The IAEA Internet Reactor Laboratory project: status, feedback from recent broadcasting and future expansion

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Abstract. In the last few years the IAEA, together with the help of its Member States, has developed a specific scheme of services to facilitate the access to research reactors for nuclear capacity building. This scheme is addressed to countries operating or planning research reactors, interested in utilizing them as a primary facility to develop nuclear science and technology capabilities, or in some cases, as a supporting step to embark on a national nuclear power programme. This scheme is now composed of four complementary instruments, each of them being targeted to specific objectives and audience. One of those instruments is the web-based training, called Internet Reactor Laboratory (IRL). By using a Research Reactor Facility (host institution), the IRL provides access to students from remote locations (guest institutions), generally from countries without research reactors, to attend online the experiments carried out in a research reactor and that are relevant in the process of developing human capacity related to nuclear.

The IAEA's IRL project was established in 2015 with two host reactor facilities. The first one is based on the ISIS reactor, at CEA Saclay center in France and another one is based on the RA-6 reactor located in Bariloche Atomic Centre, CNEA, in Argentina. Since September 2016, two host reactors (CNEA – RA-6 in Argentina and CEA – ISIS in France) are broadcasting reactor laboratories (respectively, in Spanish and in English) to guest institutions located in Latin America, Europe and Africa regions. Transmissions from each reactor are carried once a year in the frame of the IAEA project with major support from Peaceful Uses Initiative (PUI) funds from United States Department of State. The expansion of the project includes additional research reactor facilities, already pre-selected and to be designated as host reactors during 2017. One, for the Asian-Pacific region, is the AGN-201K reactor, located at the Kyung Hee University's (KHU) Reactor Research and Education Center in Republic of Korea. The other one, to serve the African region, is the TRIGA Mark-II, located at the Centre National de l'Energie des Sciences et Techniques Nucléaires (CNESTEN) in Rabat, Morocco.

In this paper, we explain the different approaches regarding the development and implementation of the IRL capabilities based on different research reactor facilities. We also present the results and feedback collected after the very first broadcasting sessions from ISIS and RA-6. Finally, we outline the plans and schedule for the expansion of the IAEA IRL project to Africa and Asia Pacific Regions with IRL host-reactors the AGN-201K in Korea and the TRIGA Mark-II in Morocco. Development of IRL for Russian speaking countries is also being considered in cooperation with the Russian Federation.

1. Introduction – The IAEA scheme for Nuclear Capacity Building based on Research Reactors

In the last few years the Research Reactor Section (RRS) has developed a specific scheme of services to facilitate the access to research reactors for nuclear capacity building. This scheme is addressed to Member States operating or planning research reactors, interested in utilizing them as a primary facility to develop nuclear science and technology capabilities, or in some cases, as a supporting step to embark on a national nuclear power programme. This scheme is now composed of four complementary instruments, each of them being targeted to specific objectives and audience. Hereafter each instrument is described. The paper will then focus on the experience and future implementation of the IRL.

a) Distance training: Internet Reactor Laboratory (IRL) (< 1 week)

Objective: IRL connects an operating host reactor to guest institutions, generally within the same region of the World. It provides live connection with a research reactor where participants can interact with the reactor team, while practical experiments are conducted. Usually targeted at participants from a Member State without a research reactor, the programme objective is to complement theoretical lectures by reactor experiments giving a practical insight into reactor physics, safe operation and applications.

Programme: Five to six half day sessions are broadcasted every year to students' classrooms within the framework of an agreement signed between the IAEA and guest institutions. Reactor experiments include neutron flux monitoring, criticality experiments, reactor start-up, control rod calibration, temperature coefficient measurement, and study of the reactivity effects of devices/materials inserted in the reactor core.

Participants: The IRL sessions are mainly addressed to nuclear engineering and nuclear physics students in the frame of their academic programmes. The IRL sessions can also be extended to other targeted audience, such as young professionals, by proposing specific experiments or demonstration exercises.

Status: Since September 2016, two host reactors (CNEA – RA6 in Argentina and CEA – ISIS in France) are broadcasting reactor laboratories (respectively, in Spanish and in English) to guest institutions located in Latin America, Europe and Africa regions. Transmissions from each reactor are carried once a year in the frame of the project with major support from Peaceful Uses Initiative (PUI) funds from United States Department of State. In 2017-2018, the IRL project will be extended to Africa and Asia Pacific Regions, with the CNESTEN - MA1 (Morocco) and KHU-AGN-201K (The Republic of Korea) reactors, respectively. Additional facilities have plans to implement IRL capabilities: Czech that has sent to the IAEA a letter of interest to become a host reactor in the future, Indonesia which has an undergoing project to develop internet capabilities for national and regional uses with the assistance of the IAEA. Development of similar capability for Russian speaking countries is also planned in cooperation with the Russian Federation.

b) Basic ands-on-training: Regional Research Reactor Schools (2 weeks)

Objective: Regional research reactor schools provide basic knowledge and hands-on-training on research reactor physics, operation and utilization. They offer a unique on-site training experience taking advantage of practical research reactor experiments generally conducted at different research reactors of the region. The programme objective is to assist Member States building and further developing nuclear competence through hands-on-training experience. It

aims at providing basic background and technical skills to carry out activities related to safe operation and efficient utilization of research reactors.

Programme: The programme involves theoretical classes and hands-on experimental activities. Topics addressed include reactor physics, reactor kinetics and dynamics, safety-security-safeguards, radiation protection, neutron and gamma detection, as well as various reactor applications. Half of the programme is dedicated to hands-on-training exercises, which include facility walk-through the facility as well as extensive reactor experiments. In general, the two week school takes place at two different reactor facilities, located in two different countries of the region.

Participants: The programme is mainly aimed at young professionals with a technical degree in nuclear engineering, nuclear physics or related fields. Their current or future assignments should be linked to a research reactor facility, already available or in advanced planning. Participants from Member States, planning to embark or embarking on a nuclear power programmes, can also gain benefit in attending such Schools.

Status: Two hands-on-training research reactor schools have been organized in cooperation with the IAEA in the Asia-Pacific region, in 2015 and 2017. They were hosted by Indonesia and Malaysia, and by Thailand and Vietnam, respectively. Based on a similar model, the 1st AFRA RR School took place in South Africa in 2016. Further expansion of such schools to other regions is planned with the support from the IAEA: in Europe, for the Russian speaking countries, and in Latin America and the Caribbean Regions, for the Spanish speaking countries.

c) Intermediate Hands-on-training: EERRI group fellowship training programme (6 weeks)

Objective: In 2009, a sub-regional coalition of research reactors has been established with the support from the IAEA - the East European Research Reactor Initiative (EERRI). The group fellowship training programme, developed by the EERRI, offers an extensive hands-on-training experience which is carried out at least on two different research reactors located in EERRI partner organizations (Technical University Vienna-ATI, Czech Technical University, the Slovenian Josef Stefan Institute, the Budapest University of Technology and Economics and the Budapest Research Reactor). The programme objective is to support Member States building nuclear competence at large and providing research reactor-based hands-on-training. The programme also offers the necessary background to carry out activities related to planning, commissioning, safe operation, utilization and maintenance of research reactors.

Programme: The programme involves theoretical classes, facilities walk-trough and extensive hands-on experimental activities. It covers a broad range of topics related to nuclear safety-security-safeguards, radiation-protection, research reactor physics, kinetics and thermal-hydraulics, safe operation and utilization, as well as an introduction to nuclear power plants. Throughout the course the participants are examined and evaluated. They receive an attendance certificate at the completion of the course.

Participants: The programme is aimed at young technical professionals with some nuclear experience. Candidates should hold graduate technical degrees in engineering or science, with some nuclear background and current or future assignments linked to a national nuclear programme (either a research reactor or nuclear power). Through partial attendance (typically for two weeks focused on specific topics), the course can also be used as a train-the-trainers event for professors or reactor staff wishing to further develop their education and training programmes using their national research reactor facilities.

Status: The EERRI course is running since 2009. It is organized in cooperation with the IAEA generally once per year. By the end of 2016, close to 100 fellows were trained from as many as 28 different countries.

d) Advanced training: International Centers based on Research Reactors (ICERR) (a few weeks/months)

Objective: The IAEA initiative on ICERR is intended to help Member States gain timely access to relevant infrastructure based on Research Reactors to achieve both their nuclear R&D and Capacity Building objectives. ICERRs designated in the field of Education and Training and Professional Training (Hands-on-Training) can be used as an efficient mechanism for capacity building since it provides the access to the state-of-the-art nuclear facilities and competences. Member states wishing to gain access to an ICERR will have to become an affiliate by signing a bilateral agreement with the ICERR, where the IAEA is acting as a facilitator only.

Programmes: ICERRs can exhibit a broad spectrum of offers related to nuclear capacity building. Here are some examples of what an ICERR can offer: basic and specific training (e.g. set of reactor laboratories, development of micro-projects) for young professionals in nuclear science and engineering; hands-on-training programme dedicated to specific activities on research reactors (e.g. irradiation and testing services) or their ancillary facilities (e.g. hot cells or analytical laboratories); on-the-job training for operators (reactor and hot cells), maintenance personnel, radioprotection specialists or regulators. The main objective of the training is to foster knowledge, rules- and skill-based behaviors, as well as to develop the nuclear safety culture. Duration of the programme can range from a few weeks to a few months, depending on needs and training objectives. The detailed content of the training programme is established and agreed between the ICERR and the affiliate organization.

Participants: In the frame of a fellowship training programme, ICERRs are particularly well adapted for hands-on-training aimed at professionals with some background experience in research reactor operation, maintenance and utilization. Nevertheless, ICERRs can also be used as capacity building instruments for initial education and training.

Status: Currently, two organizations have obtained the ICERR designation from the IAEA: the CEA in France (in 2015) and the SSC RIAR in the Russian Federation (in 2016). From 2017, additional organizations, including other regions, are expected to be designated. One of the objectives of the scheme is to create a network of ICERRs (ICERRnet) offering a broad spectrum of capabilities which will cover in a comprehensive manner the needs for nuclear capacity building of the Member States in all regions.

Trainers, such as university professors or reactor staff, wishing to develop their skills in establishing and delivering reactor hands-on-training courses at their national facilities may also join the distance IRL training or Hands-on-training Regional Research Reactor Schools, or attend part of the EERRI Hands-on-training Group Fellowship Programme (e.g. for 2 weeks) to get an insight into the content and pedagogical approach used in these instruments (train-the-trainers approach).

Table 1 presents a resumed scheme of the four instruments.

In the frame of these instruments, we will now focus on the description of the IRL, experience and feedback for operating facilities and description of planned facilities in the world to join the IRL program.

Table 1: Guidance on the type of training programmes available to targeted audiences

Targeted Audience	Distance training: Internet Reactor Laboratory (IRL)	Basic Hands-on-training: Regional Research Reactor Schools	Intermediate Hands-on-training: EERRI Group Fellowship Training Programme	Advanced training: International Centers based on Research Reactors (ICERR)
	5 to 6 half-day sessions	2 weeks	6 weeks	Few weeks to 3 months
Undergraduate and Graduate Students (Nuclear engineering or related fields)	**Agreement to be signed with the IAEA to become a Guest institution** *IAEA provides financial support to the Guest institution for the equipment & Laboratories are free of charge for the Guest (1 set of sessions per year)*			
Young professionals (Nuclear engineering or related fields)	**Bilateral arrangement to be made between with a Host reactor and a Guest institution** *IAEA act only as a facilitator*	**School held by the hosting organizations, in cooperation with the IAEA** *Funding might be provided through established mechanisms (e.g. under relevant TC projects or extra budgetary contributions)*	**EERRI course held by the hosting organizations, in cooperation with the IAEA** *Funding might be provided through established mechanisms (e.g. under relevant TC projects or extra budgetary contributions)*	**Bilateral arrangement to be made between the ICERR and an Affiliate institution** *IAEA act as a facilitator but, if applicable, funding might be provided through established mechanisms (e.g. under relevant TC projects or extra budgetary contributions)*
Professionals seeking for advanced and specific training				**Bilateral arrangement to be made between the ICERR and an Affiliate institution** *IAEA acts as a facilitator but, if applicable, funding might be provided through established mechanisms (e.g. under relevant TC projects or extra budgetary contributions)*

2. IRL at CEA – Description and feedback

Background

The International Atomic Energy Agency (IAEA) and the French Alternative Energies and Atomic Energy Commission (CEA) signed an agreement in 2014 in order to establish the Internet Reactor Laboratory (IRL) project in Europe and neighboring countries. Within this agreement, the ISIS research reactor at CEA Saclay acts as the host reactor of the IRL project, the National Institute of Science and Technology (INSTN) being in charge of the delivery of the Core experiments.

In October 2015 the leading professors from guest institutions - Tunisia, Tanzania, Belarus and Lithuania - attended a week-long training workshop at the host reactor facilities. During the workshops, participants from each guest institution presented their academic curriculum and the integration of the IRL core experiments in the program was discussed. After a comprehensive presentation of the facility, each reactor core experiment was conducted with the professors using the protocols developed by the host reactor. Protocols and experiments were discussed from a technical and pedagogical point of view in order to make the professors familiar with the content of the experiments and their delivery. Preparation of the students for each exercise was discuss, establishing what students need to know to ensure that they will get full benefit from the training.

In fall 2016, the first set of IRL laboratories have been conducted with the guest institutions. This document provides detail information on the delivery of the Laboratories, its results and feedback, as well as the suggested recommendations to further improve the IRL.

1. Description of the equipment at the Host Reactor

Using a system based on videoconference equipment, the following information can be sent from the ISIS host reactor to the remote classroom at the guest institutions:

1) Power point presentations,
2) Pages from the supervision system used by the operator to follow the state of the different systems of the reactor (control rods, neutron detection systems, cooling system, safety system…),
3) Interactive white board were the lecturer can present and explain the experiments and results,
4) Graphs from the supervision system showing the time evolution of selected parameters for each experiment,
5) Tables of selected data recorded by the supervision system,
6) Curves plotted using the recorded data after calculation,
7) Movies to be shown to introduce or illustrate some experiments or phenomena,
8) Video signals from four cameras looking at: the lecturer, the reactor hall, the core, the operator at control desk.

Figure 1 gives the schematic representation of the capabilities of the system which transmits two video signals from the reactor control room to the guest institution’s classroom.

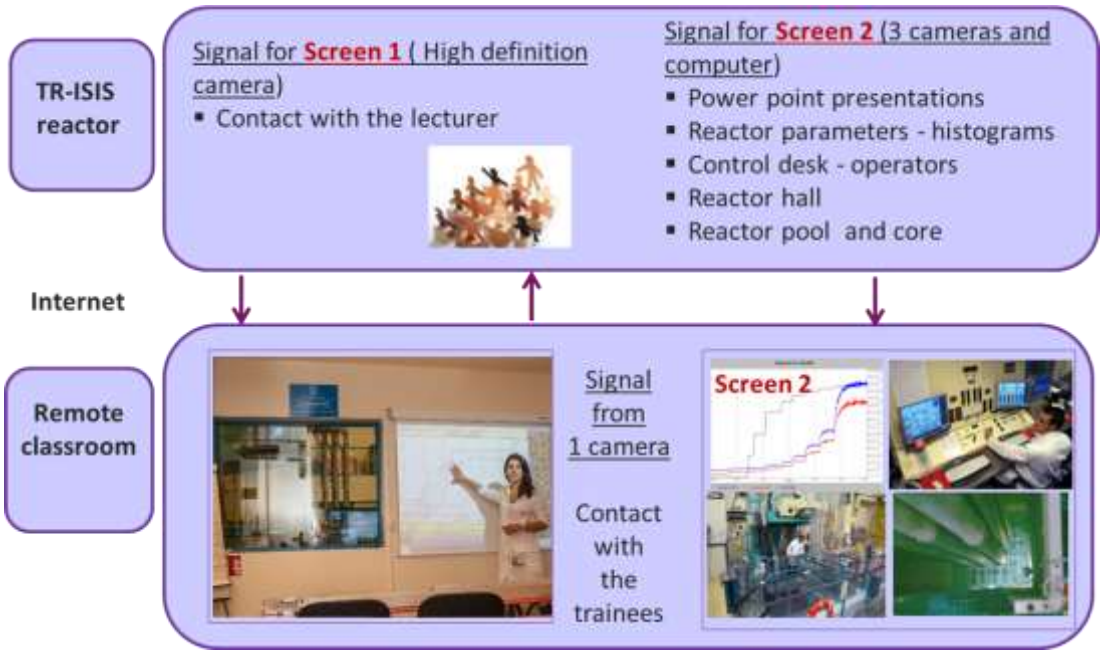

Figure 1: Schematic presentation of the information sent from the Host Reactor

Participating Guest institutions

In Africa, two institutions had presented themselves as recipient facilities: the Tanzania Atomic Energy Commission and the Tunisian National Centre of Nuclear Sciences and Technologies while in Europe guest institutions where the Vilnius University (Lithuania) and the Faculty of Chemistry of Belarusian State University (see Table 2).

Coordinating the schedules of students at universities in different countries, along with those of the host facility, was quite challenging. The period of the year in which the labs were scheduled was the busiest for both, academic institutions and ISIS facility. As a consequence, most of the experiments from ISIS reactor had to be broadcasted in the first week of December since this was the best time for the major part of the counterparts.

Belarusian State University (BSU), and precisely the Faculty of Chemistry decided to take a step forward and invited lecturers form CEA to give introductory courses and to assist the guest lecturer during the broadcasting. In the frame of an additional agreement between BSU and CEA, Slavica Ivanovic visited the faculty of Chemistry at the end of November 2016 where she gave lectures on operational reactor physics related to the experiments performed on the ISIS reactor. Two weeks later, Xavier Wohleber went at BSU to provide assistance to the guest lecturer and to the students for the remote conduction of the experiments. This also gave the opportunity to provide additional technical and practical details and explanations on the ISIS facility. His presence was described later as a bridge for successful communication between the host instructors, the operating team at the reactor and students in the remote guest's classroom.

Table 2: List of participants in the IRL at CEA

	Guest institution	Professor	Contact	Students specialization	Number of students
Tunisia	National Center for Nuclear Sciences and Technologies	Mohamed Sadok Guellouz	sadokguellouz@gmail.com	Final year of Enery Systems Engineering	36
Tanzania	Tanzania Atomic Energy Commission	Simon Doe	yusufu.jande@nm-aist.ac.tz official@taec.or.tz slcmdoe@taec.or.tz	/	0
Belarus	Faculty of Chemistry Belarusian State University	Kimlenka Iryna Savitskaya Tatsiana	Kimlenka@bsu.by ta_savitskaya@mail.ru	Third year on High Energy Chemistry	24
Lithuania	Faculty of Physics Vilnius University	Laurynas Juodis	laurynas@ar.fi.lt	Third year Energy physics program	6

Broadcasting of the Core experiments

According to the Agreement, five experiments were broadcasted form the host reactor:

- Lab1- Fuel Loading
- Lab2- Approach to Criticality, Reactor Strat-up, Reactivity effect around criticality
- Lab3- Reactivity effect of devices placed in the core, Road calibration curve, Global worth by the road drop technique
- Lab4- Role of Precursors, Temperature effect
- Lab5- Detection system in pulsed mode and in current mode

Before the course broadcasting a series of connectivity test was conducted in order to ensure that a good quality of image was available at the guest institutions. This required an adjustment of the videoconferencing protocols on both sides, at the guests and the host. It was also necessary to ensure a proper setting of the CEA global security system for the transmission of the videoconference signal in order to avoid any blockage of the transmitted signals. Finally, the setting of the videoconference system had to be adjusted to ensure that the image fluxes sent form ISIS reactor were properly shown at the host institution, i.e presenting the two video fluxes on two different monitors. This task that seemed easy turned out to be complex when considering a growing number of participants connected in parallel. Indeed each additional guest provides an additional video signal to the transmission. To keep the attention of the students on the exercises carried out at the host reactor, it is better to avoid exhibiting the video signal of all the guest institutions at a given institution.

Table 3 summarizes the details of each course transmission along with the dates and particular information of every guest institution. It has to be noted that Tanzania that was initially involved in program and which benefited from a specific broadcasting on the 27th of September in the frame of an IAEA workshop, didn't attended the core experiments. Despite attempts from the host reactor responsible to get in contact with Tanzania's counterpart, Tanzania did not join the transmissions.

Table 3: Details of the IRL at CEA broadcasting for the year 2016

Date	Experience	Lecturer	Country		
			Lithuania	**Belarus**	**Tunisia**
9 November am	**Lab 5**	B.Lescop	**Broadcasting interrupted after an hour due to technical problems**		
5 December pm	**Lab 2**	S. Ivanovic	Medium quality of the received image	Satisfying quality of the received image	Late to join the course at the beginning due to the technical difficulties. After establishing connection everything went smooth with good image quality
6 December am	**Lab 3**	S. Ivanovic	Poor quality of the received image	Satisfying quality of the received image	Good quality of the received image
6 December pm	**Lab 4**	S. Ivapovic	Poor quality of the received image	Satisfying quality of the received image	Good quality of the received image
7 December pm	**Lab 1**	S. Ivanovic	Medium quality of the received image	Satisfying quality of the received image	Didn't participate

General feedback

The equipment at the Host Reactor gave satisfactory results for the transmission of the video signal and the display of the data of the reactor. However, the system has shown some limitations in switching rapidly from one signal to another: a delay of a few seconds is needed to switch from one camera or graph display to another. This makes more difficult the task of the person assisting the host lecturer in the delivery of the course. In order to improve this feature, CEA decided to upgrade its transmission system and installed a new system, which will ensure better quality and easier handling from the Host Reactor side for the future. Concerning the pedagogical aspects, the IRL itself provides a good opportunity for the students to participate and conduct reactor exercises. However, interacting with multiple guests and a large number of students (60 in total) bring some limitation in the interaction between the lecturers (both at the host and the guests) and the students. Indeed it has to be noted that standard on-site training at ISIS reactor are carried out with a maximum of 10 students. Thus it is recommended to limit the guest institution to a maximum of 4. A limitation of the number of student at each guest institution could also be considered. The main learning of these first transmissions is that an increase in the number of guest and students at each site reduces the effectiveness of the exercises. However the approach adopted by BSU, i.e. having a host lecturer who was familiar with the Host reactor facility and exercises, joining the class at the guest institution to foster interaction with the host reactor, to give additional explanations and to discuss the data of the reactor with the student, has proven to be very effective enhancing the impact of the IRL and overcoming the loss of efficiency due to multiple site transmission.

At the Guest institutions, as it was shown in the Table 3, the quality of the received image varied trough labs. This caused difficulties for the students at Vilnius University to follow the course. Tunisia faced connection problems for the course transmitted on 5th of December for technical reasons. It is important to mention that for both-guest and host institutions this was a ‘first of its kind’ project.

In Belarus, the IRL project was widely covered in national mass-media and recognized as a tool that enhances the nuclear education capabilities and development of the competences of

the specialists involved in the Belarus nuclear energy program. The presence of visiting lecturers allowed to train the students in depth so that the best are recruited to be peer-leaders. They will act as facilitators for small groups of students for the following academic years.

Despite the minor technical issues and the pedagogical limitations described above, the overall course was recognized as a precious contribution to the understanding of the nuclear reactor principles and operation.

In addition, Table 4 gathers the main remarks form guest institution. Lead professors from guest institutions where asked to provide those information so that they can be used for future development and improvement of the IRL quality.

Table 4: Observations and suggestions for the future collaboration from guest institutions

Country	Remarks
Lithuania	The experiments were broadcasted too late in the autumn semester. The lab description text could be improved or supplemented with additional information. Quality of the recived image wasn't satifying for every lab. Making the broadcasting even more interactive.
Belarus	The collected students' feedback was very positive regarding the interest and the effectiveness of this "nontraditional" learning tool. They concluded that the practical experience obtained from IRL strongly enhanced their background in nuclear reactor physics.The IRL project was widely covered in national mass-media.
Tunisia	Participants where students at their finaly year on Enery Systems Engineering. Labs were incorporated in the course "Nucelar energy". The students where delight to perform the course and they learned a lot.

3. IRL at CNEA – Description and feedback

Introduction

The RA-6 Research Reactor was designed and constructed to support the teaching activities at the Balseiro Institute, and was inaugurated on 26 of October of 1982. It is an open pool type reactor, 1MW thermal power, moderated and refrigerated for light water. The core, with variable configuration, is composed for MTR type fuel elements. As academic laboratory, the RA-6 has supported the education and training of hundreds Argentinian and foreign professionals. To enhance the extent of the courses at RA-6, the CNEA has developed with partial financial support by the IAEA a data acquisition and integral management tool, the ***RA-6 Online***.

The aim of the RA-6 Online platform is to give the students digital access to all the reactor operation information on-line to perform the experiences and to post-process the laboratory data off-line when needed. Each student has access to an interactive and customized link to the reactor operation data, allowing the student to perform the practice in a personalized way.

This platform is the main component of the IRL at RA-6, which is complemented with Videoconference system to support local-remote interaction during the laboratory broadcasting. Figure 2 shows the architecture of the IRL based on the RA-6 reactor.

CNEA and IAEA cooperation for the establishment of the IRL Project in Latin America

On the 4th of April 2013, the CNEA and the IAEA signed an agreement concerning the establishment of the Internet Reactor Laboratory (IRL) project in Latin America. The agreement establishes the basis for the collaboration between institutions, and defines the role of each one. The agreement also defines the third part remote institutions participating in the IRL in Latin America.

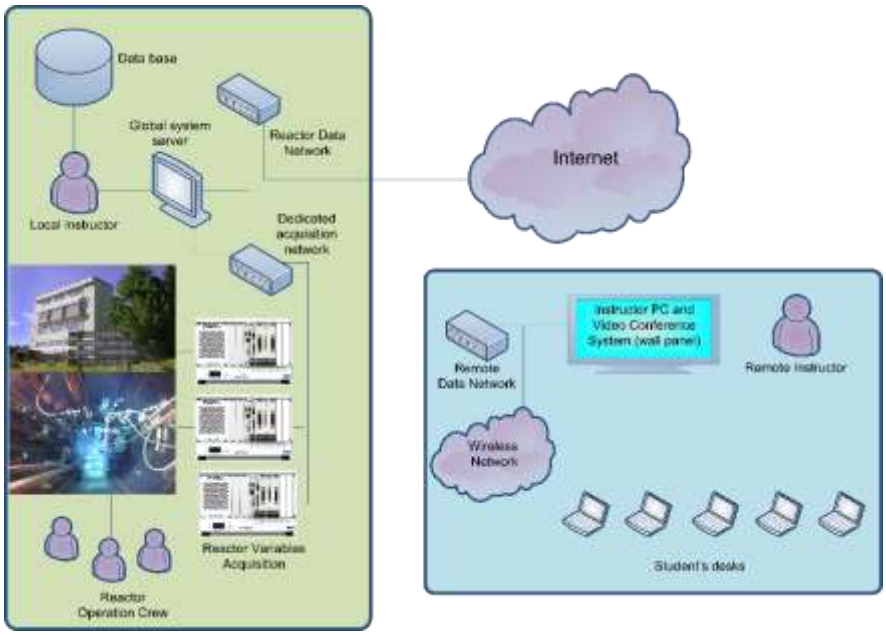

Figure 2: IRL architecture at RA-6

The main aspects of the agreement are:

- IAEA financially supports the new equipment needed to establish the IRL in Latin America using the RA-6 Reactor as Host Reactor.
- IAEA covers the fee of each transmission to three guest institutions for a period of 5 years.
- IAEA financially supports a training and orientation workshop for the principal instructors from the Guest Institutions.
- CNEA, with its RA-6 Reactor, acts as Host Institution for IRL project in Latin America.
- CNEA installs all the equipment needed to support the IRL project in Latin America.
- CNEA procures the internet infrastructure needed to support the IRL project in Latin America.
- CNEA will broadcast six experiments once a year during five years to the remote institutions. The experiments are:
    1) Nuclear instrumentation in a Research Reactor;
    2) Critical approach;
    3) Control rod calibration;
    4) Control rod reactivity measurement (rod drop);
    5) Temperature reactivity coefficient; and
    6) Void coefficient calculation.
- CNEA will provide the curriculum and laboratory protocols for each of the six core experiments to the Guest Institutions.
- The agreement identifies three initial Guest Institution:
    - Cuba,
    - Ecuador,
    - Uruguay,

  then extended to seven but limited to three simultaneous gests, including:
    - Bolivia,
    - Colombia,

- Universidad del País Vasco – Spain,
- Universidad Politectnica de Madrid – Spain,

Within the context of the agreement, CNEA and IAEA started the implementation of the work plan. In March 2015, the RA-6 Online was ready to start the tests. In September 2015, CNEA hosted the training and orientation workshop for the principal instructors from the Guest Institutions. The workshop had the participation of the IAEA, and the main professors of the Universidad Mayor de San Andres, **Bolivia**; the Escuela Politécnica Nacional de **Ecuador**; the Universidad Nacional de **Colombia**; the Instituto Superior de Tecnologías y Ciencias Aplicadas, **Cuba**; the Universidad Politecnica de Madrid, Spain and Universidad del País Vasco, **Spain**.
During the workshop, the CNEA staff introduced the remote instructors to the RA-6 reactor as a machine. This activity was of great relevance in order to familiarize the remote instructors to the RA-6 reactor, the future laboratory of the experiments.
Also during the workshop, the CNEA staff presented the six protocols developed to use in the IRL in Latin America. The local and remote instructors analysed the protocols and their implementation in the IRL platform.
After that, the host institution presented how they intend to include the IRL activities into the curricula of their institutions.
Finally the CNEA staff conducted 2 reactor experiments out of the 6 that will be transmitted during the IRL project, acting as local and remote instructors in order to show the participants how should be the dynamic of the sessions to be broadcasted by the IRL for Latin America. Figure 3 shows on the left the remote setup with the instructors from guest institution performing the experience. On the right part of Figure 3, the local instructor from the CNEA can be identified conducting the experience from the training control room at the RA-6 reactor.

Figure 3: Transmission during the Orientation Workshop conducted in Bariloche, Argentina - September 2015.

Based on the availability of the RA-6 reactor and the academic curricula of the participating guest institutions at the training and orientation workshop, the participants agreed on officially commencing with the transmissions on the second semester of 2016.

CNEA IRL Broadcasting during 2016

During 2016, the first period of broadcasting from IRL at RA-6 took place. The schedule was agreed in order to fit into the academic activities of the remote institutions simultaneously. This led to the agenda shown in Table 5.

Figure 4 shows two images taken from different broadcasting sessions of the IRL at RA-6. The image on the left presents the monitor of the Videoconference administrator where you can see the local instructor, the main control room of the RA-6 reactor and the three remote institution connected. The image on the right presents the setup that has been adapted in training control room in the RA-6 in order to fit the IRL capabilities. It also can be seen a local instructor taking the lecture for remote institution, in this case the experience was control rod calibration.

Date	Experience	Participants	Comments
13-09-2016	Nuclear instrumentation in a Research Reactor	**Ecuador - Colombia**	**Cuba had connection clearance restrictions for the 4 first sessions.**
27-09-2016	Critical approach	**Ecuador - Colombia**	
11-10-2016	Control rod calibration	**Ecuador - Colombia**	
25-10-2016	Control rod reactivity measurement (rod drop)	**Ecuador - Colombia**	
08-11-2016	Temperature reactivity coefficient	**Ecuador – Colombia – Cuba**	
22-11-2016	Void coefficient calculation	**Ecuador – Colombia – Cuba**	

Table 5: IRL schedule for 2016 at RA-6 reactor

The general feedback from all the remote sites participating in the program was that it was very useful for them to have the opportunity to attend to real experiments developed in real facilities to complement the theoretical content that they have in their classes. The remote participants find this tool very interesting and a good approach to real experiences in a virtual scenario.
The quality of the connection was very good in all cases. The main issue was the connection clearance limitation that Cuba had for the first four session. This problem was solved and Cuba is online in 2017 from the first session.

Figure 4: Broadcasting sessions at the RA-6 IRL

The IRL at RA-6 is already broadcasting in 2017 with the same schedule approach i.e. starting in the second Tuesday of September and then every two Tuesday. In 2017, Ecuador could not join to the broadcasting because their local professor is pursuing a Master Thesis, but they will to join again in 2018.

4. IRL IN KOREA

The Kyung Hee University (KHU) has agreed to schedule and broadcast the six (6) Core Experiments in a year, plus an introductory video conference to orient students; the exact schedule will be agreed upon with Guest Institutions. Guest Institutions have agreed to integrate these six laboratories into their current curriculum. Other laboratories may be arranged as requested by Guest Institutions, and if the KHU has availability.

The KHU will provide curriculum in the form of laboratory experimental protocols for the Guest Institutions to use. However, there is no presumption that other curricula outside of these lab protocols will be provided. All courses will be taught by instructors from the KHU, in collaboration with instructors at the Guest Institutions. Should the Guest Institutions wish to acquire other curricula from the KHU, this may be negotiated between the two parties individually.

Table 6 gives a model
of IRL operation schedule during one semester. The actual schedule will have to be defined and agreed upon according to the educational programmes of the participating Guest institutes.

Table 6: Operation schedule during one semester of the IRL at Korea.

Week	Host Site	Guest Site	Activity
1	-	Lecture	Introduction to Course & AGN-201K
2	-	Lecture	Theory for Exp.#1 (Reactor Operation)
3	Experiment	Experiment	Exp.#1 (Reactor Operation)
4	-	Lecture	Student Presentation for Exp.#1 Theory for Exp.#2 (Reactivity Measurement)
5	Experiment	Experiment	Exp.#2 (Reactivity Measurement)
6	-	Lecture	Student Presentation for Exp.#2 Theory for Exp.#3 (Approach to Criticality Experiment)
7	Experiment	Experiment	Exp.#3 (Approach to Criticality Experiment)
8	-	Lecture	Student Presentation for Exp.#3 Theory for Exp.#4 (Rod Worth Measurement)
9	Experiment	Experiment	Exp.#4 (Rod Worth Measurement)
10	-	Lecture	Student Presentation for Exp.#4 Theory for Exp.#5 (Thermal Flux Mapping)
11	Experiment	Experiment	Exp.#5 (Thermal Flux Mapping)
12	-	Lecture	Student Presentation for Exp.#5 Theory for Exp.#6 (Temp. and Ref. Effects)
13	Experiment	Experiment	Exp.#6 (Temp. and Reflector Effects)
14	-	Lecture	Student Presentation for Exp.#6 Examination
15	Presentation	Presentation	Student Group Competition for the Best Presentation
16	-	Lecture	Wrap-up Class

An agreement has been effective between IAEA and Kyung Hee University since Nov.27 when the signing ceremony was held at Agency. A pilot IRL facility was installed and tested at KHU RREC in March 2017. During the month of December, domestic and foreign guests

will be invited for the official partnership under the IAEA project. A test **operation of IRL will be performed in January through February as an open workshop with professors from guest universities. The first broadcasting is planned to start in March.**

5. IRL AT MOROCCO

The Moroccan TRIGA MARK II research reactor hosted by the National Center of Energy Sciences and Nuclear Techniques CNESTEN has been selected to be the host reactor for Africa. The official notification was received from IAEA in April 2017. The implementation of the project will start shortly, two institutions had already presented themselves as recipient facilities:

a) the Tanzania Atomic Energy Commission and
b) the Tunisian National Centre of Nuclear Sciences and Technologies.

To initiate the project, it was agreed to schedule and broadcast the six (6) Core Experiments in a year, plus one or two orientations workshops to give the lecturers from guest institutions the fundamentals related to the facility, the protocols and the proposed dynamics for the broadcasting sessions. Connections to National universities and laboratories may be arranged depending on the facility availability.
Discussions with national universities to integrate the experiments in their curricula are ongoing. Table 7 gives a list of experiment which is planned to be broadcasted.

ID	Laboratory
1	**Reactor startup** Reactor control (operating modes) and stabilization Reactivity Excess, shutdown margin determination
2	**Approach to criticality**
3	**Reactivity measurement** Fuel element worth
4	**Control rod worth measurement** Positive period method
5	**Reactor dynamics** Void effect & coefficient
6	**Reactor thermal power determination**

Table 7: Experiments to be broadcasted in the CNESTEN IRL

The CNESTEN will provide virtual access to the Moroccan TRIGA MARK II research reactor, and the experimental protocols will be broadcasted to Guest Institutions (maximum 4 simultaneously) by local instructors from the CNESTEN, in collaboration with instructors at the Guest Institutions.

A graphical interface gathering all data needed to perform and broadcast the experiment was developed and successfully tested. This interface will greatly facilitate the project implementation.

Until now, the agreement is not yet signed between IAEA and CNESTEN. However, we expect to start broadcasting in the second or the third quarter of 2018 after the organization of the first orientation workshop.

6. CONCLUSIONS

IRL represents a successful collaboration between the IAEA and the Member States to support the Nuclear Capacity building programme of the IAEA.
The already running host reactors in France and Argentina, the panned ones in Korea, Morocco and the future developments in the Russian federation will potentially cover almost all the regions.
The feedback of the first year of broadcasting is promising. Remote users find this technology useful for the domestic nuclear capacity building activities in their own countries.
Although it does not replace real hands on experimentation at a research reactor facility, the IRL concept is a cost-effective option to include practical reactor experiments into existing university nuclear curricula.
With the IRL programme, the IAEA intends to promote similar bilateral cooperation among research reactors and universities. It also promotes the expansion of the transmissions beyond the timeline of the IRL agreement and outside of the financial support of the IAEA, so guest institutions can build one-on-one partnerships with host reactors for future transmissions.