STATUS OF THE ISO DRAFT STANDARD FOR DETERMINING SOLAR IRRADIANCES (CD 21348)

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ABSTRACT

The ISO Technical Committee 20, *Aircraft and space vehicles*, Subcommittee 14, *Space systems and operations*, Working Group 4, *Space Environment – Natural and Artificial* is developing a draft solar irradiance standard that is designated CD 21348, "Process for Determining Solar Irradiances." The draft standard specifies all representations of solar irradiances and is applicable to measurement sets, reference spectra, empirical models, and theoretical models that provide solar irradiance products. Its purpose is to provide a standard method, with common, understandable formats, for specifying all solar irradiances for use by space systems and materials users. The process for developing an International Standard, the basis for a solar irradiance international standard, the scope of CD 21348, the solar product types, the spectral irradiance categories, the draft standard compliance criteria, and the compliance certification process are described.

BACKGROUND

The process of developing an International Standard

The International Standards Organization (ISO) is a worldwide federation of national standards bodies that have become ISO member bodies. International organizations, both governmental and non-governmental, act in liaison with ISO to develop standards of mutual benefit. ISO also collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization. International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2, "Rules for the structure and drafting of International Standards" (2001).

What is an International Standard? In the broadest sense, an International Standard can be described as a reference framework, or a common technological language, between suppliers and their customers which facilitates trade and the transfer of technology. Compliance with an International Standard means compliance with a set of requirements that will facilitate the exchange of data or products.

The work of preparing International Standards is normally carried out through ISO technical committees that convene under the direction of the member bodies. The main task of technical committees is to prepare International Standards. For example, ISO Technical Committee (TC) 20 covers all standardization issues related to Aircraft and Space Vehicles. There are six active subcommittees (SC) in TC20, four of which work with specific products such as aircraft electrical equipment (SC1), air cargo and ground equipment (SC9), aircraft fluid systems and components (SC10), and airframe bearings (SC15). Two subcommittees work with space issues and are considered sectoral committees. They have a larger areas of responsibility distributed among several working groups (WG). Of the two subcommittees, Space Data and Information Transfer Systems (SC13) and Space Systems and Operations (SC14), the latter (SC14) has direction over the work described in this paper. Within SC14, there are six broad working groups and Working Group (WG) 4 organizes the standardization work directly relevant to the "Space Environment – Natural and Artificial."

The process of drafting an international standard starts with the selection of a Project Lead (PL) to organize the work. The PL is a designated expert in the field, is expected to have adequate resources for carrying out the project, is required to act in a purely international capacity, and should be prepared to act as a consultant regarding technical matters. The PL organizes the drafting of the International Standard, starting with the submission of a New Work Item (NWI) and proceding through the writing and WG acceptance of a Working Draft (WD), Technical Specification (TS), or Technical Report (TR). Once a WG has accepted the draft, it is submitted to SC14 for vote by the member bodies to become a Committee Draft (CD) where the draft standard is accepted for standardization consideration and review. The PL maintains cognizance of the draft standard's status through the CD, Draft International Standard (DIS), Final International Standard (FIS), and International Standard (IS) stages. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. A DIS requires approval by at least 75% of the member bodies casting a vote to become a FIS. The Geneva ISO office takes the FIS and publishes it as an International Standard.

The basis for a Solar Irradiance International Standard

Solar irradiance, as shown in Figure 1, is the Sun's radiation integrated over the full disk of the Sun expressed as a unit of power, W, through a unit of area, m^{-2}, centered at a specified wavelength, λ, and integrated across a wavelength bandwidth, $\Delta\lambda^{-1}$. Space systems and materials users, from a variety of scientific and engineering disciplines, understood by the late 1990's that a common method of specifying solar irradiances was needed. This recognition occurred at a time when, from a scientific point-of-view, measurements and modeling of solar irradiances began to mature. A wide variety of solar irradiance measurements had been or were being made using space- and ground-based instrumentation that depended upon wavelength or bandpass selection. The measurements had differing degrees of accuracy and precision, as well as spectral and temporal resolution, and became increasingly difficult to reconcile from an empirical modeling perspective. In addition, spatial (radiance) measurements were becoming more abundant as they detailed the physical processes occurring in the Sun's thermal and non-thermal features. From an engineering viewpoint, space-related systems such as Earth satellite orbits, attitudes, and surfaces were long-known to be directly affected by solar irradiances across the spectrum. In addition, solar irradiance forcing of the Earth's ionosphere is known to affect activities such as operational HF signal reflection and GPS signal delay (single-frequency, absolute location) specification.

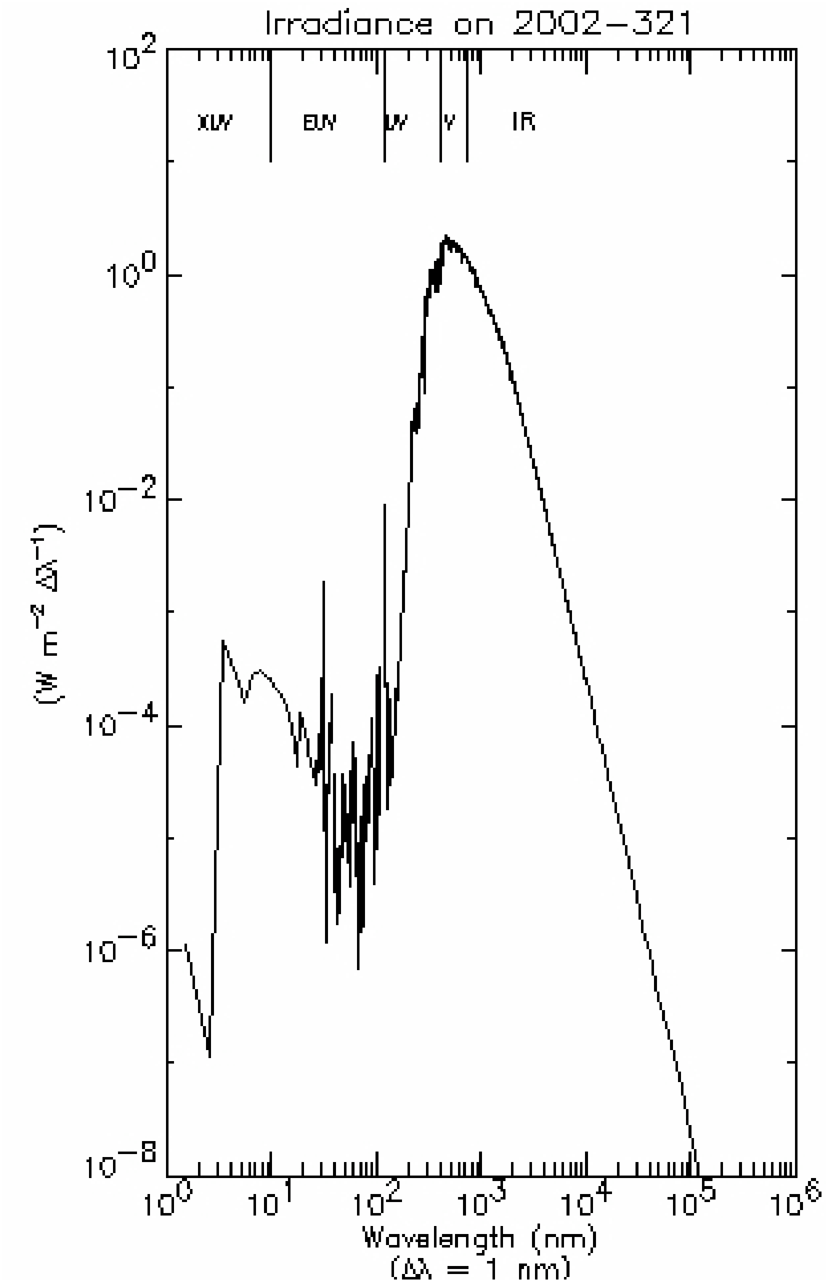

Fig. 1. Solar spectrum from the X-rays to the radio wavelengths at 1 nm resolution with several spectral bands identified.

Because of the breadth of effects by solar irradiances upon engineering activities, and coincident with the maturation of measurements and empirical/numerical modeling by the scientific communities, it was recognized that, at the beginning of the 21st Century, a major effort was needed to standardize solar irradiance production and use. In this context, ISO CD 21348, "Process for Determining Solar Irradiances," was envisioned by Technical Committee 20, *Aircraft and space vehicles*, Subcommittee 14, *Space systems and operations*, Working Group 4, *Space Environment – Natural and Artificial*. Project Leads W. Kent Tobiska (USA) and Anatoliy A. Nusinov (Russia) were selected in 1997-1998 by ISO TC20/SC14/WG4 to organize this work and reported on early progress (Tobiska and Nusinov, 2000). The overall process owner for developing the draft standard is ISO TC20/SC14/WG4 while the direct process participants are the delegates and technical experts to ISO TC20/SC14/WG4. The expertise of the international solar science and material science communities have been utilized in the development of this draft standard.

SCOPE OF THE DRAFT STANDARD CD 21348

The ISO CD 21348 draft International Standard, "Process for Determining Solar Irradiances," specifies all representations of solar irradiances and is applicable to measurement sets, reference spectra, empirical models, and theoretical models that provide solar irradiance products. Its purpose is to provide a standard method for specifying all solar irradiances for use by space systems and materials users.

Solar irradiance products are derived from measurements and/or models and are frequently reported to space systems users. Examples of solar irradiance products include, but are not limited to, spectral and time series intensities, surrogates or proxies intended to represent solar irradiances, and solar images with spectral content. Because knowledge of solar irradiance spectral and temporal characteristics is fundamental to the understanding of a wide variety of physical processes and technical issues, and because solar irradiances have been reported in a variety of formats, it is recognized that a standardization of solar irradiance specification is important. Standardized specification of solar irradiances enables suppliers and users of these products to exchange information with common, understandable formats.

A fundamental concept of the draft solar irradiance standard assumes that there will be continued technical improvements in the accuracy and precision of measurements as ground-based and space-based instrumentation use new detectors, filters, and computer hardware/software algorithms and as there is improved understanding of the physical processes occurring at the Sun. There is also the expectation of continual improvements to the reporting and calculation of reference spectra, empirical, and first-principles models. It is likely that there will be an evolving solar standard user community. Given the continual change in these areas, the draft solar irradiance standard is developed to be a robust document and this is seen as a way of supporting and encouraging these changes.

Robustness is achieved with the way in which the draft standard is written. First, the draft solar irradiance standard does not specify one measurement set, one reference spectrum, or one model as the single standard. Second, in order to encourage continual improvements in solar irradiance products, the solar irradiance standard is written as a process-based standard. In other words, in the course of developing a solar irradiance product, a reporting process is followed in order to certify compliance with the standard.

Because the draft standard is process-based, and no specific product is selected as the standard, it was recognized by all participants in this work that the scientific and engineering communities required some type of detailed solar irradiance specification for their separate activities. As a result of this understanding, a parallel work has been established in the scientific community to provide a published volume of measurement sets, reference spectra, and models that certify compliance with this standard. It is anticipated that a volume will be published as part of a special 2004 COSPAR session and that the volume will contain adequate material to satisfy the solar science, space systems, and materials users communities.

SOLAR PRODUCT TYPES

Solar irradiance product types are established in the draft standard so that the suppliers and users have a common, easy-to-recognize method of identifying standard-compliant solar irradiance products. A solar irradiance product can be a measurement set, reference spectrum, empirical model, or first-principles model and has the characteristics of only one type.

Type 1

This type designates a measurement set product. Solar irradiances are measured by space- or ground-based instrumentation (including balloons) at specified wavelengths, with an identifiable wavelength bandpass, having a quantifiable intensity based upon a calibrated reference source, integrated over an identified spatial area, and measured over a unit of time.

Type 2

This type designates a reference spectrum product. Reference spectra can be derived from single and/or multiple measurement sets and can be combined with models. Reference spectra represent generalized characteristics of solar irradiances for specified solar activity conditions or unique dates.

Type 3

This type designates an empirical model product. An empirical solar irradiance model is derived from space- or ground-based measurement sets (including balloons). It uses proxies to represent solar irradiances at specified wavelengths and produces irradiances with an identifiable wavelength bandpass, having an intensity related to the measurements, integrated over an identified spatial area, and reported over a unit of time.

Type 4

This type designates a first-principles model product. A first-principles solar irradiance model is derived from the fundamental physics describing energy, momentum, and/or mass conservation, transfer, and change between states. It produces solar irradiances at specified wavelengths, with an identifiable wavelength bandpass, having an intensity related to the energy processes, integrated over an identified spatial area, and reported over a unit of time.

SPECTRAL IRRADIANCE CATEGORIES

Spectral irradiance category definitions are derived from the recommendations or usage by provider/user communities. There are differing definitions used by several communities and these definitions are provided for reference only. The draft standard does not recommend one definition over another in cases where differences exist. These definitions may be changed in the future as convention dictates and as relevant to the contents of the draft standard.

X-rays

Hard X-rays

Hard X-ray irradiances are defined in the wavelength range of 1 nm > λ. This wavelength range is commonly used by providers of the data of this spectral range.

Soft X-rays

Soft X-ray irradiances are defined in the wavelength range of 10 nm > λ ≥ 1 nm. This wavelength range is commonly used by providers of the data of this spectral range. The aeronomy community sometimes considers soft X-rays, also called the XUV, to extend to 30 nm.

Vacuum Ultraviolet

Vacuum Ultraviolet or VUV irradiances are defined in the wavelength range of 200 nm > λ ≥ 10 nm. This wavelength range is commonly used by providers of the data of this spectral range as well as by the materials sciences community.

Extreme Ultraviolet. Extreme ultraviolet or EUV irradiances are defined in the wavelength range of 100 nm > λ ≥ 10 nm. This wavelength range is commonly used by providers of the data of this spectral range. Some members of the aeronomy community have used a definition with the lower wavelength cutoff at 30 nm and a higher cutoff at 120 nm.

Far Ultraviolet. Far Ultraviolet or FUV irradiances are defined in the wavelength range of 200 nm > λ ≥ 100 nm. This wavelength range is commonly used by providers of the data of this spectral range. Some members of the aeronomy community consider the start of this wavelength range at 120 nm.

Middle Ultraviolet. Middle Ultraviolet or MUV irradiances are defined in the wavelength range of 300 nm > λ ≥ 200 nm. This wavelength range is commonly used by the aeronomy community.

Ultraviolet

The ultraviolet wavelengths have been assigned a variety of divisions, depending upon user community, measurement techniques, and instrumentation capabilities. The following are commonly accepted divisions for the Global Solar UV Index (UVI) (WHO, 2002).

Ultraviolet. Ultraviolet or UV irradiances are defined in the wavelength range of 400 nm > λ ≥ 100 nm.

Ultraviolet A. Ultraviolet A or UVA irradiances are defined in the wavelength range of 400 nm > λ ≥ 315 nm.

Ultraviolet B. Ultraviolet B or UVB irradiances are defined in the wavelength range of 315 nm > λ ≥ 280 nm.

Ultraviolet C. Ultraviolet C or UVC irradiances are defined in the wavelength range of 280 nm > □ ≥ 100 nm.

<u>Visible</u>

Visible or optical or VIS irradiances are defined in the wavelength range of 700 nm > □ ≥ 400 nm.

<u>Infrared</u>

Infrared or IR irradiances are defined in the wavelength range of 10 □m > □≥ 0.70 □m. Infrared is often divided into 3 spectral categories, i.e., the near, mid and far-infrared. The definitions are not yet agreed upon.

Near Infrared. Near infrared irradiances are often defined in the wavelength range of 5 □m > □ ≥ 0.70 □m.

Mid Infrared. Mid infrared irradiances are often defined in the wavelength range of 40-25 □m > □ ≥ 5 □m.

Far infrared. Far infrared irradiances are often defined in the wavelength range of 350-200 □m > □ ≥ 40-25 □m.

<u>Microwave</u>

Microwave irradiances are often defined in the wavelength range of 1.5 cm > □ ≥ 1 mm. Microwave bands include the W (□ = 3.3 mm), V (□ = 5.0 mm), Q (□ = 7.5 mm), Ka (□ = 10.0 mm), and K (□ = 13.6 mm).

<u>Radio</u>

Radio irradiances are often defined in the wavelength range of □ ≥ 1.5 cm.

<u>Total Solar Irradiance</u>

Total Solar Irradiance (TSI) is the full-disk solar irradiance at 1 AU integrated across all wavelengths.

COMPLIANCE CRITERIA

The compliance criteria for the draft standard consist of four overarching activities that are common to irradiance measurements, reference spectra, empirical models, and first-principles models. These criteria are derived from characteristics common to solar product types and spectral categories such as the reporting, documenting, publishing, and archiving of solar irradiance products.

Reporting

The draft standard requires that, as a minimum condition, solar irradiances are reported in SI units, W m^{-2} □□$^{-1}$, corrected to 1 AU.

Documenting

The draft standard requires that the method of determining irradiances is documented and, as appropriate, includes data collection, retrieval, processing, calibration, validation, verification, accuracy, and precision methodology and/or algorithms, as well as archiving information.

Measurements. For measurements, including space-based satellite observations, rocket experiment data sets, and ground-based observations (including balloons), a description of the responsible agent/institution and the instrumentation used to collect and retrieve the irradiances is provided. The data processing algorithms, the instrument calibration techniques and heritage, the method of determining accuracy and precision, the validation and verification methodology, as well as the archival processes are documented.

Reference spectra. For reference spectra, including the mean of spectra over several solar cycles or spectra for a variety of solar activity conditions, the rationale for specifying a spectrum as a reference is described. The measurement set(s) used to derive the reference spectrum, the method of resolving discrepancies between multiple data sets, the data processing algorithms, the method of determining accuracy and precision, the validation and verification methodology, as well as the archival processes are documented.

Empirical models. For empirical models, including those based on one or many space- or ground-based measurement sets, a description of the rationale for developing the model, of its areas of application, and of the rationale for selecting proxies is described. The measurement data sets used in the derivation, the mathematical formulation of the model, the method of resolving discrepancies between multiple data sets, the derivation algorithms, the method of determining accuracy and precision, the validation and verification methodology, as well as the archival processes are documented.

Theoretical models. For theoretical models of solar processes, a description of the physical principles that are used as the basis of the model, of the rationale for developing the model, and of its areas of application are described. The numerical algorithms that produce solar irradiances, the mathematical formulation of the model, the method of determining accuracy and precision, the validation and verification methodology, as well as the archival processes are documented.

Publishing

The draft standard requires that the documented solar irradiance product is published in an internationally-accessible journal which uses scientific or discipline-area peer review in the publication process. For any irradiance product, the published article may point to a permanent electronic archival location where the archived measurements, spectra, or models can be found, accessed, or recreated by an international community.

Archiving

The draft standard requires that the documented and published solar irradiance product is archived in a method consistent with any contemporary technology that ensures international accessibility.

CERTIFICATION PROCESS

The draft standard requires that certification of compliance is achieved by complying with the criteria listed above. Self-declaration of compliance in an archival publication can be accomplished by using the statement "The process used for determining solar irradiances reported herein is compliant with ISO International Standard 21348: Space Environment (Natural and Artificial) – Process for determining solar irradiances." The type designation and/or the solar irradiance spectral categories may be optionally identified in the self-declaration of compliance.

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