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Minutes of the 32nd Meeting of the International Nuclear Data Committee

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Chairman's Summary

This 32st meeting of the IAEA International Nuclear Data Committee (INDC) was held in Vienna from 18 to 21 June 2018. According to the INDC terms of reference the principal functions of the INDC is to "advise the IAEA on its programmatic activities in the field of nuclear data". In particular INDC is supposed to "provide feedback on current activities" of the Nuclear Data Section and to "make specific recommendations regarding future programmatic activities." The following reports of the two Working Groups give a detailed account of the INDC deliberations regarding this mandate. Below I would like to summarize my impressions and main take-aways from the meeting that is fully documented in this extended report.

Regarding current NDS activities the INDC members were very pleased to commend the excellent services provided to the member countries. These services include data dissemination (mostly through Web), data development (through Coordinated Research Projects and Data Development Projects), and training (through various workshops). The NDS continues to effectively operate NRDC and NSDD - the two nuclear data networks that coordinate world-wide effort in nuclear reaction compilation and in nuclear structure evaluation, respectively. In both cases IAEA plays a global leading role. Among many accolades expressed by the INDC members I would like to single out the extraordinary contribution of the Section to the international CIELO project followed up by establishment of the third network (International Nuclear Data Evaluation Network) dedicated to reaction data evaluation. It is important to notice that the latter has been achieved without upsetting a delicate balance of capabilities and responsibilities between NDS and NEA Data Bank. I would also like to stress that NDS maintains its leadership as world prime developer of the nuclear data for medical applications. It also continues, along with NNDC and NEA, to be one of the three comprehensive nuclear data repositories ensuring preservation of the nuclear data libraries and know-how.

The second function of the INDC is to make recommendations regarding future activities. Traditionally, INDC endorses most of the CRPs and DDPs proposed by the Section and this meeting was not an exception to this practice. All put forward proposals were well focused and justified, relevant to the stakeholders, and feasible within available resources. At no surprise INDC strongly upheld continuous development of reaction modeling, training of new evaluators, and maintenance of physics and processing codes. As a novelty there has been a clear message that the Section should catch up with the evolving technology. In particular, the Web services, admittedly powerful and comprehensive, would benefit from redesign. They should be "accessible, easy to navigate, and suitable for a broader community." In this respect, INDC commended recent Isotope Browser App designed and deployed by the Section. The INDC also suggested implementation of the version-control system for all the NDS products, provided the underlying software, such as Github, is supported by IAEA's IT. With the new GNDS format poised to become a standard with the next release of major reaction data libraries the Section should prepare for the modernization of the entire nuclear data infrastructure including nuclear structure and decay data and EXFOR library. These are definitely very challenging tasks and the Section might be in need of seeking additional resources to retain its current position among the three leading nuclear data centers in the world. In this context, maintaining a close collaboration with the NEA Data Bank, NNDC and national/regional projects will be crucial to effectively use resources, avoid duplications, and reduce cost.
Finally, I would like to thank management and staff of the NDS for preparing very detailed information on Section activities over the last two years and on the future plans. As the previous member of the NDS I'm perfectly aware how much work is behind these reports and presentations. This is the time which could be spent on activities that would directly benefit NDS services of importance to the member countries. To economize on this effort, without

hindering INDC capability to fulfill its mandate, I propose to abandon the preparation of the NDS report to INDC and to retain only Web-available presentations that are totally sufficient for the purpose.
I would also like to thank the members of the INDC for their diligent work during the meeting, and to express my special gratitude to Mr G.F. Stein for accepting again and again(!) the arduous task of taking minutes and preparing this report.

M. Herman
INDC Chair

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Working Group 1: Nuclear Data Development

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1. Coordinated Research Projects (CRPs)

1.1 Development of a reference database for Particle-Induced Gamma-ray Emission spectroscopy (PIGE)

The Working Group acknowledges the efforts made towards maintaining this database and allowing a proper dissemination of these data.

1.2 Nuclear Data for charged-particle monitor reactions and medical isotope production

The Working Group really appreciates the initiative and product that resulted from this CRP and would be in favour to maintain this activity within the NDS. The proposed Technical Meeting (TM) on further nuclear data development for medical use is strongly supported. The TM should deal with activation reactions used for medical isotope production (in particular emerging diagnostic and therapeutic isotopes) as well as cross sections of activation products relevant to proton therapy and the related nuclear decay data. In addition, those evaluations that do not yet have uncertainties should be updated.

1.3 Testing and improving the International Reactor Dosimetry and Fusion File (IRDFF)

The Working Group appreciates that IRDFF 2.0 is scheduled for release towards the end of the year. The continuation of this activity is recommended, with a potential higher energy domain extension (up to 200 MeV) as well as work on renormalization within the EXFOR database. This latter activity also has a broader importance and concerns all EXFOR data.

1.4 Primary radiation damage cross sections

Previous recommendations are of major importance for the INDC and members are waiting for the evaluated cross sections. The Working Group suggests that additional output of this activity

should include a recommendation on the most appropriate radiation damage model(s) to be used in dpa calculations, e.g. advanced "arc-dpa" versus standard "NRT dpa" and that the NDS should make available the displacement damage cross-section data, as far as produced for specific materials within the CRP.

1.5 Reference database for beta-delayed neutron emission

The Working Group considers this CRP to be very important and the final delivery of the new database is eagerly anticipated. The validation of the new 6-group and 8-group data against nuclear reactor integral measurements is proposed. In the final report, which is in preparation, recent US/LANL results (published as a new Phys. Rev. C paper on beta-delayed neutron and gamma calculations for astrophysics applications as well as a complete table of the results accepted for publication in At. Data Nucl. Data Tables) could be considered for inclusion.

Antineutrino spectrum evaluations are still needed (for safeguard applications) and thus the Working Group suggests the continuation of this activity, which may be related to the Total Absorption Gamma-ray Spectroscopy (TAGS) DDP and future Fission Yield (FY) CRP.

Indeed, the FY CRP will continue the general effort related to fission observables and a key deliverable will be evaluations for major isotopes. The Working Group strongly supports the objective of this CRP and believes it will be very helpful for various international nuclear data libraries (ENDF, JEFF, JENDL, CENDL, BROND).

1.6 Updating the photonuclear data library and generating a reference database for photon strength functions

The Working Group appreciates that model developments aiming for an enhanced predictive power were proposed in this CRP. A proper connection between averaged resonance range and continuum can be foreseen with a consistent set of average resonance properties and related strength functions. The delivery of an experimentally complete strength-function database is recognized by the Working Group as an important achievement. For the first time in 15 years, an update of the photonuclear data library is underway.

1.7 RIPL for fission cross-section calculations

The Working Group considers this activity as very important for understanding the calculation of fission barriers. Obtaining a complete set of fission parameters (fission barrier penetrabilities, class II/III states, barrier heights, level densities, etc.) consistent with the corresponding models (independent barriers, optical model for fission, etc.) in the RIPL database could permit a proper reproducibility of fission cross-section calculations using different nuclear reaction codes.

2. Data Development Projects (DDPs)

1. General statement on organization

The Working Group would like to comment on the way the DDPs are organized. Three major pillars of activities can be discerned:

- Charged particles (IBANDL, R-Matrix, etc.)
- Fission data (TAGS, Beta decay, future Fission Yield CRP)
- Evaluation (CIELO, INDEN, TSL, Standards, IRDFF, etc.)

In addition, cross cutting activities are seen (as common to the previous pillars) such as code

and model development (for processing and nuclear reaction modelling) and covariances methodology. Furthermore, nuclear structure and decay data activities are seen as very important for many of the existing DDP.

It is recommended to use a new way of presenting the activities according to the three major pillars discussed above, allowing to show a broader and coherent picture of NDS DDPs.

2. International neutron cross section standards file and evaluation techniques

This permanent activity is of great interest and recent discussions on uncertainty estimations (taking into account systematic uncertainties) are particularly noticed. Several INDC members expressed an interest to monitor the potential needs for a standards extension to other nuclear data or isotopes. It is hoped that young physicists could in future be involved in this area of activity.

3. CIELO and INDEN

The Working Group acknowledges the unique contributions of the NDS to CIELO, which include support to the coordination and technical work on the evaluation of specific cross-section data, such as ^{238}U, ^{235}U and ^{56}Fe.

The INDEN initiative, as a follow-up of the CIELO project, is strongly supported by the Working Group. It is recommended to focus on evaluation methodologies and nuclear reaction model issues as first important objectives. This should benefit all major nuclear data libraries. Evaluated files are important for validation (benchmarking) but should be done independently of existing libraries or fine tuning activities.

Besides the new high-priority list, the Working Group recommends a continued effort on the previous CIELO initial list (U, Pu, H, O, Fe).

The Working Group suggests that the organization of the meetings should be more public by placing proper advertisements. In addition, it is suggested to interconnect with NEA/WPEC future propositions (e.g. WPEC follow-ups or new subgroups). It is also recommended to define a steering committee with a precise role, which could include implementation of measures to maintain momentum, proposing items for the new high-priority list and elaborating on the objectives of this long-term project.

4. Ion Beam Analysis Nuclear Data Library (IBANDL)

The Working Group acknowledges the efforts made towards maintaining the IBANDL library and, in addition, appreciates the activity related to R-Matrix calculations for charged particles that may be able to add resonance parameters to this library. This last outcome could allow a better description of all cross-section observables, such as angular distributions and inverse channels.

5. Development of evaluation methodology and nuclear reaction modelling systems

The Working Group advises the NDS to continuously support the development of nuclear reaction modelling codes (e.g. EMPIRE and TALYS) aimed at nuclear data evaluation. Resonance range analysis could be an interesting part of modelling codes and should be supported by the NDS for the following reasons:

- In the resonance region, major advances are coming from experimentally proper descriptions. It concerns input files for SAMMY, REFIT, CONRAD, where all proper information is compiled, including details on normalization, resolution functions, etc.
- A proper connection between the resolved-resonance region (RRR) and continuum is mandatory and necessitates having R-matrix codes and High Energy codes in a shared computer framework.
- Importance of charged-particle R-matrix codes.

Several members expressed concern about the delivery of an open source R-matrix code.

6. R-matrix codes for charged-particle induced reactions in the resolved-resonance region

The Working Group supports this activity as charged-particle reactions for light elements in the RRR are of importance for ion-beam analysis (IBA), safeguards, astrophysics, medical isotope production on light elements, etc. In addition, one important aspect of this activity for light elements is related to neutron-induced cross sections for which one can use other incoming channel experiments (reverse channels). Final evaluations proposed by this DDP: resonance parameters (amplitudes + hypothesis), cross sections, covariances, etc.

7. Verification of data processing codes for generating ACE-formatted files (GAFF)

The Working Group concurs that a public processing code is still of interest to avoid a one-way processing calculation scheme with NJOY. This activity is therefore strongly supported. In addition, it is appreciated that the new GND format is taken into account by the GRUCON code to prepare the future stage of nuclear data library formatting and processing.

8. Improvement of analysis codes for nuclear structure and decay data evaluations

The Working Group strongly supports all activities related to nuclear structure and decay data evaluations. Codes are part of this and the aim of producing new versions of them (written in modern programming languages) is important.

9. Stopping power database

The Working Group acknowledges the efforts made towards maintaining this database. Stopping powers for fission fragments (FF) are important for FF transport modeling in FF detectors and fuel components. Their evaluation is different than for stable isotopes of the same charge and energy because of de-excitation during the stopping process, which can change the effective charge for FF ions. It is recommended that the NDS supports activities to obtain new experimental data as well as theoretical evaluations for FF stopping powers.

10. Total Absorption Gamma-ray Spectroscopy (TAGS) decay data

The Working Group supports this activity as it allows a proper compilation of recent TAGS measurements and also because it is part of the general fission observables evaluation activities (such as beta delay, fission yields, decay heat, etc.)

11. Nuclear data libraries for advanced systems/fusion devices (FENDL)

The development and maintenance of the FENDL-3 data library by the NDS is highly appreciated by the INDC and well recognized by the fusion community: FENDL serves as reference library for the ITER project and in other fusion and accelerator-related applications like IFMIF/DONES (EU) and A-FNS (Japan). In addition to the regular revisions/corrections

and updates applied to the neutron transport data library, it is recommended to further improve the libraries on neutron, proton and deuteron-induced activation reaction data. In particular, a dedicated effort on the further development and improvement of the deuteron data library (both transport and activation) is needed. As an example, a new set of experimental data from F. Tárkányi et al. (Debrecen group) could be used to improve the deuteron data evaluations. It is recommended to implement a quality assurance (QA) procedure to ensure the preservation of the file performance during revisions or updates. Ideally, this procedure should include a suitable benchmark suite calculation before the files are released. A suitable (and practical) scheme should be discussed at the forthcoming FENDL CM (in October 2018). In addition, the FENDL-3 web page should be separated into a dedicated work-in-progress website and a recommended library website.

12. Thermal scattering law (TSL) data

The Working Group endorses ongoing TSL activities as being of major importance for reactors as well as criticality issues, e.g. fuel transportation. It is recommended that the NDS continues supporting non-OECD contributions to WPEC SG-42 and its follow up.

The Working Group suggests that additional activities linked to the study of phonon spectra in materials of interest (moderators, metallic fuels, compounds, etc.) should be considered as well as related covariance estimations. In addition to experimental considerations, it is recommended to organize meetings related to models (e.g. molecular dynamics, phonon spectrum calculations, ab-initio models, etc.) that are used to produce $S(\alpha,\beta)$ estimations.

13. Electron and photon interaction data library (EPICS)

The Working Group acknowledges the efforts made towards maintaining this database and the release of the latest version, EPICS2017, allowing a proper dissemination of these data.

14. Thin layer activation (TLA) database for wear measurements

The importance of this database for various industrial applications is acknowledged.

3. New nuclear data needs

3.1. Data for Spent Nuclear Fuel

As several countries are starting the implementation of the final disposal of spent nuclear fuel (SNF), the behaviour of SNF and cladding in the period from unloading up to final disposal is receiving increasing attention worldwide. Understanding the fundamental out-of-core behaviour of fuel and cladding is essential to ensure safe, reliable and economical use of storage and disposal systems.

Important aspects of this behaviour include the evolution of decay heat, the neutron and gamma-ray emission rate and spectra, and the reactivity. Predictions are based on theoretical calculations in combination with results from non-destructive analysis. Theoretical calculations start from the source terms, which are defined by the irradiation history of the SNF in combination with nuclear data.

Nuclear data of importance for the source terms are fission yields and capture cross sections for reactions leading to the production of actinides and minor actinides. Calculations of the evolution of the decay heat depend on decay data, mostly for fission products, which allow calculating the so-called “recoverable heat” (i.e. average energy for atomic electrons, beta and

gamma radiation). Neutron emission calculations depend not only on decay data but also on (α,xn) cross sections for light elements.

Evolving activities and research projects in this field will trigger new nuclear data needs and requests for recommended evaluated data.

Working Group 2: Data Dissemination, International Coordination and Training

Participants

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P. Dimitriou	IAEA		
N. Otsuka	IAEA		

1. International Coordination

1. The Working Group asserts that the coordinating role of the NDS on the NSDD and NRDC networks is of vital importance and that this function should be continued.

2. The creation of the new INDEN network is very valuable for continuous and coordinated development of evaluated nuclear reaction data. It is recommended that this should also be used as an opportunity to foster interaction between experienced and junior evaluators.

3. The Working Group is concerned about the level of expertise in nuclear data worldwide and recommends that the NDS maintains its own capabilities in all relevant areas of nuclear data.

2. Dissemination

2.1. The NDS should modernize and review its website, focusing on the priorities of users to accommodate different needs. It should be accessible, easy to navigate, suitable for a broader community, and future-proof (e.g. continuous integration). The best approach should be explored, including advice and input from experts and professionals in website design. New interaction portals (e.g. for data retrieval) should also be explored.

2.2. The Working Group recommends that the NDS explores the implementation of a version control system for all its products.

2.3. The NDS should proceed with the release of the decay-data portal, including the ability to access and interrogate the ENDF evaluated files on decay data.

2.4. The Working Group compliments the NDS on the continuous effort made on providing 24-hour access to the retrieval systems of all the libraries (EXFOR, ENSDF, ENDF) and support to the mirror websites.

2.5. The Working Group appreciates the progress made in opening the distribution of codes from the NEA data Bank to non-OECD members of IAEA – this should be completed as soon as possible.

2.6. The Working Group recommends the continued maintenance and development of the Isotope Browser App.

2.7. It is recommended to continue the support for and facilitation of ENDF-6 to GND conversion (most likely via FUDGE, which has been endorsed by WPEC).

2.8. There is appreciation for the effort made to release a freely available code to generate ACE and XSDIR files for Monte Carlo transport applications, both at the IAEA and other organizations.

2.9. The continued support for mirror sites hosted in India, China, and Russia is highly valued. It is recommended to include labelling on mirror sites to identify them as such (including latest update details).

2.10. The Working Group strongly supports the continuous development of the EXFOR-NSR PDF database in collaboration with other institutions and individual evaluators. In the light of new government policies on open access to publications (USA, UK, etc.), it is recommended that the IAEA also makes available documents such as laboratory reports and publications that fall under the new open-access policies, whenever possible.

2.11. The Working Group recommends that the NDS facilitates a proper way for referencing of their databases by the users.

2.12. The Working Group appreciates and recommends further promotion of the "MyENSDF", "MyEXFOR", and "MyENDF" online tools and acknowledges that they are highly valuable for evaluation and educational purposes. These tools should be accessible to the broader scientific community.

2.13. The Working Group recognizes the benefit of developing an image correction application for extracting and digitizing data from historical publications and recommends that this should be made available to the user community

2.14. Other databases, such as IBANDL, stopping power, nuclear moments, should be kept up-to-date and further developed as required.

3. NRDC and EXFOR

3.1. The Working Group acknowledges the admirable EXFOR compilation effort by the NRDC to ensure continuity of the full coverage of new publications. Currently, 13 centers contribute, most new entries being completed within a 6-month period since publication, which is very satisfactory.

3.2. Endorsement is given to the continued collection and compilation of primary experimental data, e.g. from TOF experiments, from both unpublished sources and electronic supplementary data.

3.3. The Working Group also notes the response by the NRDC to current needs, such as compilation of papers related to CIELO, CRPs (IRDFF, beta-delayed neutron emission, medical isotope production, photonuclear data library, fission yields, etc.) and DDPs (e.g. standards, IBANDL, thermal neutron scattering data, etc.)

3.4. It is recognized that the neutron data are relatively complete in EXFOR (compared to NSR) and that the future focus should be on improving completeness for the important proton data, and subsequently fission yields, photons, alphas, deuterons, etc.

3.5. The NDS is encouraged to continue the modernization and unification of the coding style (e.g. for reactions) in EXFOR.

3.6. The Working Group acknowledges the importance of maintaining the ongoing efforts to improve inclusion of uncertainties in experimental data, by requesting missing information from the experimentalists themselves.

3.7. The ongoing effort to extend computational formats of EXFOR (e.g. C5M and C4) to include statistical and systematic uncertainties, as well as correlation matrices, is very valuable. The Working Group recommends continuing the effort to include more correlation & covariance matrices and reviewing the dissemination format and options, and who the users are.

3.8. The Working Group recommends that the EXFOR-development community remains aware of new output data formats (e.g. GND) and potential future efforts towards a unified approach across the whole field (which EXFOR then may have to adopt).

3.9. The Working Group recognizes the importance of evaluators being able to upload their changes to the online EXFOR correction system. This should be promoted as best practice among evaluators.

3.10. The production of the automated EXFOR renormalization system in a C4-corrected file is recognized as very important. It is recommended to finalize and release this file as soon as possible.

3.11. The Working Group approves of the effort to replace non-searchable, obsolete PDF files with new searchable versions from publishers. In cases where these newer versions are not available, technological options (e.g. text recognition) should be explored.

4. NSDD

4.1. The Working Group acknowledges NDS support for the NSDD network in organizing meetings and providing support to mass-chain evaluators.

4.2. It is recommended to continue the coordination of the development, maintenance and distribution of codes, including maintaining local repositories and online tools, and providing technical support. A version control system should be explored to improve the synchronization and traceability of this effort.

4.3. The Working Group recommends continued effort to develop and maintain the ENSDF tree-graph editor (ENSDF +/-) and promote its use.

4.4. Having noticed the declining number of mass-chain evaluators worldwide, the Working Group recommends that the NDS continues the effort to raise awareness of the matter and to attract new evaluators to the field. This should be accomplished via administrative and financial support.

5. Training Activities

5.1. The NDS is strongly encouraged to continue providing training activities on nuclear data modelling, experimental methods, evaluation and processing.

5.2. The Working Group recommends that the NDS interacts with Euratom calls for nuclear data modelling, evaluation and measurements (NFRP-2018-4), and on research infrastructure growth (NFRP-2018-7).

5.3. It is recommended that the NDS continues the organization of EXFOR training workshops.

5.4. EXFOR training workshops organized by other institutes (e.g. those responsible for nuclear data activities in Asian countries), with funding and support from NDS, are strongly recommended. It is noted that countries interested in hosting workshops can access additional funding sources (technical cooperation), but only if a direct request is made – the NDS should promote this route.

5.5. The NDS should continue the training activities, at both introductory and advanced levels, on nuclear structure and decay data evaluation.

5.6. The Working Group acknowledges NDS support for the ICTP Training Workshops. Targeted workshops of two-week duration are strongly recommended.

5.7. It is recommended that the training workshops also include outreach sections covering areas such as multiscale materials modelling, data processing and training, decommissioning and health physics.

FULL REPORT

32st INDC MEETING

IAEA Headquarters, Vienna, 18 − 21 June 2018

1. OPENING

Mr Arjan Koning (Head, IAEA Nuclear Data Section) welcomed the INDC members, observers and advisors, and introduced Mr Aldo Malavasi (IAEA Deputy Director General, Department of Nuclear Sciences and Applications). Mr Aldo Malavasi suggested that all attendees first introduce themselves before he presents his opening statement. The statements of INDC members were therefore completed before Mr Aldo Malavasi continued with his address. Mr Aldo Malavasi mentioned his attendance of the International Conference on Nuclear Data for Science and Technology (ND2016) which was held in Bruges, Belgium in September 2016, and that while his own professional experience was outside the nuclear data field, he was learning. He was impressed with the scope of nuclear data (ND) activities and the significant reach of ND over many disciplines and interdisciplinary fields. Mr Aldo Malavasi observed that only one of the INDC members was a female and expressed his hope that gender representation would become more balanced in future years. He informed the meeting of the visit by a ministerial group that was scheduled for later in the year, which would be of critical importance to the Agency, and the importance to convey to them that ND was helping industry as well as the peaceful application of nuclear energy and technology in health, therapy and the environment. This was evidenced by the more than 30 000 hits per month by people looking for information on the NDS website. He asked the INDC for "something new" if it would improve the Agency function. Mr Aldo Malavasi thanked the INDC members, advisors, observers and NDS staff for their attendance and emphasized that he was looking forward to their conclusions and recommendations.

Arjan Koning thanked Mr Aldo Malavasi for his opening remarks and his support of the work of the NDS, their associates in Member States and the ND Networks. He then introduced Ms Meera Venkatesh (Director, IAEA Division of Physical and Chemical Sciences). Ms Venkatesh welcomed all attendees and expressed her wish for a productive meeting. She mentioned the role of the Agency in outreach to about 170 countries, but which needs direction given by experts. Nuclear data are key ingredients in many fields and missing data may provide the necessary stimulus for new initiatives. Ms Venkatesh concluded her statement by asking the ND community to please groom young female scientists and by thanking the NDS staff for organizing the 32nd INDC Meeting.

Arjan Koning thanked Ms Venkatesh and proceeded with some important announcements. He reminded the members to submit their working documents as Ms Rosalinda Rangel Alvarez still hadn't received them all. The member for Spain, Mr Enrique Gonzalez Romero, had an emergency and could not attend. Also absent was Mr Basanta Kumar Nayak, the new member for India. Three new members attended for the first time: Mr Osamu Iwamoto for Japan, Mr Mark Gilbert for the UK, and Mr Brett Carlson for Brazil. Three advisors attended: Mr Arnd Junghans from the Helmholtz Zentrum Dresden Rossendorf, Mr Toshihiko Kawano from the Los Alamos National Laboratory, and Mr Tokio Fukahori from the Japan Atomic Energy Agency. Two observers attended: Mr Franco Michel-Sendis of the OECD Nuclear Energy Agency and Mr Jan Heyse of the Joint Research Centre, JRC-Geel. The complete list of participants is given in Appendix 2. The "Terms of Reference" of the INDC are listed in Appendix 3. After the announcements, Arjan Koning handed the meeting over to the Chairman of the INDC, Mr M. Herman.

1.1 Chairman's Remarks

The agenda was adopted (see Appendix 1) and the composition of the two Working Groups deferred until later in the meeting. Next, the "actions arising" from the 31st INDC Meeting (see Appendix 4) were briefly discussed. As these points were to be discussed in more depth during the Section Review, the relevant comments from this discussion have been incorporated there. The minutes of the 31st INDC Meeting were subsequently discussed and adopted without changes. M. Herman then called for the presentation of the Section Review.

2. NUCLEAR DATA SECTION REVIEW

During the first day-and-a-half of the meeting, there were comprehensive presentations by NDS staff describing the nuclear data work undertaken from January 2016 to May 2018. Furthermore, the work of the Atomic and Molecular Data Unit within NDS was presented for information only. A progress report for the period January 2016 to December 2017 (INDC(NDS)-0756) had been distributed to INDC members prior to the meeting and copies of NDS presentations were made available on request. These documents are also available on the INDC pages of the NDS website. The main discussion points are highlighted below.

2.1 Staffing and Budget

Arjan Koning gave a presentation on NDS staffing and budget. Staff movements were considerable during this period, especially with regards to professional staff (P-staff). Valentina Semkova was rotated out in September 2017. Stanislav Simakov retired in January 2016. Bas Braams retired in November 2016. Hyun-Kyung Chun was rotated out in September 2017. Jean-Christophe Sublet started as Head of the Nuclear Data Services Unit (NDSU) in March 2017. Christian Hill started as Head of the Atomic & Molecular Data Unit (AMDU) in October 2017. Kalle Heinola joined AMDU in May 2018. Shin Okumura will join the NDSU on 1 September 2018. With regards to support staff (G-staff), Kira Nathani rejoined the Nuclear Data Development Unit (NDDU) after an assignment in the IAEA Publications Section from October 2016 to May 2017. Several interns were appointed: Masahiro Wakukawa, Moemi Saito and Siyi Sin for the EXFOR PDF compilation effort, Emanuel Chimanski on nuclear reaction modelling, and Natalie Gaughan to assist with data for medical isotope production.

The staffing level is expected to remain stable throughout 2018/2019 (16.25 FTE) except for Andras Vasaros that will be rotated out in September 2018. Applicants for this post (AMDU scientific data manager) are being selected for interviews.

In his budget summary, Arjan Koning presented the budget breakdowns and totals from 2015 to 2018 and provided an estimate for 2019. The present NDS budgetary cost of €2 833 870 includes a 4% adjustment for inflation and funding for the extra effort required to establish the new International Nuclear Data Evaluation Network (INDEN). The additional amount translates to a 22% increase for the Technical Programme (TP). The Section continues to maintain services and address demands from Member States. Network coordination remains an important function of the Section and the use of international coordination is essential to achieve its goals. Staff activities focus on Coordinated Research Projects (CRPs), Data Development Projects (DDPs), training events and servicing requests. Consultants are used for certain tasks. Current resources do not allow the NDS to pursue all requests.

During the discussion, M. Herman inquired about the cost of cloud services. Arjan Koning replied that until 2018, there was no cost for the NDS but now the Section has to pay for these services (€21 000 per year).

2.2 Nuclear Data Section Activities (2016−2017)

Arjan Koning gave a short global overview of the NDS, summarizing the functions and activities which several members of staff will cover in subsequent presentations. He highlighted the network coordination function with regards to the International Network of Nuclear Reaction Data Centres (NRDC) and the International Network of Nuclear Structure and Decay Data (NSDD). The third network, INDEN, will also in future be coordinated by the NDS. The NDS also acts as a Data Centre and is tasked with the provision of databases, data production (via CRPs and DDPs), the provision of authoritative documents, data dissemination (mainly via the NDS website), training, compilation of bibliographical data (CINDA) and the compilation of experimental data (EXFOR). In addition to the range of data services that they provide, the NDS also carries out technical work, including compilation, evaluation and software development. Outreach in the form of training, especially to developing countries, includes the Workshops held at ICTP, Trieste. A notable highlight is the Isotope Brower App for tablets and smart phones (both for Apple and Android devices), which has been downloaded more than 70 000 times in 4 years and is now available in 10 languages. The success of this initiative may be an indication that the time has come for more services to be made available on these portable platforms. Cloud servers based at two physical locations make the services rendered by the NDS highly available to users from Member States.

A question concerning RIPL led to a discussion on the fission channel, which is problematic. Arjan Koning replied that RIPL parameters for fission are not trivial and that the issues are receiving strong attention and will hopefully be resolved for RIPL-4. Fukahori asked whether the final Tecdoc on Radiation Damage was available. Arjan Koning replied that the documentation was still incomplete but that the work will go directly to a publication, overruling the need for an IAEA Tecdoc.

2.2.1 Network Coordination (NRDC)

Naohiko Otsuka presented a report on the activities of the International Network of Nuclear Reaction Data Centres (NRDC) and the coordination role of the NDS. The composition of the NRDC remained unchanged, consisting of 13 data centres from 8 countries and 2 international organizations: NNDC (Brookhaven, USA), NEA Data Bank (Paris, France), IAEA-NDS (Vienna, Austria), CJD (Obninsk, Russia), CDFE (Moscow, Russia), CNPD (Sarov, Russia), CNDC (Beijing, China), BARC (Mumbai, India), JCPRG (Sapporo, Japan), JAEA-NDC (Tokai, Japan), KAERI (Daejeon, Korea), ATOMKI (Debrecen, Hungary), and UkrNDC (Kiev, Ukraine). The main task of the network is the collection and exchange of experimental nuclear reaction data and compilation into the EXFOR library.

The role of the NDS within the NRDC is to provide coordination via a staff member who serves as the NRDC secretary as well as other staff active in the network. The NDS also compiles data from countries not covered by the other data centres, including Asia (except China, India, Korea and Japan), Eastern Europe (except charged-particle data from Hungary), South America (with significant help from the University of São Paulo), Africa and Oceania.

The 2017 Annual Technical Meeting of the NRDC was held from 23–26 May 2017 in Vienna. It was attended by 23 participants from 12 data centres. The discussions were summarized in 32 conclusions and 97 actions. The main discussions included a suggestion to also compile data sets derived by groups other than the original authors, such as neutron-induced inelastic scattering cross sections derived from the corresponding experimental gamma emission probabilities. This is not normally done but in exceptional cases there exist a strong need from EXFOR users for such data. It was pointed out that matters of terminology are sometimes

problematic, e.g. distinguishing between phrases such as “capture yield” and “capture cross section”, which different groups may report with different normalization. The need for consistency in compilation was highlighted. More details are available in Summary Report INDC(NDS)-0736.

The 2018 Annual Technical Meeting of the NRDC was held from 1–4 May 2018 in Bahadurgarh, India. It was attended by 20 participants from 13 data centres. The discussions were summarized in 23 conclusions and 83 actions. The main points of discussion included the compilation of data published in conference proceedings, some of which are missing from EXFOR. This is important as recent conference proceedings often contain the latest data and rapid compilation should be encouraged. An EXFOR coding decision was also made concerning REACTION entries where the data concerned have unresolved or partially resolved secondary energies. Data centres were also requested to add the bibliographies of English translations of Russian articles where these exist, but often missing in EXFOR. More details are available in Summary Report INDC(NDS)-0762.

An EXFOR Workshop was held from 24–28 October 2016 at the IAEA Headquarters in Vienna. It was attended by 16 participants from 11 countries. Lectures were presented by all participants. The training included the compilation of thermal neutron cross sections and resonance integrals measured using the cadmium (Cd) ratio method, as well as the compilation of charged-particle data at low energies. More details are available in Summary Report INDC(NDS)-0749.

The NDS also supported several NRDC workshops held in Asian countries. The 7th Asian Nuclear Reaction Database Development Workshop (7th AASPP 2016) was held at CIAE, Beijing, China from 8–11 November 2016 and the 8th AASPP Workshop at the National University of Mongolia in Ulaanbaatar, Mongolia from 9–13 October 2017. The 9th AASPP Workshop is scheduled to be held from 12–15 November 2018 at Gyeongju, Korea. Details of the 7th AASPP Workshop can be found in the proceedings distributed as INDC(CPR)-062 and for the 8th AASPP Workshop in INDC(MGL)-0001.

There are now more than 22 000 experimental works compiled in EXFOR, with charged-particle data showing the largest growth, which rapidly approaches the number of entries for neutrons. During 2017 and the first half of 2018, 521 new entries were made by all data centres (of which 77 by the NDS) and 996 revised entries (of which 85 by the NDS). A total of 1304 articles were registered on the internal database for article registration, which forms part of the EXFOR coverage control system. The NDS regularly scans 56 journals, which will increase to 77 journals when the vacant position is filled. The NDS also regularly receives reports of journal scans from the NNDC, CNPD and JAEA. A recent comparison between EXFOR and NRS revealed that at least 3% of proton works and 20% of alpha works are still missing in EXFOR.

Naohiko Otsuka showed slides of the web-based monitoring tools for EXFOR, including “Articles for EXFOR Compilation (Allocation List)” and “EXFOR Entries for Corrections (Feedback List)”. These pages visually show the number of inputs and outstanding articles from each data centre and the number of pending corrections for each originating centre. There is also a systematic upgrading of old EXFOR entries, which is largely performed in collaboration with the NEA Data Bank. Laboratory reports are also sources of nuclear data that require compilation. An example was shown of 6 EXFOR entries on alpha scattering data from old IFJ (Krakow) reports. Further assessment of IFJ reports is planned by visiting the laboratory. Similar sources of valuable data may exist at many other laboratories in the world.

The NDS also systematically replaces older EXFOR article PDF files in the NDS archive with "text searchable" ones created by the publishers. In 2016 and 2017, three interns collected a total of 11 600 text searchable PDF files.

Concerning the EXFOR compilation of Time-of-Flight (TOF) spectra, the relevant data are now received from n_TOF, GELINA and ORELA when they are published due to excellent collaborations with those facilities. An effort is also made to compile spectra from Phase-I experiments. Compilation of thermal neutron scattering (TSL) and fission yield (FY) data are continuing. In the case of FY, a major database published in 1977 by Crouch (UK) and further revised by James, Mills, et al., will be compared with EXFOR (starting this autumn by the NDS) and all missing data will be added to EXFOR. A mini workshop is being planned for August 2018 to discuss the status of this project.

It was decided at the 2018 NRDC Technical Meeting that the official citation for EXFOR users will be *Nucl. Data Sheets 120 (2014) 272*. This is the second-most cited article in Nuclear Data Sheets published since 2013.

Naohiko Otsuka briefly touched upon the EXFOR Web Service, which will be discussed in more detail in a later presentation by Viktor Zerkin. More information on the NRDC can be found on the website of this network, a link of which is on the NDS opening web page.

M.Herman thanked Naohiko Otsuka and commended the NDS for doing a sterling job on EXFOR. Similar to the previous INDC Meeting in 2016, the subsequent discussion was dominated by the EXFOR compilation of Time-of-Flight (TOF) data. A question on whether the phrase *cross sections* should be used if the response functions are not known led to a lively discussion. The difficulties seem to be persistent as a lot of information is required to interpret these data. Arndt mentioned the requirements by funding agencies that pertinent steps are nowadays required for data preservation. There are also problems concerning the open access of some data and a question about at which level one should start harvesting for EXFOR.

2.2.2 Network Coordination (NSDD)

Paraskevi Dimitriou gave a presentation on the coordination of the International Network of Nuclear Structure and Decay Data Evaluators (NSDD). This network is responsible for continuously updating and developing the Evaluated Nuclear Structure Data File (ENSDF), which contains a large number of different nuclear data, e.g. levels, spins, parties, multipolarities, mixing ratios, conversion coefficients, half-lives, transition strengths, emission probabilities, etc. Data from ENSDF are used in a multitude of other major data sources, derivative data bases, derivative publications and codes, e.g. NuDat, Live Chart, NUBASE, MIRD, RIPL, DDEP, JANIS, RADWARE, Table of Isotopes, Nuclear Wallet Cards, MCNP, GEANT, etc. The NSDD coordination has been under the auspices of the IAEA since 1974 and currently has 18 participating nuclear data centres. The ENSDF database and management resides at the NNDC in Brookhaven.

The coordinating role of the NDS includes the following functions and tasks:

- Organization of meetings (NSDD Technical and Consultant Meetings);
- Training (see also presentation by R. Capote Noy on this topic);
- Technical support: codes, editors, web tools;
- Improvement of ENSDF analysis codes;
- Evaluation of Nuclear Moments;

- Financial support;
- Dissemination tools (Live Chart, Isotope Browser, Decay Data Portal, ENSDF Codes);
- Bibliography dissemination (NSR+EXFOR PDF database).

The 22nd Technical Meeting of the NSDD was held from 22–26 May 2017 at the Lawrence Berkeley National Laboratory in the USA. It was attended by 36 participants from all the NSDD data centres except PNPI (Russia). Two new ENSDF data evaluation centres were introduced to the network, namely the Cyclotron Institute of Texas A&M University and the Department of Nuclear Engineering of the University of Sofia, Bulgaria. The criteria for joining the NSDD were discussed, in particular with the view of expansion efforts in Europe and Japan. Three new committees were established, namely "Policies and Procedures", "Codes and Formats", and "Experimental Activities". More details are available in Summary Report INDC(NDS)-0733.

The total manpower effort of the NSDD remains a concern. While there was a marginal increase from about 9.4 FTE in 2015 to 10.7 FTE in 2017, the productivity is not increasing and the question on how to maintain a 10-year cycle in mass-chain evaluations is a major concern. Significant efforts to secure European funding for mass-chain evaluations had limited success to date and a change in attitude from potential funding bodies within Europe remains elusive. Efforts to address these issues are continuing by means of three approaches: (1) Increasing the number of European data centres; (2) Collaboration with the Nuclear Physics European Collaboration Committee (NuPECC) of the European Science Foundation (ESF) to promote NSDD evaluation activities in Europe; and (3) Promotion of European NSDD at conferences. The NuPECC long-range plan (LRP) released in June 2017 contains two pertinent recommendations by WG6 "Applications and Societal Benefits":

- Support activities related to the compilation, evaluation and dissemination of nuclear structure and decay data in Europe;
- Maintain a high level of expertise in nuclear data evaluation to meet the requirements of a continuously developing European research and applied sciences landscape through targeted training and mentorship schemes.

The incorporation of the two above-mentioned recommendations in the NuPECC LRP will hopefully lead to better opportunities for ENSDF evaluators in Europe to access funding.

In Japan, RIKEN is producing a significant amount of nuclear structure and decay data. There recently was a modest increase in manpower for compilation and evaluation work and a first effort to get involved in XUNDL compilation, with the aim to eventually contribute to ENSDF. An additional contribution from JAEA is also welcome.

The 2017 Technical Meeting also identified a need for a High-Priority Request List (HPRL) for nuclear structure data, along similar lines to the existing HPRL of the NEA Data Bank. Coordinators for such an initiative have been assigned and a website for the High-Priority Nuclear Structure Request List has been established, currently containing a list of priorities and a mechanism to add a request. This website, which is hosted on an LBNL server, also contains additional useful information and links to related NSDD webpages.

Financial support of about €30 000 was allocated for contracts for mass-chain evaluations, horizontal evaluations and consultancy visits during this reporting period. Technical support is provided on ENSDF codes, editor and web tools. The local repository is being maintained to ensure that all codes are running on all platforms, synchronized with the NNDC website.

A DDP on Improvement of Analysis Codes for NSDD Evaluations is active since 2014. JGAMUT was developed with financial support from the IAEA and corrected for recoil effects. ALPHAD_NEW was developed with financial support from the IAEA and recently released. V.AveLib and Gamma ABSolute (GABS) have been improved and updated. BetaShape is currently being reviewed. Several other codes are being developed, e.g. BrIccEmis, T-RULER (for treatment of uncertainties by means of distribution functions obtained via Monte Carlo methods), a new ENSDF editor, etc.

A new Decay Data Portal collects all decay data in one place and allows a comparison of currently available information. Data from ENSDF, DDEP, CRP and XUNDL are already included and ENDF/B, JEFF and JENDL are still to be included.

Conferences and meetings that were strongly supported include the International Nuclear Physics Conference (INPC 2016) in Adelaide; the UK National Conference on Applied Radiation Metrology (CARM 2016) during which the UK Nuclear Data Network (UKNDN) was launched; the 2016 and 2017 meetings of the United States Nuclear Data Program (USNDP); and the NuPECC meeting in 2017 already mentioned. Future meetings of the NSDD include:

- An ICTP-IAEA NSDD Workshop from 15–26 October 2018. The schedule will include lectures as well as hands-on practical courses on XUNDL compilation and ENDSF mass-chain evaluations.
- A Technical Meeting on Improvement of Analysis Codes for NSDD Evaluations from 3–7 December 2018 at the IAEA Headquarters in Vienna.
- The 23rd Technical Meeting of the NSDD in April 2019.

During question time, M. Herman commended the NDS on their role in code development. He also commented that now there are two High-Priority Request Lists and asked whether it would not be better if there would be only one? Paraskevi Dimitriou replied that it is easier having two due to the way the different communities operate. A lengthy discussion followed concerning the funding for NSDD activities, which remains a major concern. Outside the USA there is no "direct funding" for mass-chain evaluations and there is a reliance on individuals freely giving some of their time for these activities. M. Herman commented that also in the USA funding is in decline and that evaluators also have to contribute towards other research activities. The effort at the NNDC went down somewhat but should recover. A minimum threshold of 0.2 FTE should be maintained by contributors, else the network will collapse. The situation worldwide does not look very good. Expertise should be retained but for that "new blood" should be invested. A particular worry is that some experts retire or pass away and are not being replaced. In some centres only one individual is involved.

2.2.3 Atomic and Molecular Data Unit

Kalle Heinola gave an overview of the work of the IAEA Atomic and Molecular Data Unit (AMDU) on the activities on atomic (A), molecular (M) and plasma-material interaction (PMI) data for fusion applications. This was for completeness only as the INDC has no formal role in reviewing the work of this unit – atomic and molecular data studies fall exclusively under the auspices of the Subcommittee on Atomic and Molecular Data for Fusion of the International Fusion Research Council (IFRC).

AMDU is responsible for the development and maintenance of the bibliographical (AMBDAS) and the numerical (ALADDIN) databases as well as a Knowledge Base Wiki search engine

(GENIE), and various other data sets. AMDU also fulfils the role of coordinator of the International Atomic and Molecular Data Centre Network (DCN), which is an international collaboration amongst the principle A+M+PMI data centres. Currently the DCN has 10 participating centres that meet biennially (last held in September 2017). Two new members will join in 2019, namely CNEA (Argentina) and QUB (UK). A major component of current and future activities of the network concerns ITER.

AMDU also maintains the web pages of the VAMDC Consortium (Virtual Atomic and Molecular Data Centre) as well as coordinating the Code Centre Network (CCN). The CCN is a joint effort to gather and provide access to any information relevant for modellers in fusion plasma science. It has biennial meetings, the most recent of which was held in October 2017, with 15 participants from 13 countries. The topics discussed included the following:

- The data model and working conventions for a database of Molecular Dynamics (MD) simulations of collisional cascade processes in materials relevant to fusion reactor design (CascadeDB);
- Plans for a "crowdsourcing challenge" to analyze a representative set of collisional cascade MD simulation data. Both experts and non-experts have been invited to analyze MD simulations of radiation damage in fusion-relevant materials to
    - identify mesoscale structures such as defects and defect clusters,
    - better visualize the damage, recoils, kinetics, etc.

A new initiative is the Experimentalists Network (EN), for which a scientific committee was established in early 2018. This resulted from a TM on Uncertainly Quantification, which was held from 19–21 December 2016 in Vienna (see Report INDC(NDS)-0728 for more information). The first meeting of the EN will be a TM at the IAEA in Vienna from 19–21 November 2018, with the following objectives:

- Planned projects to connect experimentalists with theorists and modellers working in A+M collisions in plasmas for evaluation, assessment and benchmarking;
- Focus on edge plasmas in fusion devices at energies < 100 keV;
- Relevant experiments are electron-beam ion traps (EBITs), ion beams and storage rings.

Most of the work of AMDU is done by means of CRPs. CRPs relevant to the current reporting period are the following:

- 2012–2017: "Data for erosion and tritium retention in beryllium plasma-facing materials";
- 2013–2018: "Plasma-wall interaction with irradiated tungsten and tungsten alloys in fusion devices";
- 2015–2020: "Plasma-wall interaction with reduced-activation steel surfaces in fusion devices";
- 2016–2021: "Data for atomic processes of neutral beams in fusion plasma".

A proposed CRP on Vapour Shielding has recently been recommended by the IFRC Subcommittee at their meeting in May 2018, following the recommendations of a CM held from 19–20 March 2018 in Vienna (Summary Report INDC(NDS)-0755). A related TM to be held will be announced shortly.

AMDU was also involved in various joint ICTP-IAEA schools and workshops:

- Joint ICTP-CAS-IAEA School and Workshop on "Plasma-Material Interaction in Fusion Devices", held in Hefei, China from 18–22 July 2016;
- Joint ICTP-IAEA School on "Atomic Processes in Plasmas", held in Trieste, Italy from 27 February–3 March 2017;
- Joint ICTP-IAEA School and Workshop on "Fundamental Methods for Atomic, Molecular and Materials Properties in Plasma Environments", held in Trieste, Italy from 16–20 April 2018.

A proposal has been submitted for a "Joint ICTP-IAEA School on "Atomic and Molecular Spectroscopy in Plasmas", to be held in Trieste, Italy in 2019. AMDU will also participate in other fusion-related workshops, in particular "Spectral Lineshapes in Plasmas (SLSP)" which will be held from 27–31 May 2019 in Serbia, and "Models and Data for Plasma-Material Interaction (MoD-PMI)" which will be held from 18–20 June 2019 in Japan.

Planned future activities will include the establishment of a "Database for "Dust in Fusion Devices", following a successful CRP on this topic. Various website and database upgrades will also be pursued.

2.2.4 Nuclear Data Development (CRPs and DDPs)

Roberto Capote Noy gave separate presentations on Coordinated Research Projects (CRPs) and Data Development Projects (DDPs). The final report of one CRP, completed in the previous reporting period, was published in 2017. Four CRPs have been completed in this reporting period, but their documentation is still in preparation. Two CRPs are currently active (see Table 1). One CRP endorsed by the INDC has not yet started. Eleven DDPs are ongoing but some ad hoc updates/corrections have also been made to three completed DDPs.

Some of the decisions, actions, outputs and outcomes concerning the CRPs are listed below:

- The objectives of the CRP on "Nuclear data for Particle-Induced Gamma-ray Emission (PIGE)" are available in Summary Report INDC(NDS)-0568 of a CM held in 2010. This was followed by three RCM (16–20 May 2011, INDC(NDS)-0589; 8–12 October 2012, INDC(NDS)-0625; 7–11 April 2014, INDC(NDS)-0664) as well as a 2nd CM from 16–18 December 2015 to initiate writing the final Technical Document (Tecdoc) which has been completed in 2017 (IAEA-TECDOC-1822). The outputs include more than 300 new data sets uploaded onto IBANDL as well as new evaluations for ^{27}Al(p,p′γ), ^{23}Na(p,p′γ) and ^{52}Cr(p,p′γ) performed by CRP consultants (Summary Report INDC(NDS)-0666). The data are available online at http://www.nds.iaea.org/pige/.
- The initial planning of the CRP on "Nuclear data for charged-particle monitor reactions and medical isotope production" was done at a CM held in 2011 (Summary Report INDC(NDS)-0591). Three RCM followed (3–7 December 2012, INDC(NDS)-0630; 8–12 December 2014, INDC(NDS)-0675; 30 May–3 June 2016, INDC(NDS)-0717) as well as a TM on "Intermediate-term Nuclear Data Needs for Medical Applications Cross Sections and Decay Data" (INDC(NDS)-0596). All evaluated cross sections include estimated uncertainties. A paper was published on "Reference Cross Sections for Charged-particle Monitor Reactions" (Nucl. Data Sheets 148 (2018) 338–382) and four other manuscripts are in preparation on *recommended nuclear data* according to the sub-topics "diagnostic gamma emitters", "diagnostic positron emitters", "therapeutic radionuclides" and "selected nuclear decay data for radioisotope production".

Table 1. Status of Coordinated Research Projects.

No.	Short title	Duration	Participants (contracts)	Project Officer (predecessor)	Status
1	Development of a reference database for Particle-Induced Gamma-ray Emission (PIGE) spectroscopy.	2011–2015 F41028	12 (6)	Dimitriou (Abriola)	Completed in 2015. Final report published in 2017: IAEA-TECDOC-1822.
2	Nuclear data for charged-particle monitor reactions and medical isotope production.	2012–2017 F41029	14 (6) + 1 CSA	Capote Noy	Completed in 2017. Monitor reactions published. Four papers in preparation.
3	Testing and improving the International Reactor Dosimetry and Fusion File (IRDFF).	2013–2018 F41031	13 (5)	Trkov (Simakov)	Completed in 2017. Documentation in preparation.
4	Primary radiation damage cross sections.	2013–2018 F44003	18 (1)	Sublet (Simakov)	Completed in 2017. Documentation in preparation.
5	Reference database for beta-delayed neutron emission.	2013–2018 F41030	12 (3)	Dimitriou	Completed in 2018. Documentation in preparation.
6	RIPL for fission cross-section calculations.	2016–2021 F41033	10 (4)	Capote Noy	Ongoing
7	Updating the Photo-nuclear Data Library and generating a reference database for photon strength functions.	2016–2020 F41032	14 (8)	Dimitriou	Ongoing
8	Measurement and evaluation of fission yields in neutron induced and spontaneous fission.	2019–2024 —	—	Sublet/ Dimitriou	Endorsed by INDC. Not started.

- The completed CRP on "Testing and improving the International Reactor Dosimetry and Fusion File (IRDFF)" held its 3rd and last RCM from 20–24 March 2017 (Summary Report INDC(NDS)-0731). Some of the cross-section and excitation function evaluations have already been reported (INDC(NDS)-0705 and INDC(SLO)-0002). The planned output will be the improved and validated library IRDFF-2.0, which is expected for release in December 2018. A manuscript is in preparation for Nuclear Data Sheets, publication of which is expected in early 2019.
- The completed CRP on "Primary radiation damage cross sections" held its 3rd and last RCM from 23–25 October 2017. To date, 15 publications appeared in international conference proceedings and peer-review journals. Further planned outputs will include numerical databases of recommended damage response functions for selected materials with corresponding documentation, and new methods and metrics for defect simulations

with corresponding documentation.

- The completed CRP on "Reference database for beta-delayed neutron emission" held its 3rd and last RCM from 12–16 June 2017 (Summary Report INDC(NDS)-0735). A final CRP report is in preparation and will be submitted to Nuclear Data Sheets.
- The ongoing CRP on "RIPL for fission cross-section calculations" held a 1st RCM from 6–9 June 2017 (Progress Report INDC(NDS)-0734). The main goal is an improved RIPL database as well as documentation with the focus on parameters for fission cross-section calculations (masses, fission barriers, transitional and class II/III states, level densities, etc.)
- The ongoing CRP on "Updating the Photonuclear Data Library and generating a reference database for photon strength functions" had a 2nd RCM from 16–20 October 2017 (Summary Report INDC(NDS)-0745). More than 200 new evaluations have been completed in collaboration with JAEA, KAERI, CNDC, Moscow SU and IFIN-HH. A CM to review the evaluations will be held from 25–27 June 2018. New experimental measurements of photoneutron cross sections using direct multiplicity sorting are being performed by the PHOENIX collaboration. The compilation of existing photon strength function (PSF) data is almost complete. Validation of experimental and theoretical PSF is in progress. A new "Atlas of Average Resonance Capture Data" was released in August 2017 (INDC(NDS)-0738).

A summary of DDP activities is presented below:

- Maintaining the International Neutron Standards File and evaluation techniques: New evaluations were reported in Report INDC(NDS)-0739 [^{7}Li(n,n$'_{\gamma 478\ keV}$)], Report INDC(NDS)-0740 [^{48}Ti(n,n$'_{\gamma 948\ keV}$)] and a new publication "Evaluation of the neutron data standards" in Nucl. Data Sheets 148 (2018) 143–188. One conclusion of the latter work is that rather small uncertainties have been obtained for some standards in previous evaluations. Some underestimation is suspected in some cases, requiring an investigation of systematic uncertainties, in particular unknown systematic uncertainties based on an observed spread in normalization factors.
- Several NDS staff members were active in the CIELO collaboration, which was managed by the NEA WPEC SG-40. This large project is now completed, which led to the creation of the INDEN network. Some of the technical contributions from IAEA staff members are briefly listed below:
    - PFNS CRP;
    - Validation of the IRDFF CRP;
    - Neutron Standards: Thermal constants and new GMA fit of ^{235,238}U(n,f) and ^{238}U(n,γ);
    - New ^{238}U evaluation in the fast range solving the elastic/inelastic discrepancies;
    - New ^{235}U evaluation in the fast range using a ^{3}H fission barrier;
    - File assembly, verification and extensive benchmark testing;
    - New RR evaluation of ^{235}U in collaboration with ORNL;
    - New RR evaluation of ^{238}U provided by IRMM;
    - Collaboration with NNDC on ^{56}Fe evaluation (both in the RR and fast range up to 150 MeV);

- CMs on “Inelastic scattering on actinides” (2015), on “Capture in ^{235}U” (2016).

A highlight is the 8th major release of ENDF (ENDF/B-VIII.0) with CIELO-project cross sections, new standards and thermal scattering data.

- Ion Beam Analysis Nuclear Data Library (IBANDL): The new re-engineered webpage has been completed and many new features and options added. A new CD-ROM has been prepared with the updated IBANDL data library.
- Development of evaluation methodology and nuclear reaction modelling systems: Additional work on the development and testing of EMPIRE and TALYS has continued, and on GANDR by an external consultant. Setup-free versions of EMPIRE have been developed by Viktor Zerkin for Mac, Linux and Windows platforms. Many technical papers have been published on EMPIRE and TALYS applications.
- R-matrix Codes for Charged-particle Reactions in the Resolved Resonance Region: A 2nd CM of the above DDP was held from 57 December 2016 (Summary Report INDC(NDS)-0726). During this meeting, a 1st joint exercise to compare R-matrix algorithms for p+^{6}Li had a rough start but now all codes agree within 1–2%. A 3rd CM was held from 27–29 June 2017 (Summary Report INDC(NDS)-0737) and a 2nd exercise was held on fitting and evaluation for p+^{6}Li. The preparation of final publication and processing of charged-particle files in ENDF-6 format is to be addressed at a scheduled 4th CM to be held on 27–29 August 2018. These activities also highlighted the importance of light elements for INDEN.
- Verification of data processing codes for generating ACE-formatted files (GAFF): There is a need for an open-source code by Member States. The GRUCON code has been tested for some time and new features added, e.g. reconstruction of angular distributions from resonance parameters, validation of ACE at higher energies, extended capabilities to process gamma-production data in ACE files, generating heating and kerma data, etc. Other activities include the verification and validation of ACE libraries on ICSBEP benchmarks, extension of Pre-Pro codes to generate multi-band (MB) in the Unresolved Resonance Region (URR) and validation of MB on ACE libraries and ICSBEP benchmarks (Report INDC(NDS)-0711).
- Improvement of Analysis Codes for Nuclear Structure and Decay Data Evaluations (see subsection 2.2.2 for more information).
- Stopping-power database: The electronic stopping-power database created by Prof. Helmut Paul of the University of Linz is being maintained by the NDS since 2015. The database and online retrieval interface are available at www-nds.iaea.org/stopping/.
- Total Absorption Gamma-ray Spectroscopy (TAGS) decay data for decay-heat calculations and other applications: A CM on “Updating data needs for TAGS measurements” was held from 1921 February 2018 at the IAEA Headquarters in Vienna. A final report is in preparation for publication in a peer-reviewed journal and will include the following:
    - New TAGS measurements and results for beta feedings;
    - Current status of decay data libraries with respect to TAGS data;
    - Impact of recent TAGS data on decay-heat calculations and anti-neutrino spectra;
    - New priority tables for total absorption and high-resolution gamma-ray spectroscopy measurements;

    - Repository of measured decay-heat data.
- Nuclear Data Libraries for Advanced Systems: Fusion Devices (FENDL-3). Maintenance ongoing, with three updates in this reporting period. FENDL-3.1d was released on 24 January 2018, with changes reported on https://www-nds.iaea.org/fendl/.
- Thermal scattering law (TSL) data: The IAEA provides some financial support and also support to WPEC SG-42. For library generation, the "Thermal Scattering Law Interpolator" developed by Centro Atomico Bariloche was found to be very useful, with smooth interaction within CIELO. This is expected to continue within INDEN.
- Evaluation of Nuclear Moments: A CM on this topic was held from 27–30 March 2017 in Vienna (Summary report INDC(NDS)-0732). The objective is to produce a table of evaluated magnetic dipole moments, taking the following into consideration:
    - Assessment of different measurement techniques and required corrections (diamagnetism, hyperfine anomaly, half-lives and external-field parameterization for short-lived states, new Electric Field Gradient calculations for Q, etc.);
    - Proposing a method of implementing all the required corrections;
    - Agreement on a timeline for producing tables of evaluated μ and Q (end of 2018);
    - IAEA Online Nuclear Moments database to be updated.
- Electron and Photon Interaction Cross Sections: EPICS2017 is the Electron Photon Interaction Cross Section library that provides the atomic data needed to perform coupled electron-photon transport calculations. EPICS2017 includes three separate databases that are designed to be used in combination, namely Evaluated Atomic Data Library (EADL), Evaluated Electron Data Library (EEDT) and Evaluated Photon Data Library (EPDL). An error was discovered in the EPDL library. It applies to the EPDL data in ENDL-format only. The corrected data were uploaded on 15 February 2018.
- Thin Layer Activation (TLA) technique for wear measurement: The TLA technique provides effective and precise online remote monitoring of wear, corrosion and erosion of critical parts in machines under real operating conditions. A calculation tool, TLA2017, helps to plan irradiations for TLA applications. The original tool was developed by ATOMKI in 2010 and updated in 2017.

During the discussion, a question was asked about the choice of CRP or DDP for thermal scattering law (TSL) data and the generation of covariances. Roberto Capote Noy replied that there has never been a CRP on covariances but a DDP. The choice of CRP or DDP is normally an operational decision. A CRP must be clear to produce a database on a well-defined timeline. Other activities are more conveniently managed by DDPs.

2.2.5 Training and Workshops

Roberto Capote Noy gave an overview of the IAEA-sponsored workshops and training schools over the period 2016–2017.

- Joint ICTP-IAEA Workshop on Nuclear Structure and Decay Data: Experiment, Theory and Evaluation, ICTP, Trieste, 22 August–2 September 2016. The workshop directors were P. Dimitriou (IAEA), E. McCutchan (BNL) and M. Thoennessen (MSU). It was attended by 23 selected trainees.
- IAEA Workshop on the Experimental Nuclear Reaction Database (EXFOR), Vienna, 24–28 October 2016. The Scientific Secretary was V. Semkova. It was attended by 15

participants and IAEA staff.

- Joint ICTP-IAEA Workshop on Monte Carlo Radiation Transport and Associated Data Needs for Medical Applications, ICTP, Trieste, 18–29 September 2017. The workshop director was R. Capote Noy (IAEA). It was attended by 68 participants and IAEA staff.
- Joint ICTP-IAEA Workshop on Nuclear Reaction Data for Nuclear Power Applications, ICTP, Trieste, 2–13 October 2017. The workshop directors were A. Arjan Koning (IAEA) and J.-C. Sublet (IAEA). It was attended by 27 trainees.

2.2.6 Computer Operations

Arjan Koning gave a presentation on NDS computer operations on behalf of Vasaros, who had to attend to other business. Some of the activities and challenges during the 2016–2017 period are listed below:

- Migration of all unsupported physical servers to VM-based MTIT hardware;
- Converting the migrated physical servers to network-attached calculation workstations;
- Upgrading SLES12 to SLES13 on all Linux servers;
- Commissioning and implementation of one high-speed 88 CPU calculation server based on the MTIT standard;
- IAEA migration from Windows 7 to Windows 10.

Some of the highlights of the 2016–2017 period are listed below:

- Upgrading the majority of servers to the most recent operating system version, including the cloud;
- Implementation of NDS internal monitoring of all services;
- Rack-mounted, Linux-based calculation workstations with nearly 200 CPUs are now in place;
- Improving the performance load balancing of NDS endpoints;

Mirror sites in Russia, China and India are fully operational and regularly updated. This improves the speed of regional access and provides a degree of redundancy. Most software is shared with the NNDC but some local copies also provide additional redundancy. Plans for the future include the implementation of an NDS managed public SVN (subversion) server to maintain Empire source codes.

2.2.7 User Services for Nuclear Reaction Data

Viktor Zerkin gave a presentation on user services for nuclear reaction data for the 2016–2017 period. Briefly, online recalculation of cross sections includes inverse reactions in EXFOR, inverse kinematics in EXFOR-IBANDL, cross-section ratios between different data sets and reconstruction of ENDF elemental reaction data in the EXFOR-ENDF web system. Several examples were shown, including the recalculation of angular distributions to inverse kinematics and integration with Web-IBANDL.

Integration of databases started in 2005 by extending CINDA to include photonuclear and charged particle reaction data. Since 2010, CINDA has regularly been extended by new information from EXFOR and NSR (twice per year). Since 2017, the import of data from EXFOR and NSR to CINDA is done fully automatically. This enables CINDA to be updated

on a monthly basis. Recent extensions to CINDA make it more useful for the searching of candidates for EXFOR compilation.

The EXFOR-NSR PDF database has seen many developments since its creation in 2005. Since 2016, the CINDA web retrieval system provides access to PDF files for authorized users. In addition to EXFOR, NSR and CINDA, web access can also be obtained via MyENSDF and MyEXFOR.

The processing of user's data on the NDS web server is oriented towards nuclear data professionals (i.e. people who produce nuclear data, compilers and evaluators). Services comprise modern types of cloud computing, namely "Software as a Service" (SaaS), "Infrastructure as a Service" (IaaS) and "Platforms as a Service" (PaaS). Software for database retrieval, calculations, reformatting, presentations, etc., runs on the web (i.e. not just as a repository). The user's own data can be processed together with data from databases. Various web-server tools are made available by the NDS for working with users' data, as summarized in Table 2:

Table 2. Web tools for nuclear data available on the IAEA web.

2009	MyPlot	Plotting with Web-ZVView
2010	MyEXFOR	EXFOR Uploading System for EXFOR compilers, ZCHEX, ZORDER, XTRACT, X4TOC4, Web-EXFOR
2011	MyENSDF	Uploading System for ENSDF, PREPRO, XPQCHK, FMTCHK, ALPHAD, GTOL, BrIcc, BrIccMixing, GABS, LOGFT, PANDORA, RADLST, RULER, NDSPUB, edit-NDSPUB, Nnsdf-viewers (Ensdf+, iTree), ENSDF Web-editor
2013	EMPIRE-3.1	Web Interface to Empire-3.1 /test-version/
2015	MyENDF	ENDF Uploading System, CHECKR, FIZCON, STANEF, PSYCHE, INTER, PREPRO, ENDVER, Web-EXFOR-ENDF, FUDGE, GRUCON
2015	MyX4Data	Uploading experimental data as text to the EXFOR system for constructing covariance matrices, plotting, inverse reaction calculations, etc.

Viktor Zerkin also discussed the status of several pilot projects, listed below:

- Running Empire on the web: Current status – frozen.
- Web without Internet on Oracle-VirtualBox: Current status – ready.
- Light EXFOR Editor: Current status – frozen.
- Light ENSDF Editor: Current status – active.
- Web image tools (2014–2018): Current status – active. A 2D-calibration tool is available for checking the results of digitizing (integrated with the Web-ZVView plotting package)

which is also useful for improving scanned results from figures in old papers before digitizing (especially where such figures are distorted).

Viktor Zerkin made some final remarks in conclusion:

- Recent development of "nuclear reaction data service" is mostly oriented to "professional needs" of nuclear data compilers and evaluators;
- It is useful to arrange using web tools of database retrieval systems also for data uploaded by the user on-the-fly;
- Continued development of server calculation systems for running legacy codes and as a perspective platform for future cloud computing;
- Continued development of the Web ENSDF Editor as an experimental project;
- Continued development of the EXFOR-NSR PDF database and try to establish open public access when possible.

During the subsequent discussion, Paraskevi Dimitriou commented how the web tools have become extremely useful for members of the NSDD network. These tools are used on a daily basis and they really would like these developments to continue. Evaluators need these tools, which also make the "learning curve" much faster. Kibedi commented that this is especially valuable as manpower resources are scarce. There was some discussion on OSTI (Office of Scientific and Technical Information in the US) and drives to make science information freely available for public use. It was mentioned that sometimes the possibility to make information "open access" was not clear and/or not easily identifiable, especially for certain PDF files.

2.2.8 Nuclear Data Dissemination

Viktor Zerkin presented a report on the nuclear data dissemination activities of the NDS for the period 2016–2017. Numerous ways are used for the dissemination and distribution of data and information, including the following databases, files, documents and other measures:

- EXFOR – experimental reaction database;
- CINDA and NSR – scientific bibliography;
- ENDF – collection of evaluated libraries (ENDF/B, JEFF, CENDL, JENDL, etc.);
- ENSDF, LiveChart, NuDAT – nuclear structure and decay database systems;
- Standards, IBANDL, RIPL-3, IRDFF, FENDL, PGAA, NAA, Medical Portal, Stopping Power database, and other specific application-oriented databases;
- Documentation – INDC Reports, Technical Documents, NDS Newsletters and online news, Staff publications, etc.

The form can be the original data, data converted to other formats, calculated/derived data, plots, etc. An integrated system includes databases as well as application software with system components. Nowadays, the main way of distribution is by means of web retrieval systems (mainly the NDS website and those of the mirror sites, as well as websites of partners such as the NNDC). The NDS can also respond to individual requests for hard copies and/or mass storage media (DVD-ROM, USB-disks, etc.) which can be sent by post.

The EXFOR data library now contains data sets of more than 22 000 experiments and is updated about once a month. The number of new/modified entries in 2016 and 2017 were 471/1149 and 413/763, respectively. Neutron-induced reactions constitute about 47% of all entries, followed

by proton-induced reactions (20%), deuteron-induced reactions (9%), α-particle induced reactions (8%), γ-induced reactions (6%), and other ions the rest. The quantities include cross sections (51%), differential and partial differential data with respect to angle (39%), resonance parameters (9%), partial cross-section data (9%), polarization data (5%), fission product yields (5%), double-differential data with respect to both angle and energy (5%), miscellaneous fission quantities (2.36%), and other quantities the rest. The EXFOR database contains the current EXFOR library as well as the EXFOR archive (all updates as per the EXFOR history in all data centres). A common EXFOR-NSR database in PDF format is kept with original publications, available to all authorized users, compilers and evaluators. EXFOR data dissemination is mainly via the web database retrieval system but a standalone database retrieval system is also available. EXFOR data are also exported to various software packages (such as EMPIRE, TALYS, etc.) in XC4 format.

Development of the EXFOR/CINDA web retrieval system is continuing and several new features are available:

- Calculation of cross sections for inverse reactions using detailed balance theory;
- Recalculation of angular distributions to inverse kinematics (via Web-IBANDL);
- Plotting cross sections coded with SF8=DAM (cross-section data divided by atomic mass of target);
- Calculating cross-section ratios between different datasets on-the-fly;
- Affine transformations and distortion ZVView plots using 2D-calibration;
- Search by DOI and NSR-Keyno in CINDA;
- Access from CINDA to NSR information and to the EXFOR-NSR PDF database;
- Search for possible candidates for EXFOR compilation using the CINDA database extended by NSR data.

The Evaluated Nuclear Data Files (ENDF) database currently contains 24 libraries for general use or application-oriented use, i.e. all major and national libraries. There are also 23 archival libraries and 3 derived libraries. The total ENDF has 58 libraries. The most essential updates during the 2016–2017 period are summarized below:

- TALYS-based Evaluated Nuclear Data Library (TENDL-2015, TENDL-2017);
- Japanese JENDL Photonuclear Data File (JENDL/PD-2016);
- Fusion Evaluated Nuclear Data Library (FENDL-3.1b, 3.1.c);
- Evaluated Nuclear Data Library (ENDF/B-VIII.0 US);
- Evaluated Nuclear Data Library (ENDF/B-VIII.β3, β4, β5 – US, preliminary);
- Differential data for ion-beam analysis (IBA-EVAL).

New functionality in the web database retrieval system is online reconstruction of ENDF elemental reaction data as well as some plotting additions (MF23 “smooth” photon interaction cross sections, MF8/MT454/MT459 fission product yields, etc.).

Several other libraries (not included in ENDF) have also been updated in the 2016–2017 period:

- ACT-DDL, which is the Decay Data Library for Actinides (2017).
- The Ion Beam Analysis Nuclear Data Library (IBANDL) was extended from 3 328 datasets in 2015 to 3 662 datasets in 2017. The NDS has done 30 updates in this reporting period. The web interface to IBANDL and SigmaCalc data was extended by the inclusion of a "search data by first author" functionality, importing data directly from the EXFOR web retrieval system on-the-fly, running Sigmacalc remotely (on the Obninsk-server) and using results together with data from the database.
- The Nuclear Moments Database (magnetic dipole and electric quadrupole moments) is regularly updated and available from the NDS server.
- POINT-2018 is an ENDF/B-VII.1 point-wise library processed into temperature-dependent form using the PREPRO-2017 codes at a set of discrete temperatures ranging from 0–1800 K (0.1 eV – 10 keV).
- Stopping power database for light ions, updated 3 – 4 times a year.

Various updates to the code collection have also been reported for the 2016–2017 period. This includes the 2017 version of LARELKIN, which is a two-body relativistic kinematics code. PREPRO-2017 is the latest version of the PREPRO ENDF/B-6 pre-processing code. The URR-PACK code is used for calculating self-shielding in the unresolved resonance region. GRUCON is an evaluated data processing package, supplied by the Kurchatov Institute. DICEBOX is a code for simulating gamma cascades, developed by Charles University in Prague, which will be released soon. The ENSDF analysis codes are available from a dedicated website and are regularly updated and disseminated.

Viktor Zerkin also gave feedback on the status of scientific bibliography resources that the NDS is responsible or part-responsible for, including CINDA, NSR and EXFOR, which are hyper-linked, allowing for a quick search of documentation. The CINDA web retrieval system displays PDF files from the EXFOR-NSR database and is updated 12 times a year. The NDS publication portal contains more than 3 800 documents, including Tecdocs, reports, staff publications, etc. About 98% of these documents are now available electronically. There is ongoing collaboration with the main IAEA Library and the International Nuclear Information System (INIS) administered by the IAEA Department of Nuclear Energy. An effort is made to search for rare and/or historical documents, mainly for EXFOR. All of the NDS documents have become part of the IAEA Library Catalogue. The cataloguing project was completed in January 2017 and where available, electronic access was added in the catalogue.

During the 2016–2017 period, 314 CDs/DVDs with databases were dispatched as well as 336 hardcopies of INDC reports, Charts of Nuclides, Nuclear Wallet Cards, etc. Almost all of the information on CDs and DVDs can now be downloaded directly from the NDS website. Four NDS Newsletters (Issues 61–64) were released. Individual requests were serviced if possible, both from developing and advanced countries. NDS staff provide answers or replies to questions and requests from both beginners and advanced users of the products that the Section develop, maintain and provide to Member States.

Data dissemination via the three mirror sites is also functioning well (BARC, India; CNDC, China; "Atomstandart", Russia). All mirror-site system maintenance is done by mirror-site staff. From the IAEA side, it is possible to upload packages and send notifications & instructions. From the mirror-site side, it is possible to download packages, install and test them. Regular updates of databases and software are performed, mostly on a monthly basis.

The NDS web statistics mainly indicate an increase in accesses and downloads compared with the previous reporting period. The leading downloads for (2016, 2017) show the following distribution: ENDF (27%, 28%); LiveChart (24%, 27%); EXFOR (25%, 23%); CINDA/NSR (5%, 4%). IBANDL/Sigmacalc (4%, 4%); and Documents (3%, 4%). The (2016, 2017) dissemination geography is as follows: Western Europe (31%, 39%); US and Canada (28%, 30%); Developing Countries (29%, 18%); former USSR (4%, 5%). There is a notable increase for Western Europe and a notable decrease for Developing Countries.

During question time, a comment was made about the NDS web front-page (opening page) that is identical also on all the mirror sites. This can lead to a user believing that he/she is accessing the NDS website while in fact it may be a mirror site. Sometimes a regular user of a mirror site may want to deliberately access the NDS site and may even have pages of both sites open in a browser. A request was made to clearly indicate on the opening page of each mirror site which website was being accessed.

2.2.9 Visualization

Marco Verpelli gave a presentation on nuclear data visualization. Various examples were shown of 3D interactive displays of data on web pages and colour coding to highlight selected information. An example of a decay data comparison on the Decay Data Portal was shown as well as an example on a mobile device. The quality of visualization can be poor on a small mobile device (cellphone) due to the small screen size and text can become unreadable, especially if information intended for a computer screen is displayed in such a manner. This highlights the need for dedicated apps for mobile devices, such as the Isotope Browser, which now has about 70 000 users and is available in 10 languages. Marco Verpelli also demonstrated a Radionuclide Production app that is still being developed. The produced activities versus time of radionuclides are calculated based on TENDL cross sections, where the user has to enter or select the desired input information online in 10 fields (product, projectile, target nucleus, target area, target density, beam energy, back-end energy, beam current, irradiation time, and cooling time.) The running mode can be “on-the-fly” or “when ready”.

Michel Sendis asked if only TENDL cross sections can be used. Marco Verpelli replied that at the moment only TENDL values are being used while the app is being developed. At a later stage, they will introduce evaluated cross sections from the Medical Portal also, which will increase the accuracy.

3. 2018−2019 PROGRAMME REVIEW

Arjan Koning gave a presentation in which he summarized the work to be undertaken by the NDS during the next reporting period, 2018–2019. The work is organized into three Projects which largely cover the work of the three Units. Although the NDS forms part of the Department of Nuclear Sciences and Applications (NA), most of the Section's activities resort under Major Programme 1 (MP1), carried out by the Department of Nuclear Energy (NE). The NDS thus supports both departments. Most staff members are intensively involved with technical work, which involves the following:

- Developing and maintaining a comprehensive website;
- Many interactive web tools;
- Databases produced by CRPs;
- Training workshops;
- Production of technical papers and reports.

3.1 Provision of Data Services

This work comprises a series of continuous and ongoing activities:

- General Management, which is a generic function;
- Provision of computer systems and networks;
- Provision of the NDS multiplatform website;
- Web-based tools – development of multiplatform software formats;
- Data Services – user assistance, data retrievals and dispatch, preparation and distribution of data libraries and NDS publications;
- Newsletters and Reports;
- Biennial reviews of the programme by the INDC and the A+M Subcommittee of the IFRC;
- Courses/Workshops at ICTP, Trieste, Italy as well as in Vienna;
- International Networks – NRDC, NSDD, INDEN, A+M Data, A+M Codes;
- International Collaboration: e.g. NEA cooperation (JEFF); BNL cooperation (ENDF).

3.2 Nuclear Data Development

Several CRPs have terminated and are now closed, except for the creation of final documentation in some cases. Two CRPs are active and another one will start in 2019. Those CRPs with activities/tasks for the 2018–2019 period are listed below:

- F41029 CRP on Charged Particles – Coordinate a CRP on Nuclear data for charged-particle monitor reactions and medical isotope production. This CRP is now closed but some output/results are still to be published (5 planned papers) and webpages updated.
- F41031 CRP IRDFF Dosimetry – Coordinate a CRP on testing and improving the IRDFF dosimetry library. This CRP is now closed but the IRDFF-2.0 library is to be released in December 2018, with the final report to be submitted in 2019.
- F44033 CRP on Material Damage – Coordinate a CRP to upgraded the NRT-DPA

standard with new physics to capture the annealing of defects in the recoil cascade. This CRP is now closed, with the final report to be submitted in 2018.

- F41030 CRP on Beta Delayed Neutrons – Coordinate a CRP on beta-delayed neutron emission. This CRP is now closed, with the final report to be submitted in 2018.
- F41032 CRP on Photons – Updating the photonuclear data library and generating a reference database for photon strength functions. The final RCM will be held at the end of 2018.
- F41033 on Recommended Input Parameter Library (RIPL) for Fission Cross Section Calculations – Coordinate a CRP to improve RIPL, particularly for the fission parameters. The first RCM was held in December 2017, while measurement and evaluation of fission yields will start in 2019.

The Data Development Projects (DDP) are summarized below:

- Maintain the international neutron cross section standards file and evaluation techniques;
- INDEN (International Nuclear Data Evaluation Network): coordination and technical work;
- Development of evaluation methodology and nuclear reaction modelling systems (EMPIRE);
- Evaluation of charged-particle induced reaction data in the resolved-resonance region for applications (R-matrix codes);
- Improvement of analysis codes for nuclear structure and decay data evaluations;
- Stopping power database;
- Total absorption gamma-ray spectroscopy (TAGS): Decay data for decay-heat calculations and other applications;
- Intercomparison of PIGE analysis codes;
- Data for Safeguards (if requested);
- Nuclear Data Libraries for Advanced Systems: Fusion Devices (FENDL);
- Thermal scattering law data;
- Open source processing codes. Testing, development and validation (ACE format).

Concerning the International Nuclear Data Evaluation Network (INDEN), Arjan Koning gave a brief summary, with more detail given by Roberto Capote Noy in a separate presentation.

The role of the NDS in INDEN will be to coordinate nuclear data evaluation efforts worldwide, to define priorities and avoid overlapping, to strengthen technical interactions and to interact strongly with the NEA on benchmarking and validation. An INDEN Consultants Meeting was held from 21–24 December 2017 at the IAEA in Vienna. The list of nuclides with highest evaluation priority was defined as follows:

- Light elements: ^{9}Be, ^{14,15}N, ^{23}Na;
- Structural elements: ^{58}Ni, ^{59}Co;
- Actinides: ^{238,240,241,242}Pu.

Some re-evaluations were requested due to issues identified:

- ^{56,57}Fe: Issues in elastic cross sections and angular distributions from 0.85–6 MeV;
- ^{239}Pu: Use of newly recommended thermal PFNS, thermal nubar, resonance region;
- ^{238}U: 14 MeV leakage issues traceable to inelastic spectra, PFNS for E_n = 5–8 MeV.

Additional nuclei discussed included ^{54}Fe, isotopes of Cr, and ^{233}U. Three INDEN Consultants Meetings (CM) have been scheduled for 2018:

- Resonance range of ^{235}U (8–11 May 2018);
- R-matrix evaluation of light nuclides (30–31 August 2018);
- Challenges in evaluating structural materials (29 October – 1 Nov 2018).

3.3 Planned Meetings for 2018–2019

- CM on photonuclear cross sections (25–27 June 2018);
- CM on nuclear data needs for TAGS (February 2018);
- CM (INDEN) on ^{235}U resonance range (May 2018);
- Nuclear Reaction Data Centres (NRDC) meeting (May 2018, India);
- Nuclear Reaction Data Centres (NRDC) meeting (2019, Vienna);
- Nuclear Structure and Decay Data (NSDD) meeting (2019, Vienna);
- CM (INDEN) on light nuclides (30–31 August 2018);
- CM (INDEN) on structural materials (29 October – 1 November 2018);
- CM on nuclear data visualization (August 2018);
- CM on radiation characterization integral database (August 2018);
- CM on R-matrix codes for charged particles (27–29 August 2018);
- CM on photon strength functions (24–28 September 2018);
- TM on nuclear data processing (September 2018);
- TM on Covariances (late 2018);
- CM on PIGE analysis codes (1–4 October 2018);
- CM on FENDL (October 2018);
- TM on medical isotope production (December 2018);
- RCM on photon strength functions and photonuclear library (17–21 December 2018);
- RCM on fission parameters for RIPL (2019);
- RCM on fission yields (late 2019).
- Analysis codes for ENSDF (December 2018).

At this time questions were taken. M. Herman observed that the CRPs seem to be getting fewer. Arjan Koning replied that this was indeed so but that the NDS put a big effort into CIELO and that this will continue and grow within INDEN. A question concerning the December meeting on medical isotope production was whether a new network should not be considered? Arjan

Koning replied that a network would not be the most appropriate way forward, neither was there a well-defined plan for a next CRP. A DDP to keep producing data, in conjunction with a number of contracts, would probably be the best approach for the time being.

3.4 International Radiation Characterization Benchmark Experiment Project (IRCBEP)

Sublet gave a presentation on IRCBEP, starting by first introducing the concept of "multi-scale modelling" in materials sciences. He showed how different disciplines and models fit on a plot of "timescale versus length scale" over many orders of magnitude. Traditionally, different disciplines focus on different length scales. Multi-scale modelling of materials across length scales requires overcoming the borders between the disciplines for a seamless integration of the models on different length scales into one coherent multi-scale modelling framework. He explained the concept of NAMMS, which is a progression from Nuclear to Atomic to Molecular to Material Sciences. The purpose of IRCBEP will be the following:

- To transfer into technology the experimental integral radiation information that can be used as part of the Validation and Verification (V & V) processes of *nuclear models* and code systems;
- To provide various schema to perform the V&V steps;
- The IAEA will task, organize institutions to construct several of these databases based on their own extensive V&V activities associated with *inventory and source term codes.*

The key elements of IRCBEP will be the following:

- Identify and compile a comprehensive set of experimental Integral Radiation Characterization Benchmark information: spectral indices, reaction rates, decay heat, RI, MACS, particle counts and fluxes, etc.,
- Evaluate the data, quantify, compute rank of their overall uncertainties, then compile the data into computer format for dissemination,
- Perform simulations of each experiment with the suitable code system and selected nuclear libraries and produce a database/repository of the necessary input files to repeat those simulations for other nuclear data libraries.

Sublet showed some examples for MACS (Maxwellian-averaged cross sections) temperature-dependent integral tests as well as "random walk uncertainty" in decay power at the Fusion Neutronics Source (FNS) at JAERI, Japan.

A CM on IRCBEP is scheduled to take place from 6–9 August 2018 in Vienna.
Note: Shortly after the INDC meeting the name of the project IRCBEP was changed into CoNDERC: Compilation of Nuclear Data Experiments for Radiation Characterisation.

3.5 Consultants Meeting on Nuclear Data Portal Web Tools

Sublet gave a presentation on the forthcoming CM on nuclear data portal web tools. The purpose of the meeting will be as follows:

- To first evaluate, assess the existent, the actual capabilities, successfully deployed tools to establish best practices, efficiency rating and user satisfaction;
- The second phase will be to step away from the actual frameworks with the intention to propose/test/deploy new tools: data analytics, visualization and physics imaging capable

of better answering the challenges faced in the modelling, access and testing of nuclear databases for the many applications that need them;

- To seek advice will from professional scientific portal developers.

An example was shown of a "short-lived fission pulse nuclide inventory" that gives a response-specific picture of fission-yield differences in decay-heat (DH) probing. Another example was an app that queries data, built with Plotly Dash in just under 100 lines of code.

The CM is scheduled to take place from 30 July – 1 August 2018 in Vienna.

3.6 International Nuclear Data Evaluation Network (INDEN)

Roberto Capote Noy gave a more in-depth presentation on INDEN. A TM on "Long-term International Collaboration to Improve Nuclear Data Evaluation and Evaluated Data Files" was held from 18–21 December 2017 at the IAEA Headquarters in Vienna. This was a follow-up of the CIELO project (OECD/NEA SG-40) which ran from 2011–2017 and to which the IAEA contributed. The objectives of the TM were as follows:

- To define the scope and goals of the new International Nuclear Data Evaluation Network (INDEN) and coordinate interaction among international evaluators, theoreticians and experimentalists;
- To define the evaluation process and technical interactions, which are as important as the evaluated files.

In the foreseeable future, the IAEA plans to hold a series of TM and CM within the INDEN collaboration. The following salient points from attendees have been singled out:

- One should be interested in both the processing as well as the results. The name of the project maybe doesn't capture this. Experimental data is the main source of improvement, even if not included in the title.
- There is a need for improvement and extension of covariance data (cross correlations, angular distributions, secondary neutron spectra from inelastic scattering, photon production data, and delayed neutron data).
- Continued work on CIELO (now INDEN) is justified by the success of the previous project. International collaboration is essential as it is the only way to bring together the required expertise.
    - A completely new solution to criticality was found, achieving good benchmark results with new evaluation.
    - Continued progress on main CIELO isotopes – work here is not done though. Covariances were late and are incomplete: there are significant differences between subject matter experts and what is in the files. There is also a need for more consensus.
    - Consider more nuclei: deuterium, other actinides (^{233}U, Am, Cm, ^{240}Pu, etc.)
- About the use of integral data in evaluations: One of the noticeable outcomes from the use of integral data constrains is the *reduction of uncertainties for integral quantities*, obtained from the reduction of the nuclear data uncertainties and from the rise of correlations between cross sections of the three main actinide isotopes. Another example was presented, using the "mcf benchmark" which includes water and the three main actinides. This leads to correlations between ^{16}O and the actinides, indicating that by

cleverly selecting integral quantities, one can correlate all important isotopes from a nuclear data library.

The aims and activities of INDEN are briefly summarized below:

- The network will be aimed at streamlining the evaluation activities, taking advantage of expertise in different laboratories in IAEA Member States;
- The activities would follow the pattern of the highly successful CIELO project, organized through the NEA Data Bank with a very strong technical contribution from IAEA research projects.
- The aim will be to define evaluation priorities, identify issues and discrepancies, and minimise duplication of work, except for the testing of different approaches to the evaluation;
- Team work and technical discussions to resolve issues are foreseen;
- Evaluated data files will be produced with a broad consensus that can be adopted fully or in parts by other Data Evaluation projects.

Roberto Capote Noy discussed the list of nuclides with highest priority, most of which have already been mentioned in Section 3.2. In addition are the Si isotopes (for pebble-bed reactors and fusion), Cr isotopes, Pb isotopes, Zr isotopes, the U-suite of isotopes, ^{237}Np and ^{241,243}Am.

The current plan for INDEN is to hold one large TM approximately every 3 years to set priorities and discuss results. Additional CMs will be held to focus on identified issues. The meetings planned for 2018 are as follows:

- CM #1: ”On the Resonance Parameter Evaluation of the Fissile Actinides” from 8–11 May 2018;
- CM #2: “R-matrix evaluation of light elements” from 30–31 August 2018;
- CM #3: “Issues and challenges in evaluation of structural materials” from 29 October – 1 November 2018;
- INDEN TM: “Intercomparison of evaluated covariances in recent libraries” (IAEA CIELO, ENDF/B-VIII.0, BROND-3.1, JEFF-3.3, JENDL-4) in November/December 2018.

The goals of the first CM, which was recently held, were to identify problems in the existing resolved resonance region (RRR)/unresolved resonance region (URR) evaluations of fissile actinides, to recommend new experimental programs targeted at improving the evaluations, and to define the timeline to solve the problems in the evaluations. Concerning the analysis of the RRR, the INDEN program aims to coordinate new evaluation works, specifically on ^{239}Pu and ^{233}U by using an evaluation strategy similar to the one use for ^{235}U and ^{238}U (in the CIELO project). This program also provides the opportunity to introduce in the evaluation procedure improved physical ingredients (TNC, PFNS, STD integrals, etc.). Discussions during the meeting were mainly focused on the ^{235}U, ^{233}U, ^{238}U, and ^{239}Pu isotopes. Connections with other important actinides, such as ^{240}Pu and ^{241}Pu, were not addressed. A new set of evaluations for fissile actinides are expected in the frame of the INDEN project and some recommendations for the evaluators are listed below:

- Use the latest version of the Thermal Neutron Constants (and thermal PFNS);
- For ^{235}U, minor issues were identified in the capture cross section below 10 eV and between 100 eV and 200 eV;
- For ^{239}Pu, investigate the possibility of using the (n,γf) reaction in the evaluation procedure and to calculate the neutron multiplicity on-the-fly.

Short-term actions for the next INDEN meeting are as follows:

- Collect ^{238}U data to improve the resonance parameters above 500 eV: transmission data from Harvey (1988), capture and fission data from n_TOF;
- Calculations of the self-shielding corrections for transmission data measured with samples of different thicknesses. Tantalum, Au and ^{238}U data are good candidates. The description of the proposed benchmarks will be shared amongst the participants of the meeting;
- Review the existing description of the URR, verify the consistency between MF=2 and MF=3 and propose solutions that better described the structures observed in the microscopic data, especially the broad intermediate structures observed in fission;
- Propose new sets of ^{239}Pu and ^{233}U RPs and plan benchmarking activities.

3.7 Proposal for CRP on Improving Fission Yields Data

Paraskevi Dimitriou gave a presentation on the proposed CRP on "Improving Fission Yield (FY) Data". In reactor physics, fission usually faces stiff competition from radiative capture in the same energy range. In the fuel UO_2, fission is on ^{235}U, while capture is on ^{238}U. The importance and treatment of the fission processes differ depending on the application. For reactor physics fission, the following are important:

- The energy release(s) and fission neutron maps during operation and shortly thereafter (accidental scenarios also);
- The fuel burnup rate, which is affected by the poisonous fission fragments that capture the neutrons, thus competing with the induction of further fissions.

A TM in 2016 on "Fission Yields: current status and perspectives in measurement, theory and evaluations" as well as NEA/WPEC SG-37 made several recommendations to improve the FY data, including new experiments, improvement of systematics, updating the compilation and evaluation of FY data, validation of evaluated FY using benchmark data on beta-delayed neutron emission, antineutrino spectra, decay heat, etc. The objective of the new CRP will be to provide updated FY data with associated uncertainties for the evaluated nuclear data libraries. The scope of the CRP will be as follows:

- Compilation of experimental data: all experimental data on independent FYs (IFY), cumulative FYs (CFY) and FY(E_n) to be incorporated in EXFOR (including experimental covariances);
- Evaluation: new evaluations at different E_n (thermal, fast, 14 MeV + more) with associated uncertainties (evaluation methodology, evaluation of FYs, uncertainties and correlations, covariances, formats, etc.);
- Theory: improve models and systematics based on new experimental data (include all-in

approaches that consider *E*-dependence, TKE, ν multiplicities, etc.);

- IFY vs CFY (consistency, propagation of uncertainties, updated decay data libraries);
- Validation: test new FY data against integral data, i.e. nubars, anti-neutrino spectra, decay heat, high burn-up rates, etc.;
- Actinides to be selected from priority list: ^{235,238}U, ^{239,241}Pu, ^{252}Cf;
- Dissemination, data retrieval and visualization.

The deliverables will be a searchable database of FY data with vizualisations. Plotly-based interactive data interrogation is already under development. Paraskevi Dimitriou showed several examples of the benefits in scrutinizing data with these tools.

The participating countries will be Belgium, China, Finland, France, Germany, India, Japan, Russia, Sweden, UK, and USA. The number of participants will be 10–15 with approximately 5 contracts foreseen. There will be 3 RCM and one CM, and the duration will be 5 years. The timeframe will be as follows:

- Preparation and submission of CRP proposal in the 4th quarter of 2018;
- Approval/clearance in the 1st quarter of 2019;
- Agreements/contracts between the 1st and 3rd quarters of 2019;
- The 1st RCM by the end of 2019.

4. NUCLEAR DATA NEEDS

A report was prepared by each national representative outlining their country's activities and needs for nuclear data, as well as a short summary and a brief oral presentation on specific nuclear data needs.

4.1 Individual Needs

4.1.1 Australia

Kibédi had prepared a report on nuclear data needs in Australia (INDC/P(18)-10).

- Low-energy Auger and conversion electron data to benchmark Auger yield calculations for targeted cancer treatment using medical isotopes and ion-induced metallic radiosensitization.
- Improved nuclear structure data on medical isotopes:
  - ^{103}Pd/^{103m}Rh (level scheme normalisation);
  - ^{119}Sb EC (multipole mixing ratio);
  - ^{135}La (multipole mixing ratio);
  - ^{195m}Pt (multipole mixing ratio, level scheme normalisation);
  - ^{201}Tl (multipole mixing ratio, level scheme normalisation).
- Improved atomic transition energies and rates from the multi-configuration Dirac-Fock model.
- General procedures and computer tools for uncertainty propagation using Monte Carlo techniques.

4.1.2 Brazil

Carlson had prepared a report on nuclear data activities and needs in Brazil (INDC/P(18)-01).

- Besides the Brazilian multipurpose reactor, CNEN is currently developing two light-water small modular reactors in collaboration with the Brazilian Navy: one to be used in a nuclear submarine and another to be used for power generation (25 MW) and simultaneous water desalination. The quantity and types of data of interest to these projects are potentially large. However, the details are unknown to me.
- Data for new medical radioisotope production are of extreme interest, to increase the range of products available in Brazil. At the moment, the available facilities restrict this interest to radioisotopes produced by proton-induced reactions in a low-energy cyclotron (up to at most 30 MeV). Higher-energy proton-induced reactions will become of interest if the IPEN institute in São Paulo succeeds in its bid to obtain a higher energy (possibly 70 MeV) cyclotron. Interest in reactor production of radioisotopes will resurge when the Brazilian multipurpose reactor begins operation.
- Nuclear data for particle production in proton-induced reactions in the range of the cosmic ray peak (about 200 to 600 MeV) as well as more consistent modeling of these reactions is of interest in the area of aerospace dosimetry. At present, the available models give different results (by a factor of about 2) for neutron and alpha production.
- More data on neutron production in deuteron-induced reactions are also of purely theoretical interest, at the moment, but could be of use in eventual applications of surrogate reactions.

4.1.3 China

Ge Zhigang had prepared a report on nuclear data needs in China (INDC/P(18)-1). Nuclear data requirements from different application fields in China obtained in the past few years are focused on the improvement of the quality of current data files (CENDL, ENDF, JEFF, JENDL, etc.), addressing the discrepancies between them for important materials, establishing covariance files for the important nuclei, improvement of the accuracy of data and extending the range of nuclei and neutron energies.

- Nuclear Data for General Purposes

  a) Actinides: ^{233}Pa, ^{232,233,234,234m}Th, ^{233,234,235,238}U, ^{237,238}Np, ^{239,240,241}Pu, ^{241,242,242m,243}Am, ^{242,243,244,245,246,247,248,250}Cm, ^{249,250}Bk, ^{249,250,251,252}Cf;

  b) Structural materials: ^{23}Na, ^{27}Al, ^{28,29,30}Si, ^{40}Ca, ^{0,50,51,52,53,54}Cr, ^{46,47,47,49,50}Ti, ^{0,54,55,56,57,58}Fe, ^{59}Co, ^{63,64,65,66}Cu, ^{90,91,92,93,94,95,96}Zr, ^{93,93m,94,95,95m,96}Nb, ^{204,206,207,208}Pb, ^{0,180,181,182,183,184,1} ^{85,186}W;

  c) Fission products: ^{155,157}Gd, ^{106}Ru, ^{125}Sb, ^{133,134}Cs, ^{142,143,144}Nd, ^{148,149,150,151,152}Sm, ^{154}Eu, ^{166}Er;

  d) Light nuclides: ^{6,7}Li, ^{9}Be, ^{12}C, ^{14,15}N, ^{16,17}O, ^{19}F;

  e) Thermal scattering law (TSL) data: D_2O, CF_2, Liquid Flibe, SiC.

- Nuclear Data for special purposes

  For the future development and application of nuclear energy, Sodium-cooled Fast Reactor (SFR), Thorium Molten Salt Reactor (TMSR), Very High Temperature Reactor (VHTR) as the Generation IV nuclear energy systems are being studied, and some demonstration and experimental facilities of them are under construction in China. In addition, some research activities on Accelerator Driven Sub-critical Systems (ADS) and fusion energy (the ITER international collaboration) are also being performing in China. The following requirements for nuclear data have been proposed:

  For the SFR project research purposes

  a) Covariances for materials in common use;

  b) KERMA, DPA;

  c) Lumped fission products: ^{232}Th, ^{233,235,238}U, ^{237}Np, ^{238,239,241,242}Pu, ^{241}Am, ^{244}Cm;

  d) Delayed gamma multiplicity and spectrum for gamma-heat deposition calculations: ^{238}U, ^{241}Pu;

  e) Photonuclear data: ^{9}Be, ^{12}C.

  For the TMSR project research purposes

  a) Covariances of cross sections for important nuclei, e.g. ^{232}Th, ^{233}U, ^{233}Pa;

  b) Photonuclear data: ^{6,7}Li, ^{9}Be, ^{12}C, ^{19}F;

  c) Fission product yields and covariances: ^{231,232,233}Pa, ^{242}Am.

  For the ADS project research purposes

  a) For the neutron files, the neutron energy should be extended up to 200 MeV. Most of these data in the current files were obtained by model calculations and differences between them should be eliminated.

  b) More complete proton data at energies higher than 1 GeV are needed, such as for ^{209}Pb,

^{209}Bi, etc., and there is still a need for improved accuracy.

c) The lack of evaluated data for higher energy neutron and proton-introduced reactions on actinides still need to be properly addressed.

d) The accuracy and validation of excited data for structure materials relevant to ADS purposes should be improved.

For fusion study purposes

Nuclear data for light nucleus structure materials are also needed for fusion studies. Although these data have been included in the FENDL and other evaluated data files, better accuracy and reliability are required, especially for deuterium and tritium.

- Other fields of application

For nuclear medicine and isotope production, more accurate information on nuclides, such as the half-lives, decay data, Q values, level schemes, etc., are also needed. This information is also very useful for education, fundamental research and nuclear technology applications.

For isotope production purposes

a) Isotopes produced by accelerators: Production of ^{11}C, ^{13}N, and more than 30 isotopes, which need improved excitation functions. Production yields of charged particle-induced reactions (p, d, t, etc.) leading to ^{14}N, ^{16}O, ^{24}Mg, ^{30}Si, ^{40}Ar, ^{50,52}Cr, ^{55}Mn, ^{57}Fe, ^{60}Ni, ^{63}Cu and up to ^{203}Tl.

b) Isotopes produced by reactors: Production of ^{3}H, ^{14}C, ^{24}Na, and more than 150 isotopes, and the targets containing ^{6}Li, ^{14}N, ^{24}Na, etc. Production yields of the (n,γ), (n,p), (n,α) reactions, including the cross sections, decay data, half-lives, etc.

For medical isotopes purposes

a) Currently widely-used isotopes: ^{32}P,^{89}Sr, ^{90}Y, ^{103}Pd, ^{125,131}I, ^{137}Cs, ^{153}Sm, ^{186}Re,^{188}Re, ^{192}Ir.

b) New medical isotopes: ^{47}Sc, ^{67}Cu, ^{91}Y, ^{103}Pd, ^{117m}Sn, ^{166}Ho, ^{186}Re, ^{195m}Pt, ^{213}Bi, ^{225}Ac.

c) Isotopes that will be increasingly used in future: ^{64}Cu, ^{67}Ga, ^{86}Y, ^{105}Rh, ^{111}In, ^{114m}In, ^{124}I, ^{149}Pm, ^{169}Yb, ^{177}Lu, ^{211}At, etc.

4.1.4 France

A presentation and a report on French nuclear data needs and activities (INDC/P(18)-09) were prepared by Saint Jean.

French nuclear data needs are coming mainly from CEA, CNRS and IRSN physicists working on nuclear data evaluation, measurements, benchmarking, or directly from users of nuclear data. Physicists and engineers are involved in fission-related applications (reactors, fuel cycle, etc.), nuclear physics, astrophysics, medical applications, etc. The following needs are linked to experiments and theoretical activities:

Accurate and validated nuclear data are a crucial ingredient in various studies on nuclear system design and related fuel cycle (GEN 2, 3 and 4 concepts, in nominal and accidental conditions), experimental reactors (JHR, EOLE, MASURCA, CABRI, etc.) and naval propulsion reactors. Improvement of nuclear data precision, reduction of biases in simulation neutronic codes devoted to reactor applications is expected. In reactors, the energy range of interest (for neutron energy and related induced reactions) is from thermal energies up to several 10s of MeV.

- Microscopic/differential/integral measurements

  An improved knowledge of angular distributions is necessary for basic cross-section evaluation and the related nuclear reaction parameters (e.g. spin and parity of resonance, fission channels decorrelation). The impact is important for large-size cores (fast and thermal spectrum) as well as heterogeneous cores, where transport effects are crucial.

  Inelastic cross sections (and the related angular distributions) of major fuel components (^{235,238}U, ^{239,240,241}Pu) as well as some structural materials (such as Fe and MgO) are insufficiently known due to a lack of precise measurements; there are still inconsistencies in evaluated files (JEFF, ENDF, JENDL). These uncertainties and biases contribute highly to the neutronic parameter uncertainties for reactors.

  To validate evaluations in the resolved resonance region, time-of-flight experiments are needed in the temperature interval from a few K to 2000 K. Low-temperature measurements could disentangle the effects of the crystal lattice on the knowledge of resonance parameters for major isotopes (^{238}U, ^{239,240,241}Pu) and high-temperature measurements could validate models for resonant scattering.

  Capture measurements of fissile isotopes (especially for plutoniums) are still needed as these cross sections are major contributors to MoX-fuel-based reactors (fast and thermal).

  For (n,γ ,f) processes (models) and nu-bar(E), eta(E), alpha(E) new microscopic measurements in thermal and epithermal range for fissile nuclei are necessary to exhibit fluctuations on nu-bar as well as temperature effects on cross-section slopes (capture/fission).

  Thermal data (phonon spectrum, $S_{\alpha\beta}$) for various moderators and structural materials are crucial for a proper knowledge of the light water reactor spectrum. In addition, resonant scattering of heavy isotopes (^{238}U) was proved to be a first-order effect on reactivity of PWR/BWR reactors by having an induced effect on ^{238}U capture and thus ^{239}Pu build-up. Proper modelling of this effect is still a challenge when both resonant scattering and crystal lattice effects are taken into account. WPEC SG-42 was created during this time frame. It could be interesting to have an international and collaborative effort on molecular dynamics models as well as phonon spectrum measurements.

  In the unresolved resonance region, both innovative experiments (integral and microscopic) as well as headways in terms of nuclear model representations are needed even for well-known isotopes (uranium and plutonium).

  DPA data are important for fuel designs using innovative structural materials. Iron is important as well as other steel components (Cr, Ni, etc.). The conclusion of a CRP on such nuclear data as well as the proposition of a standard DPA procedure is welcome.

  Prompt neutron and gamma fission spectra and multiplicities are still of major interest for plant lifetime extension considerations as well as for nuclear heating and for large-size cores in terms of uncertainties on reactivity as well as power map tilts. Innovative experiments are needed. In particular, for induced neutron energies between 1 keV and a few MeV only very few experimental results are available. Furthermore, experimental uncertainties are very important for the low and high-energy parts of spectra. Breakthroughs in terms of experimental devices are needed.

  For challenging nuclear models, global fission experiments are needed, such as fission yields with neutron prompt spectra and multiplicities, cross sections/fission yields, as proposed by FALSTAFF@NFS at GANIL, FIPPS at ILL and ChiNu in the United States.

Better fission yields (for Residual Power and Reactivity loss with burn-up) measurements are needed at different energy ranges: for the time being, most data are coming from thermal experiments – the keV and MeV region are of interest for fast reactors (NFS might give a solution in the higher-energy region.)

- Structure data and basic nuclear physics

  Efforts on nuclear structure data are needed for:

  - The interpretation of existing and future inelastic cross sections for heavy isotopes. They appear to be a major source of uncertainties (lack of knowledge).
  - Neutrino studies using nuclear reactors or fuel components as sources: need for precise beta and antineutrino spectra. A *collaborative international effort* should continue. Specialists of beta-spectrum calculations as well as experimentalists may contribute towards an *evaluated database*.

  This effort is related to basic compound nucleus physics (level densities, spin densities, etc.), gamma and x-ray intensities for dosimetry analysis, beta spectra, etc. Furthermore, decay-data evaluation databases as an international effort could be pursued as decay-data specialists are lacking.

- Theoretical/models needs

  For fission yields and neutron/gamma multiplicities and spectra, in terms of nuclear models, there is a necessity to have an overview of the state-of-the-art in evaluation and related codes (GEF, FIFRELIN, SPY, Moller propositions, etc.) by a *dedicated international effort*.

  From a general point of view, low-energy nuclear fission breakthroughs in terms of theoretical approaches are needed. The calculation of fission barriers as well as their penetrability factors is based on approximations related to phenomenological theories. Progress is needed and the international experts should collaborate to estimate the state-of-the-art, the potential issues (theoretical as well as experimental) and some hints of what could be feasible in a short/mid/long term.

  Surrogate-reaction measurements (aiming at producing a targeted compound nucleus by other entrance channels than the neutron) exhibit difficulties in terms of theoretical interpretation (P_f, P_γ) due to spin/parity distribution issues. This activity may be part of the previous general physics issue or could be fruitfully discussed in dedicated meetings.

- Uncertainties

  Uncertainties for all nuclear data are expected. In this framework, various issues need to be addressed:

  - Full energy range covariances → correlation between different energy ranges: *bridging the gap between thermal and continuum range*.
  - Multi-observable correlations (spectra/multiplicities/cross sections, etc.)
  - Incapacity of phenomenological models to reproduce experimental results.

- Specific Evaluation

  Photofission evaluated data of neptunium, uranium and plutonium are also very important in this field as well as for fuel non-intrusive inspection issues.

- Miscellaneous

  In addition, various generic needs are reported regarding the status of existing zero-power reactors (ZPRs) and their abilities for proposing analytic experiments. (One may think of new integral experiments for inelastic and elastic cross section of iron, uranium and plutonium.)

  Furthermore, there is a real concern related to the shortage of international radioisotope production capabilities for medical diagnostics. Also, for nuclear medicine, emergent radioisotopes are studied and a need for their related decay data is reported.

  Lastly, a general concern was expressed regarding the lack of young physicists working in the nuclear data area.

4.1.5 Germany

An extensive report entitled "Progress Report on Nuclear Data Research in The Federal Republic of Germany for the Period 2016−2018" (INDC/P(18)-05) was compiled by Fischer as a working document to the Committee. Various German research institutions are active in the fields of fission and fusion reactor technology, accelerator facilities including spallation and material irradiation neutron sources, medical physics and astrophysics, as reported in the 2016−2018 progress report. The related activities include nuclear data evaluations with a focus on the needs for fusion technology and accelerator applications (KIT), and, in the experimental field, measurements of neutron cross-section data and fundamental nuclear properties (HZDR, Dresden-Rossendorf; FZJ, Jülich; Goethe University Frankfurt; PTB, Braunschweig).

- Fission reactor technology

  Germany is participating in the JEFF project of the OECD where most data needs for fission reactor applications are addressed. There are no specific requests to the NDS at this time. It has to be pointed out, however, that Germany is active in the decommissioning of nuclear facilities where specific nuclear data needs related to the activation of reactor components may arise. Any efforts by the NDS in this field will be welcome.

- Fusion reactor technology

  Germany is participating in the European programme for the development of fusion nuclear data, which is now conducted within the PPPT (Power Plant Physics and Technology) programme of the EUROfusion consortium. There is also a close cooperation with the JEFF project, to which nuclear data evaluations are provided, both for the general purpose neutron data library as well as specific sub-libraries such as the JEFF-3.3 radiation damage library.

  Germany has actively participated in the FENDL-3 project at the IAEA, which has highest importance to fusion including ITER and the IFMIF/DONES neutron source which is considered of high priority in the European fusion programme. In addition to the regular revisions and corrections applied to the neutron data library, it is recommended to further improve the sub-libraries on neutron, proton and deuteron-induced activation reaction data.

  There is also great interest in the results of the CRP conducted on the radiation damage models and data, providing advanced data for assessing the behavior of materials under

irradiation at high neutron fluences, as required for the IFMIF/DONES neutron source. Continued efforts at the NDS to provide reference data for damage calculations would be welcome.

- Fundamental nuclear properties

  The ongoing and planned activities related to the RIPL database (e.g. CRPs on photon strength functions and fission parameters) are very much supported as they lead to improvements in nuclear reaction models (codes TALYS, EMPIRE, GEF, etc.) that are of general relevance for nuclear applications in science and technology. In the short-term future, the knowledge of double-differential cross sections for light charged particles will be essential in assessing the risk of secondary tumors in particle radiation therapy.

4.1.6 Hungary

Tárkányi had prepared a report on nuclear data activities in Hungary (INDC/P(18)-02) that contains the following needs summary:

- Upgrading NUDAT for missing isotopes;
- Upgrade of earlier evaluations on nuclear reactions for production of medical isotopes.

4.1.7 Japan

Iwamoto had prepared a report on nuclear data activities and needs in Japan (INDC/P(18)-04). Nuclear data needs related to nuclear energy are listed below.

- ADS:
  - Neutron cross sections of ^{15}N, Fe, Pb, Bi, Pu, Am and Cm;
  - Fission spectrum of Pu, Am and Cm;
  - Covariance of isomeric transition ratio for ^{241}Am neutron capture cross section.
- LWR:
  - Neutron cross sections and covariances of actinides (U, Np, Pu, Am, Cm) and neutron absorber (Gd, Ag, In, Cd, W) to improve k_{eff} and Cm production;
  - Activation cross sections of ^{177}Hf;
  - Resonance parameters of ^{181}Ta.
- Fusion and shielding:
  - Covariance data of H, Li, Be, F, Si, Cr, Ti, Fe, Cu, Pb, W, Nb, Sn;
  - Gamma-ray emission and recoil spectra for all nuclei for estimation of KERMA factors.

4.1.8 Republic of Korea

Lee had prepared a progress report on nuclear data needs in Korea (INDC/P(18)-12). Facing a phase-out of nuclear energy by the new government since May 2017, Korea is reallocating its nationwide nuclear R&D fund. Major changes are in the fields of the sodium-cooled fast reactor (SFR) and the pyro-process where their resources are requested to shrink to an optimized level, while keeping core technology R&D. On the other hand, the safety of existing nuclear power plants (NPP), the decommissioning of shutdown NPPs, the management of spent nuclear fuel

(SNF), and radiation applications are the main focus areas.

- *SNF management* has been, and will be one of the national high-priority problems to cope with since the number of NPPs to be shutdown starts to increase sharply in several tens of years. Budget decreases in SFR and pyro projects deepens this issue. A challenging proposal is under review to precisely predict the pellet-wise discharge burnups in SNF assemblies through an ultra-fine grid numerical model with highly reliable M&S and nuclear data. Target accuracies of the isotopic densities in SNF are set, and corresponding uncertainties of the neutron nuclear data as well as fission yields and decay data of actinides and fission products are being estimated.
- Nuclear data needs in Korea are still mostly from the field of the *SFR linked with the pyro-process* despite the shrinking situation. The SFR project is at the stage of the prototype design, and needs to quantify the cross-section uncertainties in the validation and verification of the neutronics calculations.
- Due to the limitation of the cross sections and the covariance data in their base library ENDF/B-VII, the *SFR neutronics team* are performing a series of integral benchmark experiments in BFS of IPPE to validate key design parameters. Throughout these benchmark analyses, not only the actinides, but also sodium and iron isotopes cross sections have been found to be highly sensitive to the quantified uncertainty, and need to be improved accordingly.
- The Korean *ITER neutronics team* requires reliable fast neutron nuclear data of the key materials for its neutronics performance, shielding design and activation analyses. The ITER neutronics team mainly uses the FENDL 2.1 library implemented in MCNPX 2.5 while the KAERI nuclear data center is improving the nuclear data of some key structural isotopes in parallel.

4.1.9 Russian Federation

A nuclear data needs summary was received from Khryachkov (INDC/P(18)-03).

- Improvement of neutron cross section standards. Prompt neutron spectra for ^{252}Cf(sf), and cross section for the ^{6}Li(n,t) and ^{10}B(n,α) reactions.
- Supporting of EXFOR database.
- Gas accumulation in nitride, carbide and oxide fuel ((n,p) and (n,α) reactions for ^{16}O, ^{14}N and ^{12}C).
- Gas accumulation in structural materials ((n,p) and (n,α) reactions for Fe, Cr and Ni isotopes).
- The reaction ^{209}Bi(n, γ)^{210}Po with isomer yield branching for E_n < 20 MeV.
- Production of ^{14}C in the FB reactors (^{14}N(n,p), ^{13}C(n,γ), ^{17}O(n,α) reactions).
- The FBR with lead and Pb-Bi coolants. The (n,γ), (n,inl) reactions cross sections for E_n < 2 MeV (^{204}Pb, ^{206,207,208,209}Bi).
- The (n,el), (n,inl) reactions cross sections for E_n <4 MeV (^{23}Na, ^{56}Fe) for FBR reactivity calculations.
- Fission neutron spectrum, average neutron energy for intercomparison of microscopic and integral data. The shape of the spectrum in the region of low energies of prompt

fission neutrons is badly known. PFNS shape measurements are needed in the energy range $10 < E_n < 500$ keV for thermal incident neutrons.

- The total delayed neutron yield, the relative abundances of delayed neutrons and half-lives of their precursors in 6- and 8-groups presentation, the energy spectra of delayed neutrons in 6- and 8-groups presentation, are needed.
- The energy dependence of the total delayed neutron yield for major and minor actinides.

4.1.10 South Africa

Steyn submitted a report on nuclear data activities in South Africa (INDC/P(18)-06) as received from the Radioactivity Standards Laboratory of the National Metrology Institute of South Africa (NMISA), the South African Nuclear Energy Corporation (Necsa) and iThemba LABS. Specific needs were only expressed by one group. No specific requests on nuclear data needs were received.

4.1.11 United Kingdom

Gilbert had prepared a report on nuclear data activities and needs in the UK (INDC/P(18)-08).

- Fusion nuclear data
  - UKAEA/CCFE and Europe in general fully embraced TENDL, but some things have been lost from historical fusion-specific libraries, e.g. $^{12}C(n,n2\alpha)\alpha$ channel that has significant (experimentally measured) cross section at 14 MeV.
  - Two-way communication required with TENDL developers to make improvements.
- Nuclear data for alpha-induced reactions

  Strong interest exists for fusion in analysis of a potential alternative integral plasma diagnostic:
  - "Alpha-loss activation foils";
  - Foils exposed to the alpha particles emitted from the plasma during reactor operation;
  - Subsequent gamma spectroscopy of these activated foils could be used to calculate the corresponding alpha (and hence neutron) output;
  - Alpha-induced gamma signals must be distinguishable from neutron-induced ones;
  - Limited data on alpha reactions, particularly in the 3.5 MeV range of fusion-alphas.

  A project in this area should also be of interest to the fission community:
  - Significant neutron dose from spent fuel arises from alpha particles emitted from U, Pu, Am, Cm interacting with light elements in the fuel.
- Improving predictions for accident tolerant fuels (and cladding)

  A UK project identified deficiencies in previous versions of JEFF and ENDF/B libraries:
  - e.g. for ^{12}C, ^{13}C, ^{18}O, ^{180m}Ta, etc., especially for activation calculations;
  - More recent libraries (JEFF-3.3, TENDL-2017, ENF/B-VIII) correct this (data included);

- but validation is still required.

- Views from outgoing UKNSF chair (Alan Nichols)

  New activities on Fission yields:

  - Nothing for more than 10 years? (IAEA STI/PUB/1286);
  - FY database initiative – IAEA CRP – to re-engage a new generation of specialists (work on previous FY CRP was almost 20 years ago).

  Follow-up CRP to recently ended CRP on cross-section measurements:

  - Further reactions need to be quantified (INDC(NDS)-0535 & -0596);
  - Particular interest in measurements for reactions relevant to nuclear medicine;
  - "Draft Case for IAEA-CRP Improvements in Nuclear Data of Medical Radionuclides"- lists many reactions!

  Further work on TAGS measurements:

  - Particularly gamma-singles and gamma-gamma coincidence measurements.

4.1.12 United States of America

M. Herman had prepared a report on US nuclear data needs (INDC/P(18)-013).

Specific Data Needs

- An extended and very detailed list of US Nuclear Data needs was reported in the previous INDC report. This list has been compiled as the outcome of the Berkeley workshop on nuclear data needs and it remains still valid. A large number of nuclides for various applications, including many for isotope production and medical applications, remain a high priority.

General Data Needs

- The US appreciates continuing RIPL activities that largely impact model code development at US facilities, especially on Empire at BNL, CoH/CGMF at LANL, and FREYA at LLNL and LBNL. This is particularly important for reducing uncertainties in the Hauser-Feshbach code predictions, which are widely used in nuclear data evaluation.

- The US holds high regard for IAEA/NDS support of data processing capabilities, NJOY and Fudge, in connection with the new GNDS data format and quality of integral benchmark calculations.

- The US fully supports the IAEA/NDS initiative to maintain the international evaluation cooperation efforts (INDEN) as a collaborative effort with the NEA. Organizing focused meetings on a regular basis is preferred.

- The US strongly supports development of EXFOR and ENSDF. They are crucial resources for nuclear science and technology in the US.

- The US is in urgent need of improved data on fission product yields (FPY). Soon there will be a new project on the FPY evaluation in the US and the foreseen CRP on FPY is

viewed in the US as a complementary activity. The synergy between the two undertakings will improve quality and extend the scope of the evaluated FPY data and is in the best interest of all parties.

4.1.13 Nuclear Data Services of the NEA Data Bank

Michel-Sendis gave a presentation on the activities of the Nuclear Data Services (NDS) section of the Nuclear Energy Agency (NEA) Data Bank. The NEA was established in 1958 as a forum for cooperation of the most advanced countries in the world. Currently it serves 33 Member Countries, has 7 standing technical committees, 71 working parties and expert groups and 22 international joint projects. The Data Bank was founded in 1978 and has 27 participating Member Countries and an annual budget of about € 3M. It has three main functions, namely Computer Programme Services (CPS), Nuclear Data Services (NDS) and Thermochemical Database (TDB). The Data Bank has a staff of 11 people with NDS allocated 3 official members of staff. The functions of the NDS are summarized below:

- Co-ordination and compilation of data:
  - Experimental nuclear data (EXFOR) through its participation as core member of the NRDC network;
  - Evaluated nuclear data for the JEFF nuclear data library, with responsibility for its assembly and release.
- Analysis and ND validation tools:
  - Developing testing, processing and benchmarking capabilities for nuclear data at DB (NDEC);
  - Developing databases with NEA-IT for dissemination of nuclear data (JANIS, collaborative repositories, support to other NEA divisions, etc.)
- Secretariat of all Nuclear Data activities at NEA:
  - JEFF & nuclear data (ND) weeks, NSC/WPEC, ND Training;
  - NDS website update and maintenance.

Three weeks a year are devoted to the support of ND meetings (two ND weeks + JEFF and one week for WPEC). The NDS partakes in the compilation of EXFOR data, mostly data coming from NEA DB countries. About 300 new and updated entries are contributed each year and the total contribution to date represents about 25% of the EXFOR database. The compilation effort is complex but well organized. It is a joint effort conducted in close cooperation with the IAEA. The workload is more than internal staff can handle and contractors/consultants are essential to maintain the current effort. Concerning the dissemination of nuclear data, JANIS provides access and visualization to all nuclear data libraries, and is continuously maintained and developed by the NEA DB. Michel-Sendis explained the new NEA tool NDEC in some detail. NDEC is an acronym for Nuclear Data Evaluation Cycle and is a platform developed by the NEA DB for ND analysis and verification. It has the following capabilities:

- Automate processing with different codes. Process using agreed upon inputs based on users' best practices;
- Link to NEA tools (JANIS, others in future);
- Help to rapidly identify potential problems in files and track down where and why;
- Provide a repeatable, standardized process for testing and benchmarking nuclear data.

It is foreseen that in the medium term, NDEC will process all major libraries. It currently facilitates the quality assurance (QA) process for JEFF-3.3.

The JEFF-3.3 library was released online in December 2017 and a major effort is underway on the development of JEFF-4, which will continue until 2021. With JEFF-4 the aim is to make a major qualitative leap forward but already the NDS is looking further. A Stakeholders Meeting is being planned, possibly for early 2019, to look into the 2024 and beyond horizon, to assess the reality of resources versus desired deliverables and to establish what the expectations of stakeholders are for future nuclear data libraries.

In his WPEC status update, Michel-Sendis explained its organization and working method. WPEC is composed of representatives of each participating file project plus subgroup coordinators. The participating files are ENDF, JEFF, JENDL, BROND, CENL and TENDL. There is a close collaboration with the IAEA Nuclear Data Section as well as with a number of non-NEA evaluation projects. The chair is rotated on a 2-yearly basis and is currently held by A. Plompen. The current WPEC mandate ends in June 2019. The WPEC holds an annual meeting with the following tasks/objectives:

- To review the progress in each project and related experimental activities;
- To identify common nuclear data issues and establish subgroups to address these issues;
- To review the progress of subgroups.

Since its inception, the WPEC has established two long-term expert groups (EG) and 43 short-term subgroups (SG). The expert groups comprise the "High Priority Request List" (WPEC EG/HPRL) and "Recommended Definition of a General Nuclear Database Structure" (WPEC EG/GNDS). Currently five subgroups are complete and/or closing (SG-37 → SG-41), two are ongoing (SG-42 and SG-43), three proposals were made in 2017 (SG-44 → SG-46) and two in 2018 for new projects (SG-47 and SG-48). The EGs and current SGs (ongoing and proposed) are briefly discussed below.

- WPEC EG/HPRL reviews requests for nuclear data improvement. It has an extended mandate until 2020 which includes two deliverables, namely
    - A report on the status of all requests;
    - An up-to-date online version of the HPRL.

  A new classification scheme will segment active, upcoming and archived entries as well as the way to change and/or update entries.
- WPEC EG/GNDS has a mandate to establish an international body to endorse, promote and maintain the new nuclear data structure as the future standard. A recent adjustment of its mandate includes two deliverables:
    - Release of GNDS with periodic updates;
    - To choose a collaborative platform and establish practices to maintain and discuss recommended definitions.

  Remarkable success was achieved, built on SG-38 and in parallel with SG-43. CIELO and ENDF/B-VIII.0 were distributed with GND formats. There is an active development of codes and a *de facto* standard set by the LLNL FUDGE code. Cross-collaboration with e.g. SG-42 yields continuous improvement/extension to meet the demands of users and evaluators.

- WPEC SG-40, "Collaborative International Evaluated Library Organization (CIELO)", focused on two main objectives:
    - To bring together, as a pilot project, the world's experts on the evaluation of a subset of important nuclei, namely ^{235,238}U, ^{239}Pu, ^{56}Fe, ^{16}O and ^{1}H;
    - To make recommendations on improving the evaluation of S(α,β) + covariances.

  A final report is currently in draft form and will be published in 2018. The new evaluated files have been distributed and eight NDS publications (up to February 2018) were published as direct outcomes of the CIELO project.
- WPEC SG-42, "Thermal Scattering Kernel S(α,β): Measurement, Evaluation and Application", has to assess methodologies for generating S(α,β) and make recommendations for improving the evaluation of S(α,β) and associated covariances. Progress is being made on data evaluations, measurements, theory-measurements connections, benchmarks and covariance data. New *a priori* calculations show significant improvements. Parallel code development (FLASSH) for processing of more sophisticated data is continuing, which is not possible with standard codes such as NJOY. Some new evaluations for TSL have already been included in the most recent nuclear data libraries.
- WPEC SG-43, "Code infrastructure to support a modern general nuclear database (GND) structure", has the following tasks/objectives:
    - To define an interface (API) for reading/writing GNDS;
    - To develop checks to "validate" new evaluations;
    - To develop and share implementations.

  The current status includes FUDGE version 1.9, offering full GNDS functionality. There are also multiple parallel code development projects in the ENDF, JEFF and JENDL communities.
- WPEC SG-44, "Investigation of Covariance Data in General Purpose Nuclear Data Libraries", has the following main tasks:
    - To review existing covariances and methodologies;
    - To define a set of guidelines for covariance generation;
    - To generate a suite of examples for different aspects of nuclear data physics, with documentation for methods and data.
- WPEC SG-45, "Validation of Nuclear Data Libraries (VaNDaL) Project", has the following main tasks:
    - To collect simulation input decks from participants;
    - To draft prototype QA standards for input decks;
    - To establish QA input suites;
    - To generate automated tools for execution of simulations;
    - The release of outputs to the nuclear data community.

  The community has responded with strong support for this project. A requirement for a repository system with universal subgroup access has been identified.

- WPEC SG-46, "Efficient and Effective Use of Integral Experiments for Nuclear Data Validation", has been proposed as a follow-up of SG-39. The SG-39 report is nearing completion and will be released in 2018. Activities during the year will include the selection of benchmarks and preliminary analyses to justify the selection.
- Proposed WPEC SG-47, "Use of Shielding Integral Benchmark Archive and Database for Nuclear Data Validation", will have as main outcomes the identification of benchmarks for nuclear data validation as well as strategies for nuclear data adjustments. It will be a collaborative effort with other subgroups and the Expert Group on Radiation Transport and Shielding (EGRTS). The focus will be on the use of nuclear data validation activities, providing valuable data for EGRTS activities and developing the capabilities of the 'user' nuclear data community to employ SINBAD and other shielding benchmarks for nuclear data evaluation. This proposal enjoys the support of the WPEC.
- Proposed WPEC SG-48, "CIELO: Computational methods for integration of integral and differential nuclear data insights & covariance advances, for improved international evaluated cross section databases". This proposal includes several aspects of the evaluation process, with an objective to automate and improve the full process with machine learning techniques. This project was received with considerable interest but was found to be very broad and currently without a detailed focus and deliverable. These views were shared by the JEFF, CENDL and JENDL representatives. A revised proposal was strongly encouraged as well as a proposal to consider a long-term EG instead of a SG.

Michel-Sendis concluded by mentioning the upcoming events concerning nuclear data that the NEA will either host or support, including the next WPEC Meeting that will be held at the NEA Headquarters from 24–28 June 2019 as well as several training courses. More information can be found on the NDS website: db-nds@oecd-nea.org.

4.2 Addressing the Needs for Nuclear Data

Arjan Koning thanked the Committee for their input and various recommendations. He reminded the Committee that the current biennium is 2018/2019 and the next one 2020/2021. The working groups were asked to discuss the issue on how to quantify the evaluation efforts. Evaluation knowledge should not disappear with the departure or retirement of the evaluator.

There was some discussion on the needs for ensuring reproducibility in evaluations and the storage of metadata relevant to each evaluation. M. Herman remarked that computer readable formats should be used for this purpose and not "difficult to read" formats such as LaTeX or "primitive" PDF files. If this culture is not developed, each new evaluator has to redevelop the wheel.

A request was accepted by all attendees that technical and/or specific issues on nuclear data needs should be diverted to the deliberations of the two Working Groups.

5. SUGGESTED ACTIVITIES IN THE FUTURE (2020−2021)

5.1 Future 2020 – 2021 programme

Arjan Koning gave a presentation on possible future activities and recommendations for future CRPs. In some ways, the 2020–2021 programme will be as usual. There will be the coordination of the NSDD and NRDS. EXFOR activities will continue the quest to record every measurement in history, at least for neutrons, photons and light charged particles. Compilation methods will be improved, e.g. by using searchable PDF files. There will be an expansion in the variety of methods providing EXFOR to users, e.g. web interfaces, further development of monitor/standard adjustment possibilities, and further development of large databases (including covariance data). Computational infrastructure will be adjusted to the nuclear data needs of Member States. The following specific items were highlighted:

- Continuation of INDEN;
- Continuation of CRP on fission yields;
- Finalization of the CRP on fission parameters for RIPL;
- Monitor and organize meetings on neutron standards;
- Develop nuclear databases for medical isotope production.

There will also be challenges that require innovative approaches and/or solutions:

- Further development of Apps, especially for medical isotope production;
- Standardized approach and format for experimental data evaluation
    - For structure (XUNDL → ENSDF ?);
    - For EXFOR: subjective quality database directly related to EXFOR subentries.
    - No final evaluation for ENDF and independent of model codes, GLS, GMA, etc. Pure experimental data evaluation, unless the remaining < 10 data evaluators in the world don't mind to reinvent the wheel forever;
    - Useful to all data library projects;
    - Quantifying knowledge;
    - Less interesting than inventing better physical models or performing a new measurement: very challenging to organize.
- After the RIPL fission CRP: establish convergence of model codes (EMPIRE, COH3, CCONE, TALYS) especially for actinides (finally).

Arjan Koning concluded by mentioning statistical verification and validation of databases and the need for global quality scoring.

During the discussion, Paraskevi Dimitriou commented that the gamma-ray strength function project will feed into RIPL. Future IRDFF activities may include a possible extension to higher energies. M. Herman commented that INDEN is the first new network in 30–40 years and needs to be properly advertised, and ways should be found to invite select members to the network.

6. ANY OTHER BUSINESS

6.1 Workshops, Symposia and Conferences

- 4th International Conference on Theoretical and Experimental Studies in Nuclear Applications and Technology (TESNAT 2018), Antalya, Turkey, 20–22 April 2018;
- The Physics of Reactors Conference (PHYSOR 2018), Cancun, Mexico, 22–26 April 2018;
- 9th International Particle Accelerator Conference (IPAC'18), Vancouver, Canada, 29 April – 4 May 2018;
- 3rd Nuclear Science Summer School (NS3), East Lansing, MI, United States, 13–19 May 2018;
- 14th Nordic Meeting on Nuclear Physics, Longyearbyen, Spitsbergen, Norway, 22–25 May 2018;
- XV Seminar on Software for Nuclear, Subnuclear and Applied Physics, Alghero, Sardegna, Italy, 27 May – 1 June 2018;
- 26th International Seminar on Interaction of Neutrons with Nuclei (ISINN-26), Xían, China, 28 May–1 June 2018;
- NuPECC Meeting, Oslo, Norway, 15–16 June 2018;
- Computer Simulation of Radiation Effects in Solids Conference (COSIRES), Shanghai, China, 18–22 June 2018;
- 15th International Conference on Nuclei in the Cosmos (NIC-XV 2018), Laboratori Nazionali del Gran Sasso, Assergi, Italy, 24–29 June 2018;
- International Conference on Atomic and Nuclear Physics, Osaka, Japan, 23–25 July 2018;
- Nuclear Structure Conference 2018, East Lansing, MI, United States, 5–10 August 2018;
- Zakopane Conference on Nuclear Physics 2018 "Extremes of the Nuclear Landscape", Zakopane, Poland, 26 August – 2 September 2018;
- IX International Symposium on Exotic Nuclei (EXON-2018), Petrozavodsk, Russia, 10–15 September 2018;
- XI International Conference on Nuclear Structure Properties, Trabzon, Turkey, 12–14 September 2018;
- 23rd Topical Meeting on the Technology of Fusion Energy (TOFE 2018), ANS Winter Meeting and Nuclear Technology Expo, Orlando, Florida, United States, 11–15 November 2018;
- 27th International Conference Nuclear Energy for New Europe (NENE2018), Jožef Stefan Institute, Nuclear Training Centre (ICJT), Portorož, Slovenia, 10–13 September 2018;
- 30th Symposium on Fusion Technology (SOFT-2018), Giardini Naxos, Sicily, Italy, 16–21 September 2018;
- 8th Workshop on Elastic and Inelastic Neutron Scattering (WINS 2018), Predeal, Romania, 19–21 September 2018;

- NUSTAR week 2018, Milano, Italy, 24–28 September 2018;
- 6t^{h} International Workshop on Compound-Nuclear Reactions and Related Topics (CNR*18), Berkeley, USA, 24–28 September 2018;
- GANIL Community meeting “Avenues for GANIL: Today and Tomorrow”, Caen, France, 8–12 October 2018;
- 5th International Workshop on Nuclear Data Evaluation for Reactor Applications (WONDER-2018), Aix-en-Provence, France, 8 – 12 October 2018;
- Joint ICTP-IAEA Workshop on Nuclear Structure and Decay Data: Experiment, Theory and Evaluation, Trieste, Italy, 15–26 October 2018;
- 2nd International Conference on Radioanalytical and Nuclear Chemistry (RANC 2019), Budapest, Hungary, 5–10 May 2019;
- 13th European Conference on Accelerators in Applied Research and Technology (ECAART13), Split, Croatia, 5–10 May 2019;
- ND2019 International Conference on Nuclear Data for Science and Technology, Beijing, China, 19–24 May 2019;
- International Conference on Mathematics and Computational Methods Applied to Nuclear Science and Engineering (M&C 2019), Portland, OR, United States, 25–29 August 2019.
- 14th International Symposium on Fusion Nuclear Technology (ISFNT14), Budapest, Hungary, 22–27 September 2019.

7. FINAL REPORTS AND RECOMMENDATIONS

The final reports of the two Working Groups, given at the beginning of this document, refer. During the final plenary session of the Committee, both Working Groups tabled their reports. During the discussions, only a few minor corrections were made as there were no substantive disagreements and/or additional comments.

The Plenary meeting accepted all the recommendations of the two Working Groups. M. Herman thanked the Working Groups, chairmen and secretaries for their reports. He also thanked the NDS staff for their high-quality work and the smooth organization of the meeting. The NDS continues to develop and maintain high-quality products and he is excited about the suggestions for new CRPs and other projects. M. Herman also thanked the INDC members, advisors and observers for their contributions to the meeting.

Arjan Koning thanked the INDC members, advisors, observers and NDS staff for their participation and wished everybody a safe journey home.

The Chairman closed the meeting.

Appendix 1

International Atomic Energy Agency

32nd International Nuclear Data Committee Meeting

IAEA Headquarters
Vienna, Austria

18−21 June 2018

AGENDA

Monday, 18 June

09:30-10:30 **A Opening** *Plenary, C0229*

Opening statements – Mr A. Malavasi, DDG-NA
Ms M. Venkatesh, DIR-NAPC

Announcements

Statements of INDC members

Adoption of Agenda

Adoption of Minutes of the 31th INDC Meeting (INDC/P(16)-16)

Actions from previous meeting

10:30-10:45 *Coffee Break*

10:45–12:00 **B Section Review (2016-2017)** *Plenary, C0229*

B.1 Global Overview of the Nuclear Data Section *Arjan Koning*

B.2 Staffing and Budget *Arjan Koning*

12:00–13:00 *Lunch*

13:00–17:00 B.3 Nuclear Data Section Activities (2016-2017)

Network coordination (NRDC) *Naohiko Otsuka*

Network coordination (NSDD) *Paraskevi Dimitriou*

Atomic and molecular data	*Kalle Heinola*
Nuclear data development (CRPs and DDPs)	*Roberto Capote Noy*
Training and workshops (ICTP, Trieste)	*Roberto Capote Noy*
Computer operations	*Arjan Koning*
User services for nuclear reaction data	*Viktor Zerkin*
Data dissemination	*Viktor Zerkin*
Visualization	*Marco Verpelli*

15:00–15:30 *Coffee Break*

Tuesday, 19 June

09:00–09:30	**C 2018-2019 Programme**	*Plenary, C0229*
	C.1 Review	*Arjan Koning*
	C.2 INDEN: International Nuclear Data Evaluation Network	*Roberto Capote Noy*
	C.3 IRCBEP	*Jean Christophe Sublet*
	C.4 Nuclear Data web portal	*Jean Christophe Sublet*
	C.5 New CRP on fission yields	*Paraskevi Dimitriou*
09:30–11:30	**D Nuclear Data Needs**	*Plenary, C0229*
	D.1 INDC members: statements on data needs	
	D.2 Activities of the NDS at NEA Data Bank	*Michel-Sendis*
	D.3 Addressing needs for nuclear data development–comments	*NDS staff*
10:00–10:15	*Coffee Break*	
11:30–12:30	**E Suggested Activities for Future (2020-2021)**	*Plenary, C0229*
	E.1 Future Activities	*Arjan Koning*
	E.2 Workshops and Conferences	*INDC members*
12:30–13:30	*Lunch*	
13:30–17:30	E.3 Nuclear Data Development (WG1)	*C0229*
	E.4 Data Dissemination, International Co-ordination and Training (WG2)	*C0237*
15:00–15:30	*Coffee Break*	
19:00	*INDC Social Event – Restaurant Rembetiko*	

Wednesday, 20 June

09:00	E.5	Nuclear Data Development (WG1)	*C0229*
all day	E.6	Data Dissemination, International Coordination and Training (WG2)	*C0237*
	F	**Production of Final Report/Recommendations**	
	F.1	Discussion of area conclusions	
	F.2	Drafting of WG reports	

Thursday, 21 June

09:0012:00	**G**	**Summary and Concluding Activities**	*Plenary, C0229*
	G.1	Presentation and discussion of WG reports	
	G.2	INDC Membership (outgoing, new and renewals)	
	G.3	Other business – date of 33rd INDC Meeting	
	G.4	Adjournment	

Appendix 2

International Atomic Energy Agency

32nd International Nuclear Data Committee Meeting

IAEA Headquarters, Vienna, Austria

18−21 June 2018

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(in addition to NDS Staff)

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Appendix 3

TERMS OF REFERENCE OF THE INTERNATIONAL NUCLEAR DATA COMMITTEE

FUNCTIONS

1. The International Nuclear Data Committee (INDC) will advise the IAEA on its programmatic activities in the field of nuclear data for applications. In particular, it will:

(a) provide feedback on current activities in the IAEA's subprogramme on Nuclear and Atomic Data ("the subprogramme") in order to ensure that the important data needs of Member States are being met;

(b) make specific recommendations regarding future programmatic activities of the IAEA in this field and for the efficient and effective implementation of those activities; and

(c) facilitate the exchange of information on nuclear data programmes in Member States.

MEMBERSHIP

2. Members of the INDC will be appointed by the Deputy Director General responsible for the subprogramme, in consultation with their Governments, for an initial term of 4 years, ~~with a maximum of two renewals foreseen.~~ which can be renewed up to a maximum of 12 years.

3. The INDC will include a maximum of 15 members, each selected from a Member State which maintains a major nuclear data programme, which provides particular technical expertise, or which offers a needed regional perspective.

4. Each member of the Committee will be a senior expert in the field of nuclear data having broad responsibilities for the direction of nuclear data programmes or widely recognized for accomplishments in this field.

5. Each member of INDC will be requested to serve on the Committee in his personal capacity and will not represent his or her Government.

CHAIRMAN

6. The Chairman of INDC will be selected from Committee members, after consultations, and appointed by the Deputy Director General responsible for the subprogramme.

SECRETARIAT AND ADMINISTRATIVE SUPPORT

7. The IAEA Secretariat will provide administrative support for INDC meetings. A member of the IAEA's Secretariat will also serve as Scientific Secretary of the INDC, to assist the INDC in its work and to facilitate communications between the Committee and the Secretariat.

METHODS OF WORK

8. The Committee will determine its own methods of work.

9. The Committee will consider issues submitted by the Deputy Director General responsible for the subprogramme, and by its members.

10. Observers from Member States or other international organizations may be invited by the Deputy Director General responsible for the subprogramme to attend INDC meetings, or particular sessions during such meetings.

11. The Deputy Director General responsible for the subprogramme and representatives nominated by him will be entitled to participate in the meetings of INDC.

12. The INDC will record its recommendations in a biennial report submitted to the Deputy Director General responsible for the subprogramme.

MEETINGS

13. The INDC will meet, normally in Vienna, at intervals of at least once every 2 years, with each meeting lasting up to 5 working days. Meetings will be conducted in English.

14. Members may be accompanied to INDC meetings by advisors.

15. All travel costs associated with the participation in INDC meetings of members, advisors and observers are expected to be borne by the respective sponsoring organizations. However, where possible, support will be provided by the IAEA for the participation of members from developing Member States.

Appendix 4

ACTIONS ARISING FROM 31st INDC MEETING

No.	Respondent	Action	Status
1	NDS	NDS should put an increased effort on the quality of libraries with activation cross sections, especially for protons and deuterons. It will also benefit WG1-1.1, medical isotopes production.	Not currently possible to pursue this idea.
2	NDS	Continue the efforts to develop a public code for R-matrix analysis for charged particles.	Successfully addressed.
3	NDS	Support international efforts to improve light-nuclide data, including relevant EXFOR compilation and integral experiments.	Ongoing
4	NDS	Remain involved in WPEC SG-42 on TSL.	Ongoing.
5	NDS	Consider a CRD on fission yields.	Successfully addressed.
6	NDS	Coordinate CIELO and define follow-up activities.	INDEN started. Activities ongoing.
7	NDS	Release a new IRDFF library.	Ongoing.
8	NDS	Resolve the issue of code distribution to non-OECD countries by the NEA.	Ongoing.
9	NDS	Extend the graphical capabilities for decay data.	Ongoing
10	NDS	Give more priority to the EXFOR compilation of photonuclear data.	Ongoing

Appendix 5

ACTIONS ARISING FROM 32nd INDC MEETING

No.	Respondent	Action
1	NDS	Support international efforts to improve light-nuclide data, including relevant EXFOR compilation and integral experiments.
2	NDS	Remain involved in WPEC SG-42 on TSL.
3	NDS	Release a new IRDFF library.
4	NDS	Resolve the issue of code distribution to non-OECD countries by the NEA.
5	NDS	Extend the graphical capabilities for decay data.
6	NDS	Give more priority to the EXFOR compilation of photonuclear data.
7	NDS	Make available the displacement damage cross-section data of the CRP
8	NDS	Investigate a new initiative on nuclear data for back end of the fuel cycle
9	NDS	Enlarge the output options of EXFOR regarding C5M, XC5 and covariance formats
10	NDS	Organize training workshop, possibly with ICTP, on nuclear data for multiscale materials modeling

Appendix 6

International Atomic Energy Agency

32nd International Nuclear Data Committee Meeting

18−21 June 2018

LIST OF WORKING PAPERS

(Also available online from http://www-nds.iaea.org/indc/)

No.	Author	Title
INDC/P(16)-16	G.F. Steyn	Minutes of the 31st Meeting of the International Nuclear Data Committee
INDC(NDS)-0756	J. Arjan Koning, R.Capote Noy	Report of the IAEA Nuclear Data Section to the International Nuclear Data Committee for the period January 2016–December 2017
INDC/P(18)-01	B.V. Carlson	Report on Brazilian Nuclear Data Needs and Activities
INDC/P(18)-02	F. Tárkányi	Progress Report on Nuclear Data Research in Institute for Nuclear Research, Hungarian Academy of Sciences (ATOMKI)
INDC/P(18)-03	V. Khryachkov	Report on the Russian Nuclear Data Needs and Activities
INDC/P(18)-04	O. Iwamoto	Recent Nuclear Data Needs and Activities in Japan
INDC/P(18)-05	U. Fischer	Progress Report on Nuclear Data Research in the Federal Republic of Germany for the Period 2016–2018
INDC/P(18)-06	G.F. Steyn	Nuclear Data Activities and Expressed Nuclear Data Needs in South Africa
INDC/P(18)-07	E. Gonzalez	Spanish Report on Nuclear Data Needs and Activities for the 32nd INDC Meeting in June 2018.
INDC/P(18)-08	M. Gilbert	Nuclear Data Efforts 2016–2017 and Future Interests/Needs (UK)
INDC/P(18)-09	C. De Saint Jean	Statement on French Nuclear Data Needs and Activities for the Period May 2016 – May 2018
INDC/P(18)-10	T. Kibédi	Nuclear Data Needs – Australia
INDC/P(18)-11	Ge Zhigang	Recent Nuclear Data Needs in China
INDC/P(18)-12	Y.-O. Lee	Nuclear Data Needs in Korea
INDC/P(18)-13	M. Herman	Nuclear Data Needs in the United States
INDC/P(18)-14	F. Cantargi, J.I. Márquez Damián	Progress Report of Nuclear Data Research in Argentina

Appendix 7

Work Programme Proposals

Proposals submitted and approved for joint ICTP-IAEA Workshops (2018-2019)

Joint ICTP-IAEA School and Workshop on Fundamental Methods for Atomic, Molecular and Materials Properties in Plasma Environments (2018/1)

Joint ICTP-IAEA Workshop on Nuclear Structure and Decay Data: Theory, Experiment and Evaluation (2018/2)

Joint ICTP-IAEA School on Atomic and Molecular Spectroscopy in Plasmas (2019/1)