UDC 621.039

H. Pauwels[1], P. Daures[1], Y.J. Stockmann[2], J. Végh[2]

[1]European Commission, DEVCO
[2]European Commission, JRC

Cooperation between SSTC NRS and the EU in the area of nuclear safety

The paper first briefly outlines the main characteristics of the EU assistance programs aimed to enhance nuclear safety in the Beneficiary countries. Then EU assistance provided to the Ukrainian regulator (SNRIU) is detailed, with specific emphasis on projects enhancing the capabilities of SSTC NRS as technical support organisation (TSO) to SNRIU, including training and tutoring (T&T) activities. The changing role of SSTC NRS in the cooperation activities is described as well. The broad range of cooperation is then illustrated by some selected projects focusing on various technical areas (e.g. severe accident management and mitigation, radioactive waste and spent fuel management, NPP service time extension, plant performance monitoring and operating experience feedback).

Finally, the paper briefly discusses the future perspectives of the nuclear safety cooperation between the EU and Ukraine.

Keywords: nuclear safety, assistance program, nuclear regulator.

Г. Пауелс, П. Даурес, І. Штокман, Я. Вег

Співпраця між ДНТЦ ЯРБ і ЄС у сфері ядерної безпеки

На початку статті коротко викладені основні характеристики програм підтримки ЄС, спрямованих на підвищення ядерної безпеки в країнах-бенефіціарах. Далі детально описується підтримка ЄС, що надається українському регулюючому органу (ДІЯРУ) з акцентом на проекти, спрямовані на розширення можливостей ДНТЦ ЯРБ як організації технічної підтримки (ОТП) ДІЯРУ, охоплюючи навчання і наставництво. Описується зміна ролі ДНТЦ ЯРБ у заходах зі співробітництва, широкий спектр співпраці в рамках деяких вибраних проектів з акцентом на різні технічні області (наприклад, управління важкими аваріями і пом'якшення наслідків, поводження з радіоактивними відходами та відпрацьованим паливом, продовження терміну експлуатації АЕС, контроль робочих характеристик станції та обмін досвідом експлуатації).

Стисло обговорюються майбутні перспективи співпраці ЄС та України у сфері ядерної безпеки.

Ключові слова: ядерна безпека, програма надання підтримки, орган ядерного регулювання.

The Instrument for Nuclear Safety Cooperation (INSC) is aimed at "financing measures to support the promotion of a high level of nuclear safety, radiation protection and the application of efficient and effective safeguards of nuclear material in third countries". One of its specific objectives is to provide "continuous support for regulatory bodies, technical support organisations, and the reinforcement of the regulatory framework, notably concerning licensing activities". INSC supports nuclear safety, not nuclear energy.

With respect to the reinforcement of nuclear safety infrastructure, INSC pays special attention to the establishment and further development competent, capable and independent national nuclear regulators, as well as their TSO network. The EC believes — in accordance with the International Atomic Energy Agency (IAEA) — that a strong and independent national nuclear regulator has a key role in establishing and maintaining a high level of nuclear safety in any country. Inside the EU, this is ensured by the nuclear safety directive [1].

Before the adoption of the INSC, the TACIS (Technical Assistance to the Commonwealth of Independent States) programme was launched by the European Commission (EC) in 1991 to help members of the Commonwealth of Independent States (CIS) and Mongolia during their transition to democratic market-oriented economies. The Nuclear Safety component of TACIS provided assistance to improve the safety of civil nuclear facilities in the CIS countries. TACIS is now partly included in the EuropeAid programme [2], while from 2007 on, the nuclear safety assistance is provided in the frame of INSC [3], in this article also INSC-I. INSC provides a global coverage outside the European Union (EU). In 2014 INSC-I was replaced by a new, INSC-II instrument with the same name [4].

While TACIS was orientated to help the former Soviet states and Mongolia, the INSC has no geographical limits outside the EU: it is a global instrument assisting any country eligible for support. Note that INSC-II also includes nuclear safety cooperation with EU candidate countries (e.g. Serbia), previously covered by the PHARE and later the IPA (Instrument for Pre-accession Assistance) instrument.

Fig. 1 shows the geographical distribution of the different support types in INSC-I, illustrating the "global" operation of the instrument.

INSC activities are implemented by the EC Directorate General International Co-operation & Development (DG DEVCO) by applying centralised management, in which all projects are managed directly by EC project managers residing in Brussels. Detailed program planning is performed by means of Annual Action Programmes (AAPs) containing actions jointly proposed by the partner countries and the European Commission and approved by the EU member states.

Most actions are implemented with projects, which are implemented by contractors, following the EU financial rules. The tendering and contracting procedure follows the regulations laid down in the implementation rules for EC external instruments [5]. Experts from the Joint Research Centre (JRC) provide technical and scientific support to DG DEVCO during the definition and implementation phases of the INSC projects.

Table 1 shows some characteristic numbers describing the completed and ongoing nuclear safety assistance projects. Note that until 2014 Ukraine had a highly privileged status in the INSC: between 1991 and 2013, **50 %** of the INSC budget was spent in Ukraine. INSC-II was launched in 2014 and it had significantly lower budget than the previous instrument. The share of assistance provided to Ukraine decreased to **10 %**, as well. INSC-II also introduced a significant change

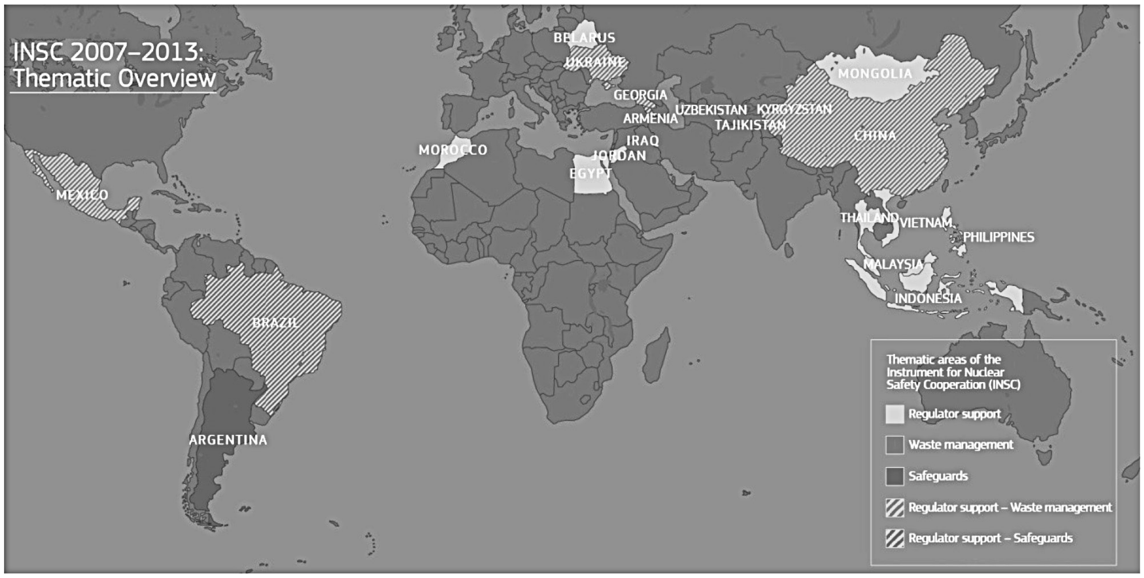

Fig. 1. Thematic areas of support in the INSC-I instrument (2007—2013) [3]

in the thematic areas of assistance: the new instrument focused on nuclear safety culture (**50 %** of the budget); management of spent nuclear fuel and radioactive waste (**35 %**) and nuclear safeguards (**10 %**). The remaining **5 %** of the budget was allocated to various support measures (see [6] for more details). The on-site assistance to nuclear power plant operators — an area dominant in TACIS and continued in the previous INSC-I instrument — was practically eliminated from INSC-II, for mainly two reasons, firstly the involved nuclear operators were judged mature enough to manage their safety enhancement and plant modernisation projects themselves and secondly, not safety related, Ukraine was going to enter the EU energy market and such support activities could be perceived as distorting market competition.

Table 1. TACIS and INSC budgets [6, 7]

EC Instrument	Status	Total [m EUR]	Ukraine [m EUR]	%
TACIS, 1991—2006	Completed	1260	626	50
INSC-I, 2007—2013	Completed	524	261	50
INSC-II, 2014—2020	Ongoing	225	21(1) + 30(2)	10

(1) Committed amount as of 31.12.2016

(2) Contribution to Chernobyl Shelter Fund in addition to INSC-II budget

Regulatory assistance projects are under implementation or have been approved for e.g. Armenia, Belarus, China, Indonesia, Iran, Jordan, Morocco, Tanzania, Thailand, Turkey, Ukraine and Vietnam. Projects supporting radioactive waste (RAW) management are carried out in Armenia, Iraq and Ukraine. A special area of RAW management is the remediation of contaminated and legacy sites: related INSC projects were launched in Kyrgyzstan, Mongolia, Tajikistan (Fig. 2), Ukraine (Prydniprovskiy Chemical Plant) and Uzbekistan. So far, INSC safeguards projects were mainly focusing on Africa and China. The multi-country Training and Tutoring (T&T) project is a successful initiative attracting a large number of trainees worldwide. In this project, T&T is provided for

Fig. 2. The "Yellow Hill" containing uranium ore waste at the Taboshar legacy site in Tajikistan, its remediation is supported by the INSC [3]

the experts of the nuclear regulators and their TSOs, as well as for specialists of radiation protection, safeguards and RAW management facilities. SSTC NRS is part of one of the consortia which take care of the training activities [8].

For more details on the EU nuclear regulatory assistance see [9].

The Ukrainian Nuclear Sector and the INSC Support

Nuclear Power Plants. Ukraine currently has 15 nuclear power plant (NPP) units in operation at four sites. These plants are operated by the National Nuclear Energy Generating Company (NNEGC) "Energoatom" which is responsible to the Ministry of Energy and Coal Industry of Ukraine. The total installed net capacity of the plants is 13.1 GWe. Nuclear represents approximately 25 % of the installed electricity generating capacity of Ukraine, but usually it provides more than 40 % of the electricity generated. In addition, the latest energy

Fig. 3. View of the Zaporizhzhia NPP, the largest nuclear electricity generating centre in Europe

strategy of Ukraine proposes at least 5.0 GWe of new nuclear electricity generating capacity by 2030.

All Ukrainian VVER units belong to the 2nd generation reactors and they went into operation after 1981. In the last decade the service time extension of the units is going on, e.g. the two VVER-440/V213 units at Rivne have been granted 20 years license extensions in 2010. The two VVER-1000/302 and /338 type units of the South Ukrainian NPP underwent major upgrades and their operating license extension until 2025 was approved at the end of 2015. In 2015 Energoatom requested 15 years licence extension for the first two VVER-1000/320 type units of the Zaporizhzhia NPP (Fig. 3). Further service time extensions are expected in the future; based on the experience with the accomplished lifetime extension (LTE) programs.

After the disintegration of the Soviet Union, Ukraine faced two major nuclear safety related problems: the design- and operational safety of its power reactors and the legacy of the Chernobyl accident. Note that in the early nineties three RBMK units were still in operation at Chernobyl NPP and the last RBMK was shut-down permanently in 2000.

In 2010 a joint study of the European Commission, the IAEA and Ukraine was prepared to assess the safety level of all operating Ukrainian NPPs. The study showed that the Ukrainian NPP units generally complied with most of the requirements outlined in the IAEA nuclear safety standards, if the effect of planned safety upgrade measures were duly taken into account in the safety assessments. Note that the planned safety upgrade measures were outlined in the Complex (Consolidated) Safety Upgrading Programme (CCSUP) containing a series of safety enhancement measures for all Ukrainian NPPs. In 2015 Energoatom received loans from EURATOM and the EBRD (each loan equalled €300 million), as a substantial help to finance the implementation costs (totalling to €1.4 billion) of the CCSUP.

After the Fukushima accident in 2011, Ukraine participated in the EU stress tests exercise together with the EU member states and Switzerland [10]. The stress test assessments of Ukrainian NPPs were completed and a number of safety improvement measures to increase the robustness of plant responses were identified. Those measures that were not already included in the CCSUP would be implemented in the frame of the Ukrainian National Action Plan.

A large number of modernisation and safety enhancement projects were implemented at the Ukrainian NPPs in the past decades. As from the financial support side, TACIS and INSC programmes were the major contributors to these projects. TACIS supported a large safety upgrade programme of Ukrainian NPPs through the on-site assistance (OSA) programmes and through the supply of safety-related equipment. The INSC-I programme contained mainly "soft" assistance targeted at the Ukrainian NPPs, providing transfer of EU know-how and best practice related to NPP operational safety and safety culture.

In the INSC-II instrument the role of direct support to the NPP operators has decreased to a minimum and the on-site assistance is to be gradually phased out. The last OSA projects for Ukraine were programmed in the 2012 AAP. However, all actions that were already programmed and approved will be implemented with the agreed content.

Management of Spent Fuel and Radioactive Waste. Ukraine has to deal with a complex situation, if management of radioactive waste and spent nuclear fuel is considered. In addition to its 15 operating NPP units, the country has 2 research reactors and 6 interregional specialised enterprises built in the 1960s for disposal of institutional radioactive waste ("Radon" facilities). These disposal facilities are currently considered as temporary storage facilities. At the Chernobyl NPP site, there are three RBMK reactors in shutdown and the damaged Unit 4, surrounded by an Exclusion Zone of 30 km radius, where more than 800 temporary radioactive waste facilities are located. A new disposal site (Vektor) was recently licensed to accept Chernobyl NPP decommissioning waste. The Buryakovka disposal site, which was built shortly after the 1986 accident, is currently under assessment and considered for extension.

The spent nuclear fuel is mainly stored in wet storage facilities at the NPP sites, with the exception of Zaporizhzhia NPP, where a dry storage facility was constructed. A new dry storage facility (ISF-2) is currently under construction for the Chernobyl NPP. Radioactive waste and spent nuclear fuel inventory will increase in the future due to the operation of the current NPPs, site remediation activities, use of radioisotopes, development of new nuclear facilities and from the return of vitrified waste from the spent fuel reprocessing in Russia.

Since 2009, a comprehensive national strategy for managing Ukraine's legacy waste and future radioactive waste is in place addressing all stages of radioactive waste management and all types of radioactive waste produced in Ukraine. Based on this strategy, a national organization for radioactive waste management for long-term storage and disposal was established in 2010. This state specialized enterprise "Centralized Radioactive Waste Management Enterprise" reports to the State Agency of Ukraine on Management of the Exclusion Zone (SAUMEZ).

Ukraine continues to deal with the consequences of the 1986 Chernobyl accident and radioactive waste generated by past practices. With help from the EU TACIS and INSC programmes, as well as the large financial support from the Chernobyl Shelter Fund (CSF) and Nuclear Safety Account (NSA), both of which are international donor funds managed by the European Bank for Reconstruction and Development (EBRD), improvements have been made in the organisation of radioactive waste management.

Within the Exclusion Zone, the following key elements of the radioactive waste management infrastructure were developed:

- Industrial Complex for Solid Radioactive Waste Management (completed);
- Liquid Radioactive Waste Treatment Plant (completed);
- New Safe Confinement (Fig. 4, completed in 2016);
- Centralized Long-Term Storage Facility for Highly Radioactive Sources (completed);
- Interim Spent Fuel Storage Facility (ongoing; expected completion 2017).

Fig. 4. View of the Chernobyl safe confinement (“shelter”) during its construction

Fig. 5. Mobile radiation survey laboratory (RanidSONNI vehicle) delivered to Ukraine in the frame of an IAEA project, by Sweden and Finland + training was provided through an INSC project

The regulatory body of Ukraine, the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) is supported by a capable Technical Support Organisation (the State Scientific and Technical Centre for Nuclear and Radiation Safety, SSTC NRS). Both organisations have benefitted from the cooperation with the EU through the TACIS and INSC programmes (Fig. 5). Note that the INSC-II instrument shifted the focal point of the assistance to supporting national nuclear regulators and radioactive waste management activities; therefore — since 2014 — the Ukrainian INSC support is primarily targeted at SNRIU and SSTC.

Helping the safe operation of 15 NPP units in the neighbourhood of the EU, as well as handling the legacy of the Chernobyl disaster justified the high level of TACIS and INSC assistance provided to Ukraine in the past and continues to provide a rationale for continued cooperation.

Recent INSC Projects with New Focus Areas

Management of Severe Accidents. Several safety upgrade projects are being implemented at Ukrainian NPPs to increase their severe accident management (SAM) and mitigation capabilities. In the frame of UK/TS/43 INSC project

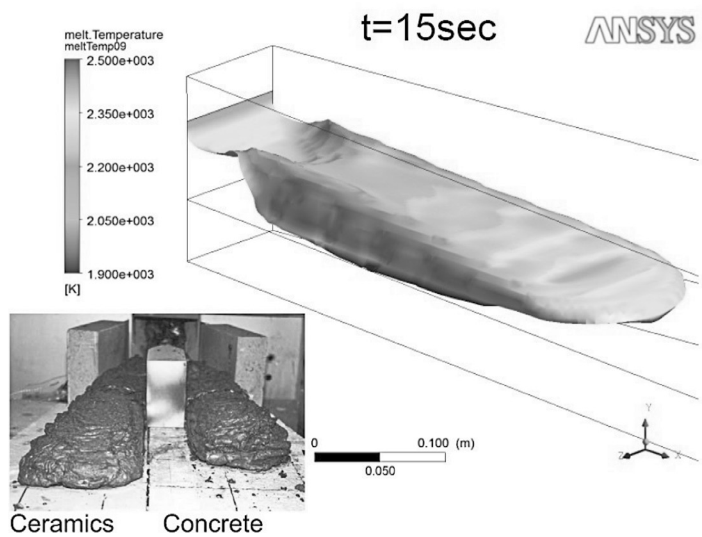

Fig. 6. Simulation of the VULCANO VE-U7 corium spreading experiment by SSTC, with the “real” experiment shown in the lower left corner of the picture (© SSTC)

(Component C of U3.03/08 = Assessing the operating organization materials on severe accidents analysis and management) EU experts provided support and know-how transfer to cover regulatory aspects of SAM. The joint work with SNRIU and SSTC included the reinforcement of the Ukrainian regulatory requirements (including incorporation of Fukushima lessons learned), and a joint review of the SAM guidelines. The relevant Ukrainian regulation was harmonised with the IAEA standards, the WENRA reference levels and the corresponding EC directives. In order to support the validation and verification (V&V) of the SAMG set, SSTC — among others — performed a series of MELCOR calculations [11]. SSTC also carried out ANSY CFX calculations to simulate the results of the VOLCANO VE-U7 (Fig. 6) corium spreading test experiment [12] performed at CEA (France).

Licensing of a New Neutron Source Facility. Currently Ukraine is constructing a novel Neutron Source Facility (NSF) at the premises of KIPT (Kharkiv Institute of Physics and Technology) in Kharkiv (Fig. 7). The project is carried out in co-operation with the Argonne National Laboratory (USA). The NSF is based on the ADS (Accelerator Driven System) concept, where a subcritical assembly is driven by a linear

Fig. 7. The building of the Neutron Source Facility under construction in Kharkiv (© SSTC)

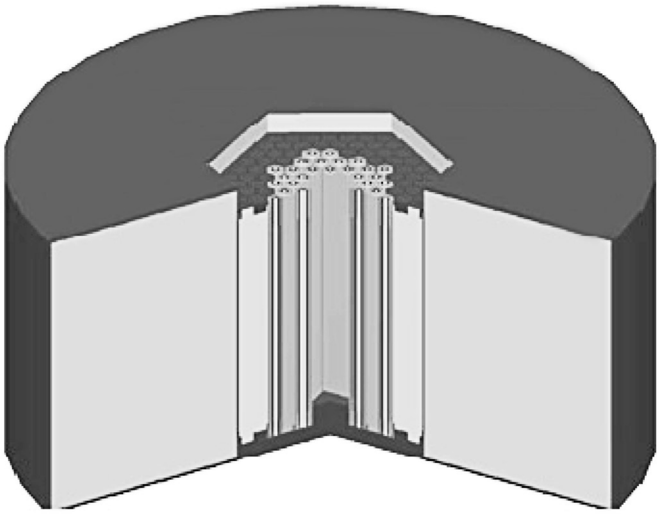

Fig. 8. Computer model of the subcritical assembly developed by SSTC (© SSTC)

electron accelerator. The subcritical core is constructed from standard, low enriched research reactor fuel assemblies of type VVR-M2, routinely applied in Russian-designed research reactors. The basic aim of the project is to develop an intense and safe neutron source to be utilised in various neutron research areas, such as reactor physics, materials research, industrial and medical experiments, etc.

The licensing of such a facility is a challenging task for the Ukrainian nuclear regulator; therefore, project UK/TS/49 (Comp. B of U3.01/12) provides assistance to SNRIU and SSTC during the licensing of the new NSF in the following areas:

- transfer of EU experience in the field of regulatory activities for ADS facilities;
- development and improvement of the Ukrainian regulations for ADS;
- collaboration to develop models for supporting the safety assessment of NSF;
- development of a methodology for V&V of the developed models.

During the course of the project SSTC carried out several tasks related to the reactor-physical and thermal-hydraulic modelling and safety analysis of the SNF. Fig. 8 shows the model developed by SSTC to calculate the reactor core, while Fig. 9 illustrates the result of a transient calculation.

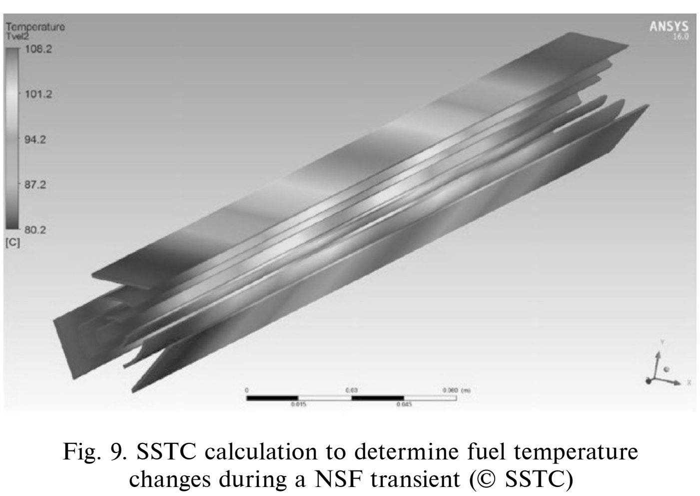

Fig. 9. SSTC calculation to determine fuel temperature changes during a NSF transient (© SSTC)

Risk-informed Regulatory Decision Making. Following recent international regulation trends, SNRIU decided to include risk-informed approaches into its activities, mainly in areas related to NPP operation and maintenance. The associated INSC project UK/TS/42 (Comp. A of U3.03/08) provided assistance to SNRIU and SSTC in the following areas:

- development of the concept of an integrated regulatory oversight system;
- compilation of an adequate system of NPP safety indicators;
- development of procedures for risk-informed planning of plant inspections;
- implementation of the integrated regulatory oversight system (IOS);

SSTC actively participated in all project activities and contributed to the successful completion of the project to a great extent. Among others, the project produced the document "Guideline for NPP Safety Oversight" and an inspection guide based on the results obtained by using the pilot version of the IOS. Fig. 10 shows the distribution of root causes of abnormal events happened in Ukrainian NPPs between 2008 and 2012, based on the [10] annual report. The decreasing tendency

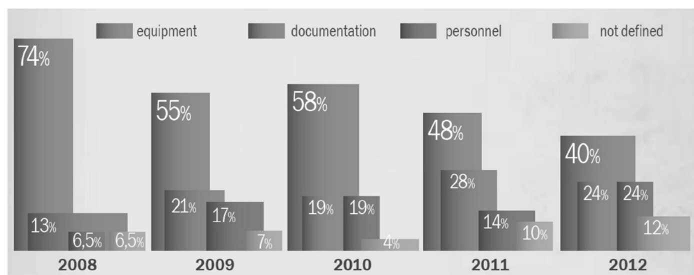

Fig. 10. Distribution of root causes of abnormal events in Ukrainian NPPs [13]

of events related to equipment failures is obvious, but the picture also indicates that new, more sophisticated (e.g. risk-informed) approaches are needed to further reduce the number of events in the other event categories.

Future Cooperation

The nature and scope of cooperation between the EU and SSTC has changed during the past 25 years to a great extent. After its establishment SSTC received EU assistance to build-up its organisation and its technical/scientific capacity, to become a capable and efficient TSO to SNRIU. In the early times the EU assistance focused on consultancy services, equipment (hardware) supply and provision of professional training to SSTC staff members. Later SSTC started to work in various INSC projects as local subcontractor, providing local expertise and technical support services. After 2010 SSTC was mature enough to participate in several INSC consortiums providing regulatory support as an equal consortium member, thus acting as a fully qualified player in the knowledge and know-how transfer to third countries.

Meanwhile the international reputation of SNRIU and SSTC was steadily improving. In 2015 Ukraine (SNRIU) joined the WENRA as full member. In 2016 Ukraine joined the EURATOM Research and Training Programme, one year after joining the Horizon 2020 programme. SSTC also participates (as observer) in the European Clearinghouse, which is an organisation of EU nuclear regulators for NPP operating experience analysis and feedback, as well as in several EU-wide research initiatives.

The EU—SSTC cooperation in the area of nuclear safety is bound to be continued in the future, because it is beneficial for both parties. Until 2020 the scope and financial resources of INSC cooperation are defined in the INSC-II instrument, but as relations between the EU and Ukraine continue to develop and evolve, new and innovative approaches, as well as additional R&D funds may play increasingly important role in the future. These additional channels are to be specified and detailed in the coming years, establishing further maturing of the EU-SSTC cooperation in the near future.

***

The authors alone are responsible for the facts and opinions expressed in the article. The views contained herein do not necessarily reflect the official position of the European Commission.

References

1. Council Directive 2014/87/Euratom of 8 July 2014 amending Directive 2009/71/Euratom establishing a Community framework for the nuclear safety of nuclear installations.
2. http://ec.europa.eu/europeaid/home_en, accessed March 2017.
3. Council regulation (EURATOM) No 300/2007 of 19 February 2007 establishing an Instrument for Nuclear Safety Cooperation.
4. Council regulation (EURATOM) No 237/2014 of 13 December 2013 establishing an Instrument for Nuclear Safety Cooperation.
5. Regulation (EU) No 236/2014 of the European Parliament and of the Council of 11 March 2014 laying down common rules and procedures for the implementation of the Union's instruments for financing external action.
6. Evaluation of the INSC, Draft Evaluation Report, Volume 1: Main Report; Volume 2: Annexes, January 2017.
7. EU assistance to Ukraine, Special report No 32, European Court of Auditors, 2016.
8. https://nuclear.jrc.ec.europa.eu/tipins/europeaid-safety-training, accessed March 2017.
9. Stockmann Y. et al. European Union International Cooperation to Improve Regulatory Effectiveness in Nuclear Safety, Proc. of the International Conference on Effective Nuclear Regulatory Systems: Sustaining Improvements Globally, IAEA, Vienna, Austria, 11—15 April 2016.
10. http://www.ensreg.eu/EU-Stress-Tests/, accessed March 2017.
11. Dybach O. et al. Knowledge transfer and exchange between EU and Ukrainian experts in the area of severe accident analysis and management under the INSC project UK/TS/43, Proc. of the EUROSAFE Forum 2015 conference, Brussels, Belgium, 2—3 November 2015.
12. Journeau C. Experimental Data Set from VULCANO VE-U7 for Spreading Code Assessment, Technical Report, CEA, Cadarache, France, 2002.
13. Annual Report on Nuclear and Radiation Safety in Ukraine 2012 (http://www.snrc.gov.ua/nuclear/en/), accessed March 2017.

Received 25.04.2017.