More than 20 years of experience of the IAEA in providing training on nuclear instrumentation for developing countries

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Abstract—**For more than 20 years the IAEA has been supporting Member States for effective and safe use of their nuclear instruments and the most important part of this activity is the provision of training. Starting in the early 80ies it continues until today. Hundreds of engineers, technicians and physicists mainly from developing countries have been trained. This paper shortly describes the strategy adopted during the years, the results obtained, the present strategy, the difficulties and challenges met.**

Index Terms—**Training on nuclear instrumentation, instrumentation teaching material, training kits, nuclear instrumentation maintenance, nuclear instruments upgrading/refurbishing.**

I. INTRODUCTION

ONE of the main tasks of the IAEA is the dissemination of the peaceful applications of the nuclear energy. For fulfilling this job, the IAEA supports Member States (MSs) providing expertise, training and basic infrastructure so that they can apply nuclear techniques safe and correct in a large variety of fields, for example, agriculture, industry, medicine, energy production, research, etc. Since all applications of the nuclear technology requires measuring instruments, the basic knowledge and necessary tools for the correct utilization, the quality control/assurance, calibration and maintenance of the instrumentation is a fundamental part of the "technology transfer". This is not a simple task since MSs are very different and the approaches should be adequate to their levels. Developed countries are more interested in advanced (higher level) applications, for example, reactor control which is not a case in most of the developing countries.

During the 80ies many countries were interested in the nuclear technology for power generation. Those countries did a lot of efforts for developing regulatory bodies and also to create research groups. This generated a demand for nuclear instruments properly installed, operated, calibrated and maintained. Consequently a demand for training in nuclear instrumentation emerged and the IAEA received many requests in this field.

Due to a small market, the manufacturers provided little support to the users of the instrumentation, and the maintenance of instruments was a main topic. Later, with the advent of microprocessor based systems and the personal computers, the new topic was interfacing instruments with PCs and utilization of microcontrollers. Until the 90ies the IAEA trainings were financed mostly by the regular budget and the relevant training activities were of "interregional" nature since candidates from all over the world could attend. The cost of such trainings were rather high, and as the number of MSs increased, the IAEA decided to change its training strategy and shifted the support of MSs to the technical cooperation projects. The projects could involve only a single country (national project) or a region (regional project) or, in specific cases the countries from all over the world (interregional project). New modalities of training were introduced like individual fellowship training programs and national/regional training courses.

New technologies, equipment and components like Surface Mounted Devices, Programmable Logic Controllers, Digital Signal Processors, Field Programmable Gate Arrays etc. came to the market which created a demand for an adequate training in these new fields. In parallel, there was a continuous demand for a basic training due to the needs of new MSs joining the IAEA and due to staff turnover (rotation) in many MSs.

Almost all modern instruments are based on microcontroller, DSP or FPGA, and this introduced a new demand for a complex training in maintenance and effective use of this equipment. Since such instruments often include hardware and firmware without full technical documentation, it is almost impossible to deal with maintenance without the direct involvement of the manufacturers.

Information technology brought new possibilities for the provision of training. Due to the internet, the communication among the MSs is fast and inexpensive. Following E-learning methodology a variety of topics are available on CDs and via the internet.

This paper describes how the IAEA implemented training in the past, what is the present situation in the relevant field, and gives proposal for the future.

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II. ACTIVITIES PERFORMED FROM THE 60IES TO 2000

The first activities related to nuclear instrumentation in the IAEA were in the field of nuclear reactors instrumentation. In 1965 the IAEA organized a panel meeting on Instrumentation for Nuclear Power Plant Control. At that time almost only developed countries dealt with this technology through their research institutions. The meeting covered new techniques and methods for measuring, handling and testing the nuclear power plant parameters for control and safety purposes.

The Panel attracted 35 participants and observers from 16 Member States and 2 International Organizations (ECO and ENEA). The main topics included:

- Reliability, its achievements and prediction and means of exchanging data;
- On-line computers - reasons for their use and future application to nuclear power plants;
- Dynamics measurements and noise analysis techniques, and
- Measurement of in-core data for control and protection.

The results of this panel meeting are summarized in the IAEA TECDOC number 119 [1].

It is a common experience that the maintenance of scientific instruments in developing countries presents numerous difficulties beyond those experienced in developed countries.

A few years later the differences between the needs, interests and technical infrastructure of the developed and developing countries were better recognized, and it was realized that developing countries are affected by the additional specific difficulties such as:

- Severe environmental conditions;
- Absence of factory-based service engineers;
- Lack of local technical staff;
- Shortage of spare parts;
- Administrative complications;
- Financial constraints and others.

In 1975 an advisory group meeting was organized for discussing the maintenance of nuclear medicine instruments in developing countries [2]. Participants from the developed countries and developing countries, like Ghana and Sudan, attended the meeting and discussed a number of issues related to the maintenance of nuclear medicine instruments including quality control to better identify the reasons of malfunctioning of the instrument. The following topics related to the maintenance were pointed out:

- Prevention of faults;
- Diagnosis of faults;
- Spare parts;
- Organization of maintenance services, and
- Training for maintenance.

This meeting concluded that the instrument technician (occasionally an engineer) responsible for the instrument maintenance requires both a general training in electronics and a specialized training related to the complex instruments to be serviced. At that time it was suggested that an important part of this general training could be accomplished through a good course on radio and TV electronics, but for nuclear medicine units an intense training in analogue pulse electronics and digital electronics was needed. The special training required for the complicated instruments depends upon the instrument. Preferably it should be conducted as in-service training at the factory after the technician has completed the general training. It became obvious that the training process for the maintenance of nuclear instruments requires the involvement of the manufacturers. The duration of this specialized training may vary from weeks to one year.

At this time the IAEA already organized general trainings in analogue and digital electronics applied in nuclear measuring instruments. The main training course was the 13 weeks long “Interregional Training Curse on Nuclear electronics”. It was organized for more than 25 years, until 1997. From 1980 to 1997 nearly 360 persons have been trained. These training courses called “interregional trainings” involved students from the entire world and were implemented in China, Germany, Italy, and in the United States.

In order to support and complement the training courses the following technical documents were developed:

- Selected Topics in Nuclear Electronics IAEA-TECDOC-363 [3]
- Troubleshooting in Nuclear Instruments, IAEA-TECDOC-426 [4]
- Nuclear Electronics Laboratory Manual, IAEA-TECDOC-530 [5]

The first TECDOC dealt with the theoretical part of a conventional spectrometry channel and covered the following major topics:

- Functional approach
- Circuit design
- Noise and resolution
- Further analog signal processing before the analog-to digital conversion
- Amplitude analysis
- Analog-to-digital conversion
- Multichannel analyzer
- Time measurement
- Power supplies

The second one describes how to organize a nuclear instrumentation maintenance laboratory and gives hints on how to troubleshoot the different blocks of a spectrometry system including some dedicated instruments like radiation monitors and radiation detectors.

The third document is a collection of various practical experiments for a better comprehension of each component of a spectrometry system and other common nuclear instruments.

Microcomputers, shortly after their appearance, became also part of most scientific instruments including those applied in nuclear field. A new demand for training in this field emerged quickly, and a specific training program was established. This eight weeks long training course under the name of “Interregional Training Course on Interfacing” was initiated in 1988, and approximately 170 students from the entire world were trained until 1997.

In addition to the above mentioned technical documents, a set of Eurocard system boards were developed to support the trainings. It included modules like amplifier, high voltage power supply, counter/timer, single channel analyzer (SCA), multichannel analyzer (MCA), area monitor and interface modules. Approximately 100 pieces of SCA kits have been distributed to Member States under national TC projects.

At the beginning of the 90ies, the “interregional” or “global” approach to training was phased out due to the high associated costs, and was replaced by the training at regional or national levels.

National projects involve only individual countries and assist these countries to solve their specific problems which involve nuclear technology.

Regional projects involve a region (Africa, Asia, Europe and Latin America) or a group of countries in a region and are implemented for solving the common problems which require the application of nuclear technology and to establish/develop regional cooperation among the countries in the nuclear field. At that time, some developing countries in various regions, were able to establish some infrastructure to deal with nuclear instrumentation and developed already expertise in this field based on their own efforts and/or with a support of the IAEA. Since they started to play a special role in the cooperation with the IAEA and other countries in the region, they became “Regional Centers”. These centers have contributed (and still contribute) to the development of the regions acting as “bridges” between the more advanced and less developed countries. The role of the Regional Centers is essential since the countries managed to overcome the problems characteristic for the less developed countries, and the acquired experience made the technology transfer easier and more effective. In addition, a common language (as for example in Latin America), closeness and a similar culture contribute to the success of the training provided in the “Regional Centers”. Unfortunately, the geographical distribution of these centers is not homogeneous, and some regions have a few centers while others have just one (or none).

The training provided under the regional TC projects is based, whenever possible, on local expertise. Nowadays experts from the regions are sent abroad and trained on new technologies. Then they are responsible to transfer the knowledge to the region.

In 1991 a technical meeting to discuss the regional cooperation in the field of nuclear instrument maintenance was held in Vietnam [6]. The meeting pointed out some problems in the developing countries which were already mentioned before, such as:

- Climate and line instability problems
- Lack of manufacturers' support
- Shortage of trained personnel
- Shortage of literature
- Poor in-country cooperation

Some of the conclusions were in line with the regional approach to strengthen regional cooperation and to use the more advanced institutions as regional centers:

- Countries that gained experience in environmental and line conditioning in their laboratories can help other countries in the region to solve similar problems.
- The problem of the lack of manufacturer support can be reduced by a suitable exchange of experiences.
- The introduction of a regional information network may allow maintaining a pool of information concerning the availability of documentation in the region.
- Accumulation of maintenance experience and skills would lead to a stage that staff is in position to modify or even extend instrumentation designs which are needed in nuclear laboratories. In particular, through a regional cooperation those teams could carry out successful designs. It was also stated that the modification and development of instrumentation brings confidence and more recognition
- Regular calibration, quality control and careful parameter adjustment of nuclear instrumentation is required to achieve the necessary accuracy of demanding research projects. A basic understanding of the operation and the necessary steps for calibration should become an integral part of education for service engineers and physicists.

The last conclusion shows that there was a need to take actions for bringing the “quality culture” to the nuclear instrumentation laboratories.

In frame of the regional cooperation, the participants designed some interfaces that were used by the whole region, including “tools” that are very useful for the maintenance/developing activities, such as:

- Low currents/charges source (to test electrometers)
- Geiger Müller simulator;
- Pulse generator;
- X-ray wave form detector;
- Densitometer for QC in radiology, etc.

In parallel with the maintenance and development activities, countries with an appropriate technological level to deal with the reactors, continued cooperation and additional technical documents were published (see references [7], [8], [9] and [10]).

III. THE GROUP FELLOWSHIP TRAINING IN THE IAEA LABORATORIES AT SEIBERSDORF

The training in nuclear instrumentation requires basic knowledge in electronics in order to understand and follow the most advanced topics of nuclear electronics. In many developing countries even a minimum set of tools for electronics (oscilloscope, mutimeter, soldering/desoldering tools, etc.) was not available. Although the candidates for the training have an academic degree, some of them have never worked with basic laboratory electronic instruments. Because of lack of funds at the universities, students have usually very limited laboratory practical exercises.

These MSs also want to use and benefit from nuclear technology in different fields, like medicine, agriculture and industry. Simultaneously the maintenance staff is under-qualified, the support from the manufacturers is very limited or not existing, and therefore the utilization of the equipment is also very low. Moreover, the countries suffer from a poor quality of the mains supply which often is unreliable and affected by various interferences (big variations in the amplitude, noise, surges, etc.).

Member States requested the IAEA to provide a complex training on operation and maintenance of nuclear instruments for the fellows with limited background. This special training starts from teaching the proper use of measuring instruments, like multimeters and oscilloscopes, and includes also modern topics such as microcontrollers. Nuclear related institutions in the developed MSs were not interested in offering this type of training since it requires extensive resources (including time and facilities) and full dedication of the supervisors and lecturers.

In order to increase effectiveness and reduce cost of such training, a group fellowship training (GFT) model was adopted in 1985 (still continued up to now). The program of the training is continuously updated to follow the changes in electronics technology and instrumentation (for comparison of the 1998 and 2008 programs see Table I).

A special infrastructure for lecturing was established, and the fellows have their own work benches with a full set of tools required for all the classes. The lectures provide the fellows with the adequate theoretical knowledge essential for the practical works. For most of the topics the fellows receive training kits to be assembled in order to develop practical skills and improve the hands-on experience (for example, twelve kits for power supplies are currently used during the GFT).

Most of the fellows attending the GFT come from Africa, Asia and Middle East (see Fig. 1). This shows that there are few institutes in these regions where this type of training is available. Perhaps a good solution would be if the Regional Centers could train fellows from the region on a GFT-like program with a limited support of the IAEA.

The GFT (for 8 – 10 fellows) starts on 1st October and ends 31st March the following year. Fig. 2 shows the geographical distribution of the participants trained from 1985 to 2008. It is obvious that most fellows came from the African region, where the local infrastructure is inadequate or non-existing.

The selection of the fellows for the GFT is a complex problem. As already mentioned, some fellows have almost no practical experience. The technical knowledge of the group is often very inhomogeneous. Another constraint is the language proficiency. Fellows coming from non-English speaking countries have some problems (in spite of submission of positive language certificate).

The GFT program shows both advantages and disadvantages.

The main advantages are:

- Teaching a group of fellows is less expensive and more effective also from organizational point of view
- External experts can support the training program which is rather impossible in case of the individual fellows
- Fellows can share their knowledge and experience
- Fellows become familiar with functioning of the IAEA and its laboratories at Seibersdorf (important for the future effective interactions between MSs and the IAEA)
- Network of people working in the nuclear instrumentation field can be created/expanded.

The main disadvantages are:

- Different level in the background of the participants create some difficulty in teaching
- Equalizing the level of the fellows requires extra time and efforts of the lecturers/instructors.

Based on a long experience, the GFT can be considered a great success. Every year many new candidates apply; in some

TABLE I
PROGRAM FOR GROUP FELLOWSHIP TRAINING IN NUCLEAR SPECTROSCOPY INSTRUMENTATION MAINTENANCE IN 1998 AND 2008

1998	2008
General Introduction	General Introduction
Operation of test instruments and tools	Ionization radiations and detectors
Ionizing radiations and detectors	Power supplies
Trace signal/shaping in nuclear spectroscopy	Instruments' protection
Troubleshooting in microprocessor-based instruments	SMT technology
Multi-channel analyzers (MCAs) principles and maintenance	Personal computers
Personal computer principles and maintenance	Transducers and computer interfacing
Specific individual projects	Analog electronics applied in nuclear instrumentation
	Introduction to virtual instrumentation
	Introduction to microcontrollers
	Introduction to FPGA
	Introduction to PLCs
	Basic maintenance of Gamma Cameras
	Specific equipment (radiation monitors, TLD readers, LSCs, x ray machines)
	Quality systems applied to nuclear instrumentation maintenance and development laboratories
	Practices on x-ray fluorescence, alpha, beta and gamma spectrometry

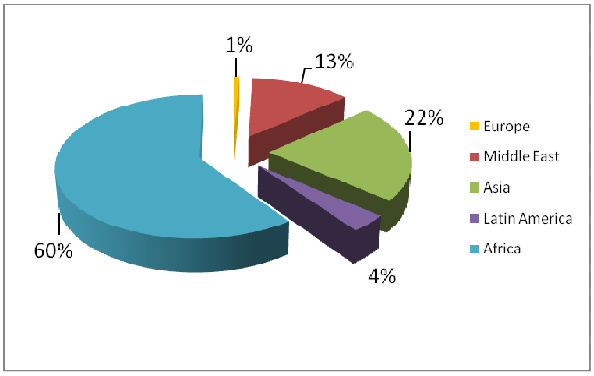

Fig. 1. Distribution of fellows participated in the Group Fellowship in the IAEA Laboratories at Seibersdorf per region from 1985 to 2008.

countries almost all technical personnel involved in the development and maintenance of nuclear instrumentation attended the GFT, and carry out their job to a full satisfaction of their supervisors and end users. In some cases, the participants of GFT became promoted to group leaders or section heads (unique assistance in career development in many developing countries).

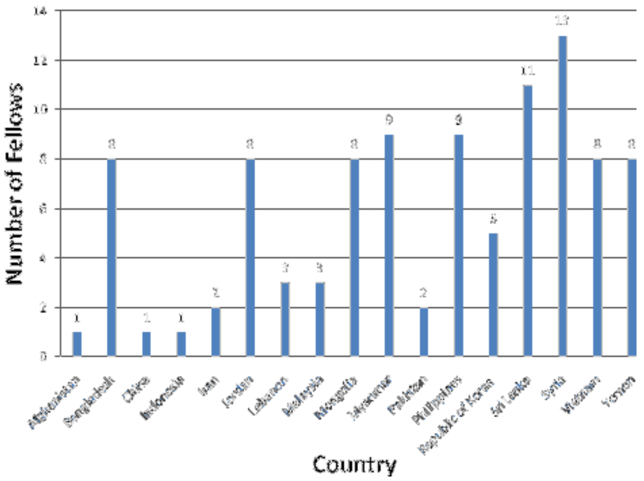

Fig. 2A. Asia

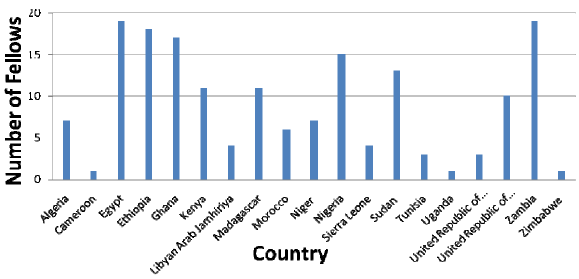

Fig. 2B. Africa

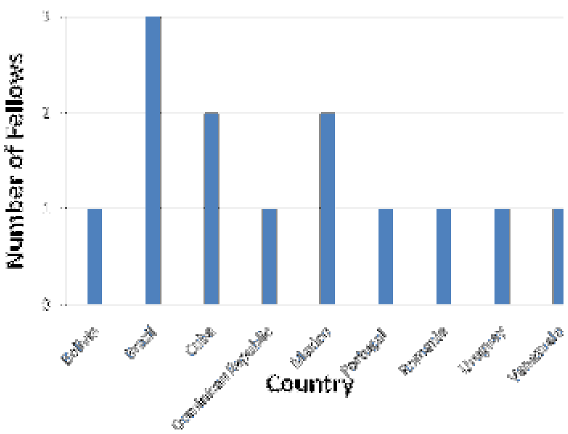

Fig. 2C. Latin America and Europe

Fig. 2. Distribution of fellows participated in the Group Fellowship in the IAEA Laboratories at Seibersdorf per region and per country from 1995 to 2008.

IV. MODERNIZATION AND REFURBISHING OF INSTRUMENTS

Extending the lifetime of equipment in developing countries is very important. Equipment and instruments are often donated and their replacement is almost impossible due to lack of local funds. In many cases, the quality of the instruments would allow extended utilization for a long period but some parts might be outdated or less reliable. Good examples are old and costly equipment like TLD readers, Liquid Scintillation Counters, Gamma Cameras, etc. On the other hand nowadays modern equipment requires a possibility of being connected to a computer for its control and data processing. In order to expand the lifetime of such equipment, the laboratories in Member States decided to develop interfaces and software to allow connecting the equipment to PCs. The most successful development took place in Nuclear Medicine where the usable lifetime of a large number of Gamma Cameras was extended by using interface boards and software developed by some Member States (Cuba, India, Slovenia, etc.) and later also by private companies.

For such interfaces it is necessary to develop hardware which creates some constraints for countries where the infrastructure to produce good quality printed circuit boards is not available and/or the necessary components cannot be found. Therefore, our efforts were focused on training on software development and not on the hardware. This was facilitated with the advent of the "virtual instrumentation" (using for example software like LabVIEW from National Instruments) where a large part of the software is "ready to be used". On the other hand some "versatile hardware" was needed for the interfaces that could also be applied for teaching.

In cooperation with the Forschungzentrum Jülich in Germany, through their Zentral Elektronik Labor (ZEL), a set of three general purposes interface boards were developed.

- DSP32-Kit - Based on a 32 bit floating point DSP associated to 40 MHz ADC, PCI bus interface and an already implemented data acquisition channel for nuclear applications (MCA and SCA) - see Fig. 3A
- UNI I/O 52 – Based on FPGA technology and using a micro-controller and USB bus for PC interfacing. It incorporates also and already implemented MCA, ADC, DAC, stepper motor control, digital I/O, counters, etc. – see Fig. 3B

Fig. 3A. DSP32-Kit board

- DAQ 52 – Similar to the UNI I/O 52 also based on FPGA technology but with a slower ADC and no MCA implemented.

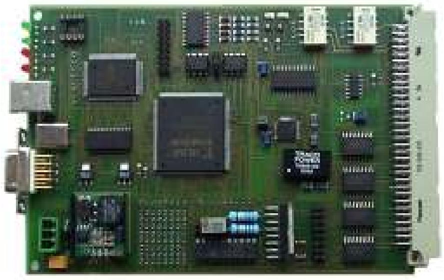

Fig. 3B. UNI I/O 52 board

For interfacing the FPGA based boards a mezzanine board based on a microcontroller was developed (Fig. 3C) as well as all DLL libraries for interfacing with the software LabVIEW. Mezzanines with serial, USB and Ethernet connections are available.

Fig. 3C. Mezzanine board with USB interface

From 2000 to 2008 twenty-five training courses were implemented using these boards for teaching DSP, FPGA and data acquisition. Fig. 4 shows the geographical distribution of the implemented trainings.

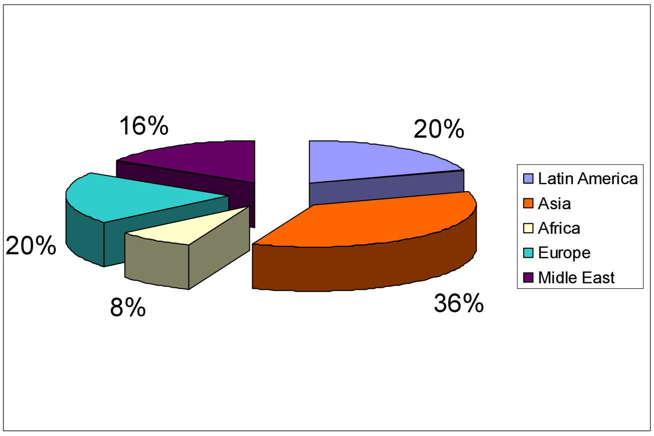

Fig. 4. Regional training distribution where the boards developed in cooperation with ZEL Jülich were applied.

It is worth mentioning that few Member States have also developed some real applications as for example:

- Madagascar – Multi-Inputs MCA for foodstuff monitoring
- Malaysia – Whole body counter upgraded
- Peru –Automated system for radiation protection monitoring in the Radioisotopes production plant
- Cuba – Refurbishment of an x-ray diffraction meter
- IAEA – Control system for an x-y radiation distribution mapping.

V. E-Learning

It is admitted today that Information Communication Technologies (ICTs) allows us to exploit the latest technologies to achieve new goals including education at our own convenience and pace. ICTs can foster innovations, enhance our capacity to understand and act, and reduce costs when used in an optimum manner. ICT training tools help to save time - which is one of the most valuable resources we have, as well as to reduce financial resources in the case of development of educational programmes to assist self-training in developing countries.

As a result of the tremendous growth in the ICT market, multiple ICT vendors and service providers have sprung up in developing countries, although basic infrastructural necessities such as electricity and telephone lines are still lacking in many places. This situation is particularly visible in the least developed Member States which are less prepared than others to face the challenge of globalization and information age.

Experience gained from the assistance provided to Member States in manpower development over the past four decades showed that the conventional form of educational/training through fellowships suffers from a number of restrictions; such as limited access, language and/or cultural barriers, etc. It is generally recognized that human resource development programmes in the majority of the Member States face the following challenges:

1. Many countries have no national human resource development strategies and programmes to guide the national capacity-building effort in nuclear science and technology.
2. Most of the countries rely on short-term plans
3. Most of the countries continue to rely on IAEA supported training programmes to develop their manpower;
4. Brain-drain is significant in a few countries and this is visible in fields such as maintenance and repair, human health and some specific agricultural disciplines.
5. Knowledge preservation and management needs to be improved in terms of strategy and content.

It is also recognized that although a few Member States made some attempts to introduce distance-assisted training programmes in selected applications at the level of universities, the most challenging issue remains the reliability of infrastructural necessities (electricity supply, Internet servers and telephone lines) as well as the economic viability of the selected training tools. Accordingly, it seems that Member States' training needs (in particular in the least developed countries) in the medium term will continue to rely on the IAEA input without real expectations that the majority of them will take full charge of their human resources development. In this context, ICT-based training/learning tools and methodology can help to overcome some of the above-mentioned deficiencies.

The major thrust of the IAEA technology transfer programs in support of the developing countries is to promote the application of useful nuclear technologies in such areas as nuclear instrumentation, human health, water resource management, and others. Common to all these fields is the preventive maintenance, troubleshooting and repair of scientific instruments and equipment. The IAEA has taken some active steps for the incorporation of ICT materials and multimedia tools for training. During the last years numerous ICT-based training materials have been developed including nuclear electronics and nuclear instrumentation as well.

Materials have been developed under the IAEA Technical Cooperation projects INT/0/078 on "ICT-assisted training/learning materials in nuclear instrumentation" and RAF/0/013 "ICT-based training to strengthen Least Developed Countries capacity", by consultants from various countries. The training materials were integrated into two packages:

- CD1 - Nuclear Electronics (Digital Electronics, Gas Detectors, Linear Electronics, Nuclear Radiation and Power Supply), and
- CD2 - Nuclear Instrumentation (Expert system for linear electronics modules, LSC Maintenance, Radiation Survey Meters and TLD Readers).

Other, equipment oriented ICT based materials have also been developed such as:

- Maintenance of Siemens ECAM
- Maintenance of Pantak X-ray equipment
- Quality Management in Calibration, Maintenance and Repair of Nuclear Instrumentation.
- Protection of Instrument from electrical disturbances (under development)

VI. WHAT IS PROPOSED AND PLANNED FOR FUTURE

1) Maintenance

Presently, due to the technological development almost all new instruments incorporate a microprocessor, a FPGA, a DSP or a combination of them. Therefore a very large part of equipment is now the firmware for control or communication. In the past it was possible to generalize the training for maintenance and design. If proper tools were available, in many cases it was possible to follow a test signal through the system. This approach was often successful even in such cases where the circuit diagrams for the equipment under test/repair were not available. Nowadays in complex systems this simple way is not applicable anymore. This introduced a serious constraint in teaching a technician or an engineer on how to maintain a nuclear instrument. Most instruments are now software based and the only way to know about how this software works is through a support and cooperation of the manufacturers.

To involve manufacturers in the training process, a proper action should be taken at an early stage (usually during formulation of the purchase contract). For the high cost equipment it is not difficult to include training for the maintenance but a problem appears for low cost instruments when the manufacturers do not show interest and willingness to meet the expectations. If they add the training cost to the price of the equipment the total costs become prohibitive. Even in these cases there might be a solution called "equipment standardization". If a larger number of (standard) instruments are purchased from one supplier the additional costs for the training become acceptable. In such cases one "bulk order" can be issued by the IAEA, and an additional unit to be used exclusively for training purposes (maintenance, operation, installation, testing and quality control) can be included in the bid.

As already mentioned, manufacturers can provide some specific training for their products. This training, if not included in the purchase contract, is usually very expensive and short in duration. Such training requires that the trainee must have a good background in basic instrumentation and electronics. During a training dedicated to a specific instrument, manufacturers do not cover basic topics such as using the conventional maintenance tools. If requested, they might do that but the associated training costs will be prohibitive. Therefore, the provision of a basic training which introduces the fellow to the nuclear instrumentation (detectors, special electronic modules, etc.) is still needed and this type of training is not available in some regions. For this reason, some Member States continue to request the IAEA to support/provide this type of training.

A good example is the maintenance of Gamma Cameras (GCs). Under national TC projects, the IAEA provides new GCs with a full five years warranty. The IAEA Laboratories managed to establish a training laboratory (see Fig. 5) with the same GC model that is being delivered to Member States, and a few group and individual training programs were already provided in the field of basic maintenance, quality control and acceptance tests. If the fellows have no adequate background, they can benefit from a basic training in nuclear electronics and nuclear instrumentation under the GFT program. Afterwards, the fellows are able to test and calibrate the gamma cameras, often with the assistance of service engineers from supplier who come periodically to Seibersdorf. Experienced engineers from the manufacturer are also invited to contribute to the training courses as lecturers, and a partnership is established between them and the fellows. Later, if a problem appears and the fellow is not able to solve it, he/she can contact the manufacturer directly using the Internet. The expert can provide remotely some advice or guide the fellow to identify the fault and fix the problem. This remote troubleshooting is possible only because the fellows have already acquired a good background and are familiar with this model of GC. We expect that with this procedure, after the five years of warranty period, Members States will be able to keep their machines working for a longer time at a lower cost.

2) “Tele-maintenance” support through the Internet

Another possibility that is being tested is to provide support for maintaining nuclear instruments using external advice and, whenever possible, “remote control” through the Internet. This is now feasible since Internet is accessible from everywhere and the communication is fast and cheap. In some cases it is even possible to use the computer to control the instrument via the Internet and an experienced engineer can control and test it remotely.

This also requires that the person who receives the remote support has a good background and basic knowledge about instrumentation and the specific instrument under test.

Some manufacturers have already being contacted and it is possible to contract a service engineer to provide advice for a defined time through the Internet. We expect that using this modality many problems can be solved faster and at a lower cost.

Fig. 5 – Gamma Camera’s training laboratory in the IAEA Laboratories at Seibersdorf, Austria

3) Regional Cooperation

To enhance the regional cooperation to improve sharing knowledge, equipment and infrastructure we intend to utilize the more advanced institutions in each region as a “regional center”. The idea is to use the existing infrastructure of these centers, and, if necessary, to assist them in improving/updating professional skills of the local experts through training (under train-the-trainer mechanism). These experts will be responsible for transferring the knowledge to other countries of the region. In the cases where no regional center is currently available, the IAEA might utilize its laboratory at Seibersdorf until transferring the duties to the new centers when established and also to act as a coordinator for the regional centers’ network taking action to assure the homogeneity of the training provided by different centers and also the overall quality.

4) E-Learning

From our previous experience, E-Learning is a very good tool for preparing a trainee before attending a training course. It can help to homogenize the background of the participants, save time and help in optimizing the learning process. Since the conventional teaching materials for basic topics were already developed in the past, now specific ICT-based modules are under development. Implementation of the “equipment standardization” concept would promote the development of E-Learning material for the specific instruments as well.

5) Improving the quality in nuclear instrumentation laboratories.

The activities performed by the nuclear instrumentation laboratories, including maintenance services, should also comply with the international standards related to quality (mainly ISO9001 and ISO17025). As a result, nuclear instrumentation laboratories need to implement a quality system that includes development of quality manual, writing procedures, assuring traceability, etc. as required by the international standards ISO 9002 and ISO 17025. To assist MSs in these efforts, relevant supportive materials and procedures have been developed [11], [12], [13]. In addition, to help the developing countries to assure the traceability of the instruments they apply for development/maintenance of their nuclear instruments (like oscilloscopes, multimeters, etc.); a special calibration program is being implemented. Under the scheme, a small calibration laboratory has been established in the IAEA Laboratories at Seibersdorf to perform calibration of low cost reference equipment acquired by MSs Laboratories. Moreover, training courses and calibration procedures are under development as well as intercomparison exercises for checking the quality of the instruments are planned.

VII. Conclusions

Bringing nuclear technology to developing countries is a complex task which requires proper operation, calibration, maintenance and development of nuclear instrumentation. This is of particular importance in the results-based approach applied for planning and implementation of the IAEA projects. The IAEA has been successful in assisting its MSs Laboratories, under TC projects, in effective use of nuclear instruments through provision of basic infrastructure and training of electronics technicians and engineers dealing with nuclear instrumentation. Due to new technologies applied, new MSs and staff turnover, the assistance of the IAEA is still of importance for many countries. To make this support more effective and efficient, a combination of various modalities including regional cooperation, regional centers, application of modern teaching technologies, and wider use of the Internet becomes inevitable.

References

[1] IAEA, *Instrumentation for Nuclear Power Plant Control*, IAA-TECDOC 119, 1969

[2] IAEA, *Maintenance of Nuclear Medicine Instruments in Developing Countries,* IAEA TECDOC 184, 1975

[3] IAEA, *Selected Topics in Nuclear Electronics* IAEA-TECDOC-363, 1986

[4] IAEA, *Troubleshooting in Nuclear Instrume*nts, IAEA-TECDOC-426, 1987

[5] IAEA, *Nuclear Electronics Laboratory Manual*, IAEA-TECDOC-530, 1989

[6] IAEA *Regional cooperation on nuclear instrument mai*ntenance, IAEA-TECDOC-598, 1991

[7] IAEA, The *role of automation and humans in nuclear power plants,* IAEA-TECDOC´668, 1992

[8] IAEA, *Research reactor instrumentation and control technology,* IAEA-TECDOC-973, 1995

[9] IAEA, *Modernization of instrumentation and control in nuclear power plants,* IAEA-TECDOC-1016, 1998

[10] IAEA, *Managing modernization of nuclear power plant instrumentation and control systems,* IAEA-TECDOC-1389, 2004

[11] IAEA *Validation Procedures of Software Applied in Nuclear* Instrumentation, IAEA-TEC_DOC1565, 2007

[12] IAEA, *Quality Control Procedures Applied to Nuclear Instruments*, IAEA-TECDOC-1599, 2008

[13] IAEA *A Training Module for Quality Management in Calibration, Maintenance and Repair of Nuclear Instrumentation*, IAEA Training Course Series 33, 2008