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Inventory of Safeguards Software

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Nuclear Nonproliferation Science and Technology Center

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Japan Atomic Energy Agency

日本原子力研究開発機構

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Inventory of Safeguards Software

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The purpose of this survey activity will serve as a basis for determining what needs may exist in this arena for development of next-generation safeguards systems and approaches. 23 software tools are surveyed by JAEA and NMCC.
Exchanging information regarding existing software tools for safeguards and discussing about a next R&D program of developing a general-purpose safeguards tool should be beneficial to a safeguards system design and indispensable to evaluate a safeguards system for future nuclear fuel facilities.

Keywords: Next-generation Safeguards, Software Tool, Safeguards System

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This work has been performed as Phase I activities in Japan/US GNEP SGPPWG and based on JAEA/DOE PAS#03. And the summary of this work was presented at Symposia on Tools for Safeguards on Simulation and Modeling which was held Feb. 6-7, 2008, Washington DC.

*Nuclear Material Control Center

保障措置関連ソフトウエアの調査

日本原子力研究開発機構

核不拡散科学技術センター

鈴木 美寿、堀野 浩一*

（2008 年 5 月 16 日受理）

本調査の目的は、次世代の保障措置システム及び保障措置アプローチの開発を行う時に、本分野にどのようなソフトウエアに関するニーズが有るかを検討する際の基礎となる材料を提供するものである。（独）日本原子力研究開発機構及び（財）核物質管理センターによる本調査によって、２３のソフトウエアツールが在ることが分かった。

現在用いられているソフトウエアツールに関する情報交換を行うこと、及び、汎用の保障措置ソフトウエアツールに関する将来の研究開発計画について議論することは、保障措置システム設計に有益であり、また、将来の核燃料施設の保障措置システムを評価する上で必要不可欠のことである。

本調査は、日米間の GNEP 行動計画に基づく、保障措置・核物質防護ワーキンググループのフェーズⅠにおける研究協力の一環として、また、原子力機構と米国エネルギー省間の保障措置取り決めに基づくプログラムアクションシート No３の協力として実施した。本調査結果は、2008 年の２月に米国ワシントンで開催されたシミュレーション＆モデリング、保障措置に係るツールのシンポジウムにおいて発表された。

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1. Introduction

Under the Japan/US GNEP Action Plan, a new JAEA/DOE Program Action Sheet (PAS) 03 has been signed in Nov. 2007 and started as a firstly-collaborated activity in a GNEP phase I period. As US stated in the similar report on US side, numbered LA-UR-07-6991, the purpose of this activity will serve as a basis for determining what needs may exist in this arena for development of next-generation safeguards systems and approaches.

Exchanging information regarding existing software tools for safeguards and discussing about a next R&D program of developing a general-purpose safeguards tool should be beneficial to a safeguards system design and indispensable to evaluate a safeguards system for future nuclear fuel facilities.

2. The Inventory

The software in this inventory was developed and owned by JAEA and NMCC. The original purposes of the software are very diverse and those are used in a different way. Based on the classification decided by the US report, we will categorize the software as follows. One category includes software used primarily for local safeguards at domestic facilities and for a specific purpose such as safeguards evaluation. In this category, the software such as PROMAC-J, PFPF MC&A System, CNMAS, and most of the safeguards software, which are used for MC&A, safeguards inspection and reporting to internal safeguards authority and the IAEA.

The other broad category consists of software that is not primarily used for specific use, and is mainly used for a R&D activity to investigate future safeguards characteristics of advanced nuclear fuel cycle. And sometimes those are used to support and develop the internal safeguards. In this category, the software such as SANFCE, SEPHIS-J, MSPCA, FPGS90, and PHITS, and SPEEDI, that is used a risk evaluation originated by various PP threat.

The software are separated according to the format described in the US report, as Appendix 1., that includes typical information provide a glimpse of the overview of the software, Appendix 2., that are the source language, export restriction information, and the related publications, and Appendix 3, that more detail information as software description and safeguards applications are described.

3. Summary of Software

Twenty-three pieces of software were compiled for the inventory. The breakdown of software is shown in the table below.

Table 1. Inventory submissions by organization

	JAEA	NMCC	Total
# items	10	13	23

3.1 Types of Software

The software reported was assigned functional categories as the US report and summarized in the table below.

Table 2. Category assigned by submitter

Category	#
Data management & analysis	13
System analysis	1
Process simulation	5
Sensor response modeling	1
System design	1
Other	6

When broken out by Primary use as shown in Table 3.

Table 3. Inventory by Primary use

Primary use	#
Process simulation/modeling	4
Statistical analysis	1
Detector modeling	1
Material accounting	2
Physical protection	1
Data analysis	1
SG evaluation/risk assessment	13
Training	

3.2 Construction Details

The languages used to construct the software are different. Most of the R&D-purpose software is written in Fortran and C, and the other safeguards-evaluation software is PL/1, mainframe languages and database languages, SQL and Oracle.

Table 4. Languages used in inventories software

Language	#
Fortran 77	8
C	7
PL/1	2
Natural	5
Java	2
SQL, Oracle	6

Much of the code was written by Fortran and C in R&D-purpose software. Therefore the source code is available to modify, but it is not adapted to help the user to make an input data. Graphical and friendly user-interface is desired. On the contrary, the safeguards-purpose software is developed to be easily handled by the inspector at the real facilities and to be developed more efficiently. So it seems to have a user-friendly structure using various languages as Java, MS visual basic, etc. However, the safeguards-purpose software may not be usable to modify and connect to the other software to develop the future safeguards software.

3.3 Additional Consideration

Similarly as US colleague mentioned in the report, the R&D-purpose software listed form Japan side has been mostly developed over the last one or two decades. The present computational architecture is not reflected into the software, and objective-based and visualized-modeling techniques are not taken into a consideration. Moreover, commercial software is widely used in various industries and the material flow simulation in the reprocessing process is easily calculated using the well-known commercial software such as EXTEND. One drawback, however, is that the source program is not opened, so that the modification and/or integration with the other software is not simple.

4. Contacts

Inventory contacts are listed in Table. 5.

Table 5. Inventory contacts

Organization		Name	Software number
JAEA	NPSTC	Mitsutoshi Suzuki	1-10
NMCC	Planning Division	Koichi Horino	11-23

Appendix 1. Software by Primary Use

The designations in the Type column refer to the following list of software types:

a. System Design
b. System Analysis
c. Process Simulation
d. Sensor Response Modeling
e. Data Management & Analysis
f. Other, please explain

No	Tool Name	Brief description	Description	Primary use	Type
1	SANFCE	Process flow simulation, measurement & MUF calculation, statistical test evaluation	This system is a comprehensive MC&A Design and Effectiveness Evaluation System for Nuclear Fuel Cycle Facility. This system is composed of seven functional modules, as PROFR, EARTH, PROMAC, SADAC, MOON, SIMBC, and SPT.	Process Simulation	a,b,c
2	SEPHIS-J & MIXSET	Simulation of solvent extraction system	SEPHIS-J code was developed for inventory estimation of solvent extraction system of TRP. This code based on SEPHIS Mod 3 and PUBG code.	Data Analysis	e
3	PROMAC-J	NRTA software of TRP	The PROMAC-J system of NRTA data processing was developed for TRP (TASTEX project). This system is composed of data processing, calculation of material balance and statistical test.	Process Simulation	c
4	MSPCA	Process monitoring with multi-scale principle component analysis	MSPCA code is developed to investigate an applicability of multi-scale principle component analysis using wavelet decomposition to an advanced algorism for process monitoring. Both time information and frequency information have conserved even after the decomposition and those are used to investigate an abrupt and protracted diversion loss. Principle Component Analysis enable us to reduce a number of variables drastically.	Statistical Analysis	e

5	FPGS90	Fission products and actinides calculation	FPGS90 code is calculating the number of nuclides, decay heat and spectrum of emitted γ ray from fission products and nuclear fuel nuclides under various kinds of burn-up condition. The code has a function of processing a nuclear library from evaluated nuclear data file such as ENDF/B, JENDL, ENSDF.	Process Simulation (Reactor Physics)	c,f
6	SPEEDI & WSPEEDI	Meteorological Flow field Calculation	SPEEDI code system for prediction of environment dose from radioactive materials accidentally released from a nuclear plant has been developed to assist the organizations responsible for an emergency planning. WSPEEDI system is worldwide version SPEEDI.	Physical Protection	c,f
7	SRAC2006 (SRAC95)	Burn-up calculation	The SRAC is a system applicable to neutronics analysis of variety types. This system includes major neutron data libraries (JENDL, ENDFB, JEFF, etc), and integrates for neutron transport, diffusion calculation and collision probability method applicable cell calculation. The system covers production of effective microscopic and macroscopic group cross-sections, and static cell and core calculations including burn-up analysis.	Process Simulation (Reactor Physics)	c,f
8	PHITS	Monte Carlo calculation	PHITS system is the first general-purpose heavy ion transport Monte Carlo code over the incident energies from several MeV/nucleon to several GeV/nucleon. This system based on NMTC/JAM, JQMD code, SPAR code and MCNP code.	Detector modeling	d
9	PFPF MC&A System	Material Accounting	This system is developed at PFPF to operate various automated equipments and implement real time material accountancy. The systems are divided into three levels. First level is central control computer, and corrects and records measurement data (weighing data of the transfer container, DA data, etc.) as material accountancy information. And it also calculates amount of Pu, U, etc based on the measurement data. Every accountancy reports are made by this computer. Second level is process control computer and controls the process and transfer systems in each process area. Third level is equipment control computer and controls process equipment.	Material accounting	e

10	CNMAS	Material Accounting	This system makes the accountancy report of individual facility using a JAEA-wide database. In terms of keeping strict security control, the system is designed to be protected from any cyber threat.	Material accounting	e
11	σ_{MUF} calculation system	Nuclear Material Balance	To calculate σ_{MUF}, this system is composed of 3 parts; 1 to bring accountancy data(PIL and ICR) together, from data base and then manipulate and store them as new data 2 to manage the data manipulated in 1 3 to calculate σ_{MUF} using data in 2	Safeguards Evaluation	f
12	σ_{SRD} calculation system	Nuclear Material Balance	To calculateσ_{SRD} , this system is composed of 3 parts; 1 to bring accountancy data(PIL and ICR) together, from data base and then manipulate and store them as new data 2 to manage the data manipulated in 1 3 to calculate σ_{SRD} using data in 2	Safeguards Evaluation	f
13	IDMS (Inspection Data Management System)	Inspection Data Management	To manage the data related to inspection sample measurement including operator's declarations, inspector's DA or NDA results, this system includes all required functions to maintain measurement data	Safeguards Evaluation	f
14	IDAS (Inspection Data Analysis System)	Inspection Data Analysis	To calculate error estimates associated with operator's declarations or inspector's measurement(including DA and NDA), this system provides all required functions. The model of error estimation is "N=2 Measurement Method".	Safeguards Evaluation	f
15	MDRS (Measurement Data Reference System)	Database for IDMS	This system is specialized in the referring to the database built by IDMS.	Safeguards Evaluation	f
16	Inspection Data Management and Analysis System	Inspection Data Management	This system provides all functions included in IDMS, IDAS and MDRS; to maintain database and to calculate errors.	Safeguards Evaluation	f

17	Data Analysis System for 3 laboratory	Error Estimation of N=3 Model	This system is specialized in calculating error estimates of N=3 Model	Safeguards Evaluation	f
18	90(a),(b) Statement Management System	Report Management System	To manage the report of Statement on Safeguards Agreement 90(a) and (b), this system provides all required function to maintain to the database of the reports (including header information as well as problem description).	Safeguards Evaluation	f
19	PFPF NRTA Data Evaluation System	NRTA	To evaluate Data for NRTA declared by PFPF, this system provides statistical tools.	Safeguards Evaluation	f
20	TRP NRTA Data Evaluation System	NRTA	To evaluate Data for NRTA declared by TRP, this system provides statistical tools.	Safeguards Evaluation	f
21	RRP NRTA Data Evaluation System	NRTA	To evaluate Data for NRTA declared by RRP, this system provides statistical tools.	Safeguards Evaluation	f
22	Mail Box Data Processing System	Mail Box Data	To maintain and summarize Mail Box data for SNRI carried out in LEU Fabrications, this system provides all required functions.	Safeguards Evaluation	f
23	DAI : Data Analysis and Interpretation	Solution Monitoring Evaluation System	The software has been developed for analysis of process data , such as liquid level, density, temperature, etc. from the equipments of solution process, and then confirmation that the process is operated as declared.	Safeguards Evaluation	f

Appendix 2. Software Summary

The designations in the Type column refer to the following list of software types:

a. System Design
b. System Analysis
c. Process Simulation
d. Sensor Response Modeling
e. Data Management & Analysis
f. Other, please explain

No	Tool Name	Brief description	Primary use	Type	Language(s)	Export restrictions?	Documentations
1	SANFCE	Process flow simulation, measurement & MUF calculation, statistical test evaluation	System Design Systems Analysis Process Simulation	a,b,c	Fortran 77, C	No	Presentation Materials
2	SEPHIS-J & MIXSET	Simulation of solvent extraction system	Data Analysis	e	Fortran 77, C	No	Report Summary
3	PROMAC-J	NRTA software of TRP	Process Simulation	c	Fortran 77, C	No	Report Summary
4	MSPCA	Process monitoring with multi-scale principle component analysis	Data Analysis	e	Fortran 77	No	Paper1 Paper2
5	FPGS90	Fission products and actinides calculation	Process Simulation (Reactor Physics)	c,f	Fortran 77, C	No	Report Summary
6	SPEEDI & WSPEEDI	Meteorological Flow field Calculation	Physical Protection	c,f	Fortran 77, C	No	Report Summary
7	SRAC2006 (SRAC95)	Burn-up calculation	Process Simulation (Reactor Physics)	c,f	Fortran 77	No	Report Summary

8	PHITS	Monte Carlo calculation	Sensor response & modeling	d	Fortran 77, C	No	Paper1 Paper2
9	PFPF MC&A System	Nuclear Material Data Management	Data Management	e	NA	Yes	Presentation Materials
10	CNMAS	Nuclear Material Data Management	Data Management	e	MS Visual Basic, Access, SQL	Yes	No
11	σ_{MUF} calculation system	Nuclear Material Balance	Safeguards Evaluation	f	PL/I(function 1) NATURAL for mainframe (function 2 and 3) Database; ADABAS for mainframe Data Analysis Section	Yes	Not available at this time
12	σ_{SRD} calculation system	Nuclear Material Balance	Safeguards Evaluation	f	PL/I(function 1) NATURAL for mainframe(function 2 and 3) Database; ADABAS for mainframe Data Analysis Section	Yes	Not available at this time
13	IDMS (Inspection Data Management System)	Inspection Data Management	Safeguards Evaluation	f	Natural for PC DB; ADABAS for server Data Analysis Section	Yes	Not available at this time
14	IDAS (Inspection Data Analysis System)	Inspection Data Analysis	Safeguards Evaluation	f	Natural for PC DB; ADABAS for server Data Analysis Section	Yes	Not available at this time

15	MDRS (Measurement Data Reference System)	Database for IDMS	Safeguards Evaluation	f	Natural for PC DB; ADABAS for server Data Analysis Section	Yes	Not available at this time
16	Inspection Data Management and Analysis System		Safeguards Evaluation	f	Java DB; Oracle Data Analysis Section	Yes	Not available at this time
17	Data Analysis System for 3 laboratory	Error Estimation of N=3 Model	Safeguards Evaluation	f	Java DB; Oracle Data Analysis Section	Yes	Not available at this time
18	90(a),(b) Statement Management System	Report Management System	Safeguards Evaluation	f	PL/SQL DB; Oracle Data Analysis Section	Yes	Not available at this time
19	PFPF NRTA Data Evaluation System	NRTA	Safeguards Evaluation	f	SQL for Windows DB;SQL Base Data Analysis Section	Yes	Not available at this time
20	TRP NRTA Data Evaluation System	NRTA	Safeguards Evaluation	f	SQL for Windows DB;SQL Base Data Analysis Section	Yes	Not available at this time
21	RRP NRTA Data Evaluation System	NRTA	Safeguards Evaluation	f	SQL for Windows DB;SQL Base Data Analysis Section	Yes	Not available at this time
22	Mail Box Data Processing System	Mail Box Data	Safeguards Evaluation	f	SQL for Windows DB;SQL Base Data Analysis Section	Yes	Not available at this time
23	DAI : Data Analysis and Interpretation	Solution Monitoring Evaluation System	Safeguards Evaluation	f	C# for Win2000-XP	Yes	Not available at this time

Appendix 3. Inventory Questionnaire Responses

Question 10 asks for reports or whitepapers that describe or illustrate the use of the software. In most case, referenced reports are written in Japanese, so the one-page English-written summary will be found in the companion set of files to this paper. In some cases, the referenced report or paper was not available due to safeguards confidentiality.

It is possible that these reports may be obtained by contacting the POC for the individual organization which produces or is responsible for the software, or the contact for the software itself.

Safeguards SW Inventory Summary

1. What is the name of the tool?	SANFCE
2. Who is the primary developer?	JAEA NPSTC
3. Provide a brief descriptive summary of the tool and its application (1-2 paragraphs)	This system is comprehensive MC&A Design and Effectiveness Evaluation System for Nuclear Fuel Cycle Facility. This system is composed of seven functional modules. 1. PROFR code is designed to model true flows and inventories of all declared nuclear material for reprocessing plant, Pu conversion plant and MOX fuel fabrication plant.This Code is based on standard Monte Carlo techniques and is written to simulate the operation of the process. When an event is scheduled in particular process step, the value of all volume and concentrations, materials transfers, and in-process inventory associated with those steps are computed and calculated results are stored. 2. Model measurements are applied to the simulated process-flow and in-process inventory data using Monte Carlo computer code EARTH (measurement simulation) developed for random generation purpose. EARTH simulates instrument operation using a multiplicative measurement-error model, and then stores the measured values with their uncertainties. 3. PROMAC code calculates the MUF of material balance area and material balance period for near real time material accounting model applied to the Nuclear Fuel Cycle Facility. A materials balance is a linear combination of measured transfer and measured inventories. The variance and co-variance matrix computed in PROMAC is based on the safeguard data-analysis. 4. SADAC is safeguards measurement data analysis computer code. Nuclear material accounting data analysis algorithms include Shewhart chart, cumulative MUF, average Loss (Kalman filter), MUF residual and GEMUF. The algorithms for these methods are structured to account for correlated data so that the correct variances are computed for the associated decision tests. 5. MOON simulates man-power data of measurement operation. This Code is based on standard Monte Carlo techniques and is written to simulate manpower of the measurement operation for Key Measurement Point and inspection man-power. 6. SIMBC code simulates threshold value of page's test, truncated CUMUF and GEMUF statistics using Monte Carlo techniques. 7. SPT code indicates alarm-sequence chart of the decision tests. The decision tests must examine all possible sequences of the available materials balance data because, the time at which a sequence of Loss or diversion begins is never known beforehand. It is essential to have a graphic display that indicates those alarm-sequences specifying each by its length, time of occurrence, and significance.
4. Provide a list of safeguards applications for which the tool has been used.	NRTA model (10-days detection time model) studies for TRP (TASTEX). NRTA model of Large Fuels Reprocessing studies for LASCAR project and RRP. This system was used for process and analyses of PFPF real NRTA data. Preliminary NRTA data evaluation studies for Next-generation FBR Reprocessing Plant.
5. What is the tool used for?	a,b,c
a. System Design b. Systems Analysis c. Process Simulation d. Sensor Response Modeling e. Data Management & Analysis f. Other, please explain	
6. What is the form of the tool?	d
a. Commercial software (including shareware & freeware) b. Commercial software with a specialized interface (script, macro, user-defined environment, chaining of multiple packages, etc) c. Non-commercial distributed software (e.g., available through RSICC or written exclusively for the IAEA, NRC, etc.) d. In-house code that is not routinely distributed e. Excel spreadsheet f. Script g. Other, please explain	
7. What platform does the tool use?	a (Unix & Linux)
a. stand alone executable code (DOS/WIN/MAC/UNIX OS) b. Interpreter shell c. Simulation environment (which one?) d. Spreadsheet e. Other, please explain	
8. What language is the tool written in? (NA for commercial codes)	Fortran 77, C
9. Does this software have export control restrictions or other sensitivities? If yes, please explain.	No
10. Please attach illustrative reports or white papers for safeguards work that was done using this tool to substantiate the pedigree of the tool. ・Based on the report, that is made by Hakkila, E. A., Barnes, J. W., Canada, T. R., Cobb, D. D., Hsue, S. T., Langer, D. G., Parker, J. L., Shipley, J. P., Smith, D. B., Los Alamos Laboratory report LA-6881, Vol. II (1977), we have developed this code.	

Safeguards SW Inventory Summary

1. What is the name of the tool?	SEPHIS-J & MIXSET
2. Who is the primary developer?	JAEA NPSTC
3. Provide a brief descriptive summary of the tool and its application (1-2 paragraphs)	SEPHIS-J code was developed for inventory estimation of solvent extraction system of TRP. This code based on SEPHIS Mod 3 and PUBG code.
4. Provide a list of safeguards applications for which the tool has been used.	This code was used inventory estimation study of solvent extraction system for Mixer-settler model for TRP (TASTEX).
5. What is the tool used for?	e
a. System Design b. Systems Analysis c. Process Simulation d. Sensor Response Modeling e. Data Management & Analysis f. Other, please explain	
6. What is the form of the tool?	d
a. Commercial software (including shareware & freeware) b. Commercial software with a specialized interface (script, macro, user-defined environment, chaining of multiple packages, etc) c. Non-commercial distributed software (e.g., available through RSICC or written exclusively for the IAEA, NRC, etc.) d. In-house code that is not routinely distributed e. Excel spreadsheet f. Script g. Other, please explain	
7. What platform does the tool use?	a (Unix & Linux)
a. stand alone executable code (DOS/WIN/MAC/UNIX OS) b. Interpreter shell c. Simulation environment (which one?) d. Spreadsheet e. Other, please explain	
8. What language is the tool written in? (NA for commercial codes)	Fortran 77, C
9. Does this software have export control restrictions or other sensitivities? If yes, please explain.	No
10. Please attach illustrative reports or white papers for safeguards work that was done using this tool to substantiate the pedigree of the tool. ・Hitoshi IHARA, Hideo NISHIMURA, Koji IKAWA and Masaru IDO “Investigation of an Inventory Calculation Model for a Solvent Extraction System and the Development of its Computer Programme – SEPHIS – J – “, JAERI-M 86-168, Nov. 1986. (in Japanese)	

Safeguards SW Inventory Summary

1. What is the name of the tool?	PROMAC-J
2. Who is the primary developer?	JAEA NPSTC
3. Provide a brief descriptive summary of the tool and its application (1-2 paragraphs)	The PROMAC-J system of NRTA data processing was developed for TRP (TASTEX project). This system composed data processing, calculation of material balance and statistical test same as SG simulator module.
4. Provide a list of safeguards applications for which the tool has been used.	PROMAC-J was used for process and analyses of NRTA data obtained a full scale filed test of the proposed NRTA model(10-days detection time model) for TRP(TASTEX).
5. What is the tool used for?	c
a. System Design b. Systems Analysis c. Process Simulation d. Sensor Response Modeling e. Data Management & Analysis f. Other, please explain	
6. What is the form of the tool?	d
a. Commercial software (including shareware & freeware) b. Commercial software with a specialized interface (script, macro, user-defined environment, chaining of multiple packages, etc) c. Non-commercial distributed software (e.g., available through RSICC or written exclusively for the IAEA, NRC, etc.) d. In-house code that is not routinely distributed e. Excel spreadsheet f. Script g. Other, please explain	
7. What platform does the tool use?	a (Unix & Linux)
a. stand alone executable code (DOS/WIN/MAC/UNIX OS) b. Interpreter shell c. Simulation environment (which one?) d. Spreadsheet e. Other, please explain	
8. What language is the tool written in? (NA for commercial codes)	Fortran 77, C
9. Does this software have export control restrictions or other sensitivities? If yes, please explain.	No
10. Please attach illustrative reports or white papers for safeguards work that was done using this tool to substantiate the pedigree of the tool. ・Hitoshi IHARA, Hideo NISHIMURA and Koji IKAWA, “An NRTA Data Processing System“, JAERI-M 91-042, Mar. 1991. (in Japanese)	

Safeguards SW Inventory Summary

1. What is the name of the tool?	MSPCA
2. Who is the primary developer?	JAEA NPSTC
3. Provide a brief descriptive summary of the tool and its application (1-2 paragraphs)	MSPCA code is developed to investigate an applicability of multi-scale principle component analysis using wavelet decomposition to an advanced algorism for process monitoring. Both time information and frequency information have conserved even after the decomposition and those are used to investigate an abrupt and protracted diversion loss. Principle Component Analysis enable us to reduce a number of variables drastically.
4. Provide a list of safeguards applications for which the tool has been used.	At the present stage, this code is used for the R&D application to investigate process monitoring algorithm.
5. What is the tool used for?	e
a. System Design b. Systems Analysis c. Process Simulation d. Sensor Response Modeling e. Data Management & Analysis f. Other, please explain	
6. What is the form of the tool?	d
a. Commercial software (including shareware & freeware) b. Commercial software with a specialized interface (script, macro, user-defined environment, chaining of multiple packages, etc) c. Non-commercial distributed software (e.g., available through RSICC or written exclusively for the IAEA, NRC, etc.) d. In-house code that is not routinely distributed e. Excel spreadsheet f. Script g. Other, please explain	
7. What platform does the tool use?	c (MSP, SSLII)
a. stand alone executable code (DOS/WIN/MAC/UNIX OS) b. Interpreter shell c. Simulation environment (which one?) d. Spreadsheet e. Other, please explain	
8. What language is the tool written in? (NA for commercial codes)	Fortran 77
9. Does this software have export control restrictions or other sensitivities? If yes, please explain.	No
10. Please attach illustrative reports or white papers for safeguards work that was done using this tool to substantiate the pedigree of the tool. ・ Mitsutoshi SUZUKI, Masato HORI, Ryoji ASOU, and Shigekazu USUDA, "Numerical Consideration for Multiscale Statistical Process Control Method Applied to Nuclear Material Accountancy", J. Nucl. Sci. & Tech., 43(10), pp.1270-1279(2006). ・ Mitsutoshi SUZUKI and Hitoshi IHARA, "Development of Safeguards System Simulator Composed of Multi-Functional Cores", J. Power and Energy Systems, 2(2), pp.899-907(2008).	

Safeguards SW Inventory Summary

1. What is the name of the tool?	FPGS90
2. Who is the primary developer?	JAEA NPSTC
3. Provide a brief descriptive summary of the tool and its application (1-2 paragraphs)	FPGS90 code is calculating the number of nuclides, decay heat and spectrum of emitted γ ray from fission products and nuclear fuel nuclides under various kinds of burn-up condition. The code has a function of processing a nuclear library from evaluated nuclear data file such as ENDF/B, JENDL, ENSDF.
4. Provide a list of safeguards applications for which the tool has been used.	FPGS90 code has been widely used at JAEA for the analysis of fission products and actinides produced from FBR reactor such as JOYO and MONJU. Burn-up calculation has been done to investigate the SRD problem.
5. What is the tool used for?	c, f
a. System Design b. Systems Analysis c. Process Simulation d. Sensor Response Modeling e. Data Management & Analysis f. Other, please explain	
6. What is the form of the tool?	d
a. Commercial software (including shareware & freeware) b. Commercial software with a specialized interface (script, macro, user-defined environment, chaining of multiple packages, etc) c. Non-commercial distributed software (e.g., available through RSICC or written exclusively for the IAEA, NRC, etc.) d. In-house code that is not routinely distributed e. Excel spreadsheet f. Script g. Other, please explain	
7. What platform does the tool use?	a (Unix & Linux)
a. stand alone executable code (DOS/WIN/MAC/UNIX OS) b. Interpreter shell c. Simulation environment (which one?) d. Spreadsheet e. Other, please explain	
8. What language is the tool written in? (NA for commercial codes)	Fortran 77, C
9. Does this software have export control restrictions or other sensitivities? If yes, please explain.	No
10. Please attach illustrative reports or white papers for safeguards work that was done using this tool to substantiate the pedigree of the tool. ・Hitoshi IHARA, Jun-ichi KATAKURA and Tsuneo NAKAGAWA, "A Computer Code for calculation of Radioactive Nuclide Generation and Depletion, Decay Heat and γ Ray Spectrum – FRGS90 -", JAERI-Data/Code 95-014, Nov. 1995. (in Japanese)	

Safeguards SW Inventory Summary

1. What is the name of the tool?	SPEEDI & WSPEEDI
2. Who is the primary developer?	JAEA
3. Provide a brief descriptive summary of the tool and its application (1-2 paragraphs)	SPEEDI code system for prediction of environment dose from radioactive materials accidentally released from a nuclear plant has been developed to assist the organizations responsible for an emergency planning. WSPEEDI system is worldwide version SPEEDI.
4. Provide a list of safeguards applications for which the tool has been used.	SPEEDI system has been widely used at JAEA for the analysis of radioactive materials accident such as Chernobyl nuclear accident and JCO criticality accident. CTBT verification system of JAPAN based on WSPEEDI.
5. What is the tool used for?	c, f
a. System Design b. Systems Analysis c. Process Simulation d. Sensor Response Modeling e. Data Management & Analysis f. Other, please explain	
6. What is the form of the tool?	c
a. Commercial software (including shareware & freeware) b. Commercial software with a specialized interface (script, macro, user-defined environment, chaining of multiple packages, etc) c. Non-commercial distributed software (e.g., available through RSICC or written exclusively for the IAEA, NRC, etc.) d. In-house code that is not routinely distributed e. Excel spreadsheet f. Script g. Other, please explain	
7. What platform does the tool use?	a (Unix & Linux)
a. stand alone executable code (DOS/WIN/MAC/UNIX OS) b. Interpreter shell c. Simulation environment (which one?) d. Spreadsheet e. Other, please explain	
8. What language is the tool written in? (NA for commercial codes)	Fortran 77
9. Does this software have export control restrictions or other sensitivities? If yes, please explain.	No
10. Please attach illustrative reports or white papers for safeguards work that was done using this tool to substantiate the pedigree of the tool. ・Masamichi CHINO, Hirohiko ISHIKAWA, Hiromi YAMAZAWA, Haruyasu NAGAI and Shigeru MORIUCHI, "WSPEEDI (Worldwide Version of SPEEDI) : A Computer Code System for the Prediction of Radiological Impacts on Japanese due to a Nuclear Accident in Foreign Countries", JAERI-1334, Mar. 1995. (in Japanese) ・Hiroaki TERADA, Akiko FURUNO and Masamichi CHINO, "Improvement of World Version of System for Prediction of Environmental Emergency Dose Information (WSPEEDI), (I) New Combination of Models, Atmospheric Dynamic Model MM5 and Particle Random Walk Model GEARN-new", J. Nucl. Sci. Technol., 41(5), pp.632-640(2004).	

Safeguards SW Inventory Summary

1. What is the name of the tool?	SRAC2006(SRAC95)
2. Who is the primary developer?	JAEA
3. Provide a brief descriptive summary of the tool and its application (1-2 paragraphs)	The SRAC is a system applicable to neutronics analysis of variety types. This system includes major neutron data libraries(JENDL, ENDFB, JEFF, etc), and integrates for neutron transport, diffusion calculation and collision probability method applicable cell calculation. The system covers production of effective microscopic and macroscopic group cross-sections, and static cell and core calculations including burn-up analysis.
4. Provide a list of safeguards applications for which the tool has been used.	The SRAC system is designed to permit neutronics calculation for various type of thermal and fast reactors. This system has been widely used at JAPAN for standard reference code using nuclear design of reactors.
5. What is the tool used for?	c, f
a. System Design b. Systems Analysis c. Process Simulation d. Sensor Response Modeling e. Data Management & Analysis f. Other, please explain	
6. What is the form of the tool?	c
a. Commercial software (including shareware & freeware) b. Commercial software with a specialized interface (script, macro, user-defined environment, chaining of multiple packages, etc) c. Non-commercial distributed software (e.g., available through RSICC or written exclusively for the IAEA, NRC, etc.) d. In-house code that is not routinely distributed e. Excel spreadsheet f. Script g. Other, please explain	
7. What platform does the tool use?	a (Unix & Linux)
a. stand alone executable code (DOS/WIN/MAC/UNIX OS) b. Interpreter shell c. Simulation environment (which one?) d. Spreadsheet e. Other, please explain	
8. What language is the tool written in? (NA for commercial codes)	Fortran 77
9. Does this software have export control restrictions or other sensitivities? If yes, please explain.	No
10. Please attach illustrative reports or white papers for safeguards work that was done using this tool to substantiate the pedigree of the tool. ・Keisuke OKUMURA, Teruhiko KUGO, Kunio KANEKO and Keichiro TSUCHIHASHI “SRAC2006: A Comprehensive Nuetronics Calculation Code System”, JAERI-Data/Code 2007-004, Jan. 2007. (in Japanese)	

Safeguards SW Inventory Summary

1. What is the name of the tool?	PHITS(Particle and Heavy-Ion Transport code System)
2. Who is the primary developer?	JAEA and RIST
3. Provide a brief descriptive summary of the tool and its application (1-2 paragraphs)	PHITS system is the first general-purpose heavy ion transport Monte Carlo code over the incident energies from several MeV/nucleon to several GeV/nucleon. This system based on NMTC/JAM, JQMD code, SPAR code and MCNP code.
4. Provide a list of safeguards applications for which the tool has been used.	The PHITS system has been widely used at JAPAN for Magnetic Field, Gravity Optical and Mechanical devices. This system was used for accelerator(J-PARC), RI Beam Factory(RIKEN) and Boron Neutron Capture Therapy(BNCT) of JRR-4.
5. What is the tool used for?	d
a. System Design b. Systems Analysis c. Process Simulation d. Sensor Response Modeling e. Data Management & Analysis f. Other, please explain	
6. What is the form of the tool?	c
a. Commercial software (including shareware & freeware) b. Commercial software with a specialized interface (script, macro, user-defined environment, chaining of multiple packages, etc) c. Non-commercial distributed software (e.g., available through RSICC or written exclusively for the IAEA, NRC, etc.) d. In-house code that is not routinely distributed e. Excel spreadsheet f. Script f. Other, please explain	
7. What platform does the tool use?	a (WIN/UNIX)
a. stand alone executable code (DOS/WIN/MAC/UNIX OS) b. Interpreter shell c. Simulation environment (which one?) d. Spreadsheet e. Other, please explain	
8. What language is the tool written in? (NA for commercial codes)	Fortran 77, C
9. Does this software have export control restrictions or other sensitivities? If yes, please explain.	No
10. Please attach illustrative reports or white papers for safeguards work that was done using this tool to substantiate the pedigree of the tool. ・Hiroshi IWASE, Koji NIITA and Takashi NAKAMURA, "Development of General-Purpose Particle and Heavy Ion Transport Monte Carlo Code", J. Nucl. Sci. & Tech. 39(11), pp.1142-1151(2002). ・Koji NIITA, Tatsuhiko SATO, Hiroshi IWASE, Hiroyuki NOSE, Hiroshi NAKASHIMA, and Lembit SIHVER, "PHITS – a particle and heavy ion transport code system", Radiation Measurement, 41, pp.1080-1090(2006).	

Safeguards SW Inventory Summary

1. What is the name of the tool?	PFPF MC&A System
2. Who is the primary developer?	JAEA PFPF
3. Provide a brief descriptive summary of the tool and its application (1-2 paragraphs)	This system is developed at PFPF to operate various automated equipments and implement real time material accountancy. The systems are divided into three levels. First level is central control computer, and corrects and records measurement data (weighing data of the transfer container, DA data, etc.) as material accountancy information. And it also calculates amount of Pu, U, etc based on the measurement data. Every accountancy reports are made by this computer. Second level is process control computer and controls the process and transfer systems in each process area. Third level is equipment control computer and controls process equipment.
4. Provide a list of safeguards applications for which the tool has been used.	Automated transaction software is operated at PFPF by the coding of accountancy information and standardization of transfer procedures. The software collects and records on-line accountancy information in real time basis. The inventory information is always watched by persons who is in charge of material accountancy. The inventory information and the state of nuclear material transfers are indicated on the graphic panel.
5. What is the tool used for?	e
a. System Design b. Systems Analysis c. Process Simulation d. Sensor Response Modeling e. Data Management & Analysis f. Other, please explain	
6. What is the form of the tool?	d
a. Commercial software (including shareware & freeware) b. Commercial software with a specialized interface (script, macro, user-defined environment, chaining of multiple packages, etc) c. Non-commercial distributed software (e.g., available through RSICC or written exclusively for the IAEA, NRC, etc.) d. In-house code that is not routinely distributed e. Excel spreadsheet f. Script g. Other, please explain	
7. What platform does the tool use?	a WIN
a. stand alone executable code (DOS/WIN/MAC/UNIX OS) b. Interpreter shell c. Simulation environment (which one?) d. Spreadsheet e. Other, please explain	
8. What language is the tool written in? (NA for commercial codes)	
9. Does this software have export control restrictions or other sensitivities? If yes, please explain.	Yes
10. Please attach illustrative reports or white papers for safeguards work that was done using this tool to substantiate the pedigree of the tool. See Attached	

Safeguards SW Inventory Summary

1. What is the name of the tool?	CNMAS(Comprehensive Nuclear Material Accountancy System)
2. Who is the primary developer?	JAEA NPSTC
3. Provide a brief descriptive summary of the tool and its application (1-2 paragraphs)	This system makes the accountancy report of individual facility using a JAEA-wide database. In terms of keeping strict security control, the system is designed to be protected from any cyber threat.
4. Provide a list of safeguards applications for which the tool has been used.	The system has been used to report JAEA MC&A data to Japan government under the national accountancy framework since 2006. In Japan, there is many questions about an amount of separated-Pu from Diet and NGO. Whenever JAEA is asked about the amount the system work well and speedily, and this performance enables JAEA to increase openness and transparency for peaceful use of nuclear energy.
5. What is the tool used for?	e
a. System Design b. Systems Analysis c. Process Simulation d. Sensor Response Modeling e. Data Management & Analysis f. Other, please explain	
6. What is the form of the tool?	d
a. Commercial software (including shareware & freeware) b. Commercial software with a specialized interface (script, macro, user-defined environment, chaining of multiple packages, etc) c. Non-commercial distributed software (e.g., available through RSICC or written exclusively for the IAEA, NRC, etc.) d. In-house code that is not routinely distributed e. Excel spreadsheet f. Script g. Other, please explain	
7. What platform does the tool use?	a WIN
a. stand alone executable code (DOS/WIN/MAC/UNIX OS) b. Interpreter shell c. Simulation environment (which one?) d. Spreadsheet e. Other, please explain	
8. What language is the tool written in? (NA for commercial codes)	MS Visual Basic, Access, SQL
9. Does this software have export control restrictions or other sensitivities? If yes, please explain.	Yes
10. Please attach illustrative reports or white papers for safeguards work that was done using this tool to substantiate the pedigree of the tool.	

Safeguards SW Inventory Summary

1. What is the name of the tool?	DAI : Data Analysis and Interpretation
2. Who is the primary developer?	Ispra
3. Provide a brief descriptive summary of the tool and its application (1-2 paragraphs)	The software has been developed for analysis of process data , such as liquid level, density, temperature, etc. from the equipments of solution process, and then confirmation that the process is operated as declared.
4. Provide a list of safeguards applications for which the tool has been used.	The software had been used for analysis of the process data from the test equipment, which had been built at NMCC-Tokai for evaluation of solution movement/reaction.
5. What is the tool used for?	e. The software has been used for getting the knowledge about parameters setting, data analysis/evaluation, etc..
a. System Design b. Systems Analysis c. Process Simulation d. Sensor Response Modeling e. Data Management & Analysis f. Other, please explain	
6. What is the form of the tool?	c. Non-commercial distributed software (e.g., written exclusively for the Ispra)
a. Commercial software (including shareware & freeware) b. Commercial software with a specialized interface (script, macro, user-defined environment, chaining of multiple packages, etc) c. Non-commercial distributed software (e.g., available through RSICC or written exclusively for the IAEA, NRC, etc.) d. In-house code that is not routinely distributed e. Excel spreadsheet f. Script g. Other, please explain	
7. What platform does the tool use?	WINDOWS 2000 and PI (Plant Information system) as data base. PI has been developed by OSI software, USA.
a. stand alone executable code (DOS/WIN/MAC/UNIX OS) b. Interpreter shell c. Simulation environment (which one?) d. Spreadsheet e. Other, please explain	
8. What language is the tool written in? (NA for commercial codes)	C# for Win2000-XP
9. Does this software have export control restrictions or other sensitivities? If yes, please explain.	Yes
10. Please attach illustrative reports or white papers for safeguards work that was done using this tool to substantiate the pedigree of the tool.  As shown above figures, the software is able to confirm the operational situation by comparing the process data with the set pattern in advance.	

国際単位系（SI）

表１．SI 基本単位

基本量	SI 基本単位	
	名称	記号
長さ	メートル	m
質量	キログラム	kg
時間	秒	s
電流	アンペア	A
熱力学温度	ケルビン	K
物質量	モル	mol
光度	カンデラ	cd

表２．基本単位を用いて表されるSI組立単位の例

組立量	SI 基本単位	
	名称	記号
面積	平方メートル	m^2
体積	立法メートル	m^3
速さ，速度	メートル毎秒	m/s
加速度	メートル毎秒毎秒	m/s^2
波数	毎メートル	m^{-1}
密度，質量密度	キログラム毎立方メートル	kg/m^3
面積密度	キログラム毎平方メートル	kg/m^2
比体積	立方メートル毎キログラム	m^3/kg
電流密度	アンペア毎平方メートル	A/m^2
磁界の強さ	アンペア毎メートル	A/m
量濃度[(a)]，濃度	モル毎立方メートル	mol/m^3
質量濃度	キログラム毎立法メートル	kg/m^3
輝度	カンデラ毎平方メートル	cd/m^2
屈折率[(b)]	（数字の） 1	1
比透磁率[(b)]	（数字の） 1	1

(a) 量濃度（amount concentration）は臨床化学の分野では物質濃度（substance concentration）ともよばれる。
(b) これらは無次元量あるいは次元１をもつ量であるが、そのことを表す単位記号である数字の１は通常は表記しない。

表３．固有の名称と記号で表されるSI組立単位

組立量	SI 組立単位			
	名称	記号	他のSI単位による表し方	SI基本単位による表し方
平面角	ラジアン[(b)]	rad	1[(b)]	m/m
立体角	ステラジアン[(b)]	sr[(c)]	1[(b)]	m^2/m^2
周波数	ヘルツ[(d)]	Hz		s^{-1}
力	ニュートン	N		m kg s^{-2}
圧力，応力	パスカル	Pa	N/m^2	m^{-1} kg s^{-2}
エネルギー，仕事，熱量	ジュール	J	N m	m^2 kg s^{-2}
仕事率，工率，放射束	ワット	W	J/s	m^2 kg s^{-3}
電荷，電気量	クーロン	C		s A
電位差（電圧），起電力	ボルト	V	W/A	m^2 kg s^{-3} A^{-1}
静電容量	ファラド	F	C/V	m^{-2} kg^{-1} s^4 A^2
電気抵抗	オーム	Ω	V/A	m^2 kg s^{-3} A^{-2}
コンダクタンス	ジーメンス	S	A/V	m^{-2} kg^{-1} s^3 A^2
磁束	ウエーバ	Wb	Vs	m^2 kg s^{-2} A^{-1}
磁束密度	テスラ	T	Wb/m^2	kg s^{-2} A^{-1}
インダクタンス	ヘンリー	H	Wb/A	m^2 kg s^{-2} A^{-2}
セルシウス温度	セルシウス度[(e)]	℃		K
光束	ルーメン	lm	cd sr[(c)]	cd
照度	ルクス	lx	lm/m^2	m^{-2} cd
放射性核種の放射能[(f)]	ベクレル[(d)]	Bq		s^{-1}
吸収線量，比エネルギー分与，カーマ	グレイ	Gy	J/kg	m^2 s^{-2}
線量当量，周辺線量当量，方向性線量当量，個人線量当量	シーベルト[(g)]	Sv	J/kg	m^2 s^{-2}
酸素活性	カタール	kat		s^{-1} mol

(a)SI接頭語は固有の名称と記号を持つ組立単位と組み合わせても使用できる。しかし接頭語を付した単位はもはやコヒーレントではない。
(b)ラジアンとステラジアンは数字の１に対する単位の特別な名称で、量についての情報をつたえるために使われる。実際には、使用する時には記号rad及びsrが用いられるが、習慣として組立単位としての記号である数字の１は明示されない。
(c)測光学ではステラジアンという名称と記号srを単位の表し方の中に、そのまま維持している。
(d)ヘルツは周期現象についてのみ、ベクレルは放射性核種の統計的過程についてのみ使用される。
(e)セルシウス度はケルビンの特別な名称で、セルシウス温度を表すために使用される。セルシウス度とケルビンの単位の大きさは同一である。したがって、温度差や温度間隔を表す数値はどちらの単位で表しても同じである。
(f)放射性核種の放射能（activity referred to a radionuclide）は、しばしば誤った用語で"radioactivity"と記される。
(g)単位シーベルト（PV,2002,70,205）についてはCIPM勧告2（CI-2002）を参照。

表４．単位の中に固有の名称と記号を含むSI組立単位の例

組立量	SI 組立単位		
	名称	記号	SI 基本単位による表し方
粘度	パスカル秒	Pa s	m^{-1} kg s^{-1}
力のモーメント	ニュートンメートル	N m	m^2 kg s^{-2}
表面張力	ニュートン毎メートル	N/m	kg s^{-2}
角速度	ラジアン毎秒	rad/s	m m^{-1} s^{-1}=s^{-1}
角加速度	ラジアン毎秒毎秒	rad/s^2	m m^{-1} s^{-2}=s^{-2}
熱流密度，放射照度	ワット毎平方メートル	W/m^2	kg s^{-3}
熱容量，エントロピー	ジュール毎ケルビン	J/K	m^2 kg s^{-2} K^{-1}
比熱容量，比エントロピー	ジュール毎キログラム毎ケルビン	J/(kg K)	m^2 s^{-2} K^{-1}
比エネルギー	ジュール毎キログラム	J/kg	m^2 s^{-2}
熱伝導率	ワット毎メートル毎ケルビン	W/(m K)	m kg s^{-3} K^{-1}
体積エネルギー	ジュール毎立方メートル	J/m^3	m^{-1} kg s^{-2}
電界の強さ	ボルト毎メートル	V/m	m kg s^{-3} A^{-1}
電荷密度	クーロン毎立方メートル	C/m^3	m^{-3} sA
表面電荷	クーロン毎平方メートル	C/m^2	m^{-2} sA
電束密度，電気変位	クーロン毎平方メートル	C/m^2	m^{-2} sA
誘電率	ファラド毎メートル	F/m	m^{-3} kg^{-1} s^4 A^2
透磁率	ヘンリー毎メートル	H/m	m kg s^{-2} A^{-2}
モルエネルギー	ジュール毎モル	J/mol	m^2 kg s^{-2} mol^{-1}
モルエントロピー，モル熱容量	ジュール毎モル毎ケルビン	J/(mol K)	m^2 kg s^{-2} K^{-1} mol^{-1}
照射線量（X線及びγ線）	クーロン毎キログラム	C/kg	kg^{-1} sA
吸収線量率	グレイ毎秒	Gy/s	m^2 s^{-3}
放射強度	ワット毎ステラジアン	W/sr	m^4 m^{-2} kg s^{-3}=m^2 kg s^{-3}
放射輝度	ワット毎平方メートル毎ステラジアン	$W/(m^2$ sr)	m^2 m^{-2} kg s^{-3}=kg s^{-3}
酵素活性濃度	カタール毎立方メートル	kat/m^3	m^{-3} s^{-1} mol

表５．SI 接頭語

乗数	接頭語	記号	乗数	接頭語	記号
10^{24}	ヨタ	Y	10^{-1}	デシ	d
10^{21}	ゼタ	Z	10^{-2}	センチ	c
10^{18}	エクサ	E	10^{-3}	ミリ	m
10^{15}	ペタ	P	10^{-6}	マイクロ	μ
10^{12}	テラ	T	10^{-9}	ナノ	n
10^9	ギガ	G	10^{-12}	ピコ	p
10^6	メガ	M	10^{-15}	フェムト	f
10^3	キロ	k	10^{-18}	アト	a
10^2	ヘクト	h	10^{-21}	ゼプト	z
10^1	デカ	da	10^{-24}	ヨクト	y

表６．SIに属さないが、SIと併用される単位

名称	記号	SI 単位による値
分	min	1 min=60s
時	h	1h =60 min=3600 s
日	d	1 d=24 h=86 400 s
度	°	1°=(π/180) rad
分	’	1’=(1/60)°=(π/10800) rad
秒	”	1”=(1/60)’=(π/648000) rad
ヘクタール	ha	$1ha=1hm^2=10^4m^2$
リットル	L，l	$1L=11=1dm^3=10^3cm^3=10^{-3}m^3$
トン	t	$1t=10^3$ kg

表７．SIに属さないが、SIと併用される単位で、SI単位で表される数値が実験的に得られるもの

名称	記号	SI 単位で表される数値
電子ボルト	eV	$1eV=1.602\ 176\ 53(14)\times10^{-19}J$
ダルトン	Da	$1Da=1.660\ 538\ 86(28)\times10^{-27}kg$
統一原子質量単位	u	1u=1 Da
天文単位	ua	$1ua=1.495\ 978\ 706\ 91(6)\times10^{11}m$

表８．SIに属さないが、SIと併用されるその他の単位

名称	記号	SI 単位で表される数値
バール	bar	$1 bar=0.1MPa=100kPa=10^5Pa$
水銀柱ミリメートル	mmHg	1mmHg=133.322Pa
オングストローム	Å	$1 Å=0.1nm=100pm=10^{-10}m$
海里	M	1 M=1852m
バーン	b	$1 b=100fm^2=(10^{-12}cm)2=10^{-28}m^2$
ノット	kn	1 kn=(1852/3600)m/s
ネーパ	Np	SI単位との数値的な関係は、対数量の定義に依存。
ベル	B	
デジベル	dB	

表９．固有の名称をもつCGS組立単位

名称	記号	SI 単位で表される数値
エルグ	erg	$1 erg=10^{-7}$ J
ダイン	dyn	$1 dyn=10^{-5}N$
ポアズ	P	1 P=1 dyn s cm^{-2}=0.1Pa s
ストークス	St	$1 St =1cm^2 s^{-1}=10^{-4}m^2 s^{-1}$
スチルブ	sb	$1 sb =1cd cm^{-2}=10^4cd m^{-2}$
フォト	ph	$1 ph=1cd sr cm^{-2}$ 10^4lx
ガル	Gal	$1 Gal =1cm s^{-2}=10^{-2}ms^{-2}$
マクスウェル	Mx	$1 Mx = 1G cm^2=10^{-8}Wb$
ガウス	G	$1 G =1Mx cm^{-2}=10^{-4}T$
エルステッド[(c)]	Oe	$1 Oe \hat{=} (10^3/4\pi)A m^{-1}$

(c) ３元系のCGS単位系とSIでは直接比較できないため、等号「 ≙ 」は対応関係を示すものである。

表10．SIに属さないその他の単位の例

名称	記号	SI 単位で表される数値
キュリー	Ci	$1 Ci=3.7\times10^{10}Bq$
レントゲン	R	$1 R = 2.58\times10^{-4}C/kg$
ラド	rad	$1 rad=1cGy=10^{-2}Gy$
レム	rem	$1 rem=1 cSv=10^{-2}Sv$
ガンマ	γ	1γ=1 nT=10-9T
フェルミ		1フェルミ=1 fm=10-15m
メートル系カラット		1メートル系カラット = 200 mg = 2×10-4kg
トル	Torr	1 Torr = (101 325/760) Pa
標準大気圧	atm	1 atm = 101 325 Pa
カロリー	cal	1cal=4.1858J（「15℃」カロリー），4.1868J（「IT」カロリー）4.184J（「熱化学」カロリー）
ミクロン	μ	1 μ =1μm=10^{-6}m

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