TECHNICAL REPORT

# ISO/TR 19263-1

First edition
2017-03

# Photography — Archiving systems —

## Part 1: Best practices for digital image capture of cultural heritage material

*Photographie — Systèmes d'archivage —*

*Partie 1: Meilleures pratiques pour la capture d'images numériques du matériel de patrimoine culturel*

Reference number
ISO/TR 19263-1:2017(E)

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# Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 42, *Photography*.

# Introduction

Today digitization programs need to satisfy the demands of an interconnected dynamic user community. A digitized image can be repurposed across any number of systems and therefore needs to be well defined, technically robust and media agnostic. The digital image of an original is intended to satisfy multiple uses including access, archiving, research, conservation, education, marketing, social media, reproduction and distribution both in print and online.

Intended for organizations, such as cultural heritage institutions, ISO 19264-1 specifies a method for analysing imaging systems where it is important to control the degree of accuracy and to ensure that imaging quality is maintained over time. There are three common applications of ISO 19264-1:

a) imaging system performance evaluation (benchmarking) – used for system development and system selection

b) imaging system performance optimization – used for tailoring the system to a particular job (use case)

c) imaging system performance monitoring – used for controlling that the quality of the system remains consistent and within specifications over time

The purpose of this document is to provide practical guidance on how to apply ISO 19264-1 for cultural heritage imaging of two-dimensional originals. This includes how the image quality analysis is performed, the function of technical target features, and how to adjust/optimize the performance of imaging systems. Additionally this document illustrates how ISO 19264-1 can be used for selection of appropriate imaging systems and how to establish and maintain image quality in digitization workflows.

Annex B provides information related to developing a digitization strategy including assessment of collections, developing a hardware strategy and system selection.

ISO 19262 provides definitions for imaging terminology used in this document and ISO 19264-1.

# Photography — Archiving systems —

# Part 1:
# Best practices for digital image capture of cultural heritage material

## 1 Scope

This document specifies how to perform quality analysis of imaging systems (e.g. flatbed scanners, planetary scanners, or digital still cameras) used for digitization of reflective two-dimensional originals.

Original materials include but are not limited to books, textual documents, drawings, prints, photographs, and paintings. Certain types of two-dimensional materials with complex surface geometry and or highly reflective surface elements require special illumination techniques that can fall outside the scope of this document.

NOTE ISO/TS 19264-2 will address transmissive materials.

## 2 Analysis of image quality

### 2.1 General

In order to analyse imaging system quality ISO 19264-1 specifies a technical target (ISO 19264-1 target) designed to incorporate multiple technical features for the measurement of key imaging characteristics from a single image. Calculations are performed via software dedicated to ISO 19264-1 target analysis.

### 2.2 Image quality characteristics

Image technical analysis involves a number of interrelated measurement steps, typically the analysis process begins with validating white balance and tone reproduction followed by additional calculation steps as listed below. When all measurements are within a set of defined tolerances, an imaging system meets a defined quality level. Resolution and geometry are analysed after first analysing core image quality elements.

— **White Balance**: adjustment of electronic still picture colour channel gains or image processing so that radiation with relative spectral power distribution equal to that of the scene illumination source is rendered as a visual neutral.

— **Tone Reproduction Curve (TRC)**: curve graphically describing the relationship between the input tones and the output tones in an imaging process.

— **Gain Modulation** (highlights/other patches): variation of the gain over the signal level.

— **Noise**: unwanted variations in the response of an imaging system.

— **Dynamic Range**: the difference, over a given period of time, between maximum and minimum signal levels, expressed in decibels, contrast ratios or f-stops.

— **Banding**: unwanted stripes or bands that occur in a digital image.

— **Defect Pixels**: pixel or subpixel that operates in a way other than the one in which it is driven.

— **Colour Accuracy**: ability of an imaging system to reproduce the colours of some intended object, as specified using some colour difference metric.

— **Sampling Rate** (difference between claimed and obtained): number of samples per unit of time, angle, revolutions or other mechanical, independent variable for uniformly sampled data.

— **Resolution (limiting)**: measure of the ability of a camera system, or a component of a camera system, to depict picture detail.

— **Sharpening**: amplification of the SFR by means of image processing to achieve sharper appearing images. Also, a class of image processing operations that enhances the contrast of selective spatial frequencies, usually visually important ones.

— **MTF 50**: the modulation transfer function is, a measure of the transfer of modulation (or contrast) from the subject to the image and is used to measure spatial frequency response (SFR). In other words, it measures how faithfully the imaging system reproduces (or transfers) detail from the target to the digital image. MTF50 refers to that spatial frequency (expressed in lines per mm) at which the image retains 50 % of the test target's contrast, see ISO 12233.

— **Illumination non-uniformity** (target size related): application of visible radiation (light) to an object.

— **Colour mis-registration**: colour-to-colour spatial dislocation of otherwise spatially coincident colour features of an imaged object.

— **Distortion**: displacement from the ideal shape of a subject (lying on a plane parallel to the image plane) in the recorded image.

— **Reproduction scale**: ratio of the size of an object in a digital image and the size of the original object.

## 2.3 ISO 19264 Test chart technical features

The ISO 19264-1 target is defined in ISO 19264-1:—, Annex A. Individual chart features are reproduced here to illustrate functionality. An ISO compliant target should contain all of the technical features. Additional targets are utilized for characterizing imaging system colour and tone.

## 2.4 Grid and gray/white features

### 2.4.1 General

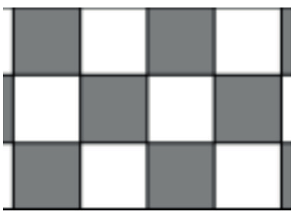


**Figure 1 — Example of grid and gray/white features**

Gray/white grids are used for analysing illumination non-uniformity and distortion. Illumination non-uniformity is similar to white balance, but applies to illumination at all tonal levels across the entire imaging field and can be adversely affected by the introduction of non-image forming light and or lens falloff. Distortion is often corrected digitally, but doing so recalculates each pixel location in an image, this may negatively influence image resolution but may also contribute to an overall improvement in image reproduction accuracy. Illumination-non uniformity results are expressed as $\Delta L^*$ differences between the maximum and minimum $L^*$ values.

### 2.4.2 Running scale features (cm and inches)

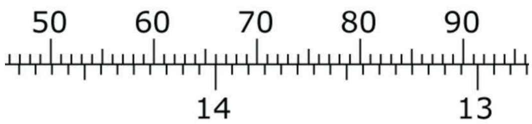



**Figure 2 — Example of running scale**

Scales are used to determine X and Y resolution, and to test for constant movement (scanners, stitching systems).

NOTE This measured function identifies the actual imaged values in both x and y directions, assuring scale integrity of the images

### 2.4.3 Grayscale and running gray/white/black bar features

**Figure 3 — Example of grayscale and running gray/white/black bar features**

The grayscale and running gray/white bars are used to determine OECF (tone recording), gain modulation, noise, and signal to noise ratio

Imaging systems should convert the tone values in the original scene to digital values; this technical term is OECF (Opto-Electronic Conversion Function). Validation of the correct selection of these parameters and appropriate representation of the digital information for the selected parameters is a critical function of image quality analysis.

Gain modulation refers to the variation of the gain (distribution of tonal values) over the signal level and is a critical factor in reproduction imaging and colour accuracy. Reported as $\Delta L^*$values. The smaller the deviation between the $L^*$ of the patches in the reference target and the $L^*$ values represented by the digital code values the more accurate the tone reproduction.

Noise is generally the digital equivalent of film grain, and presents itself as pixel-to-pixel fluctuations often seen in deep shadow areas. Noise has the effect of reducing the overall perceived smooth tonality of an image. Noise can also take a one-dimensional form called banding or streaking.

Signal to noise ratio is the ratio of the incremental output signal to the root mean square (rms) noise level, at a particular signal level.

### 2.4.4 Colour patch features

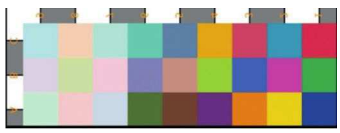


**Figure 4 — Example of colour patch features**

The colour patch element is used for determination of colour accuracy, test of the colour space, validation of ICC profiles, and survey of colour variation across the scanning area.

Results are reported in $\Delta E$ 2000* values in the form of a table for each individual patch together with the result for the mean and the max value for all patches. It is sufficient to report the mean and the max value only. Observation of the best 90 % can be helpful to help identify outlying data but is not mandatory.

$\Delta E$ 2000* values are calculated using a linear (SL=1) formula (see ISO 19264-1).

#### 2.4.5 MTF measurement features


**Figure 5 — Example of MTF measurement features**

The MTF element enables measurement of sampling resolution according to ISO 16067-1 (up to 1200 PPI max.).

Resolution (Limiting) is the highest frequency (spacing) that image detail can be distinguished. Scanners and cameras may claim very high resolutions that are unachievable due to design limitations of the total imaging system. This measure identifies the actual achieved resolution and should not be confused or considered equivalent to sampling rate.

This chart element also helps calculate sampling efficiency, and provides for visual resolution check up to 18 lp/mm. Sampling efficiency is also calculated using the MTF. Example-if the object captured is 10 in long and the sensor has 4000 pixel features capturing the 10 inches, the sampling rate is 400 pixels/in. Most imaging systems cannot achieve 100 % sampling efficiency. An accurate sampling rate is essential to knowing the size of the original object.

#### 2.4.6 Additional ISO 19264 target features/reference data

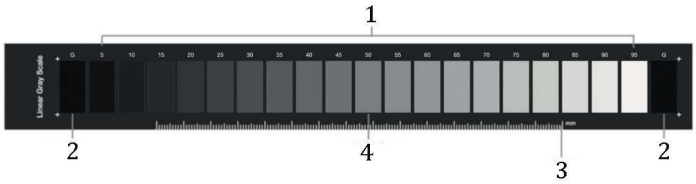
Additional chart areas may be designated for labelling, additional test patterns or chart features and manufacturing information. Chart Reference Data are typically custom measured and delivered from test chart vendors in text table form to be used as a reference for calculations. Chart reference data sets and measurement methods should be documented.

### 2.5 Additional targets

In addition to the ISO 19264-1 target other targets may be used to characterize the imaging system. The following targets aid in the characterization of imaging systems.

## 2.6 Linear grayscale




**Key**

1 semi gloss values (5$L$* to 95*$L$)

2 gloss black (4$L$*)

3 measurement scale, in mm

4 perceptual middle value (50$L$*)

**Figure 6 — Example of linear grayscale**

A linear grayscale is useful for configuration and verification of tone reproduction (OECF) and gain modulation. The target incorporates semi-gloss spectrally neutral pigments equally spaced in 5$L$* steps from $L$*5 to $L$*95 with additional gloss black patches. The gloss patches extend the dynamic range and are used to visually assess lighting reflections and glare from improper lighting geometry.

### 2.6.1 DCSG colour chart


**Figure 7 — Example of DCSG colour chart**

The X Rite Colour Checker® Digital SG (DCSG) colour chart is useful for colour calibration (device characterization). Colour charts may vary in terms of substrate, gloss factor, colour gamut and number of patches. A colour chart that closely matches the surface quality and colour gamut of the original artwork may be utilized.

### 2.6.2 Limitations of Chart Based Imaging System Analysis

Being that ISO 19264 is based upon analysis of test charts with technical patterns and reference values there are inherent limitations that need to be considered. Fabrication of technical targets varies over time, and targets have a finite life span. Baseline data used to define technical targets (chart reference data) can also vary between users and vendors. Vendors may improperly implement the analysis methods outlined in ISO 19264. Beyond these possible variables, there are variables in the surface qualities of original artworks, capture illuminants and sensors that limit the ability to ensure an exact colourimetric or perceptual match.

## 3 Image quality levels

Image analysis of a technical target results in an array of values. A core element of 19264-1 is the use of aims and tolerances to provide valuable insight into image quality. These aims and tolerances have been derived via extensive testing and feedback from cultural heritage imaging users and program managers.

ISO 19264-1 defines three image quality levels presented as a matrix. It is important to note that these quality levels are not provided for any specific use case or category of artwork therefore reaching the highest imaging quality threshold for all categories is not a universal requirement. The quality levels are meant to provide users with a reference to gauge relative image quality and to help establish workflow baselines. End users, user communities, or institutions may refer to the 19264-1 quality level matrix as needed to address different object types, to document and share results or to specify image quality requirements as part of contractual agreements with outside digitization vendors. Program managers may choose to configure and maintain systems that exceed the tolerance definition matrix defined in ISO 19264-1. It is important to document any site or project specific quality aims.

Please refer to the image quality table in ISO 19264-1.

## 4 Basic principles of image capture and processing

### 4.1 Overview

In order to record an original digital imaging systems generally follow the steps outlined in the flow diagram shown in Figure 9 which illustrates a typical array sensor device.

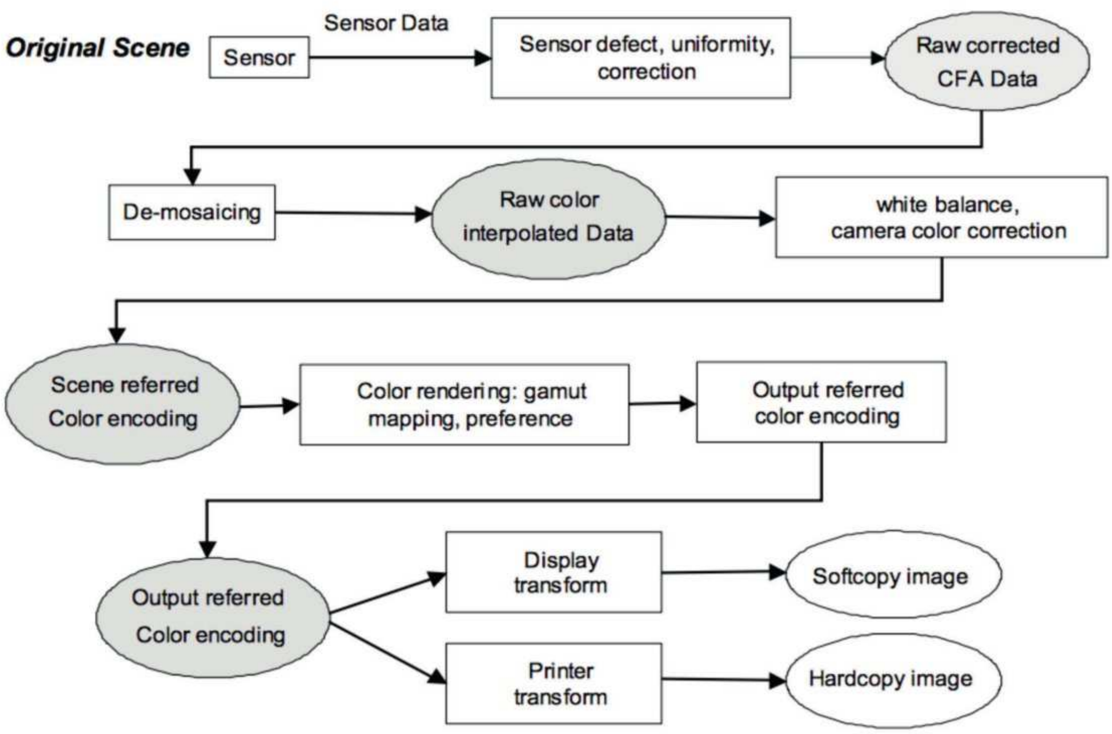



**Figure 8 — Typical array sensor device**

The reflected, or transmitted light from the object is collected by the optics and detected by an image sensor. The detected data may then be processed for sensor defects and exposure uniformity. If the imaging system used a colour filter array (CFA), the result is an encoded data array corresponding to a spatial pattern of repeated, e.g. red, green and blue, signals. At this point these raw data constitute the first form of 'raw' recorded image, the raw corrected CFA data.

The next step in a typical processing path is the generation of a fully populated three-colour image array. Propriety algorithms, aimed at minimizing colour artefacts, can be applied here. This de-mosaicing operation is the interpolation of the single-record array to a 'raw' interpolated red, green and blue data set. While de-mosaicing algorithms have improved over time, reproduction of certain originals with halftones, etchings and other materials with high frequency visual patterns can suffer from colour Moire artefacts. Moire is defined as a spatial beat phenomenon generated by the modulation of numerous spatial frequencies. Moire artefacts can impact both luminance and chrominance. Line scanners, and multi-shot sensor systems minimize the occurrence of colour Moire artefacts as de-mosaicing is not necessary in these imaging systems.

White-balance, and matrix colour-correction operations are usually applied next. The result is an image data set that is in a scene-referred colour encoding.

The final step in the image processing chain is the rendering, usually for display. The result is a finished image data array in an output-referred colour encoding. This step may be a simple colour-space transformation, but can also include choices for gamut mapping and colour preference.

While the above steps are common in colour image acquisition systems, specific implementation details will vary. Understanding the signal (colour) encoding of a raw image is as important as agreement on a particular file format.

## 4.2 Scene referred and output referred image states

The terms scene referred and output referred are essential to understand best practice for artwork digitization. ISO 19264-1 employs objective methods to help create images that refer to the original scene or object, in other words: a scene referred image. While scanners are typically engineered to provide a scene-referred response, the majority of commercially available imaging systems are engineered to deliver finished output referred images optimized for "pleasing" renditions. Unfortunately each manufacturer and observer may have different subjective opinions about what is pleasing as opposed to what is accurate. A scene-referred image can be repurposed and reformatted to any media as it contains information traceable back to the original object. When a scene-referred image is converted (via ICC or other colour conversion) or visually edited and optimized for reproduction to a specific medium or device, it becomes output-referred.

## 4.3 User controls and readouts

### 4.3.1 General

Digital imaging systems (cameras or scanners) and related control software should provide users necessary access to controls relevant to ISO 19264-1 system optimization. If an imaging system limits access to critical controls and only offers output referred or "factory" image processing functionality, image quality may suffer and users may be unable to configure systems to meet defined quality criteria. If an imaging system does not offer appropriate user controls and readouts the application of ISO 19264-1 may be limited to imaging system performance evaluation and imaging system performance monitoring only, see ISO/TR 17321-3.

### 4.3.2 Colour Processing Controls

The aim of the colour processing for ISO 19264-1 is to produce accurate scene colourimetry, with the scene adopted white chromatically adapted to the chromaticity of the image encoding adopted white. ISO 17321-1 specifies camera characterization metrology. ISO/TR 17321-2 provides considerations for determining scene analysis transforms. Cameras and scanners should fully support custom user characterization methods such as ICC colour profiles (ISO 15076-1), or DNG digital negative profiles (DCP). Users should be able to select any valid working colour space, destination colour space, custom generated input colour profiles and should be able to disable any factory or proprietary colour rendering functions (untagged). Colour encoding should be of sufficient gamut to encompass the gamut of the original.

### 4.3.3 Exposure readouts

The display of scene-referred image values converted to CIE $L^*a^*b^*$ values in the imaging system histogram is preferred. If an imaging system is not able to display scene referred $L^*a^*b^*$ values, RGB values are acceptable as long as they are clearly defined i.e. source or output encoding, see ISO/TR 17321-3.

### 4.3.4 Raw processor readouts and controls

If raw image processing software is part of the imaging workflow, the software should be able to read/display scene referred data and have the ability to disable output rendering and should also honor recorded scene adopted white chromaticity (see 4.3.2), User readouts and representation of exposure should operate as described in 4.3.3, see also ISO/TR 17321-3.

### 4.3.5 Other user controls

The ability for users to create, modify or disable image enhancement functions is helpful when using ISO 19264-1 for imaging system performance optimization. User access to generate custom flat-field corrections and lens corrections can help improve uniformity and minimize geometric distortion when using DSC systems. For scanners and turnkey systems these corrections may not be necessary. Image sharpening and other enhancements require careful attention and are generally discouraged. If and when modifications are made to user controls, for imaging system performance optimization, adjustments need to be documented.

### 4.3.6 Unwanted data modification

Imaging systems increasingly rely on proprietary image enhancement technologies. In some cases these enhancements can improve ISO 19264-1 results. For example: a DCS or Scanner may employ preset corrections for uniformity (vignetting correction) or geometric distortion, however other enhancements can cause problems. Variable or local image processing enhancements such as near neutral colour optimization, local or single colour improvements or local contrast optimization functions must be avoided. Ideally imaging systems that employ these enhancements should allow the user to disable the functions.

## 4.4 Master images and derivatives

### 4.4.1 General

Once an imaging system has been configured to meet the quality criteria as outlined in ISO 19264-1 the resulting images are typically saved as 8 bit or 16 bit RGB Tiff files. Tiff files should include either an embedded device ICC profile, or should be rendered to a standard RGB encoding space with sufficient colour gamut to contain the colour gamut of the originals being digitized. While not a part of ISO 19262 terminology, it is common to refer to these images as master image files.

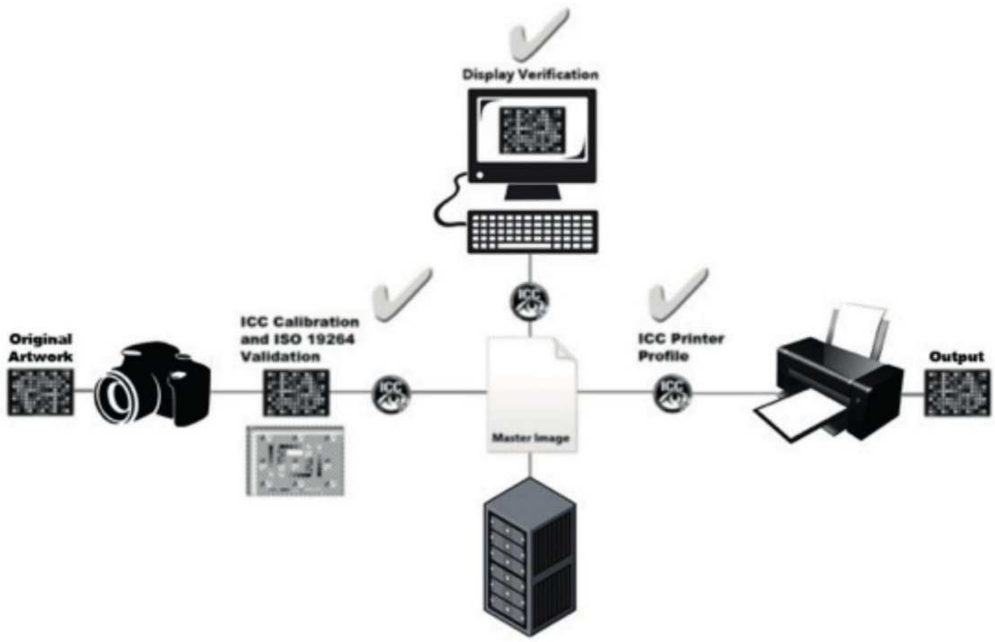
Any number of derivatives may be created from the master image. A common derivative would be a rendition that is typically down sampled, converted to an appropriate output referred colour encoding space (sRGB) in a JPEG compressed file format. Another derivative may be a set of thumbnail or preview images for a DAM, CMS or other information system. It is important to note that in order to display correctly, careful attention should be given to the proper use of embedded ICC colour profiles and colour management configuration through the entire workflow including web browsers and mobile devices.

### 4.4.2 Raw image files

A raw image file is often the starting point in the imaging process, and is typically the source for rendition to an image master Tiff image that can be analysed using ISO 19264-1. Raw image data and raw processing software tools are not standardized; therefore results can be highly variable. For example: the same raw image data and accompanying adjustments processed through one raw processor will not necessarily match when processed through another raw processor. Due to the variability of raw data formats and processing software raw images are outside the scope of this document and ISO 19264-1.

### 4.4.3 Artwork reproduction cycle

Creating a scene referred digital master image file is the first step in the larger reproduction cycle. Best practice in artwork reproduction relies on a fully colour managed workflow where each device is characterized via an ICC colour profile. While the scope of this document is limited to the creation of well-formed scene referred digital master images, it is useful to visualize where these images fit into the larger context. The diagram in Figure 9 illustrates a typical colour managed reproduction workflow. ISO 19264-1 applies only to the highlighted area.




NOTE An excellent reference is the benchmarking art interchange cycles final report

**Figure 9 — Typical colour managed reproduction workflow**

Creating and archiving scene-referred masters does not guarantee that the data will automatically translate to a faithful visual match upon display or hardcopy output. A number of factors including limitations of current technology, accuracy of charts, reliability of reference data and differences in observers and light sources (Metameric) factor into the reproduction workflow. The phenomenon whereby originals with different spectral reflection features provide different colour accuracy is called Metamerism. An imaging system configured using an ICC colour correction profile based upon a specific colour target such as the Digital ColourChecker SG can result in very low delta E values however, this does not necessarily communicate the specific colour accuracy of the originals with spectral reflection qualities other than the Digital ColourChecker SG. See also ISO 19262:2015, 3.160.

It is important to note that a scene-referred image is not expected to result in an exact facsimile of an original, but rather a digital master that can serve as a consistent, predictable source for future conversion/optimization. From this source image asset any number of optimized derivatives can be generated (manually or automatically) to satisfy reproduction via current and future output technologies. Understanding the variables in play, from the auditing of material to be digitized to the selection and configuration of appropriate equipment, is critical to success. The use of ICC colour management across the entire workflow is essential for successful image reproduction.

# 5 Imaging system setup and calibration

## 5.1 General

Configuring and validating a DSC or scanner system to meet the ISO 19264-1 specification generally follows the same procedures and begins with establishing correct exposure, tonal response and colour followed by analysis of an ISO 19264-1 compliant test target. Each camera or scanner control software presents different user interface and readout dialogues therefore the process has been generalized to encompass the key elements of configuring any digital camera system. Refer to manufacturer documentation or qualified ISO 19264-1 support professionals for specific recommendations. See 4.3 for relevant system configuration options.

## 5.2 Position camera system

— The DSC should be mounted to a stable tripod, studio stand, copy stand or other rigid support.

— The DSC should be placed to fit the required colour chart and or technical targets within the live image area. The optical axis of the camera should be positioned normal to the test target(s)

## 5.3 Establish uniformity-even illumination

### 5.3.1 General

Lighting should be placed at angles between 30° and no greater than 45° to the normal of the centre of the target area being imaged. Lighting and colour temperature should be approximately 5 000 K, and full spectrum (e.g. Xenon flash). Tungsten, High Frequency Fluorescent, HMI, HID and LED sources can optionally be used. A light source needs to carefully evaluated and relatively full spectrum. CRI in this case can be misleading and mixing lights of different types or ages can adversely impact colour uniformity. When selecting light sources it is important to consider best practice in conservation in terms of light exposure to original artworks.

Light sources should be generally placed no closer than approximately 2× the diagonal dimension of the area being imaged and the light source diameter should be no larger than 1,5× the diagonal dimension of the area being imaged. If the physical dimension of light sources are larger than 1,5× the diagonal of the area being imaged it is important to minimize glare by adjusting lighting distance and or lighting angle.

The white backside of the ISO 19264-1 target can be utilized to help verify initial uniformity. Any spectrally neutral smooth surface with an $L^*$ value of 95 to 75 can be used to establish illumination uniformity. See ISO 19264-1 for $L^*$ tolerances.

### 5.3.2 Optional flat-fielding

If DSC and or host control software support flat-fielding, this function can be employed to optimize results. It is critical to note that this functionality is directly tied to camera position, aperture, and lighting position. Improper use of flat-fielding can negatively impact image quality. Ideally every attempt should be made to achieve a uniform field without any additional manipulation. Flat-fielding implementation varies. Preferably flat-fielding should adjust pixel sensitivity and not simply via post-capture data manipulation. DSC and or host control software flat-fielding should be implemented in such a way that the function can be reversible. Care should be taken when flat-fielding to ensure the scan area and target used are clean. Surface imperfections and dust could negatively impact subsequent images. For digital cameras it is best to defocus the system when capturing the flat-fielding reference.

## 5.4 Establish exposure

Establishing exposure for DSC systems is difficult to summarize due to a current lack of standardization of UI value readouts however the following generalized steps based upon the use of grayscale targets and tolerances have proven to be reliable.

— Configure DSC or host control software to disable tone reproduction curve adjustments if possible. Note: some systems offer a “linear” or “reproduction” tone curve setting.

— Disable camera/host colour processing (to the extent possible).

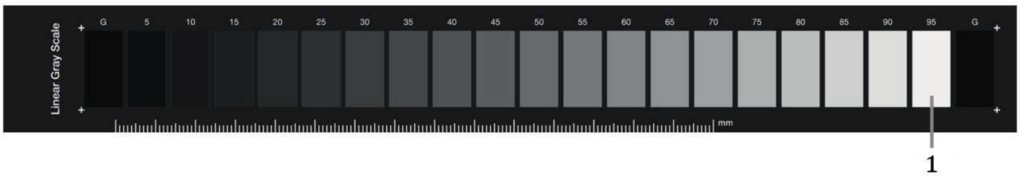
— (RIMM RGB). If RIMM RGB or suitable scene referred encoding is not an available option, the default colour encoding should be at large enough colour gamut to encompass the colour chart utilized for profile creation.

— Make sure that all image adjustments are set to default or null.

— Disable any automatic gain (analog or digital) or adaptive tone reproduction.

— The procedure for ensuring achromatic whites, grays, and blacks (white balancing) should be fixed using a known spectrally neutral chart value. The chart value for neutralization should be between *L**50 and *L**95.

— Place a linear grayscale (or any target with an *L**95 spectrally neutral patch) in the centre of the image area and make a test exposure. Adjust the system exposure (via adjustment of light output, distance and or camera settings) until a value of *L**95 is achieved (see Annex A for RGB values if the system does not support *L** readouts).




**Key**

1 95*L**

**Figure 10 — Linear gray scale for establishing exposure**

## 5.5 Establish tone reproduction curve (OECF)

— Using the linear grayscale verify the remaining values along the gray scale are within tolerance(s) Note: if tolerances for darker values do not match aims, it may be necessary to adjust lighting angle and or tone curve/histogram controls in host control software. If adjustments are necessary, these adjustments should be saved as a user preset

— All user settings should be recorded

## 5.6 Create an ICC colour profile

ICC Colour profiles can be created using integrated camera profiling functions or external third-party profiling applications. The X Rite ColourChecker® Digital SG (DCSG) colour chart is often along with appropriate chart reference data are often used for this purpose.

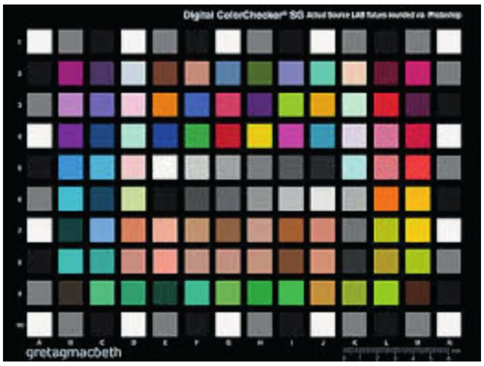



**Figure 11 — ICC colour profile**

— After having established correct chart illumination and exposure, capture the colour chart. If your software does not support built in ICC colour profiling export the file as a 16bit RGB Tiff in a colour encoding space that is larger gamut than the colour chart you wish to utilize for profiling (Note it is possible to characterize cameras using raw image data, but the process can become complicated due to a lack of standardization for raw data and its interpretation).

— Using any software capable of creating ICC input profiles, follow the manufacturer’s steps to generate an ICC profile.

— After loading the ICC input profile, select the profile in the DSC or host control software.

— Re-Verify Neutral Balance, Exposure, and Tone Reproduction (OECF).

— Capture a new chart image and re-check neutral balance, exposure, and tone reproduction. Export the file making sure to embed the custom ICC device profile or working colour encoding space.

### 5.7 Analyse colour and tone

The image of the colour chart can be compared to the chart reference data manually or via open source or commercial analysis tools. For colour evaluation the $\Delta E$ 2000 formula is recommended using a SL 1 in the calculations*. The $\Delta E$ 2000 colour difference formula as published was not specifically engineered for scene referred imaging analysis and assumes a non linear transform for lightness that is not appropriate for calculating $\Delta E$ values for scene referred imaging applications. Specifically, without modification, the $\Delta E$ calculation will report inaccurate $\Delta E$ values even when source $L^*$ target values perfectly match $L^*$ values in an image. Ensure that the software you are utilizing for image analysis supports this particular $\Delta E$ calculation method.

When configuring an imaging system it is a good idea to validate the capture of a colour chart to its reference data as well as comparing spectral measurements of sample artworks with their representations. It’s essential that the chart and reference data are verified or known.

## 6 Application of image quality analysis

### 6.1 Selection of imaging systems: preflighting equipment or vendors

The best time to implement an imaging strategy is after your project scope has been clearly defined and the collection has been assessed. If the collection goals are appropriate and the size of original work is known, one can evaluate equipment strictly based upon technical performance criteria and by analysing test targets. Due to the complexity of imaging systems it is common for imaging systems to easily pass certain criteria while failing other criteria, the results of ISO 19264 analyses will help identify and resolve problems. For example: A failure to pass illumination uniformity aims can be traced to the incorrect positioning of a light source. Failure in a single chart MTF region may reveal that the imaging system plane is not parallel to the artwork plane. If an imaging system does not pass certain criteria, a determination can be made to accept the results or not based on the material to be digitized. If an exception is made, the exception should be documented for future reference.

Taking an objective approach to equipment selection is the most effective way to define equipment needs. It is absolutely critical to evaluate internal or external vendor imaging systems against the pre-defined project criteria. It is all too common for cultural heritage sites to “clone” systems based on polling peer institutions or hardware vendors. Equipment changes too rapidly for this to be a viable approach. If new equipment is to be purchased it needs to be pre-qualified in order to avoid a worst case scenario such as finding out that a newly purchased imaging system does not satisfy project requirements. It is also critical to validate the imaging equipment and workflow BEFORE purchasing or committing to a digitization vendor. Imaging performance criteria may be defined in purchase contract language as well as a specific deliverable for new equipment configuration and installation. ISO 19264-1 is an ideal approach for the qualification of imaging systems as it is based on objective reports that can become part of contractual deliverables.

In the early days of imaging only the most costly systems were capable of high quality digitization. Today users have many options to achieve high quality results using tools readily available worldwide. As long as the digitization system satisfies the quality criteria outlined in ISO 19264-1 image quality will generally be acceptable. It is rare that a project stands alone so cameras and/or scanners need to be considered in context with larger programmatic goals. Smaller institutions may need to identify equipment that is capable of serving multiple applications as opposed to dedicated turnkey imaging systems.

## 6.2 Using ISO 19264 target: Initial system configuration

System validation is part of the system configuration process. Before one invests the time to configure a new imaging system, or contracts an outside vendor, digitizing and analysing the ISO 19264-1 target chart will provide valuable insight into the systems performance. Most systems require a certain degree of configuration in order to meet predefined quality levels. After configuring the imaging system for uniformity, colour and tone response the ISO 19264-1 target can be re-imaged and these criteria will typically show dramatic improvement. Note: The ISO 19264-1 target colour patches are not designed to validate system colour accuracy-they are incorporated to aid in establishing system baselines and ongoing quality control. The chart is captured and analysed. The analysis helps guide the process of fine-tuning system parameters until the best possible quality has been achieved.

## 6.3 Using ISO 19264 target: System performance evaluation (benchmarking)

Once the imaging system and or vendor has reached the desired level of imaging performance, the ISO 19264-1 target is utilized to capture and record the performance at a point in time. Typically this would be at the outset of a digitization effort. Once the results have been reported, it is a good time to document and back up all relevant equipment settings, profiles, metadata etc. this will serve as a valuable archival resource in the event of an equipment failure, change in vendor or other variable.

## 6.4 Using ISO 19264 target: Ongoing performance monitoring

ISO 19264-1 centers on analysing and reporting imaging system performance. It does not require a specific quality control schedule or reporting, this is left to program managers to establish. It is not uncommon to capture and analyse an ISO 19264-1 target chart on a per-system daily basis or even per operator shift basis. In practice, imaging systems and operators can introduce a number of variables that could lead to unpredictable image quality. Systems are analysed against the predefined quality criteria outlined ISO 19264-1. This approach helps ensure that the imaging systems perform well relative to other systems around the world-configured to meet the same criteria.

In practice it is common to first establish that a system meets or exceeds the ISO 19264-1 published tolerances, and then to utilize specific system baselines as a tool to resolve technical issues. In programs with multiple digitization systems each system will have its own “fingerprint” and it is helpful to understand the systems strengths and weaknesses. For example: a camera/copystand configuration is much more susceptible to illumination uniformity issues than a flatbed scanner. A digital camera/copystand configuration may need to be monitored more closely to verify illumination uniformity.

A scheduled system analysis gives program managers understanding of the most important image quality criteria.

## 7 Technical metadata for image quality analysis

When scanners and cameras create image files, they also generate a range of technical metadata about the image. Most systems write such metadata according to the Exif standard[1)]. In common image formats, such as JPEG, TIFF, and JP2000, the technical metadata are embedded in the file header, whereas for RAW formats the technical metadata can be written to a separate file (sidecar) or embedded as XMP data in the case of a DNG (Adobe Digital Negative) format image.

The technical metadata enables successive programs to process and render the images correctly. In addition, the technical metadata are useful for image quality analysis and control. Some image quality analysis programs compare the claimed sampling rate, which is written in the technical metadata, to the measured (obtained) sampling rate and calculate the difference to verify if it is within given tolerances. As for image quality assurance it is recommended to save the following technical metadata together with the results of the image quality analysis:

- date and time (when the test image was captured);
- creator (name/id of operator);
- imaging device (manufacturer and model);
- imaging software (name and version);
  - camera settings (if applicable):
    - aperture;
    - shutter speed;
    - ISO (sensitivity/speed);
  - image data:
    - image width and image height;
    - resolution (claimed sampling rate);
    - bits per sample (bit depth);
    - colour space;
    - colour profile.

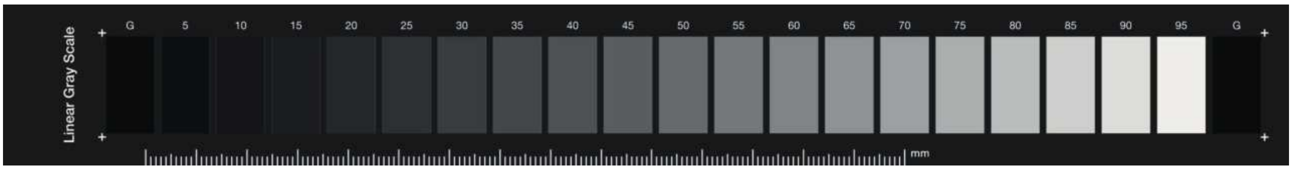
The results of the image quality analysis may be embedded in the image test file together with the technical metadata and saved for future reference. The metadata and the results may also be exported to a spreadsheet or a database for a more effective monitoring of imaging system performance[1].

1) Exchangeable image file format for digital still cameras, Exif Version 2.3, Standard of the Camera and Imaging Products Association (CIPA), Revised 2012, http://www.cipa.jp/std/documents/e/DC-008-2012_E.pdf ExifTool is a useful application for reading, writing and editing embedded metadata, http://www.sno.phy.queensu.ca/~phil/exiftool/

# Annex A
(informative)

## Linear Grayscale *L** to RGB conversion table




| **Chart *L** Value** | **4** | **5** | **10** | **15** | **20** | **25** | **30** | **35** | **40** | **45** | **50** | **55** | **60** | **65** | **70** | **75** | **80** | **85** | **90** | **95** | **4** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AdobeRGB | 22 | **24** | 33 | 42 | 52 | 62 | 72 | 83 | 94 | 106 | **118** | 131 | 143 | 156 | 170 | 183 | 197 | 211 | 255 | **240** | 22 |
| EciRGBv2 | 10 | **13** | 26 | 38 | 51 | 64 | 76 | 89 | 102 | 115 | **128** | 140 | 153 | 166 | 179 | 191 | 204 | 217 | 229 | **242** | 10 |
| ProPhotoRGB | 13 | **14** | 21 | 28 | 36 | 45 | 55 | 65 | 76 | 87 | **100** | 113 | 126 | 140 | 155 | 170 | 186 | 202 | 219 | **237** | 13 |

# Annex B
(informative)

# Subjective interpretive imaging (aesthetics)

## B.1 Overview

An image of an artwork created following ISO 19264 methodologies will record an object with improved accuracy and repeatability but there will always be situations and projects that demand a subjective aesthetic interpretation of an original. ISO 19264 imaging methods help museums, archives and libraries worldwide create and share content that is measurably consistent. Minimizing subjectivity improves consistency and throughput but does not replace the creation of visually pleasing photographic interpretations. Interpretive imaging requires skilled photographers able to combine technical abilities with the creativity and lighting skills needed to reach a desired aesthetic.

The decision to implement ISO 19264 methods or creative subjective capture practices should be carefully considered as they are not mutually exclusive. It is common for institutions to apply both methods to the same collections. For example, digitization of a large collection of objects offers important access, but the creation and promotion of a curated exhibition or publication of the same objects may require a specific interpretive photographic campaign.

ISO 19264 system validation can certainly provide the necessary technical foundation for systems utilized for interpretive imaging. Systems can be systematically configured and validated to provide a consistent starting point for interpretive stylization and illumination. It is highly recommended for program managers to define and document both technical specifications and stylization methods to ensure more consistent visual representations of original artworks over time.

## B.2 Assessment of a collection for digitization

The nature of the materials (including size, format, surface, metadata) to be digitized, their significant characteristics, value and quantity all impact the requirements for the imaging system. Important criteria to consider when developing an imaging strategy: Material Size, Size directly impacts hardware selection, physical space requirements, as well as overall productivity.

A well-configured digital imaging system may be capable of thousands of captures a day, but it is critical to understand the collection in terms of handling before addressing equipment needs, because productivity can be severely limited by the handling requirements of original works.

— Size. Can the collection be parsed by size? (what are the largest/smallest originals).

— Surface Qualities (matte, glossy, gold leaf or other reflective metallic surfaces, embossing, tool work).

— Framed/Unframed.

— Bound/unbound.

— Mixed medium.

— Depth/texture.

— Colour/gray.

— Continuous tone/halftone/line art.

— Format.

- Reflection/transmission.
- Single/multiple pages.
- Condition/special handling requirements.
- Operator Qualifications:
  - Is the operator proficient using ISO 19264 and image analysis?
  - How much training will the operator require?
  - Can a camera/scanner operator handle the materials or are other experts required?
- Other Considerations:
  - Are the works organized and labelled?
  - Are there object level records of the individual items?
  - Are there issues with transportation to and from storage?
  - How much time does it take to place the work on the imaging stage and return it to its storage?
  - Are special tools required to place the works, magnets, glass, string, weights, supports?

## B.3 Developing a digitization hardware strategy

Understanding the collection in terms of size, material, condition and quantity is the first critical step in determining appropriate hardware. The maximum original size impacts multiple specifications and will help determine appropriate hardware. For relatively uniform sized originals a flatbed scanner that supports user controls necessary for ISO 19264 is appropriate. Digital still cameras or scanners being considered should support appropriate user controls and readouts outlined in 4.3. In cases where objects vary in dimension, surface quality or are unable to lay flat, a digital still camera may be more appropriate.

When specifying a digital still camera solution, there are additional considerations:

- sensor resolution:
  - size of originals at required PPI (see table);
- lens focal length:
  - field of view;
  - camera working height;
  - lens type and quality (distortion);
- camera distance and appropriate support:
  - camera stability;
  - camera alignment;
- lighting:
  - should be configured to provide an even pool of illumination up to the maximum original size;
- determining an appropriate digitization lab floor plan:
  - appropriate area to accommodate even illumination of originals;

— appropriate area for operator;

— appropriate area for safely transporting and handling original works.

When determining an appropriate imaging system sensor resolution it is helpful to audit your collection based on the size of the original materials and desired output resolution. It is common for users to purchase digital cameras or scanners for digitization only to find that the sensor resolution is inadequate for the work at hand. This table simply illustrates the relationship between the sensor pixel long dimension and original sizes at 300 PPI and 400 PPI. It is not intended as an absolute requirement for specific object types.

**Table B.1 — Sensor size relative to 1:1 original image reproduction at 300 PPI and 400 PPI**

| **Sensor Long Dimension** | **1:1 Original Size** (Inches @300 PPI) | **1:1 Original Size** (Inches@400 PPI) |
|---|---|---|
| 2 000 | 6.67 | 5 |
| 4 000 | 13.3 | 10 |
| 6 000 | 20 | 15 |
| 8 000 | 26.67 | 20 |
| 10 000 | 33.33 | 25 |

## B.4 Other considerations when implementing ISO 19264 imaging

Paintings with deep impasto, books with gold leaf, bound documents that are not able to lay flat may require special handling and consideration. An imaging system configured to satisfy the technical ISO 19264-1 requirements may still be utilized as a starting point for imaging these more complex materials because some or all of the basic concepts and technical criteria may still apply. Using ISO 12624-1 as a baseline, individual parameters can be modified to suit the unique requirements of certain object types. Those modifications should be documented in order to achieve consistent results. An acceptable scenario would be the decision to utilize cross-polarized illumination to eliminate surface glare. The imaging system could be configured to meet ISO 19264-1 tolerances for both normal light and cross-polarized light. If the requirements of a certain material type or visualization stray too far from ISO 19264-1 (such as raking light) additional "interpretive" captures may be required. A painting may be digitized with polarized light and "normal" light adhering to ISO 19264-1 tolerances, while additional captures could be created using asymmetric or even raking light with the camera system in registration to create a more complete description of the artwork. At some point it is difficult to combine creative lighting techniques and interpretive imaging with objective capture practice simply because targets and tolerances become impossible to utilize.

Specific digitization use cases, such as imaging text for OCR, are occasionally required based on institutional goals. Program managers may always choose to optimize systems for a specific single use case but when the ultimate end use is unknown it is advisable to aim high in terms of digitization. A high quality image may serve as a true digital surrogate and even a physical access copy at any time in the future. Considering it's not always feasible to re-image a collection it is wise to aim towards the highest precision possible. While it is not advisable to aim below ISO 19264-1 quality criteria, it is acceptable to image beyond the image quality criteria set forth in the ISO 19264-1 and is ultimately a program management decision to exceed the specifications.

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**ICS 37.040.01; 01.140.20**
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