

American National Standard Data Format for Radiation Detectors Used for Homeland Security

Accredited by the American National Standards Institute

Developed by the
National Committee on Radiation Instrumentation, N42

ANSI N42.42-2020
(Revision of ANSI N42.42-2012)

STANDARDS

American National Standard Data Format for Radiation Detectors Used for Homeland Security

Developed by the

National Committee on Radiation Instrumentation, N42

Accredited by the

American National Standards Institute

Secretariat

Institute of Electrical and Electronics Engineers, Inc.

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American National Standards Institute

Abstract: The data format to be used for both required and optional data to be made available by radiation measurement instruments for homeland security applications is specified. The performance for these types of instruments is described in other standards, such as ANSI N42.32, ANSI N42.33, ANSI N42.34, ANSI N42.35, ANSI N42.38, ANSI N42.43, ANSI N42.48, ANSI N42.49A, and ANSI N42.53.

Keywords: ANSI N42.42, data format, DHS standards, homeland security, radiation detectors, radiation instruments, radiation measurement instruments

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Introduction

This introduction is not part of ANSI N42.42-2020, American National Standard Data Format for Radiation Detectors Used for Homeland Security.

This standard is the responsibility of the Accredited American Standards Committee on Radiation Instrumentation, N42. The standard was approved on N42 letter ballot.

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American National Standard Data Format for Radiation Detectors Used for Homeland Security

1. Overview

1.1 Scope

This standard specifies the data format that shall be used for both required and optional data available at the output of radiation measurement instruments that are used for homeland security applications. The performance requirements for these types of radiation measurement instruments are described in other standards such as ANSI N42.32, ANSI N42.33, ANSI N42.34, ANSI N42.35, ANSI N42.38, ANSI N42.43, ANSI N42.48, ANSI N42.49A, and ANSI N42.53.¹

The output consists of measurement data and results of any analysis performed by the radiation measurement instrument.

This standard does not address instrument control, data transmission protocols, or the physical media used for communications.

1.2 Purpose

The purpose of this standard is to provide a uniform format for data to be output from radiation measurement instruments for use in homeland security applications. This enables interpretation of data without reference to manufacturer's documentation.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

¹ Information on references can be found in Clause 2.

NOTE—Internet URLs are provided for convenience only; while accurate at the time of printing, these addresses may be changed by the information provider.²

ANSI N13.11, American National Standard for Dosimetry—Personnel Dosimetry Performance—Criteria for Testing.³

ANSI N42.32, American National Standard Performance Criteria for Alarming Personal Radiation Detectors for Homeland Security.⁴

ANSI N42.33, American National Standard for Portable Radiation Detection Instrumentation for Homeland Security.

ANSI N42.34, American National Standard Performance Criteria for Hand-Held Instruments for the Detection and Identification of Radionuclides.

ANSI N42.35, American National Standard for Evaluation and Performance of Radiation Detection Portal Monitors for Use in Homeland Security.

ANSI N42.38, American National Standard Performance Criteria for Spectroscopy-Based Portal Monitors Used for Homeland Security.

ANSI N42.42-2006, American National Standard Data Format Standard for Radiation Detectors Used for Homeland Security.

ANSI N42.43, American National Standard Performance Criteria for Mobile and Transportable Radiation Monitors Used for Homeland Security.

ANSI N42.48, American National Standard Performance Requirements for Spectroscopic Personal Radiation Detectors (SPRDs) for Homeland Security.

ANSI N42.49A, American National Standard for Performance Criteria for Alarming Electronic Personal Emergency Radiation Detectors (PERDs) for Exposure Control.

ANSI N42.53, American National Standard Performance Criteria for Backpack Based Radiation Detection Systems Used for Homeland Security.

Debertin, K., and R. G. Helmer, *Gamma- and X-Ray Spectrometry with Semiconductor Detectors*, Elsevier, 1988.

EPSG Map Datum Codes.⁵

Extensible Markup Language (XML) 1.0, Third Edition, W3C® Recommendation, 04 February 2004.^{6, 7}

ICRU Report 10b, Physical Aspects of Irradiation.⁸

ICRU Report 33, Radiation Quantities and Units.

² Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

³ ANSI publications are available from the American National Standards Institute (<http://www.ansi.org/>).

⁴ ANSI N42 publications are available from The Institute of Electrical and Electronics Engineers (<http://standards.ieee.org/>).

⁵ Available at <http://www.epsg.org>.

⁶ Available at <http://www.w3.org/TR/2004/REC-xml-20040204>.

⁷ W3C is a registered trademark of the Massachusetts Institute of Technology (MIT), European Research Consortium for Information and Mathematics (ERCIM), and Keio University (Keio).

⁸ ICRU RU publications are available from the National Council on Radiation Protection and Measurements (<http://www.ncrponline.org>).

ICRU Report 39, Determination of Dose Equivalents Resulting from External Radiation Sources.

ICRU Report 47, Measurement of Dose Equivalents from External Photon and Electron Radiations.

IEC 60050-393, International Electrotechnical Vocabulary—Part 393: Nuclear Instrumentation—Physical Phenomena and Basic Concepts.⁹

IEC 60050-394, International Electrotechnical Vocabulary—Part 394: Nuclear Instrumentation—Instruments, Systems, Equipment and Detectors.

IEC 62244, Radiation Protection Instrumentation—Installed Radiation Monitors for the Detection of Radioactive and Special Nuclear Materials at National Borders.

IEC 62327, Radiation Protection Instrumentation—Hand-Held Instruments for the Detection and Identification of Radionuclides and for the Indication of Ambient Dose Equivalent Rate from Photon Radiation.

IEC 62401, Radiation Protection Instrumentation—Alarming Personal Radiation Devices (PRD) for Detection of Illicit Trafficking of Radioactive Material.

IEC 62484, Radiation Protection Instrumentation—Spectroscopy-Based Portal Monitors Used for the Detection and Identification of Illicit Trafficking of Radioactive Material.

IEC 62533, Radiation Protection Instrumentation—Highly Sensitive Hand-Held Instruments for Photon Detection of Radioactive Material.

IEC 62534, Radiation Protection Instrumentation—Highly Sensitive Hand-Held Instruments for Neutron Detection of Radioactive Material.

IEC 62618, Radiation Protection Instrumentation—Spectroscopy-Based Alarming Personal Radiation Devices (SPRD) for Detection of Illicit Trafficking of Radioactive Material.

IEC 62694, Radiation Protection Instrumentation—Portable Radiation Scanners (PRS) for Detection of Illicit Trafficking of Radioactive Material.

IETF RFC 1590, Media Type Registration Procedure.¹⁰

IETF RFC 2045, Multipurpose Internet Mail Extensions (MIME) Part One: Format of Internet Message Bodies.¹¹

IETF RFC 2396, Uniform Resource Identifiers (URI): Generic Syntax.¹²

IETF RFC 2732, Format for Literal IPv6 Addresses in URL's.¹³

IETF RFC 3275, (Extensible Markup Language) XML-Signature Syntax and Processing.¹⁴

Internet Assigned Numbers Authority (IANA).¹⁵

⁹ IEC publications are available from the International Electrotechnical Commission (<http://www.iec.ch>) and the American National Standards Institute (<http://www.ansi.org/>).

¹⁰ Available at: <http://www.ietf.org/rfc/rfc1590.txt>.

¹¹ Available at: <http://www.ietf.org/rfc/rfc2045.txt>.

¹² Available at: <http://www.ietf.org/rfc/rfc2396.txt>.

¹³ Available at: <http://www.ietf.org/rfc/rfc2732.txt>.

¹⁴ Available at: <http://www.ietf.org/rfc/rfc3275.txt>.

Internet Assigned Numbers Authority (IANA) MIME Media Types.¹⁶

ISO 4037-3, X and Gamma Reference Radiation for Calibrating Dosemeters and Doserate Meters and for Determining their Response as a Function of Photon Energy—Part 3: Calibration of Area and Personal Dosemeters and the Measurement of their Response as a Function of Energy and Angle of Incidence.¹⁷

ISO 8601, Data Elements and Interchange Formats—Information Interchange—Representation of Dates and Times.

ISO/IEC 10646-1, Universal Multiple-Octet Coded Character Set (UCS)—Part 1: Architecture and Basic Multilingual Plane.¹⁸

ISO/IEC 11578, Information Technology—Open Systems Interconnection—Remote Procedure Call (RPC).¹⁹

ISO/IEC 11179-4, Information Technology—Metadata Registries (MDR)—Part 4: Formulation of Data Definition.

ISO/IEC 11179-5, Information Technology—Metadata Registries (MDR)—Part 5: Naming and Identification Principles.

ISO/IEC 19757-3, Information Technology—Document Schema Definition Languages (DSDL)—Part 3: Rule-Based Validation—Schematron.

IUPAC, *Nomenclature of Inorganic Chemistry*, Blackwell Science, 1990.

N42 XML Schema.²⁰

N42 XML Schematron.²¹

National Information Exchange Model (NIEM) Naming and Design Rules, Version 1.3 (In particular, the CBRN domain is relevant to this standard.).²²

National Nuclear Data Center, Brookhaven National Laboratory, Chart of Nuclides.²³

XML Encryption Syntax and Processing, W3C Recommendation, 10 December 2002.²⁴

XML Schema Part 0: Primer Second Edition, W3C Recommendation, 28 October 2004.²⁵

XML Schema Part 2: Datatypes Second Edition, W3C Recommendation, 28 October 2004.²⁶

¹⁵ Available at: <http://www.iana.org>.

¹⁶ Available at: <http://www.iana.org/assignments/media-types>.

¹⁷ ISO publications are available from the International Organization for Standardization (<http://www.iso.org/>) and the American National Standards Institute (<http://www.ansi.org/>).

¹⁸ The Unicode Standard 4.0 is equivalent to the ISO/IEC 10646-1.

¹⁹ IETF RFC 4122, A Universally Unique IDentifier (UUID) URN Namespace, an equivalent standard covering the format of the UUID, is available at: <http://www.ietf.org/rfc/rfc4122.txt>.

²⁰ Available at: <http://physics.nist.gov/N42/2011/n42.xsd>.

²¹ Available at: <http://physics.nist.gov/N42/2011/schematron/n42.sch>.

²² Available: <https://www.niem.gov/documentsdb/Documents/Technical/NIEM-NDR-1-3.pdf>.

²³ Available at: <http://www.nndc.bnl.gov/chart/>.

²⁴ Available at: <http://www.w3.org/TR/xmlenc-core/>.

²⁵ Available at <http://www.w3.org/TR/2004/REC-xmlschema-0-20041028>.

²⁶ Available at <http://www.w3.org/TR/2004/REC-xmlschema-2-20041028>.

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions, as well as those given in IEC 60050-393 and IEC 60050-394 apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined here.²⁷

air-kerma: The kerma in a small volume of air.

ambient dose equivalent $H^*(10)$: Dose equivalent at a point in a radiation field, produced by the corresponding aligned and expanded field, in the ICRU sphere at a depth of 10 mm, on the radius opposing the direction of the aligned field (see ICRU Report 39 and ICRU Report 47). (IEC 60050-395-05-43)

NOTE 1—In defining these quantities, it is useful to stipulate certain radiation fields that are derived from the actual radiation field. The terms “expanded” and “aligned” are used to characterize these derived radiation fields. In the expanded field, the fluence and its angular and energy distribution have the same values throughout the volume of interest as in the actual field at the point of reference. In the aligned and expanded field, the fluence and its energy distribution are the same as in the expanded field but the fluence is unidirectional.

NOTE 2—The ICRU sphere (see ICRU Report 33) is a 30-cm diameter, tissue-equivalent sphere with a density of $1 \text{ g}\cdot\text{cm}^{-3}$ and a mass composition of tissue equivalent material (see IEC 60050-393-14-78).

NOTE 3—The recommended depth d , for environmental monitoring in terms of $H^*(d)$ is 10 mm, and $H^*(d)$ may then be written as $H^*(10)$.

NOTE 4—An instrument that has an isotropic response and is calibrated in terms of $H^*(d)$ will measure $H^*(d)$ in radiation fields that are uniform over the dimensions of the instrument.

NOTE 5—The definition of $H^*(d)$ requires the design of the instrument to take account of backscatter.

attribute: An eXtensible Markup Language (XML) “name-value” construct contained in an XML element start tag. Details are available in Extensible Markup Language (XML) 1.0, Third Edition.

channel: A bin of a spectral histogram. Typically, a multichannel analyzer will increment the bin corresponding to the height of each recorded pulse. The contents of each bin are referred to as the “counts” in the channel (also referred to as the channel “value”). Because these histograms can be reprocessed in a variety of ways, the counts in each channel may be a real number (i.e., the counts need not be an integer).

channel position: A real number representing the position in a spectral histogram along the channel axis in terms of channels and their fractional parts. The channel number of the left edge of the first channel in a histogram of N channels is 0.0, and the channel number of the right edge of the last channel is N . Note that one can correlate a particular energy with a channel position; for example, energy 1173.2 keV may correspond to a channel position of 3437.61.

confidence indication: A measure provided by the radiation measurement instrument of the reliability assigned to the radiation source identification, with a range from 0.0% to 100.0%; higher values indicate a higher likelihood of the presence of the radionuclide.

double escape peak: In a gamma ray spectrum, peaks due to pair production in the detector and escape, from the sensitive part of the detector, of two photons of 511 keV resulting from annihilation.

²⁷ *IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org/>. An IEEE Account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

element: An XML construct consisting of a start tag contained in angle brackets, optional data, and an optional end tag. Details are available in Extensible Markup Language (XML) 1.0, Third Edition.

energy calibration: Describes the relationship between energy and channel number.

environmental background: Signals of origin other than the radiation to be detected. This may refer to:

- a) Signals caused by radiations from sources inside or outside the radiation detector other than those of interest in the measurement
- b) Signals resulting from the short-comings of the electronic circuits of the detecting system and their power supplies

exposure: The quotient of dQ by dm , where dQ is the absolute value of the total charge of the ions of one sign produced in air when all the electrons and positrons, liberated by photons in air of mass dm are completely stopped:

$$X = dQ/dm$$

The special unit of exposure used in this standard is the milliroentgen, abbreviated as mR (see ICRU Report 10b).

eXtensible Markup Language (XML): XML is a system and hardware independent language for expressing data and their structure within an XML document. An XML document is a text object that contains the data together with markup that defines the structure of the data. Details are available in Extensible Markup Language (XML) 1.0, Third Edition.

full-energy peak efficiency: The ratio of the number of photons detected in the total absorption peak for a given detection assembly and photon energy per unit time to the emission rate of a source in a specified geometry.

full-width at half-maximum (FWHM): In a distribution curve comprising a single peak, the distance between the abscissa of two points on the curve whose ordinates are half of the maximum ordinate of the peak.

full-width at half maximum (FWHM) calibration: Describes the relationship of FWHM as a function of energy.

gross counts: The total number of counts recorded by the radiation measurement instrument.

Internet Assigned Numbers Authority (IANA): IANA is responsible for the registration of globally unique internet domain names and namespaces.

intrinsic full-energy peak efficiency: The ratio of the number of photons detected in the total absorption peak for a given photon energy to the number of photons that are incident on the radiation detector in the same time interval.

item: The object being measured by the radiation measurement instrument. This object may or may not produce a radiation field.

kerma: The quotient of dE_{tr} by dm , where dE_{tr} is the sum of the initial kinetic energies of all the directly ionizing particles liberated by indirectly ionizing particles in a material of mass dm :

$$K = dE_{tr}/dm$$

The units of kerma are the gray (Gy).

live time: Duration during which a detection assembly is sensitive to the input signal.

manufacturer: A person or company that manufactures hardware or software.

Multipurpose Internet Mail Extension (MIME): is a standard which defines the encoding of non-text data, such as images and sound, in text format.

NOTE 1—For details see IETF RFC 1590.

Multipurpose Internet Mail Extension (MIME) type: Identifies the format of data; MIME types are maintained by the IANA.

N42 document: A collection of data represented in XML, formatted according to this standard.

precision: As used in this document, the number of digits that are used to express a numeric value in text form.

radiation detector: A sensor component of a radiation measurement instrument designed to produce a quantifiable response to ionizing radiation.

radiation measurement instrument: A complete system comprising one or more radiation detectors and other possible components designed to quantify one or more characteristics of ionizing radiation or of the radioactive material producing the ionizing radiation.

real time: True operational time of measurement.

single escape peak: In a gamma ray spectrum, peaks due to pair production in the detector and escape, from the sensitive part of the detector, of one photon of 511 keV resulting from annihilation.

software: Sets of instructions or data that tell a computer what to do. Software is often divided into two categories: system software, which includes the operating system (e.g., Windows 7, macOS),²⁸ and all utilities that enable the computer to function, and applications software, which includes programs that perform specific tasks (e.g., word processors, spread sheets, and databases).

spectrum: A series of monotonically increasing energy bins in which radiation counts are tallied. The energy of each successive bin begins at the energy at which the previous bin ended.

state data: Information regarding the state of an object, e.g., a radiation measurement instrument, detector, or item. This information may include location, orientation, speed, and mode of operation.

tag: A piece of text that describes a unit of data, or element, in XML. A detailed definition can be found in Extensible Markup Language (XML) 1.0, Third Edition.

UCS Transformation Format 8 (UTF-8): This encodes a character in the repertoire of ISO/IEC 10646-1 using between 1 and 6 octets.

uncertainty: A parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand.

uniform resource identifier (URI): A string of characters used to identify a name or a resource on the Internet.

²⁸ Windows is a registered trademark of Microsoft Corporation in the United States and/or other countries, and macOS is a registered trademark of Apple Inc., registered in the US and other countries. This information is given for the convenience of users of this standard and does not constitute an endorsement by the IEEE of these products. Equivalent products may be used if they can be shown to lead to the same results.

uniform resource locator (URL): A Uniform Resource Identifier (URI) that specifies where an identified resource is available and the mechanism for retrieving it.

Universally Unique Identifier (UUID): A string of characters used to uniquely identify each N42 document. The format of a UUID is described by ISO/IEC 11578.

World Wide Web Consortium (W3C): The main international standards organization that maintains the definitions for XML and associated standards.

XML Schema: Provides a means for defining the structure, content and semantics of XML documents through XML itself. Details are available in XML Schema Part 2: Datatypes Second Edition.

3.2 Acronyms and abbreviations

DU	depleted uranium
FWHM	full-width at half-maximum
HEU	highly enriched uranium
LEU	low enriched uranium
MIME	Multipurpose Internet Mail Extension
NIEM	National Information Exchange Model
NIST	National Institute of Standards and Technology
OCR	Optical Character Recognition
RGPU	reactor-grade plutonium
RID	radionuclide identifier
RPM	radiation portal monitor
URI	uniform resource identifier
URL	uniform resource locator
UTF-8	UCS Transformation Format 8
UUID	Universally Unique Identifier
W3C	World Wide Web Consortium
WGPu	weapons-grade plutonium
XML	eXtensible Markup Language

3.3 Quantities and units

Quantities associated to elements and attributes have well defined units. This standard uses the International System of Units (SI). Multiples and submultiples of SI units will be used, when practicable, according to the SI system.

This standard also uses the following units:

- For energy: kilo-electron-volt (symbol keV), $1 \text{ keV} = 1.602 \times 10^{-16} \text{ J}$
- For ambient dose equivalent: microsievert (symbol: μSv).

- For exposure: milliroentgen (symbol: mR), $1 \text{ mR/h} = 2.58 \times 10^{-7} \text{ C/kg/h}$
- For multimedia file size value: kilobytes (symbol: kB)

SI units should be used for those elements whose values require the indication of the associated “unit” attribute; the unit used should be appropriate for the recorded or measured value.

As this standard addresses data format, decimal numbers, real number, date, time and time duration require the use of a period, “.”, instead of a comma, “,”, to express a value.

The conversion of exposure to ambient dose equivalent is discussed in Annex J.

3.4 Standard word usage

In this document, the following word usage applies:

- The word “shall” signifies a mandatory requirement (where appropriate, a qualifying statement is included to indicate there may be an allowable exception.)
- The word “should” signifies a recommended specification or method
- The word “may” signifies an acceptable method or an example of good practice

4. General characteristics

4.1 Design principles used in this standard

The design principles used in the standard are the following:

- a) *Readability*: data should be in a format that can be easily accessed and understood by analysts without the need for proprietary software.
- b) *Compatibility*: data should be in a format that is compatible with accepted international standards for data representation to the broadest extent possible.
- c) *Extensibility*: the data format should provide for unforeseen future needs and for as-yet unknown requirements particular to the specific needs of individual manufacturers of radiation measurement instrumentation.
- d) *Impartiality*: the data format should not favour any particular commercial interest by adopting a particular manufacturer’s or organization’s practices.

4.2 Characteristics of the data format

With the design principles in mind, the data format, henceforth referred to as the “N42 data format,” defined by this standard is based upon Extensible Markup Language (XML) 1.0. Specifically, this standard requires the data from the radiation measurement instrument shall comply with the following data formats:

- a) The data shall be rendered in an XML document in conformance to the XML 1.0 and XML Schema Part 2 standards. In this standard, an XML document is considered identical to an XML file and the terms will be used synonymously.

- b) Documents produced according to this standard shall be capable of being validated against the master N42 schema, as well as any other schemas required by that document.
- c) Data authentication, when required, shall be provided via XML-Signature (see IETF RFC 3275).
- d) Data encryption, when required, shall be provided via XML Encryption (see XML Encryption Syntax and Processing).

NOTE—Document compression is not addressed in this standard.

This standard has the following general characteristics:

- a) Radiation measurement instrumentation information is expressed as a hierarchical structure of data items.
- b) The data format employs XML tagging as defined by XML 1.0, Third Edition, and follows the guidelines of XML Schema Part 0, ISO/IEC 11179-4, and ISO/IEC 11179-5.
- c) Mixed content is not allowed, i.e., insertion of tags inside of content is not allowed. Non-printing character data are permitted between closing and opening tags.
- d) In order to allow the data to be accessed using simple text editors, only ISO/IEC 10646-1 character encoding shall be used.
- e) The structure of the information is described by the N42 XML Schema document (see Annex A). This schema defines the standard names for data elements and attributes, and the hierarchical relationships between them. The schema document will be updated in concert with any revision to this standard.
- f) Customized elements and attributes shall not supplant use of standard elements and attributes defined in this standard.
- g) When data in this format are recorded in a file, the data filename extension shall be “N42,” either uppercase or lowercase, to allow for automated recognition.

The standard gives implementers flexibility in deciding what information to include or omit. However, implementers shall provide all data their radiation measurement instruments or accompanying software generates if there is an element in the N42 specification that matches their data. Implementers shall provide the minimum data and analysis results as specified in the standards associated with the specific radiation measurement instrument. Provision for extending the N42 schema to address new data elements has also been provided; see Annex L for details.

4.3 General description of the N42 data format

4.3.1 Basic concepts

This standard considers radiation measurement instruments to have several types of components. Radiation detectors are the primary components. They generate the raw measurement data in response to a radiation field. A radiation measurement instrument may include one or more radiation detectors. A particular radiation detector can only belong to one radiation measurement instrument.

Occupancy sensors, position sensors, and multimedia devices are other possible components of a radiation measurement instrument. Information provided by these components can provide additional context to the measured items producing a radiation field.

Measurements can include data collected by the different radiation measurement instrument components (i.e., the radiation measurement instrument’s individual radiation detectors, occupancy sensors, position

sensors, and multimedia devices) over a specific period of time. Contributions from a particular component may or may not be present in all radiation measurement instrument measurements.

An N42 document provides data from only one radiation measurement instrument. This implies that systems with more than one radiation measurement instrument must produce separate documents for each instrument (e.g., if the system is composed of an RPM and a RID, each of these radiation measurement instruments shall produce a separate document).

The <RadInstrumentData> element is the parent element for all N42 data in a document that complies with this standard. Note that ANSI N42.42-2006 uses the parent element <N42InstrumentData>; this difference in parent elements can serve as a key to distinguish which standard is applicable to the current document. Note also that the namespace in this standard is different from the namespace in ANSI N42.42-2006.

A radiation measurement instrument may produce many N42 documents over its operational life. To distinguish between these documents each should include a unique universal identifier as an attribute in its <RadInstrumentData> parent element.

The primary, high-level, child elements of <RadInstrumentData> are as follows:

- <RadInstrumentInformation>: This element describes the characteristics of the radiation measurement instrument that performed the measurements. Child elements indicate the radiation measurement instrument's manufacturer, identification, model, class, description, and version as well as quality control information. Though there can be only one radiation measurement instrument (with many components) per each N42 document, other elements may need to refer to it; therefore, the <RadInstrumentInformation> element includes an attribute that uniquely identifies the radiation measurement instrument locally within an instance of the N42 document.
- <RadDetectorInformation>: This element describes the characteristics of a radiation detector. Radiation detectors are the components of the radiation measurement instrument that actually generate the raw measurement data in response to a radiation field. The radiation measurement instrument may include one or more radiation detectors; each radiation detector must have its own <RadDetectorInformation> element. A specific radiation detector can only belong to the one radiation measurement instrument. Child elements indicate the radiation detector's name, category, kind, description, and physical dimensions as well as user-defined characteristics. A <RadDetectorInformation> element includes an attribute that uniquely identifies a specific detector locally within an instance of the N42 document.
- <RadItemInformation>: This element describes the characteristics of a specific item the radiation measurement instrument measured; this document often refers to it as "measured item" or just "item." Since a radiation measurement instrument may consist of multiple radiation detectors, the radiation measurement instrument can measure one or more measured items simultaneously. If there is a means to uniquely identify a measured item, this element captures information about the measured item; each measured item then must have its own <RadItemInformation> element. Child elements indicate the measured item's description and measurement geometry as well as user-defined quantities. A <RadItemInformation> element includes an attribute that uniquely identifies a specific measured item locally within an instance of the N42 document.
- <xxxCalibration>: This element contains calibration information. xxx can be Energy, FWHM, FullEnergyPeakEfficiency, IntrinsicFullEnergyPeakEfficiency, or TotalEfficiency. Child elements are xxx-dependent and may detail energies, energy boundaries, coefficients, windows, and uncertainties. A <xxxCalibration> element includes an id attribute that uniquely identifies a specific calibration locally within an instance of the N42 document.
- <RadMeasurement>: This element includes the data a radiation measurement instrument collects over a specific period of time from its individual radiation detectors and components such as occupancy and position sensors. The <MultimediaData> element includes the data from a radiation measurement instrument's multimedia components, see below. The radiation measurement

instrument may acquire data from all or a combination of these components during a specific period of time. The data from distinct time intervals require separate <RadMeasurement> elements. Each instance of a <RadMeasurement> element shall include an attribute that uniquely identifies it in an N42 document.

When there is a means for the radiation measurement instrument to identify the measured item or items (e.g., shipping container, package, and vehicle), a <RadMeasurement> element can also include a list of the measured items as an attribute.

A <RadMeasurement> element can belong to one or more radiation measurement groups (see the next dashed paragraph below that explains the concept of a <RadMeasurementGroup> element); an element's radMeasurementGroupReferences attribute provides the mechanism to identify each <RadMeasurementGroup> element associated with the element.

<StartDateTime> and <RealTimeDuration> child elements identify the specific period of time in which the <RadMeasurement> applies. The <RealTimeDuration> child element also represents the time resolution of associated measurement data.

Child elements, with tag names to reflect the kind of radiation measurement, detail the radiation measurement instrument's detector data. The available child elements are <Spectrum>, <GrossCounts>, <DoseRate>, <TotalDose>, <ExposureRate>, and <TotalExposure>. Each of these child elements includes an attribute that uniquely identifies a specific radiation measurement locally within an instance of the N42 document. Each element also includes an attribute that identifies the radiation detector responsible for the measurement and an attribute that references the appropriate <xxxCalibration> elements.

An <Occupancy> child element identifies the presence or non-presence of a measured item during the specific period of time the <RadMeasurement> covers.

The <RadInstrumentState>, <RadDetectorState>, and the <RadItemState> child elements indicate the state of the radiation measurement instrument, each of the radiation measurement instrument's radiation detectors, and each item the radiation measurement instrument measured, respectively. State data include location, orientation, direction of motion, and speed. For the radiation measurement instrument the state data also include the mode of operation. Radiation measurement instruments equipped with position sensors using a geolocation system is one means of capturing location data (see EPSG Map Datum Codes).

The radiation measurement instrument acquires the <RadxxxState> state data during the time interval denoted by the <StartDateTime> and <RealTimeDuration> child elements of <RadMeasurement>. These states are valid until their next update in a subsequent <RadMeasurement> element. For example, if the time resolution of a radiation measurement instrument's position must be higher than other data from the radiation detectors or other components (e.g., gross counts, spectrum, dose rate), the <RadxxxState> element can be included in a separate <RadMeasurement> element from those that include data from the radiation detectors or other components.

- <RadMeasurementGroup>: This element provides a means to identify a set of radiation measurements as a single group; for example: a sequence of radiation measurements indicative of a vehicle's traversal through a portal monitor. The <RadMeasurementGroupDescription> child element describes the group. A <RadMeasurementGroup> element includes an attribute that uniquely identifies a specific radiation measurement group locally within an instance of the N42 document.

The <RadMeasurementGroup> element also includes a unique universal identifier as an attribute. This optional identifier provides a means to distinguish a group of radiation measurements among those the radiation measurement instrument can produce in multiple documents over its operational life.

- <MultimediaData>: This element provides a means to identify data from a multimedia device such as camera, OCR, or license plate reader that supplement the radiation measurement instrument's radiation measurements. If there is more than one device, the document must include a separate

<MultimediaData> element for each device. Child elements identify the device, describe the device, indicate its MIME content type, and, detail the device data, or if the device data are not included in the document, reference their location via a URI.

Data from a multimedia device are applicable to a specific slice in time. Data collection time intervals may not directly coincide with those from any particular <RadMeasurement> element or other multimedia devices. Therefore, there are additional child elements of the <MultimediaData> element that indicate data capture start date/time and duration.

A <MultimediaData> element includes an attribute that uniquely identifies multimedia data from a specific device and time locally within an instance of the N42 document. When there is a means to associate a device's data with one or more measured items, the element provides an attribute that identifies the measured items. A device may collect more than one set of data during a specific time; a sequence number attribute provides a means to correctly order the data sets.

- <DerivedData>: This element provides data derived from radiation measurements. Child elements, representing the kind of radiation measurement, detail the derived data. The available child elements are <Spectrum>, <GrossCounts>, <DoseRate>, <TotalDose>, <ExposureRate>, and <TotalExposure>. An attribute in each of these child elements identifies the specific spectra, gross counts, dose rates, total doses, exposure rates, and total exposures from one or more radiation measurements or other derived data that are the sources of the specific derived data (cf., <RadMeasurement> element).

Derived data are applicable to a specific slice in time. Time intervals do not necessarily coincide with those from any particular <RadMeasurement> element or other <DerivedData> elements. Therefore, there are additional child elements of the <DerivedData> element that indicate the applicable start date/time and duration. A <DerivedData> element includes an attribute that uniquely identifies a specific set of derived data locally within an instance of the N42 document.

- <AnalysisResults>: This element provides the information that is the product of analysis of the radiation measurements or derived data. For example: a spectrometer may provide the radionuclides the radiation measurement instrument identified and its associated confidence indication. Child elements identify source indicators, radiation alarms, nuclides, and the details on the analysis algorithms themselves.

Analysis results are applicable to a specific slice in time. Time intervals do not necessarily coincide with those from any particular <RadMeasurement> element or other <DerivedData> elements. Therefore, there are additional child elements of the <AnalysisResults> element that indicate the analysis start date/time and computational duration. An <AnalysisResults> element includes an attribute that uniquely identifies a specific analysis results locally within an instance of the N42 document, and attributes that list the radiation measurements and derived data that are the subject of the analysis. It is possible to have more than one <AnalysisResults> within an instance of the N42 document.

Since an <AnalysisResults> element references the <RadMeasurement>, <RadMeasurementGroup>, or <DerivedData> elements that are the subject of the analysis, the order of these elements as they appear in an N42 document can vary. Annex D, Annex C, Annex E, and Annex G are examples of sequences of <RadMeasurement> elements followed by one or more <AnalysisResults> elements that reference the applicable preceding <RadMeasurement> elements. Annex I is an example of sequence of <RadMeasurement> elements each immediately followed by their associated <AnalysisResults>.

4.3.2 Example data documents

This standard supports several different types of radiation measurement instruments, each of which customarily have had different data reporting formats. Because this standard supports the requirements of all of these types of instruments, certain aspects of the standard require additional explanation.

Example data documents can be found in Annex B through Annex I:

- Annex B A “spectrometer,” described by IEC 62327 and ANSI N42.34; the document contains only a spectrum and energy calibration and demonstrates the minimum required information. It also provides an alternative energy calibration.
- Annex C A “spectrometer;” more complex than the example in Annex B, the document contains a spectrum, its calibration, and the results of the analysis of that spectrum.
- Annex D A “portal monitor,” described by IEC 62244 and ANSI N42.35; the data are a series of seven count values representing a short occupancy from a monitor with two gamma and two neutron radiation detectors. It also provides an alternative that shows an alarm occupancy fragment.
- Annex E A “spectroscopic portal monitor,” described by IEC 62484 and ANSI N42.38.
- Annex F A “personal radiation detector (PRD),” described by IEC 62401 and ANSI N42.32 (note that this example can also apply to survey meters or handheld gamma radiation measurement instruments described by IEC 62533 and ANSI N42.33); the data are a series of four count and dose rate readings.
- Annex G A “mobile” radiation measurement instrument, described by ANSI N42.43.
- Annex H A handheld neutron radiation measurement instrument, described by IEC 62534. It also provides an example on how to add an extension of a quantity measured by the radiation measurement instrument that is not defined by an element in this standard.
- Annex I A “spectroscopic personal radiation detector” (SPRD), described by IEC 62618 and ANSI N42.48.

Note that comments in the example documents (given in the form of XML comments) are not required in real radiation measurement instrument data documents. Also, the examples are indented for readability; this is desirable in real documents but not required.

The schema, these examples, and other non-normative information can be downloaded from the N42 XML Schema web page.

5. Requirements

5.1 Data types

5.1.1 Standard data types

For convenience, the definitions of standard XML Schema data types used in this standard are summarized here. These summaries are not normative; see XML Schema Part 2: Datatypes Second Edition for authoritative definitions.

- *boolean*: A true or false value (e.g., “0” or “false,” or “1” or “true”).
- *dateTime*: A date and time, in ISO 8601 format. The seconds value can be represented to arbitrary precision; the precision used should be appropriate for the value being represented. If the difference between UTC and local time is known, then the offset field (the “-6:00” part of the first example) shall be present. If the time difference is not known, then offset field shall be omitted. For example,

November 3, 2004 8:36:04.3 AM CST is represented by “2004-11-03T08:36:04.3-06:00”; February 24, 2010 7:55 AM GMT is represented by “2010-02-24T07:55:48-00:00” or “2010-02-24T07:55:48Z.”

- *decimal*: A real number represented by a series of numerals with an optional decimal point; for example, “123” or “123.456.” The precision used should be appropriate for the value being represented. This data type is used when exponent format is not allowed.
- *DECDEG*: an angle in degrees expressed as a decimal number.
- *duration*: A time duration in ISO 8601 format. For example, a 1 h, 15 min, 5.2 s time interval shall be represented by “PT1H15M05.2S,” “PT75M5.2S,” or “PT4505.2S.” The precision of the part of the value for “seconds” can be represented to arbitrary precision; the precision used should be appropriate for the value being represented.
- *ID*: A string containing no whitespace or carriage control characters. An *ID* is used to uniquely identify elements in the XML document.
- *IDREF*: Identical to the *ID* data type, an IDREF is a reference to a particular element identified by an *ID*. For example,

```
<Origin originReference=“HomePosition”>
```
- *IDREFS*: A list of IDREF values.
- *list*: A finite-length series of space-separated values of a native data type.
- *nonNegativeInteger*: An integer greater than or equal to zero.
- *positiveInteger*: An integer greater than or equal to one.
- *string*: A character (i.e., text) string.
- *token*: A string that does not contain the carriage return, line feed, or tab characters, that has no leading or trailing spaces, and that has no internal sequences of two or more spaces.

NOTE—Values are case-sensitive.

5.1.2 Derived data types

Data types specific to the N42 schema are as follows:

- *DoubleListSimpleType*: A list of double.
- *NonBlankStringSimpleType*: A *string* that is not empty and does not consist of only white space characters.
- *NonNegativeDoubleListSimpleType*: A list of *NonNegativeDoubleSimpleType*.
- *NonNegativeDoubleSimpleType*: A *double* whose value must be greater than or equal to zero.
- *PercentSimpleType*: A *double* with the value range of 0.0 to 100.0.
- *PositiveDoubleListSimpleType*: A list of *PositiveDoubleSimpleType*.
- *PositiveDoubleSimpleType*: A *double* whose value must be greater than zero.
- *ZeroToOneDoubleSimpleType*: A *double* with value range of 0.0 to 1.0.

5.1.3 Nuclide name format

Radiation measurement instruments with radionuclide identification capabilities shall create the <NuclideAnalysisResults>, <Nuclide>, and <NuclideName> elements. The <NuclideName> element is the name of a radionuclide or radioactive source identified by the radiation measurement instrument. The format of the <NuclideName> is described in the following subsections.

5.1.3.1 Standard nuclide name format

For radionuclides listed in the chart of radionuclides, these names shall use the format described in this section.

The format of the radionuclide name shall take the form:

Element-Nucleons[Isomer]

where

- *Element* is the IUPAC chemical element name (see the *Nomenclature of Inorganic Chemistry*). Note that the case of the IUPAC names shall be preserved.
- *Nucleons* is the number of protons and neutrons for this nuclide.
- *Isomer* is the metastable indicator. If the nuclide has a metastable state, the letter *m* follows *Nucleons*. If there is more than one metastable state, they are designated *m1*, *m2*, *m3*, ...
- Examples of radionuclide names listed in the chart of radionuclides are “Ag-110m,” “Cs-137,” and “I-131” (these names will represent ^{110m}Ag , ^{137}Cs and ^{131}I) (see the National Nuclear Data Center Chart of Nuclides).

5.1.3.1.1 Other radiation sources name format

For radiation measurement instruments used in the detection of illicit trafficking of radioactive materials there is a need to identify radioactive sources that have specific characteristics that cannot be described by a specific radionuclide as listed in the chart of radionuclides. For these types of radioactive sources, the following name conventions shall be used:

Name	Definition
Annihilation	The 511 keV annihilation peak. Such photopeak can be produced by positron emission tomography (PET) sources; examples of such sources are: ^{11}C , ^{13}N , ^{15}O , ^{18}F .
Bremsstrahlung	The signature of bremsstrahlung radiation has been observed. Bremsstrahlung is produced when fast electrons interact with the Coulombic field of the nucleus or when the fast electrons are decelerated when interacting with a metal target.
DU	Depleted Uranium is uranium with lower than natural abundance of ^{235}U . Approximate abundance: 99.799% ^{238}U , 0.2% ^{235}U , 0.001% ^{234}U .
HEU	Highly Enriched Uranium is uranium with high abundance of ^{235}U . The ^{235}U abundance is higher than 20%.
LEU	Low Enriched Uranium is uranium with an abundance of ^{235}U of approximately 3% to 20%.
<i>N (reaction)</i>	Nuclear reactions are indicated by the chemical element or nuclide name (<i>N</i>) followed by the reaction notation (<i>reaction</i>). Reaction notations include: — n,g — n,n’g — a,n — n,2n Examples are: “H(n,g),” “Fe(n,g),” and “O-18(a,n).”

Plutonium	If the radiation measurement instrument cannot discriminate between the different levels of plutonium enrichments (RGPu and WGPu), then they should all be indicated as "Plutonium."
N-xray	X-rays are indicated by the element name followed by "-xray." Examples: "U-xray," "Pb-xray."
Radium	Naturally occurring radium decay chain in equilibrium
Refined U	Natural uranium chemically processed to be separated from daughters (²³⁴ Th and ^{234m} Pa being short lived daughters of ²³⁸ U are still present).
RGPu	Reactor-Grade Plutonium is plutonium with > 7% ²⁴⁰ Pu
Shielded Source	The signature of a shielded radioactive source that cannot be fully identified due to the present of shielding material.
Thorium	Naturally occurring thorium decay chain in equilibrium
Unknown	Sources not identified because radionuclides are not listed in the radiation measurement instrument library or because the energy spectrum is distorted due, for example, to the presence of masking or shielding material.
U-natural	Uranium natural is equivalent to uranium-ore; that is, uranium in natural abundance and in secular equilibrium with an abundance of 99.2745% ²³⁸ U, 0.72% ²³⁵ U, and 0.0055% ²³⁴ U.
Uranium	If the radiation measurement instrument cannot discriminate between the different levels of uranium enrichments (DU, LEU, HEU and Refined U), then they should all be indicated as "Uranium."
WGPu	Weapons-Grade Plutonium is plutonium with ≤ 7% ²⁴⁰ Pu.

For other sources or conditions not covered above, the manufacturer shall provide a description of the name used and the meaning of the name.

5.2 Code lists

Where the value of a *string* or *token* data type element or attribute has a restricted range of values, a code list data type is defined providing the restricted values as enumerations. All enumeration values are case sensitive. Some code lists do not apply to all types of radiation measurement instruments.

5.2.1 AnalysisResultStatusCode

The following list describes the status states of the analysis of a measurement or measurement group.

Value	Description
Success	The analysis was successfully completed.
Failure	The analysis was not successfully completed.

5.2.2 CompressionCode

The following list describes the kinds of compression used to compress the spectrum channel data.

Value	Description
None	No compression.
CountedZeroes	The data are compressed using the CountedZeroes algorithm.

5.2.3 FaultSeverityCode

Value	Description
Fatal	The problem has caused the immediate termination of the operation. Data produced by the operation is not trustworthy.
Error	The problem has caused serious disruption of the operation. Data produced by the operation is not trustworthy.
Warning	The problem has caused no or only minor disruption of the operation; however, a condition exists that should be investigated. Data produced by the operation may not be trustworthy.

5.2.4 ImagePerspectiveCode

The following list describes the viewing perspectives for image multimedia data.

Value	Description
Front	The image is a view of the front of the subject.
Left Side	The image is a view of the left side of the subject.
Right Side	The image is a view of the right of the subject.
Rear	The image is a view of the rear of the subject.
Top	The image is a view of the top of the subject.
Bottom	The image is a view of the bottom (underside) of the subject.
Interior	The image is a view of the interior of the subject.
NA	Not applicable.
Unknown	The viewing perspective is unknown.

5.2.5 MeasurementClassCode

The following list describes the classes of spectrum measurements that a radiation measurement instrument with spectrometric capabilities can acquire for different kinds of radioactive sources or radiation fields.

Value	Description
Foreground	Measurement of an unknown radiation. The data shall be recorded without subtraction of environmental background or intrinsic activity.
Background	Measurement of environmental background. The data shall be recorded without subtraction of intrinsic activity.
Calibration	Measurement to be used for any type of calibration (e.g., energy, stabilization, efficiency).
IntrinsicActivity	Measurement of the radiation intrinsic to the radiation measurement instrument, without contribution from the environment or other sources.
NotSpecified	The measurement cannot be specified by the user or radiation measurement instrument.

5.2.6 MultimediaDeviceCategoryCode

The following list describes the kind of devices that can record multimedia data.

Value	Description
Audio	A device that records audible sounds, such as voice.
Camera	A camera that captures images on film.
Camera-D	A camera that captures images on digital/electronic media.
LPR	License Plate Reader
NII	Non-Intrusive Imaging
OCR	Optical Character Recognition
Other	Other
Reader	A device to create digital data from a physical/visual form of the data.
RFID	Radio Frequency Identifier
Scanner	A device to create a digital image of printed material.
Video	A video recording device that captures images on film.
Video-D	A video recording device that captures images on digital/electronic media.
VIS	Visual Inspection System Image

5.2.7 NuclideSourceGeometryCode

The following list describes the configurations that are applicable for the geometry of a radiation source detected by the radiation measurement instrument.

Value	Description
Point	A radiation source whose geometry is determined to a specific point.
Extended	A radiation source whose geometry is determined to be an area, not a specific point.
Undetermined	A radiation source whose geometry has not been determined.

5.2.8 RadAlarmCategoryCode

The following list describes the kinds of radiation alarms

Value	Description
Neutron	An alarm indicating presence of neutron radiation.
Gamma	An alarm indicating presence of gamma radiation.
Alpha	An alarm indicating presence of alpha radiation.
Beta	An alarm indicating presence of beta radiation.
Isotope	An alarm indicating presence of a radionuclide.
Other	An alarm produced by some other means.

5.2.9 RadDetectorCategoryCode

The following list describes the category of a radiation detector based on the type of particles and/or photon emission that it can detect from a radiological or nuclear substance.

Value	Description
Gamma	A radiation detector that primarily detects gamma rays.
Neutron	A radiation detector that primarily detects neutrons.
Alpha	A radiation detector that primarily detects alpha particles.
Beta	A radiation detector that primarily detects beta particles.
X-ray	A radiation detector that primarily detects X-rays.
Other	A radiation detector that does not fit any of the defined categories

5.2.10 RadDetectorKindCode

The following list describes the kinds of radiation detectors that may compose a radiation measurement instrument.

Value	Description
HPGe	High Purity Germanium
HPXe	High Pressure Xenon
NaI	Sodium Iodide
LaBr3	Lanthanum Bromide
LaCl3	Lanthanum Chloride
BGO	Bismuth Germanate scintillator
CZT	Cadmium Zinc Telluride
CdTe	Cadmium Telluride
CsI	Caesium Iodide
GMT	Geiger Muller Tube
GMTW	Windowed GM Tube
LiFiber	Lithium glass fiber
PVT	Polyvinyl Toluene
PS	Polystyrene
He3	³ He proportional counter
He4	⁴ He proportional counter
LiGlass	Lithium Glass
LiI	Lithium Iodide
SrI2	Strontium Iodide

CLYC	Cs ₂ LiYCl ₆
CdWO ₄	Cadmium Tungstate
BF ₃	Boron Trifluoride proportional counter
HgI ₂	Mercuric Iodide
CeBr ₄	Cerium Bromide
LiCAF	LiCaAlF ₆
LiZnS	⁶ LiZnS
Other	A radiation detector kind not otherwise defined.

5.2.11 RadInstrumentClassCode

The following list describes the classes of radiation detection instruments based on type and use.

Value	Description
Backpack or Personal Radiation Scanner	Radiation measurement instruments best described by IEC 62694 or ANSI N42.53.
Dosimeter	Radiation measurement instruments best described by IEC 61526, ISO 4037-3, ANSI N13.11, or ANSI N42.20.
Electronic Personal Emergency Radiation Detector	Radiation measurement instruments best described by ANSI N42.49A.
Mobile System	Radiation measurement instruments best described by ANSI N42.43.
Network Area Monitor	A collection of radiation measurement instruments working together as a single instrument. This type of instrument may be described by any of the radiation measurement instrument standards.
Neutron Handheld	Radiation measurement instruments best described by IEC 62534.
Personal Radiation Detector	Radiation measurement instruments best described by IEC 62401 or ANSI N42.32.
Radionuclide Identifier	Radiation measurement instruments best described by IEC 62327 or ANSI N42.34.
Portal Monitor	Radiation measurement instruments best described by IEC 62244 or ANSI N42.35.
Spectroscopic Portal Monitor	Radiation measurement instruments best described by IEC 62484 or ANSI N42.38.
Spectroscopic Personal Radiation Detector	Radiation measurement instruments best described by IEC 62618 or ANSI N42.48.
Gamma Handheld	Radiation measurement instruments best described by IEC 62533 or ANSI N42.33.
Transportable System	Radiation measurement instruments best described by ANSI N42.43.
Other	A class of radiation measurement instrument not otherwise defined.

5.2.12 RadInstrumentModeCode

The following list describes the operating modes of a radiation measurement instrument.

Value	Description
Calibrate	Calibration mode
Long Dwell	The radiation measurement instrument makes a single long measurement. For example, when a transportable system is stationary measuring a source for higher accuracy.
Search	The radiation measurement instrument makes a series of short measurements. For example, when a transportable system is moving and searching for sources, collecting gross count rates or spectra periodically. Another example: a portal monitor that collects gross count rates periodically while conveyances are in transit. Another example, a PRD displaying exposure rate readings as a function of time.
Test	Test or diagnostics mode
Other	Other

5.3 Schema outline

This subclause provides an outline of the elements and attributes contained in the N42 schema, ordered as they would appear in an instance xml document conforming to the schema. The following describes the format of the schema outline.

- The levels of indentation in the outline represent the element containment (i.e., data blocks).
- The schema outline includes element cardinality rules on the same line with the element, enclosed in brackets. The values and meanings are:
 - [1, 1] The element is required and there shall be only one instance.
 - [1, many] The element is required and there may be many instances.
 - [0, 1] The element is optional and there may be zero or one instance.
 - [0, many] The element is optional and there may be zero, one or many instances.
 - [NA] The element is abstract and therefore does not have occurrences. See Annex L for details.
- In some cases if an optional element is used, then a child element may be required. If a parent element is optional (i.e., cardinality of [0, 1] or [0, many]) and a child element is indicated as mandatory (e.g., [1, 1]) this means that the child element is required only if the optional parent element is included. Any rules more specific than this are described in the details in the sections for each of the elements.
- A cross-reference to the section number of the detailed information for an element is provided on the right side of the element name line. In the digital version of this document the element name is hyperlinked to the referenced section.
- If the element has attributes they appear enclosed by parentheses on the line immediately following the element name.
- Required attributes are indicated by “[R]” following the attribute name, and “[O]” if an attribute is optional.
- The start and end of an XML choice group is flagged by lines that contain “*****Choice” and “*****End of Choice.”
- The start and end of an XML substitution group is flagged by lines that contain “*****Substitute” and “*****End of Substitution”.

RadInstrumentData [1,1]	5.4.161
(id[O], n42DocDateTime[O], n42DocUUID[O])	
Remark [0,many]	5.4.195
RadInstrumentDataCreatorName [0,1]	5.4.162
RadInstrumentInformation [1,1]	5.4.166
(id[R])	
Remark [0,many]	5.4.195
RadInstrumentManufacturerName [1,1]	5.4.168
RadInstrumentIdentifier [0,1]	5.4.165

RadInstrumentModelName [1,1]	5.4.171
RadInstrumentDescription [0,1]	5.4.164
RadInstrumentClassCode [1,1]	5.4.158
RadInstrumentVersion [1,many]	5.4.175
(id[O])	
Remark [0,many]	5.4.195
RadInstrumentComponentName [1,1]	5.4.159
RadInstrumentComponentVersion [1,1]	5.4.160
RadInstrumentQualityControl [0,1]	5.4.172
(id[O])	
Remark [0,many]	5.4.195
InspectionDateTime [1,1]	5.4.90
InCalibrationIndicator [1,1]	5.4.88
RadInstrumentCharacteristics [0,many]	5.4.157
(id[O])	
Remark [0,many]	5.4.195
*****Choice of 1 or more of the following*****	
Characteristic [0,many]	5.4.37
(id[O], valueDateTime[O], valueOutOfLimits[O])	
Remark [0,many]	5.4.195
CharacteristicName [1,1]	5.4.40
CharacteristicValue [1,1]	5.4.41
CharacteristicValueUnits [1,1]	5.4.43
CharacteristicValueDataClassCode [1,1]	5.4.42
CharacteristicGroup [0,many]	5.4.38
(groupOutOfLimits[O], id[O])	
Remark [0,many]	5.4.195
CharacteristicGroupName [1,1]	5.4.39

Characteristic [1,many]	5.4.37
(id[O], valueDateTime[O], valueOutOfLimits[O])	
Remark [0,many]	5.4.195
CharacteristicName [1,1]	5.4.40
CharacteristicValue [1,1]	5.4.41
CharacteristicValueUnits [1,1]	5.4.43
CharacteristicValueDataClassCode [1,1]	5.4.42
*****End of Choice*****	
RadInstrumentInformationExtension [NA]	5.4.167
RadDetectorInformation [1,many]	5.4.148
(id[R])	
Remark [0,many]	5.4.195
RadDetectorName [0,1]	5.4.152
RadDetectorCategoryCode [1,1]	5.4.143
RadDetectorKindCode [1,1]	5.4.150
RadDetectorDescription [0,1]	5.4.146
RadDetectorLengthValue [0,1]	5.4.151
(units[O])	
RadDetectorWidthValue [0,1]	5.4.156
(units[O])	
RadDetectorDepthValue [0,1]	5.4.145
(units[O])	
RadDetectorDiameterValue [0,1]	5.4.147
(units[O])	
RadDetectorVolumeValue [0,1]	5.4.155
(units[O])	
RadDetectorCharacteristics [0,many]	5.4.144
(id[O])	

Remark [0,many]	5.4.195
*****Choice of 1 or more of the following*****	
Characteristic [0,many]	5.4.37
(id[O], valueDateTime[O], valueOutOfLimits[O])	
Remark [0,many]	5.4.195
CharacteristicName [1,1]	5.4.40
CharacteristicValue [1,1]	5.4.41
CharacteristicValueUnits [1,1]	5.4.43
CharacteristicValueDataClassCode [1,1]	5.4.42
CharacteristicGroup [0,many]	5.4.38
(groupOutOfLimits[O], id[O])	
Remark [0,many]	5.4.195
CharacteristicGroupName [1,1]	5.4.39
Characteristic [1,many]	5.4.37
(id[O], valueDateTime[O], valueOutOfLimits[O])	
Remark [0,many]	5.4.195
CharacteristicName [1,1]	5.4.40
CharacteristicValue [1,1]	5.4.41
CharacteristicValueUnits [1,1]	5.4.43
CharacteristicValueDataClassCode [1,1]	5.4.42
*****End of Choice*****	
RadDetectorInformationExtension [NA]	5.4.149
RadItemInformation [0,many]	5.4.178
(id[R])	
Remark [0,many]	5.4.195
RadItemDescription [0,1]	5.4.177
RadItemQuantity [0,1]	5.4.181
(id[O])	

Remark [0,many]	5.4.195
RadItemQuantityValue [1,1]	5.4.184
RadItemQuantityUncertaintyValue [0,1]	5.4.182
RadItemQuantityUnits [1,1]	5.4.183
RadItemMeasurementGeometryDescription [0,1]	5.4.180
RadItemCharacteristics [0,many]	5.4.176
(id[O])	
Remark [0,many]	5.4.195
*****Choice of 1 or more of the following*****	
Characteristic [0,many]	5.4.37
(id[O], valueDateTime[O], valueOutOfLimits[O])	
Remark [0,many]	5.4.195
CharacteristicName [1,1]	5.4.40
CharacteristicValue [1,1]	5.4.41
CharacteristicValueUnits [1,1]	5.4.43
CharacteristicValueDataClassCode [1,1]	5.4.42
CharacteristicGroup [0,many]	5.4.38
(groupOutOfLimits[O], id[O])	
Remark [0,many]	5.4.195
CharacteristicGroupName [1,1]	5.4.39
Characteristic [1,many]	5.4.37
(id[O], valueDateTime[O], valueOutOfLimits[O])	
Remark [0,many]	5.4.195
CharacteristicName [1,1]	5.4.40
CharacteristicValue [1,1]	5.4.41
CharacteristicValueUnits [1,1]	5.4.43
CharacteristicValueDataClassCode [1,1]	5.4.42
***** End of Choice *****	

RadItemInformationExtension [NA]	5.4.179
*****Choice of 0 or many of the following*****	
RadMeasurement [0,many]	5.4.187
(id[R], radItemInformationReferences[O], radMeasurementGroupReferences[O])	
Remark [0,many]	5.4.195
MeasurementClassCode [1,1]	5.4.101
StartDateTime [1,1]	5.4.210
RealTimeDuration [1,1]	5.4.191
Spectrum [0,many]	5.4.198
(energyCalibrationReference[R] fullEnergyPeakEfficiencyCalibrationReference[O], FWHMCalibrationReference[O], id[R], intrinsicDoubleEscapePeakEfficiencyCalibrationReference[O], intrinsicFullEnergyPeakEfficiencyCalibrationReference[O], intrinsicSingleEscapePeakEfficiencyCalibrationReference[O], radDetectorInformationReference[O], radRawSpectrumReferences[O])	
Remark [0,many]	5.4.195
LiveTimeDuration [1,1]	5.4.95
ChannelData [1,1]	5.4.36
(compressionCode[O])	
SpectrumExtension [0,many]	5.4.199
GrossCounts [0,many]	5.4.84
(energyWindowsReference[O], id[R], radDetectorInformationReference[R], radRawGrossCountsReferences[O])	
Remark [0,many]	5.4.195
LiveTimeDuration [1,1]	5.4.95
CountData [1,1]	5.4.45
TotalCountData [0,1]	5.4.212
DoseRate [0,many]	5.4.51
(id[R], radDetectorInformationReference[R], radRawDoseRateReferences[O])	
Remark [0,many]	5.4.195
DoseRateValue [0,1]	5.4.53

(units[O])	
DoseRateLevelDescription [0,1]	5.4.52
TotalDose [0,many]	5.4.214
(id[R], radDetectorInformationReference[R], radRawTotalDoseReferences[O], units[O])	
ExposureRate [0,many]	5.4.68
(id[R], radDetectorInformationReference[R], radRawExposureRateReferences[O])	
Remark [0,many]	5.4.195
ExposureRateValue [0,1]	5.4.70
(units[O])	
ExposureRateLevelDescription [0,1]	5.4.69
TotalExposure [0,many]	5.4.217
(id[R], radDetectorInformationReference[R], radRawTotalExposureReferences[O], units[O])	
RadInstrumentState [0,1]	5.4.173
(id[O], radInstrumentInformationReference[R])	
Remark [0,many]	5.4.195
RadInstrumentModeCode [0,1]	5.4.169
RadInstrumentModeDescription [0,1]	5.4.170
StateVector [0,1]	5.4.211
*****Choice of zero to one of the following*****	
GeographicPoint [0,1]	5.4.80
(datum[O], units[O])	
LatitudeValue [1,1]	5.4.94
(units[O])	
LongitudeValue [1,1]	5.4.97
(units[O])	
ElevationValue [0,1]	5.4.59
ElevationOffsetValue [0,1]	5.4.58
GeoPointAccuracyValue [0,1]	5.4.81

ElevationAccuracyValue [0,1]	5.4.56
ElevationOffsetAccuracyValue [0,1]	5.4.57
LocationDescription [0,1]	5.4.96
RelativeLocation [0,1]	5.4.192
RelativeLocationAzimuthValue [0,1]	5.4.193
(units[O])	
RelativeLocationInclinationValue [0,1]	5.4.194
(units[O])	
DistanceValue [0,1]	5.4.48
(units[O])	
Origin [1,1]	5.4.134
(originReference[O])	
GeographicPoint [0,1]	5.4.80
(datum[O], units[O])	
LatitudeValue [1,1]	5.4.94
(units[O])	
LongitudeValue [1,1]	5.4.97
(units[O])	
ElevationValue [0,1]	5.4.59
ElevationOffsetValue [0,1]	5.4.58
GeoPointAccuracyValue [0,1]	5.4.81
ElevationAccuracyValue [0,1]	5.4.56
ElevationOffsetAccuracyValue [0,1]	5.4.57
OriginDescription [0,1]	5.4.135
*****End of Choice*****	
Orientation [0,1]	5.4.133
AzimuthValue [1,1]	5.4.25
(units[O])	

InclinationValue [0,1]	5.4.89
(units[O])	
RollValue [0,1]	5.4.196
(units[O])	
SpeedValue [0,1]	5.4.209
(units[O])	
Fault [0,many]	5.4.71
(id[O])	
Remark [0,many]	5.4.195
FaultCodeValue [1,1]	5.4.72
FaultDescription [1,1]	5.4.73
FaultSeverityCode [1,1]	5.4.75
FaultExtension [NA]	5.4.74
RadInstrumentCharacteristics [0,many]	5.4.157
(id[O])	
Remark [0,many]	5.4.195
*****Choice of 1 or more of the following*****	
Characteristic [0,many]	5.4.37
(id[O], valueDateTime[O], valueOutOfLimits[O])	
Remark [0,many]	5.4.195
CharacteristicName [1,1]	5.4.40
CharacteristicValue [1,1]	5.4.41
CharacteristicValueUnits [1,1]	5.4.43
CharacteristicValueDataClassCode [1,1]	5.4.42
CharacteristicGroup [0,many]	5.4.38
(groupOutOfLimits[O], id[O])	
Remark [0,many]	5.4.195
CharacteristicGroupName [1,1]	5.4.39

Characteristic [1,many]	5.4.37
(id[O], valueDateTime[O], valueOutOfLimits[O])	
Remark [0,many]	5.4.195
CharacteristicName [1,1]	5.4.40
CharacteristicValue [1,1]	5.4.41
CharacteristicValueUnits [1,1]	5.4.43
CharacteristicValueDataClassCode [1,1]	5.4.42
*****End of Choice*****	
RadInstrumentStateExtension [NA]	5.4.174
RadDetectorState [0,many]	5.4.153
(id[O], radDetectorInformationReference[R])	
Remark [0,many]	5.4.195
StateVector [0,1]	5.4.211
*****Choice of zero to one of the following*****	
GeographicPoint [0,1]	5.4.80
(datum[O], units[O])	
LatitudeValue [1,1]	5.4.94
(units[O])	
LongitudeValue [1,1]	5.4.97
(units[O])	
ElevationValue [0,1]	5.4.59
ElevationOffsetValue [0,1]	5.4.58
GeoPointAccuracyValue [0,1]	5.4.81
ElevationAccuracyValue [0,1]	5.4.56
ElevationOffsetAccuracyValue [0,1]	5.4.57
LocationDescription [0,1]	5.4.96
RelativeLocation [0,1]	5.4.192
RelativeLocationAzimuthValue [0,1]	5.4.193

(units[O])	
RelativeLocationInclinationValue [0,1]	5.4.194
(units[O])	
DistanceValue [0,1]	5.4.48
(units[O])	
Origin [1,1]	5.4.134
(originReference[O])	
GeographicPoint [0,1]	5.4.80
(datum[O], units[O])	
LatitudeValue [1,1]	5.4.94
(units[O])	
LongitudeValue [1,1]	5.4.97
(units[O])	
ElevationValue [0,1]	5.4.59
ElevationOffsetValue [0,1]	5.4.58
GeoPointAccuracyValue [0,1]	5.4.81
ElevationAccuracyValue [0,1]	5.4.56
ElevationOffsetAccuracyValue [0,1]	5.4.57
OriginDescription [0,1]	5.4.135
*****End of Choice*****	
Orientation [0,1]	5.4.133
AzimuthValue [1,1]	5.4.25
(units[O])	
InclinationValue [0,1]	5.4.89
(units[O])	
RollValue [0,1]	5.4.196
(units[O])	
SpeedValue [0,1]	5.4.209

(units[O])

Fault [0,many] 5.4.71

(id[O])

Remark [0,many] 5.4.195

FaultCodeValue [1,1] 5.4.72

FaultDescription [1,1] 5.4.73

FaultSeverityCode [1,1] 5.4.75

FaultExtension [NA] 5.4.74

RadDetectorCharacteristics [0,many] 5.4.144

(id[O])

Remark [0,many] 5.4.195

*****Choice of 1 or more of the following*****

Characteristic [0,many] 5.4.37

(id[O], valueDateTime[O], valueOutOfLimits[O])

Remark [0,many] 5.4.195

CharacteristicName [1,1] 5.4.40

CharacteristicValue [1,1] 5.4.41

CharacteristicValueUnits [1,1] 5.4.43

CharacteristicValueDataClassCode [1,1] 5.4.42

CharacteristicGroup [0,many] 5.4.38

(groupOutOfLimits[O], id[O])

Remark [0,many] 5.4.195

CharacteristicGroupName [1,1] 5.4.39

Characteristic [1,many] 5.4.37

(id[O], valueDateTime[O], valueOutOfLimits[O])

Remark [0,many] 5.4.195

CharacteristicName [1,1] 5.4.40

CharacteristicValue [1,1] 5.4.41

CharacteristicValueUnits [1,1]	5.4.43
CharacteristicValueDataClassCode [1,1]	5.4.42
*****End of Choice*****	
RadDetectorStateExtension [NA]	5.4.154
RadItemState [0,many]	5.4.185
(id[O], radItemInformationReference[R])	
Remark [0,many]	5.4.195
StateVector [0,1]	5.4.211
*****Choice of zero to one of the following*****	
GeographicPoint [0,1]	5.4.80
(datum[O], units[O])	
LatitudeValue [1,1]	5.4.94
(units[O])	
LongitudeValue [1,1]	5.4.97
(units[O])	
ElevationValue [0,1]	5.4.59
ElevationOffsetValue [0,1]	5.4.58
GeoPointAccuracyValue [0,1]	5.4.81
ElevationAccuracyValue [0,1]	5.4.56
ElevationOffsetAccuracyValue [0,1]	5.4.57
LocationDescription [0,1]	5.4.96
RelativeLocation [0,1]	5.4.192
RelativeLocationAzimuthValue [0,1]	5.4.193
(units[O])	
RelativeLocationInclinationValue [0,1]	5.4.194
(units[O])	
DistanceValue [0,1]	5.4.48
(units[O])	

Origin [1,1]	5.4.134
(originReference[O])	
GeographicPoint [0,1]	5.4.80
(datum[O], units[O])	
LatitudeValue [1,1]	5.4.80
(units[O])	
LongitudeValue [1,1]	5.4.97
(units[O])	
ElevationValue [0,1]	5.4.59
ElevationOffsetValue [0,1]	5.4.58
GeoPointAccuracyValue [0,1]	5.4.81
ElevationAccuracyValue [0,1]	5.4.56
ElevationOffsetAccuracyValue [0,1]	5.4.57
OriginDescription [0,1]	5.4.135
*****End of Choice*****	
Orientation [0,1]	5.4.133
AzimuthValue [1,1]	5.4.25
(units[O])	
InclinationValue [0,1]	5.4.89
(units[O])	
RollValue [0,1]	5.4.196
(units[O])	
SpeedValue [0,1]	5.4.209
(units[O])	
RadItemCharacteristics [0,many]	5.4.176
(id[O])	
Remark [0,many]	5.4.195
*****Choice of 1 or more of the following*****	

Characteristic [0,many]	5.4.37
(id[O], valueDateTime[O], valueOutOfLimits[O])	
Remark [0,many]	5.4.195
CharacteristicName [1,1]	5.4.40
CharacteristicValue [1,1]	5.4.41
CharacteristicValueUnits [1,1]	5.4.43
CharacteristicValueDataClassCode [1,1]	5.4.42
CharacteristicGroup [0,many]	5.4.38
(groupOutOfLimits[O], id[O])	
Remark [0,many]	5.4.195
CharacteristicGroupName [1,1]	5.4.39
Characteristic [1,many]	5.4.37
(id[O], valueDateTime[O], valueOutOfLimits[O])	
Remark [0,many]	5.4.195
CharacteristicName [1,1]	5.4.40
CharacteristicValue [1,1]	5.4.41
CharacteristicValueUnits [1,1]	5.4.43
CharacteristicValueDataClassCode [1,1]	5.4.42
*****End of Choice*****	
RadItemStateExtension [NA]	5.4.186
OccupancyIndicator [0,1]	5.4.132
RadMeasurementExtension [NA]	5.4.188
RadMeasurementGroup [0,many]	5.4.189
(id[R], radMeasurementGroupUUID[O])	
Remark [0,many]	5.4.195
RadMeasurementGroupDescription [0,1]	5.4.190
EnergyCalibration [0,many]	5.4.62
(id[R])	

Remark [0,many]	5.4.195
*****Choice of one of the following*****	
CoefficientValues [0,1]	5.4.44
EnergyBoundaryValues [0,1]	5.4.61
(units[O])	
*****End of Choice*****	
EnergyValues [0,1]	5.4.64
(units[O])	
EnergyDeviationValues [0,1]	5.4.63
(units[O])	
CalibrationDateTime [0,1]	5.4.35
FWHMCalibration [0,many]	5.4.77
(id[R])	
Remark [0,many]	5.4.195
EnergyValues [1,1]	5.4.64
(units[O])	
FWHMValues [1,1]	5.4.79
(units[O])	
FWHMUncertaintyValues [0,1]	5.4.78
(units[O])	
CalibrationDateTime [0,1]	5.4.35
TotalEfficiencyCalibration [0,many]	5.4.216
(id[R])	
Remark [0,many]	5.4.195
EnergyValues [1,1]	5.4.64
(units[O])	
EfficiencyValues [1,1]	5.4.55
EfficiencyUncertaintyValues [0,1]	5.4.54

CalibrationDateTime [0,1]	5.4.35
FullEnergyPeakEfficiencyCalibration [0,many]	5.4.76
(id[R])	
Remark [0,many]	5.4.195
EnergyValues [1,1]	5.4.64
(units[O])	
EfficiencyValues [1,1]	5.4.55
EfficiencyUncertaintyValues [0,1]	5.4.54
CalibrationDateTime [0,1]	5.4.35
IntrinsicFullEnergyPeakEfficiencyCalibration [0,many]	5.4.92
(id[R])	
Remark [0,many]	5.4.195
EnergyValues [1,1]	5.4.64
(units[O])	
EfficiencyValues [1,1]	5.4.55
EfficiencyUncertaintyValues [0,1]	5.4.54
CalibrationDateTime [0,1]	5.4.35
IntrinsicSingleEscapePeakEfficiencyCalibration [0,many]	5.4.93
(id[R])	
Remark [0,many]	5.4.195
EnergyValues [1,1]	5.4.64
(units[O])	
EfficiencyValues [1,1]	5.4.55
EfficiencyUncertaintyValues [0,1]	5.4.54
CalibrationDateTime [0,1]	5.4.35
IntrinsicDoubleEscapePeakEfficiencyCalibration [0,many]	5.4.91
(id[R])	
Remark [0,many]	5.4.195

EnergyValues [1,1]	5.4.64
(units[O])	
EfficiencyValues [1,1]	5.4.55
EfficiencyUncertaintyValues [0,1]	5.4.54
CalibrationDateTime [0,1]	5.4.35
EnergyWindows [0,many]	5.4.65
(id[R])	
Remark [0,many]	5.4.195
WindowStartEnergyValues [1,1]	5.4.220
(units[O])	
WindowEndEnergyValues [1,1]	5.4.219
(units[O])	
DerivedData [0,many]	5.4.46
(id[R])	
Remark [0,many]	5.4.195
MeasurementClassCode [1,1]	5.4.101
StartDateTime [1,1]	5.4.210
RealTimeDuration [1,1]	5.4.191
Spectrum [0,many]	5.4.198
(energyCalibrationReference[R], fullEnergyPeakEfficiencyCalibrationReference[O], FWHMCalibrationReference[O], id[R], intrinsicDoubleEscapePeakEfficiencyCalibrationReference[O], intrinsicFullEnergyPeakEfficiencyCalibrationReference[O], intrinsicSingleEscapePeakEfficiencyCalibrationReference[O], radDetectorInformationReference[O], radRawSpectrumReferences[O])	
Remark [0,many]	5.4.195
LiveTimeDuration [1,1]	5.4.95
ChannelData [1,1]	5.4.36
(compressionCode[O])	
SpectrumExtension [NA]	5.4.199
GrossCounts [0,many]	5.4.84