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1 Executive summary

The EMPIR DigitalStandard project has successfully produced a new International Standard, IEC 63047, eight months ahead of schedule. To complement this, the development of software tools and algorithms for simulating data sets for compliance verification is nearing completion.

Successful interoperability of radiation detection and measurement systems will enable improved technology for safeguards and nuclear safety. European and/or international standards devised for a digitised data format will enable a combination of measurements to be compared within, and between, remote data analysis centres, which will be a significant advance in the capability of emergency response.

A New Work Item Proposal (NWIP) for an international standard data format related to digital instrumentation used for the detection and measurement of radiation was developed by the consortium partners, submitted to and subsequently approved by IEC/TC 45/WG 9. This approval represented the first major milestone (the decisions made at the IEC TC/45 WG9 "Detectors and systems" meeting, 12 March 2016) and occurred in February 2016. IEC/TC 45 appointed the 14SIP07 consortium member from JRC-Geel (Jan Paepen) as the IEC Project Leader for development of this standard, relying on the input of experts from IEC/TC 45/WG 9 "Detectors and Systems".

The work of 14SIP07 runs subsequently in parallel with the JRC work package 3883 "DiSNU: Digital Standards for Nuclear Security".

A workshop on the development of new IEC 63047 standard was held at JRC-Geel, from 15 to 17 June 2016, with the aim to discuss the draft v1.9 with the stakeholders, in preparation of the first Committee Draft (1CD), which was ultimately submitted to the IEC in October 2016.

Following this workshop, a first Committee Draft was prepared by JRC and NPL (after review by STUK, CEA and ENEA) for circulation to the IEC/TC 45 member countries on 28 October 2016 (IEC Document 45/817/CD). The 1CD was approved by IEC/TC 45 in January 2017. Comments on 1CD were received and utilised to prepare the 2nd Committee Draft (2CD).

An interim meeting of the IEC/TC 45/WG 9 was held in Brussels in April 2017, where the comments on the 2CD were analysed and acted upon.

Work has continued on the production of the Committee Draft for Vote (CDV). The CDV was presented at the main IEC/TC 45 meeting in Shanghai in October 2017. Consortium members NPL, STUK, CEA and ENEA reviewed the drafts of the standard before it was submitted to the IEC/TC 45 secretary by JRC.

The standard relies on the well-known, widely-used and internationally standardised ASN.1 notation. A tailor-made training in ASN.1 for consortium members was provided during the workshop by two ASN.1 experts from the company OSS Nokalva. The experts also provided comments on the ASN.1 implementation (v1.9).

The open-source software ASN1C was used to develop encoding and decoding software, supporting the IEC 63047 CDV draft. A report has been prepared that provides guidance on how to obtain "ASN1C" and how to use the codec so that users may easily develop their own.

Since all votes on the CDV were positive, and only minor comments/changes to the standard format were received, the IEC decided to skip the approval stage of the standard and proceed immediately to publication. At the time of preparing this report, the status of the standard is "BPUB" (being published), ahead of the scheduled publication date of March 2019.

To stimulate the use of the standard, JRC is in the process of setting up a community of practice, supported by a collaborative web space where users can interact and find training material, the codec software and demonstration data files. The JRC will soon launch a survey for all stakeholders who were involved in the development of IEC 63047, with the aim of determining the objective and expectations of users.

Finalisation of the conversion of a suite of simulated test data sets generated within 14SIP07 is ongoing, ensuring compliance with the final published IEC 63047 standard format, and will be made available via the above mentioned JRC web-space. These data sets incorporate simulated data from single and two-detector systems, enabling verification of coincidence counting data processing algorithms used in the primary standardisation of radionuclides.

2 Need for the project

The use of digital acquisition systems is rapidly increasing, however there are presently no suitable standards related to list-mode data formats. This project will work with IEC/TC45 on producing an appropriate IEC standard and provide CENELEC with information on the best way to produce a European (and International) standard on list-mode data acquisition for radioactivity measurement digital electronics.

One major outcome of EMRP JRP ENG08 MetroFission was the development of digital electronics for standardisation of radionuclides and subsequent involvement with standardisation committees (i.e. IEC) and other European projects and working groups. It became clear that even though the use of digital acquisition systems is rapidly increasing, there are presently no suitable standards related to list-mode data formats. Currently, each manufacturer provides its own data format and this ultimately hinders efficient interoperability and comparison of measurements. During EMRP JRP ENG08 MetroFission, a proposal of an initial draft list-mode data format was presented to the IEC technical committee 45 working group 9 (IEC/TC45/WG9; in 2013). This proposal was well received by the working group, which stated that they would support a new work item proposal (NP) on the production of an appropriate IEC standard.

The need for standardisation of list-mode data comes from end-user requirements to be able to compare measurements of radioactivity between users, across borders and disciplines and to enable greater confidence, transparency and harmonisation of measurements of radioactivity in Europe; and internationally. These measurements ensure the safe and efficient operation of nuclear power plants, underpin nuclear medicine and provide nuclear security. It has been recognised, for example, by CEN/TC 391 'Societal and citizen security', which executes the European Commission Mandate M/487, that European security standards should be established. In their final Phase 2 report addressed to the Commission [1], CEN/TC 391 assigned a high priority to the standardisation of list-mode data formats, including the development of standards for list-mode data acquisition for digital electronics. The European Commission's "Action Plan for an innovative and competitive Security Industry" (Section 4.1.1. Action 1) [2] has also identified that one of the main issues facing EU security is its highly fragmented nature, exhibiting a lack of Europe-wide standardisation and harmonised certification procedures. Therefore, this project will contribute to a Europe-wide standardisation of measurements with nuclear instrumentation.

Further to this, a new European Thematic Group on the Protection of Critical Infrastructure from Radiological and Nuclear Threats (ERNCIP RN TG) was instigated a few years ago to identify and work on the currently unaddressed Critical Infrastructure Protection (CIP) issues, such as the certification of radiation detectors, standardisation of deployment protocols and response procedures. The ERNCIP RN TG has identified that the accurate assay of radioactivity via the use of list-mode data files is closely related to the opportunity of utilising remote support and operation in radiation detection.

One task of the ERNCIP RN TG is to provide the European standardisation organisations with guidance on the best way to produce a standard on list-mode data acquisition based on digital electronics for radioactivity assay. Independently, CEN/TC 391 has identified that the task to standardise the data formats for list-mode data acquisition has the highest priority.

3 Objectives

The project objectives were to stimulate the development and use of accurate and effective digital instrumentation in the nuclear industry by:

- 1) The development of an accepted Committee Draft IEC standard for a digital list-mode data format to be used in nuclear instrumentation.
- 2) Development of web-based software tools for users of the standard (i.e. equipment manufacturers and developers of software for data analysis) to enable compliance verification, generation of test data sets, basic analysis and conversion to common spectral formats.

4 Results

In relation to Objective 1: Update with what has been done in terms of developing the standard.

Throughout the development of this standard, the consortium has been liaising heavily with international organisations, relevant standardisation bodies, interested parties and digitiser manufacturers, to ensure the standard is fit for purpose, and to lower the threshold in using the published standard at a later stage.

The JRC published calls for the expression of interest in the Official Journal of the EU (Ref. 2015/S 222-403785 and 2016/S 042-068536), inviting manufacturers of nuclear digital data acquisition devices. All manufacturers who expressed their interest in participating in the development of the standard IEC 63047 following publication of a Call for Expressions of Interest in the Supplement to the Official Journal of the European Union 2015/S 222-403785 and 2016/S 042-068536 were invited to the June 2016 workshop. In addition, the IEC/TC 45/WG 9 members and IEC appointed experts for the project IEC 63047 were invited.

The JRC presented the work of this consortium at the IAEA „Technical Meeting on Radiation Detection Instruments for Nuclear Security: Current Status, Future Needs and Improvements“. IAEA, Vienna, Austria, 4-8 April 2016.

The JRC presented the work of this consortium to the CENELEC/TC 45B Meeting, AFNOR, Saint-Denis, Paris, France, 13-14 April 2016.

A workshop on the development of IEC 63047 was held at the JRC, from 15 to 17 June 2016, with the aim of discussing the draft (at that time v1.9) with the stakeholders, in preparation of the first Committee Draft (1CD), which was ultimately submitted to the IEC in October 2016. The minutes of this workshop were shared with all manufacturers on the list established after publication of the Call for Expression of Interest and who have signed the data exchange agreement, the EMPIR 14SIP07 DigitalStandard consortium partners, the IEC/TC 45/WG 9 members and the IEC 63047 appointed experts.

The JRC has produced the Technical Report EUR 27811 EN “Acceptance of the proposal for a new international standard for list-mode data used in nuclear instrumentation”. EMPIR 14SIP07 "DigitalStandard", Deliverable D1, JRC work package 3883 "DiSNU", Deliverable 1.

The BIPM CCRI(II) members have been kept informed on the progress of this standard throughout its development. NPL presented the work of this consortium at the meeting of the CCRI(II) Key Comparisons Working Group, at the BIPM in Sevres, Paris, France, June 2017, as well as at two previous KCWG meetings in 2016. NPL presented the work of this consortium at the main CCRI(II) meeting in June 2017.

NPL attended the European Land Robot Trials (ELROB) in Austria, June 2016, and liaised with participants taking part in the radioactivity reconnaissance session, and promoted the impending IEC 63047 standard.

NPL presented the work of this consortium and status of the development of IEC 63047 at three Working Group meetings of the International Committee for Radionuclide Metrology (Liquid Scintillation Counting WG, Life Sciences WG and Radionuclide Metrology Techniques WG) in December 2016.

The JRC in collaboration with the Global Initiative to Combat Nuclear Terrorism (GICNT) held a two and a half day workshop “Magic Maggiore” in March 2017, to bring together technical, scientific, and policy experts with specific expertise in the area of technical reachback and those who rely on technical reachback support as an aspect of their job functions. The JRC presented the work of the 14SIP07 consortium and progress on the development of the IEC 63047 standard, in a presentation entitled “A standard for list-mode data: advantages for nuclear security”.

An interim meeting of the IEC/TC 45/WG 9 was held in Brussels in April 2017, where the comments on the second Committee Draft (2CD) were analysed and acted upon. Work has continued on the production of the Committee Draft for Vote (CDV).

The JRC presented on the development of the IEC 63047 standard at the 23rd Border Monitoring Working Group Meeting, Vienna, May 10-12, 2017. The BMWG was created in 2005 by three major donor organizations: the International Atomic Energy Agency (IAEA), the European Commission represented by the Joint Research Centre (JRC) and the United States represented by the Department of Energy Nuclear Smuggling Detection and Deterrence (NSDD).

NPL presented the work of this consortium and status of the development of IEC 63047 at the main ICRM Conference in Buenos Aires (15-19 May, 2017).

The consortium coordinator and the JRC are in liaison with the Preparedness project of the EMPIR call 2016/Environment, regarding partners implementing the standard data format in the mobile detection of radioactivity after a nuclear or radiological incident. A presentation was made at the Preparedness kick-off meeting in September 2017. Here, IEC 63047 is being promoted as a common data format standard for rotary-wing unmanned aerial vehicles. The 14SIP07 consortium will provide codecs and guidance on the use of the IEC 63047 standard. The Preparedness project is about:

- Identify nuclides and measure ambient dose equivalent rate from contaminated areas.
- Develop transportable air-sampling systems for rapid deployment during emergency.
- Assess the feasibility of using dose-rate data from open-access non-governmental networks.
- Establish procedures to measure ambient dose equivalent rates using passive dosimetry in order to harmonise passive dosimetry for environmental radiation monitoring across Europe.

The JRC presented the status of the development of the standard at the CENELEC/TC 45B Meeting, held at AFNOR, Saint-Denis, Paris, on 31 November 2017.

THE 14SIP07 consortium is also liaising with the JRC Geospatial Risk and Resilience Assessment Platform (GRRASP). <https://ec.europa.eu/jrc/en/grrasp>. This is a World Wide Web oriented architecture bringing together geospatial technologies and computational tools towards the objective of supporting the analysis of critical infrastructures. JRC.E.2 is developing an interface to import IEC 63047 data into GRRASP. This includes non-nuclear technologies.

NPL presented the work of this consortium at the “Advanced Nuclear Science and Technology Techniques” conference at iThemba Labs, Capetown in March 2018. This conference was organised by the Science & Technology Facilities Council (STFC), UK.

The CDV was translated to French and circulated for voting and commenting by the IEC on 19/01/2018 (IEC document 45/842/CDV).

On 27/04/2018, the IEC published the results on the CDV vote (IEC document 45/848/RVC). 12 National Committees with voting rights (P-members) expressed their vote. All of them voted for acceptance. Only a few national comments were received. In that case, the ISO/IEC Directives foresaw skipping the approval stage. The TC 45 Chair (Gerhard ROOS), in cooperation with the Project Leader (Jan PAEPEN) and with the TC 45 Secretary (Sergei SHUMOV) and after consultation with the office of the CEO (Charles JACQUEMART), took the decision to proceed directly to the publication of standard. At the time of preparing this report, the status of the standard is “BPUB” (being published), ahead of the scheduled publication date of March 2019.

In relation to Objective 2: Update on software development.

One of the project deliverables was a set of web-based software tools for users of the standard, in particular the equipment manufacturers and developers of software for data analysis to enable compliance verification, generation of test data sets, basic analysis and conversion to common spectral formats, providing greater confidence in, and harmonisation of, radioactivity measurements.

By engaging the relevant equipment manufacturers and software developers early on, and their integration into the project, the project partners have created opportunities for European manufacturers to be able to implement the standard *de-facto* by the end of the project, which will lead to a competitive advantage on a global scale when the international standard is published (expected to be summer 2018). These industry stakeholders will be the key promoters and users of the developed standard software routines, and the dissemination route will be chiefly through them.

The main impact will be in providing increased confidence in measured data in particular where measurements are to be compared between remote data analysis centres, and between batches of data, providing a significant advance in the capability of emergency responses, improving technology for safeguards and nuclear safety.

An interim meeting of all 14SIP07 consortium members was held on 17 June 2016. The basic elements related to the simulation of data sets were discussed and agreed by 14SIP07 consortium members. It was agreed that conversion of spectral data (generated from the IEC 63047 standard) to common spectral formats needs to be considered, including Canberra, Ortec, IAEA etc.

The IEC 63047 standard relies heavily on the use of the Abstract Syntax Notation One (ASN.1).

A dynamic link library (DLL) for encoding and decoding the draft 2CD format has been prepared and communicated to the stakeholders (equipment manufacturers). Three of the five stakeholders have successfully implemented the DLL. One manufacturer supplied a fully compliant IEC 63047 2CD data file, one day after receiving the DLL and the 2CD draft. This fact provides proof that it is not complicated to implement the standard, providing that the right tools are available.

The DLL was developed using commercially available software, purchased by JRC and made available to the consortium as an in-kind contribution. However, since the licence of this commercial software is intended for the development phase of the standard only and expires at the publication of the standard, an alternative solution in the form of open source software "ASN1C" is now being utilised. The use of open source software also lowers the threshold of implementing the standard to a minimum (compared to commercial software).

Members of the consortium have successfully managed to utilise the open source software "ASN1C" for developing a codec for IEC 63047 (the proposed CDV version). The report JRC109013 "Practical guide on using open-source software for encoding and decoding IEC 63047 CDV data" has been prepared to provide guidance on how to obtain "ASN1C" and how users may easily write their own codec.

Demonstration code has been developed using 'ASN1C', and tested the procedure on various Linux operating systems at present. Plans are in place to test compiling the code to run directly in Microsoft Windows.

This includes examples to guide equipment manufacturers (who write IEC 63047 data) and developers of software for data analysis (who read IEC 63047 formatted data). The provided guidance lowers the threshold of using IEC 63047 to a minimum, and enables stakeholders to implement the current draft standard and to provide comments on the standard, in due time before the end of the CDV commenting period (May 2018).

The JRC is in the process of establishing a community of practice for IEC 63047 users. Stakeholders can share their experience, post questions, download open-source codec software, and access training material in the form of presentations, videos and documents on how to use the standard and the software. A repository of downloadable binary data files will be added, so that users can verify if their software is able to read the data format.

5 Impact

This project has effectively led to a new International Standard for digital list-mode data format. Uptake of the use standard has been discussed with the International Committee for Radionuclide Metrology (ICRM) (via the primary supporter) and the CIPM Consultative Committee for Ionising Radiation, and all bodies agreed that the IEC 63047 data format will form the basis for enabling improved international harmonisation of nuclear instrumentation and traceability to the derived SI unit of the becquerel for a multitude of radionuclides. It will also provide greater confidence in, and harmonisation of, radioactivity measurements by end-users in a variety of fields, including nuclear physics, environmental monitoring, nuclear energy, decommissioning, radiation protection, nuclear security and safeguards.

Dissemination and engagement activities

The information relating to the development of the International Standard has been shared within the nuclear industry sector through various channels. This included presentations at international conferences and to standardisation organisations, a dedicated IEC 63047 Workshop, and two written communications in the form of a technical paper and a newsletter. Collaboration agreements with five equipment manufacturers and one university were set up, to allow maximum involvement of the primary stakeholders. A total of 13 conference presentations and posters have been presented, predominantly to the scientific community (higher education, public research organisations). JRC Technical Reports have been published documenting the acceptance of the New Work Item Proposal (JRC100968) and the submission of the various drafts (2CD JRC107306, CDV JRC109443).

The IEC 63047 workshop was attended by academic and industrial stakeholders. It pooled together experts in radioactivity measurements to develop the standard. Furthermore, it facilitated engagement with the equipment manufacturers, enabling beneficiaries of the work developed in this project to disseminate the standards work and software requirements.

The standard at its advantages in nuclear security was also presented at the Technical Reachback Workshop, co-organised by the JRC and the Global Initiative to Combat Nuclear Terrorism (GICNT) in March 2017, and at a Technical Meeting on Radiation Detection Instrumentation for Nuclear Security, held at the IAEA in April 2016.

Impact on relevant standards

The EMPIR DigitalStandard project successfully produced a new International Standard, IEC 63047. The standard complements and does not conflicts with IEC 62755 (identical to ANSI N42.42), a standard format for nuclear security equipment. IEC 63047 data may include IEC 62755 data and vice-versa. At the CENELEC/TC 45B meetings, status updates were provided with the aim to facilitate the endorsement as European Standard, should there be a need.

Impact on industrial and other user communities

Through calls for expression of interests, equipment manufacturers were invited to participate from an early stage in the development process. Five manufacturers and one university actively contributed to the development of the standard. Three manufacturers successfully implemented the IEC 63047 2CD draft format in their data acquisition software with the aid of a dynamic link library (DLL). One of them supplied a fully compliant IEC 63047 2CD data file one day after receiving the DLL and the 2CD draft (JRC103417). This demonstrates that it is not complicated to implement the standard, providing that the right tools are available. The participating manufacturers have a competitive advantage on a global scale when the International Standard is published.

Successful interoperability of radiation detection and measurement systems will enable improved technology for safeguards and nuclear safety. European and/or international standards devised for a digitised data format will enable a combination of measurements to be compared within, and between, remote data analysis centres, which will be a significant advance in the capability of emergency response.

Impact on the metrological and scientific communities

The project developed a new International Standard for digital list-mode data format. This has brought together 40 NMIs, working towards providing greater confidence in, and harmonisation of, radioactivity measurements by end-users in a variety of fields, including nuclear physics, environmental monitoring, nuclear energy, decommissioning, radiation protection, nuclear security and safeguards. By linking the work to the requirements of CEN/TC 391, and the work of the ERNCIP Thematic Group on Radiological and Nuclear Threats to Critical Infrastructure, the new standard is helping to meet the high-priority requirements for societal and citizen security. The development of standard has been repeatedly reported to the International Committee for Ionising Radiation and the CIPM Consultative Committee for Ionising Radiation, Section II.

6 List of publications

PAEPEN J., KEIGHTLEY J., BOBIN C., CAPOGNI M., ILANDER T., Acceptance of the proposal for a new international standard for list-mode data used in nuclear instrumentation - EMPIR 14SIP07 "DigitalStandard", Deliverable D1; JRC work package 3883 "DiSNU", Deliverable 1, Report EUR 27811, 2016

7 Website address and contact details

https://www.euramet.org/research-innovation/search-research-projects/details/?eurametCtcp_project_show%5Bproject%5D=1338&eurametCtcp_project%5Bback%5D=546&cHash=42677b3961af0a7a24748b769e8d5c20

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