the development of a virtual „reference gambling machine“, in a manner that benefits from other relevant work at PTB, such as the Virtual Coordinate Measuring Machine. We have no recommendations to make concerning voting machines, other than to note that the major problems in the future would be technical rather than scientific, with the move towards the use of the Internet for voting purposes.

Braunschweig, August 19, 2002

The members of the subcommission:

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Dr. P. Dellafera, T-Systems Darmstadt

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Wolfgang Redtenbacher, Fa. Redtenbacher Software Renningen

A3 List of abbreviations

BAM	Bundesanstalt für Materialforschung und –prüfung (Federal Institute for Materials Research and Testing)
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe (Federal Institute for Geosciences and Natural Resources)
BMBF	Bundesministerium für Bildung und Forschung (Federal Ministry of Education and Research)
BMF	Bundesministerium der Finanzen (Federal Ministry of Finance)
BMWA	Bundesministerium für Wirtschaft und Arbeit (Federal Ministry of Economics and Labour) (until October 22, 2002 Bundesministerium für Wirtschaft und Technologie, Federal Ministry of Economics and Technology)
BMWi	Bundesministerium für Wirtschaft und Technologie (Federal Ministry of Economics and Technology) (from October 22, 2002 Bundesministerium für Wirtschaft und Arbeit, Federal Ministry of Economics and Labour)
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (Federal Ministry for Economic Cooperation and Development)
BNM	Bureau National de Métrologie, FR
COOMET	Coopération Métrologique
DGKC	Deutsche Gesellschaft für Klinische Chemie (German Society for Clinical Chemistry)
DKD	Deutscher Kalibrierdienst (German Calibration Service)
EUROMET	European Collaboration in Measurement Standards
HGF	Hermann von Helmholtz-Gemeinschaft deutscher Forschungszentren (Hermann von Helmholtz-Society of German Research Centres)
NIST	National Institute of Standards and Technology, US
NMI	National metrology institute
NMIJ	National Metrology Institute of Japan
NPL	National Physical Laboratory, GB
OIML	Organisation Internationale de Métrologie Légale
PTR	Physikalisch-Technische Reichsanstalt
SI	Système International d' Unités
UBA	Umweltbundesamt
WELMEC	European Cooperation in Legal Metrology